# OpenShift Container Platform 4.6

## Operators

Working with Operators in OpenShift Container Platform

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## Legal Notice



## Abstract

This document provides information for working with Operators in OpenShift Container Platform. This includes instructions for cluster administrators on how to install and manage Operators, as well as information for developers on how to create applications from installed Operators. This also contains guidance on building your own Operator using the Operator SDK.

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# CHAPTER 1. OPERATORS OVERVIEW

Operators are among the most important components of OpenShift Container Platform. Operators are the preferred method of packaging, deploying, and managing services on the control plane. They can also provide advantages to applications that users run.

Operators integrate with Kubernetes APIs and CLI tools such as kubectl and oc commands. They provide the means of monitoring applications, performing health checks, managing over-the-air (OTA) updates, and ensuring that applications remain in your specified state.

While both follow similar Operator concepts and goals, Operators in OpenShift Container Platform are managed by two different systems, depending on their purpose:

- Platform Operators, which are managed by the Cluster Version Operator (CVO), are installed by default to perform cluster functions.
- Optional add-on Operators, which are managed by Operator Lifecycle Manager (OLM), can be made accessible for users to run in their applications.

With Operators, you an create applications to monitor the running services in the cluster. Operators are designed specifically for your applications. Operators implement and automate the common Day 1 operations such as installation and configuration as well as Day 2 operations such as auto-scaling up and down and backups. All these activities are in a piece of software running inside your cluster.

## 1.1. FOR DEVELOPERS

As a developer, you can perform the following Operator tasks:

- Install Operator SDK CLI.
- Create Go-based Operators, Ansible-based Operators, and Helm-based Operators.
- Use Operator SDK to build,test, and deploy an Operator .
- Install and subscribe an Operator to your namespace .
- Create an application from an installed Operator through the web console .

## 1.2. FOR ADMINISTRATORS

As a cluster administrator, you can perform the following Operator tasks:

- Manage custom catalogs
- Allow non-cluster administrators to install Operators
- Install an Operator from OperatorHub
- View Operator status.
- Upgrade installed Operators
- Delete installed Operators
- Configure proxy support

- Use Operator Lifecycle Manager on restricted networks

To know about generated files and directories from the **operator-sdk** CLI, see Appendices

To know all about the Operators that Red Hat provides, see Red Hat Operators

## 1.3. NEXT STEPS

To understand more about Operators, see What are Operators?

# CHAPTER 2. UNDERSTANDING OPERATORS

## 2.1. WHAT ARE OPERATORS?

Conceptually, *Operators* take human operational knowledge and encode it into software that is more easily shared with consumers.

Operators are pieces of software that ease the operational complexity of running another piece of software. They act like an extension of the software vendor's engineering team, watching over a Kubernetes environment, such as OpenShift Container Platform, and using its current state to make decisions in real time. Advanced Operators are designed to handle upgrades seamlessly, react to failures automatically, and not take shortcuts, like skipping a software backup process to save time.

More technically, Operators are a method of packaging, deploying, and managing a Kubernetes application.

A Kubernetes application is an app that is both deployed on Kubernetes and managed using the Kubernetes APIs and **kubectl** or **oc** tooling. To be able to make the most of Kubernetes, you require a set of cohesive APIs to extend in order to service and manage your apps that run on Kubernetes. Think of Operators as the runtime that manages this type of app on Kubernetes.

### 2.1.1. Why use Operators?

Operators provide:

- Repeatability of installation and upgrade.
- Constant health checks of every system component.
- Over-the-air (OTA) updates for OpenShift components and ISV content.
- A place to encapsulate knowledge from field engineers and spread it to all users, not just one or two.

**Why deploy on Kubernetes?**

Kubernetes (and by extension, OpenShift Container Platform) contains all of the primitives needed to build complex distributed systems – secret handling, load balancing, service discovery, autoscaling – that work across on-premises and cloud providers.

**Why manage your app with Kubernetes APIs and kubectl tooling?**

These APIs are feature rich, have clients for all platforms and plug into the cluster's access control/auditing. An Operator uses the Kubernetes extension mechanism, custom resource definitions (CRDs), so your custom object, for example **MongoDB**, looks and acts just like the built-in, native Kubernetes objects.

**How do Operators compare with service brokers?**

A service broker is a step towards programmatic discovery and deployment of an app. However, because it is not a long running process, it cannot execute Day 2 operations like upgrade, failover, or scaling. Customizations and parameterization of tunables are provided at install time, versus an Operator that is constantly watching the current state of your cluster. Off-cluster services are a good match for a service broker, although Operators exist for these as well.

### 2.1.2. Operator Framework

The Operator Framework is a family of tools and capabilities to deliver on the customer experience

described above. It is not just about writing code; testing, delivering, and updating Operators is just as important. The Operator Framework components consist of open source tools to tackle these problems:

**Operator SDK**

The Operator SDK assists Operator authors in bootstrapping, building, testing, and packaging their own Operator based on their expertise without requiring knowledge of Kubernetes API complexities.

**Operator Lifecycle Manager**

Operator Lifecycle Manager (OLM) controls the installation, upgrade, and role-based access control (RBAC) of Operators in a cluster. Deployed by default in OpenShift Container Platform 4.6.

**Operator Registry**

The Operator Registry stores cluster service versions (CSVs) and custom resource definitions (CRDs) for creation in a cluster and stores Operator metadata about packages and channels. It runs in a Kubernetes or OpenShift cluster to provide this Operator catalog data to OLM.

**OperatorHub**

OperatorHub is a web console for cluster administrators to discover and select Operators to install on their cluster. It is deployed by default in OpenShift Container Platform.

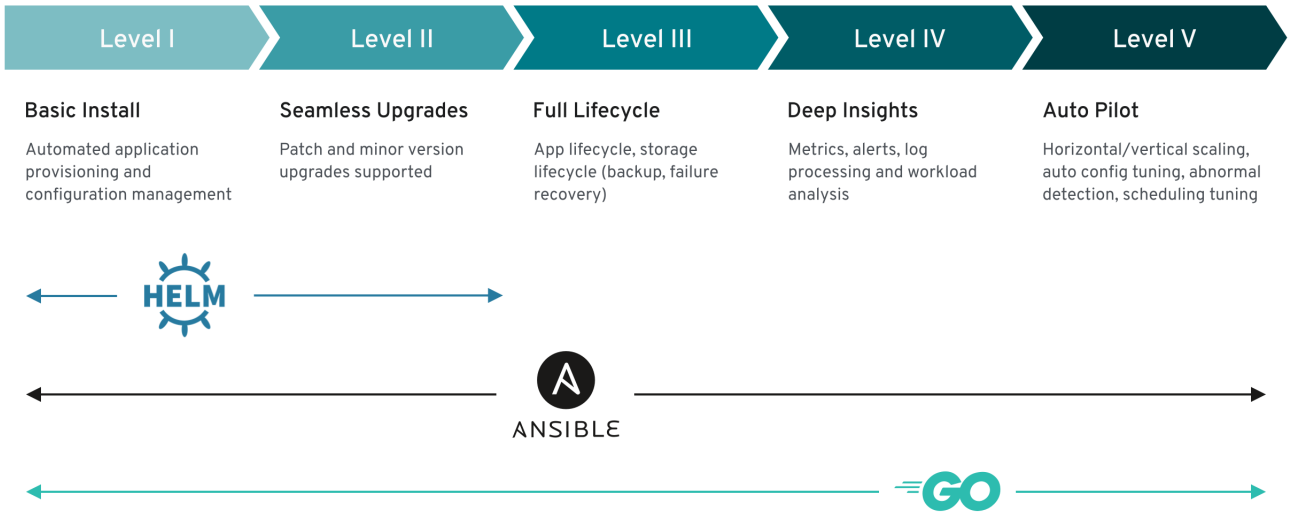
These tools are designed to be composable, so you can use any that are useful to you.

### 2.1.3. Operator maturity model

The level of sophistication of the management logic encapsulated within an Operator can vary. This logic is also in general highly dependent on the type of the service represented by the Operator.

One can however generalize the scale of the maturity of the encapsulated operations of an Operator for certain set of capabilities that most Operators can include. To this end, the following Operator maturity model defines five phases of maturity for generic day two operations of an Operator:

**Figure 2.1. Operator maturity model**




The above model also shows how these capabilities can best be developed through the Helm, Go, and Ansible capabilities of the Operator SDK.

# 2.2. OPERATOR FRAMEWORK GLOSSARY OF COMMON TERMS

This topic provides a glossary of common terms related to the Operator Framework, including Operator Lifecycle Manager (OLM) and the Operator SDK, for both packaging formats: Package Manifest Format and Bundle Format.

## 2.2.1. Common Operator Framework terms

### 2.2.1.1. Bundle

In the Bundle Format, a *bundle* is a collection of an Operator CSV, manifests, and metadata. Together, they form a unique version of an Operator that can be installed onto the cluster.

### 2.2.1.2. Bundle image

In the Bundle Format, a *bundle image* is a container image that is built from Operator manifests and that contains one bundle. Bundle images are stored and distributed by Open Container Initiative (OCI) spec container registries, such as Quay.io or DockerHub.

### 2.2.1.3. Catalog source

A *catalog source* is a repository of CSVs, CRDs, and packages that define an application.

### 2.2.1.4. Catalog image

In the Package Manifest Format, a *catalog image* is a containerized datastore that describes a set of Operator metadata and update metadata that can be installed onto a cluster using OLM.

### 2.2.1.5. Channel

A *channel* defines a stream of updates for an Operator and is used to roll out updates for subscribers. The head points to the latest version of that channel. For example, a **stable** channel would have all stable versions of an Operator arranged from the earliest to the latest.

An Operator can have several channels, and a subscription binding to a certain channel would only look for updates in that channel.

### 2.2.1.6. Channel head

A *channel head* refers to the latest known update in a particular channel.

### 2.2.1.7. Cluster service version

A *cluster service version (CSV)* is a YAML manifest created from Operator metadata that assists OLM in running the Operator in a cluster. It is the metadata that accompanies an Operator container image, used to populate user interfaces with information such as its logo, description, and version.

It is also a source of technical information that is required to run the Operator, like the RBAC rules it requires and which custom resources (CRs) it manages or depends on.

### 2.2.1.8. Dependency

An Operator may have a *dependency* on another Operator being present in the cluster. For example, the Vault Operator has a dependency on the etcd Operator for its data persistence layer.

OLM resolves dependencies by ensuring that all specified versions of Operators and CRDs are installed on the cluster during the installation phase. This dependency is resolved by finding and installing an Operator in a catalog that satisfies the required CRD API, and is not related to packages or bundles.

#### 2.2.1.9. Index image

In the Bundle Format, an *index image* refers to an image of a database (a database snapshot) that contains information about Operator bundles including CSVs and CRDs of all versions. This index can host a history of Operators on a cluster and be maintained by adding or removing Operators using the **opm** CLI tool.

#### 2.2.1.10. Install plan

An *install plan* is a calculated list of resources to be created to automatically install or upgrade a CSV.

#### 2.2.1.11. Operator group

An *Operator group* configures all Operators deployed in the same namespace as the **OperatorGroup** object to watch for their CR in a list of namespaces or cluster-wide.

#### 2.2.1.12. Package

In the Bundle Format, a *package* is a directory that encloses all released history of an Operator with each version. A released version of an Operator is described in a CSV manifest alongside the CRDs.

#### 2.2.1.13. Registry

A *registry* is a database that stores bundle images of Operators, each with all of its latest and historical versions in all channels.

#### 2.2.1.14. Subscription

A *subscription* keeps CSVs up to date by tracking a channel in a package.

#### 2.2.1.15. Update graph

An *update graph* links versions of CSVs together, similar to the update graph of any other packaged software. Operators can be installed sequentially, or certain versions can be skipped. The update graph is expected to grow only at the head with newer versions being added.

## 2.3. OPERATOR FRAMEWORK PACKAGING FORMATS

This guide outlines the packaging formats for Operators supported by Operator Lifecycle Manager (OLM) in OpenShift Container Platform.

### 2.3.1. Bundle Format

The *Bundle Format* for Operators is a new packaging format introduced by the Operator Framework. To improve scalability and to better enable upstream users hosting their own catalogs, the Bundle Format specification simplifies the distribution of Operator metadata.

An Operator bundle represents a single version of an Operator. On-disk *bundle manifests* are containerized and shipped as a *bundle image*, which is a non-runnable container image that stores the Kubernetes manifests and Operator metadata. Storage and distribution of the bundle image is then managed using existing container tools like **podman** and **docker** and container registries such as Quay.

Operator metadata can include:

- Information that identifies the Operator, for example its name and version.
- Additional information that drives the UI, for example its icon and some example custom resources (CRs).
- Required and provided APIs.
- Related images.

When loading manifests into the Operator Registry database, the following requirements are validated:

- The bundle must have at least one channel defined in the annotations.
- Every bundle has exactly one cluster service version (CSV).
- If a CSV owns a custom resource definition (CRD), that CRD must exist in the bundle.

#### 2.3.1.1. Manifests

Bundle manifests refer to a set of Kubernetes manifests that define the deployment and RBAC model of the Operator.

A bundle includes one CSV per directory and typically the CRDs that define the owned APIs of the CSV in its /**manifests** directory.

**Example Bundle Format layout**

```
etcd
├── manifests
│   ├── etcdcluster.crd.yaml
│   └── etcdoperator.clusterserviceversion.yaml
│   └── secret.yaml
│   └── configmap.yaml
└── metadata
    └── annotations.yaml
    └── dependencies.yaml
```

**Additionally supported objects**
The following object types can also be optionally included in the /**manifests** directory of a bundle:

**Supported optional object types**

- **ClusterRole**
- **ClusterRoleBinding**
- **ConfigMap**
- **PodDisruptionBudget**

- **PriorityClass**
- **PrometheusRule**
- **Role**
- **RoleBinding**
- **Secret**
- **Service**
- **ServiceAccount**
- **ServiceMonitor**
- **VerticalPodAutoscaler**

When these optional objects are included in a bundle, Operator Lifecycle Manager (OLM) can create them from the bundle and manage their lifecycle along with the CSV:

**Lifecycle for optional objects**

- When the CSV is deleted, OLM deletes the optional object.
- When the CSV is upgraded:
  - If the name of the optional object is the same, OLM updates it in place.
  - If the name of the optional object has changed between versions, OLM deletes and recreates it.

### 2.3.1.2. Annotations

A bundle also includes an **annotations.yaml** file in its /**metadata** directory. This file defines higher level aggregate data that helps describe the format and package information about how the bundle should be added into an index of bundles:

**Example annotations.yaml**

```
annotations:
  operators.operatorframework.io.bundle.mediatype.v1: "registry+v1" (1)
  operators.operatorframework.io.bundle.manifests.v1: "manifests/" (2)
  operators.operatorframework.io.bundle.metadata.v1: "metadata/" (3)
  operators.operatorframework.io.bundle.package.v1: "test-operator" (4)
  operators.operatorframework.io.bundle.channels.v1: "beta,stable" (5)
  operators.operatorframework.io.bundle.channel.default.v1: "stable" (6)
```

(1) The media type or format of the Operator bundle. The **registry+v1** format means it contains a CSV and its associated Kubernetes objects.

(2) The path in the image to the directory that contains the Operator manifests. This label is reserved for future use and currently defaults to **manifests/**. The value **manifests.v1** implies that the bundle contains Operator manifests.

3. The path in the image to the directory that contains metadata files about the bundle. This label is reserved for future use and currently defaults to **metadata**/. The value **metadata.v1** implies that
4. The package name of the bundle.
5. The list of channels the bundle is subscribing to when added into an Operator Registry.
6. The default channel an Operator should be subscribed to when installed from a registry.

NOTE

In case of a mismatch, the **annotations.yaml** file is authoritative because the on-cluster Operator Registry that relies on these annotations only has access to this file.

#### 2.3.1.3. Dependencies file

The dependencies of an Operator are listed in a **dependencies.yaml** file in the **metadata**/ folder of a bundle. This file is optional and currently only used to specify explicit Operator-version dependencies.

The dependency list contains a **type** field for each item to specify what kind of dependency this is. There are two supported types of Operator dependencies:

- **olm.package**: This type indicates a dependency for a specific Operator version. The dependency information must include the package name and the version of the package in semver format. For example, you can specify an exact version such as **0.5.2** or a range of versions such as **>0.5.1**.
- **olm.gvk**: With a **gvk** type, the author can specify a dependency with group/version/kind (GVK) information, similar to existing CRD and API-based usage in a CSV. This is a path to enable Operator authors to consolidate all dependencies, API or explicit versions, to be in the same place.

In the following example, dependencies are specified for a Prometheus Operator and etcd CRDs:

**Example dependencies.yaml file**

```
dependencies:
  - type: olm.package
    value:
      packageName: prometheus
      version: ">0.27.0"
  - type: olm.gvk
    value:
      group: etcd.database.coreos.com
      kind: EtcdCluster
      version: v1beta2
```

**Additional resources**

- Operator Lifecycle Manager dependency resolution

#### 2.3.1.4. About opm

The **opm** CLI tool is provided by the Operator Framework for use with the Operator Bundle Format.

This tool allows you to create and maintain catalogs of Operators from a list of bundles, called an *index*, that are similar to software repositories. The result is a container image, called an *index image*, which can be stored in a container registry and then installed on a cluster.

An index contains a database of pointers to Operator manifest content that can be queried through an included API that is served when the container image is run. On OpenShift Container Platform, Operator Lifecycle Manager (OLM) can use the index image as a catalog by referencing it in a **CatalogSource** object, which polls the image at regular intervals to enable frequent updates to installed Operators on the cluster.

- See CLI tools for steps on installing the **opm** CLI.

### 2.3.2. Package Manifest Format

The *Package Manifest Format* for Operators is the legacy packaging format introduced by the Operator Framework. While this format is deprecated in OpenShift Container Platform 4.5, it is still supported and Operators provided by Red Hat are currently shipped using this method.

In this format, a version of an Operator is represented by a single cluster service version (CSV) and typically the custom resource definitions (CRDs) that define the owned APIs of the CSV, though additional objects may be included.

All versions of the Operator are nested in a single directory:

#### Example Package Manifest Format layout

```
etcd
├── 0.6.1
│   ├── etcdcluster.crd.yaml
│   └── etcdoperator.clusterserviceversion.yaml
├── 0.9.0
│   ├── etcdbackup.crd.yaml
│   ├── etcdcluster.crd.yaml
│   ├── etcdoperator.v0.9.0.clusterserviceversion.yaml
│   └── etcdrestore.crd.yaml
├── 0.9.2
│   ├── etcdbackup.crd.yaml
│   ├── etcdcluster.crd.yaml
│   ├── etcdoperator.v0.9.2.clusterserviceversion.yaml
│   └── etcdrestore.crd.yaml
└── etcd.package.yaml
```

It also includes a **<name>.package.yaml** file that is the *package manifest* that defines the package name and channels details:

#### Example package manifest

```
packageName: etcd
channels:
- name: alpha
  currentCSV: etcdoperator.v0.9.2
- name: beta
  currentCSV: etcdoperator.v0.9.0
```

```
- name: stable
  currentCSV: etcdoperator.v0.9.2
defaultChannel: alpha
```

When loading package manifests into the Operator Registry database, the following requirements are validated:

- Every package has at least one channel.
- Every CSV pointed to by a channel in a package exists.
- Every version of an Operator has exactly one CSV.
- If a CSV owns a CRD, that CRD must exist in the directory of the Operator version.
- If a CSV replaces another, both the old and the new must exist in the package.

## 2.4. OPERATOR LIFECYCLE MANAGER (OLM)

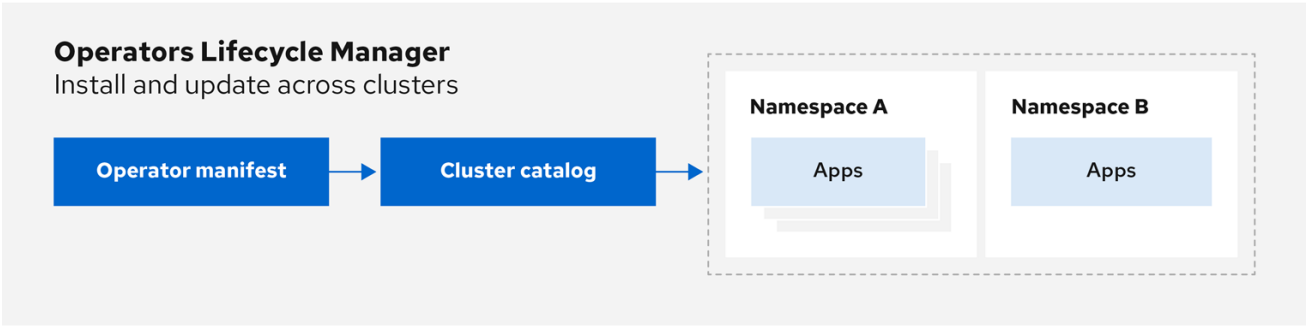
### 2.4.1. Operator Lifecycle Manager concepts and resources

This guide provides an overview of the concepts that drive Operator Lifecycle Manager (OLM) in OpenShift Container Platform.

#### 2.4.1.1. What is Operator Lifecycle Manager?

*Operator Lifecycle Manager* (OLM) helps users install, update, and manage the lifecycle of Kubernetes native applications (Operators) and their associated services running across their OpenShift Container Platform clusters. It is part of the Operator Framework, an open source toolkit designed to manage Operators in an effective, automated, and scalable way.

**Figure 2.2. Operator Lifecycle Manager workflow**




OLM runs by default in OpenShift Container Platform 4.6, which aids cluster administrators in installing, upgrading, and granting access to Operators running on their cluster. The OpenShift Container Platform web console provides management screens for cluster administrators to install Operators, as well as grant specific projects access to use the catalog of Operators available on the cluster.

For developers, a self-service experience allows provisioning and configuring instances of databases, monitoring, and big data services without having to be subject matter experts, because the Operator has that knowledge baked into it.

#### 2.4.1.2. OLM resources

The following custom resource definitions (CRDs) are defined and managed by Operator Lifecycle Manager (OLM):

**Table 2.1. CRDs managed by OLM and Catalog Operators**

| Resource | Short name | Description |
|---|---|---|
| **ClusterServiceVersion** (CSV) | **csv** | Application metadata. For example: name, version, icon, required resources. |
| **CatalogSource** | **catsrc** | A repository of CSVs, CRDs, and packages that define an application. |
| **Subscription** | **sub** | Keeps CSVs up to date by tracking a channel in a package. |
| **InstallPlan** | **ip** | Calculated list of resources to be created to automatically install or upgrade a CSV. |
| **OperatorGroup** | **og** | Configures all Operators deployed in the same namespace as the **OperatorGroup** object to watch for their custom resource (CR) in a list of namespaces or cluster-wide. |

##### 2.4.1.2.1. Cluster service version

A *cluster service version* (CSV) represents a specific version of a running Operator on an OpenShift Container Platform cluster. It is a YAML manifest created from Operator metadata that assists Operator Lifecycle Manager (OLM) in running the Operator in the cluster.

OLM requires this metadata about an Operator to ensure that it can be kept running safely on a cluster, and to provide information about how updates should be applied as new versions of the Operator are published. This is similar to packaging software for a traditional operating system; think of the packaging step for OLM as the stage at which you make your **rpm**, **deb**, or **apk** bundle.

A CSV includes the metadata that accompanies an Operator container image, used to populate user interfaces with information such as its name, version, description, labels, repository link, and logo.

A CSV is also a source of technical information required to run the Operator, such as which custom resources (CRs) it manages or depends on, RBAC rules, cluster requirements, and install strategies. This information tells OLM how to create required resources and set up the Operator as a deployment.

##### 2.4.1.2.2. Catalog source

A *catalog source* represents a store of metadata, typically by referencing an *index image* stored in a container registry. Operator Lifecycle Manager (OLM) queries catalog sources to discover and install Operators and their dependencies. The OperatorHub in the OpenShift Container Platform web console also displays the Operators provided by catalog sources.

**TIP**

Cluster administrators can view the full list of Operators provided by an enabled catalog source on a cluster by using the **Administration → Cluster Settings → Global Configuration → OperatorHub** page in the web console.

The **spec** of a **CatalogSource** object indicates how to construct a pod or how to communicate with a service that serves the Operator Registry gRPC API.

**Example 2.1. Example CatalogSource object**

```
apiVersion: operators.coreos.com/v1alpha1
kind: CatalogSource
metadata:
  generation: 1
  name: example-catalog (1)
  namespace: openshift-marketplace (2)
spec:
  displayName: Example Catalog (3)
  image: quay.io/example-org/example-catalog:v1 (4)
  priority: -400 (5)
  publisher: Example Org
  sourceType: grpc (6)
  updateStrategy:
    registryPoll: (7)
      interval: 30m0s
status:
  connectionState:
    address: example-catalog.openshift-marketplace.svc:50051
    lastConnect: 2021-08-26T18:14:31Z
    lastObservedState: READY (8)
  latestImageRegistryPoll: 2021-08-26T18:46:25Z (9)
  registryService: (10)
    createdAt: 2021-08-26T16:16:37Z
    port: 50051
    protocol: grpc
    serviceName: example-catalog
    serviceNamespace: openshift-marketplace
```

(1) Name for the **CatalogSource** object. This value is also used as part of the name for the related pod that is created in the requested namespace.

(2) Namespace to create the catalog available. To make the catalog available cluster-wide in all namespaces, set this value to **openshift-marketplace**. The default Red Hat-provided catalog sources also use the **openshift-marketplace** namespace. Otherwise, set the value to a specific namespace to make the Operator only available in that namespace.

(3) Display name for the catalog in the web console and CLI.

(4) Index image for the catalog.

(5) Weight for the catalog source. OLM uses the weight for prioritization during dependency resolution. A higher weight indicates the catalog is preferred over lower-weighted catalogs.

6 Source types include the following:

- **grpc** with an **image** reference: OLM pulls the image and runs the pod, which is expected to serve a compliant API.
- **grpc** with an **address** field: OLM attempts to contact the gRPC API at the given address. This should not be used in most cases.
- **configmap**: OLM parses config map data and runs a pod that can serve the gRPC API over it.

7 Automatically check for new versions at a given interval to stay up-to-date.

8 Last observed state of the catalog connection. For example:

- **READY**: A connection is successfully established.
- **CONNECTING**: A connection is attempting to establish.
- **TRANSIENT_FAILURE**: A temporary problem has occurred while attempting to establish a connection, such as a timeout. The state will eventually switch back to **CONNECTING** and try again.

See States of Connectivity in the gRPC documentation for more details.

9 Latest time the container registry storing the catalog image was polled to ensure the image is up-to-date.

10 Status information for the catalog's Operator Registry service.

Referencing the **name** of a **CatalogSource** object in a subscription instructs OLM where to search to find a requested Operator:

**Example 2.2. Example Subscription object referencing a catalog source**

```
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: example-operator
  namespace: example-namespace
spec:
  channel: stable
  name: example-operator
  source: example-catalog
  sourceNamespace: openshift-marketplace
```

**Additional resources**

- Understanding OperatorHub
- Red Hat-provided Operator catalogs
- Catalog priority

- Viewing Operator catalog source status by using the CLI

#### 2.4.1.2.3. Subscription

A *subscription*, defined by a **Subscription** object, represents an intention to install an Operator. It is the custom resource that relates an Operator to a catalog source.

Subscriptions describe which channel of an Operator package to subscribe to, and whether to perform updates automatically or manually. If set to automatic, the subscription ensures Operator Lifecycle Manager (OLM) manages and upgrades the Operator to ensure that the latest version is always running in the cluster.

**Example Subscription object**

```
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: example-operator
  namespace: example-namespace
spec:
  channel: stable
  name: example-operator
  source: example-catalog
  sourceNamespace: openshift-marketplace
```

This **Subscription** object defines the name and namespace of the Operator, as well as the catalog from which the Operator data can be found. The channel, such as **alpha**, **beta**, or **stable**, helps determine which Operator stream should be installed from the catalog source.

The names of channels in a subscription can differ between Operators, but the naming scheme should follow a common convention within a given Operator. For example, channel names might follow a minor release update stream for the application provided by the Operator (**1.2**, **1.3**) or a release frequency (**stable**, **fast**).

In addition to being easily visible from the OpenShift Container Platform web console, it is possible to identify when there is a newer version of an Operator available by inspecting the status of the related subscription. The value associated with the **currentCSV** field is the newest version that is known to OLM, and **installedCSV** is the version that is installed on the cluster.

**Additional resources**

- Viewing Operator subscription status by using the CLI

#### 2.4.1.2.4. Install plan

An *install plan*, defined by an **InstallPlan** object, describes a set of resources that Operator Lifecycle Manager (OLM) creates to install or upgrade to a specific version of an Operator. The version is defined by a cluster service version (CSV).

To install an Operator, a cluster administrator, or a user who has been granted Operator installation permissions, must first create a **Subscription** object. A subscription represents the intent to subscribe to a stream of available versions of an Operator from a catalog source. The subscription then creates an **InstallPlan** object to facilitate the installation of the resources for the Operator.

The install plan must then be approved according to one of the following approval strategies:

- If the subscription's **spec.installPlanApproval** field is set to **Automatic**, the install plan is approved automatically.
- If the subscription's **spec.installPlanApproval** field is set to **Manual**, the install plan must be manually approved by a cluster administrator or user with proper permissions.

After the install plan is approved, OLM creates the specified resources and installs the Operator in the namespace that is specified by the subscription.

**Example 2.3. Example InstallPlan object**

```
apiVersion: operators.coreos.com/v1alpha1
kind: InstallPlan
metadata:
  name: install-abcde
  namespace: operators
spec:
  approval: Automatic
  approved: true
  clusterServiceVersionNames:
    - my-operator.v1.0.1
  generation: 1
status:
  ...
  catalogSources: []
  conditions:
    - lastTransitionTime: '2021-01-01T20:17:27Z'
      lastUpdateTime: '2021-01-01T20:17:27Z'
      status: 'True'
      type: Installed
  phase: Complete
  plan:
    - resolving: my-operator.v1.0.1
      resource:
        group: operators.coreos.com
        kind: ClusterServiceVersion
        manifest: >-
        ...
        name: my-operator.v1.0.1
        sourceName: redhat-operators
        sourceNamespace: openshift-marketplace
        version: v1alpha1
      status: Created
    - resolving: my-operator.v1.0.1
      resource:
        group: apiextensions.k8s.io
        kind: CustomResourceDefinition
        manifest: >-
        ...
        name: webservers.web.servers.org
        sourceName: redhat-operators
        sourceNamespace: openshift-marketplace
        version: v1beta1
      status: Created
    - resolving: my-operator.v1.0.1
      resource:
```

```
      group: ''
      kind: ServiceAccount
      manifest: >-
      ...
      name: my-operator
      sourceName: redhat-operators
      sourceNamespace: openshift-marketplace
      version: v1
    status: Created
  - resolving: my-operator.v1.0.1
    resource:
      group: rbac.authorization.k8s.io
      kind: Role
      manifest: >-
      ...
      name: my-operator.v1.0.1-my-operator-6d7cbc6f57
      sourceName: redhat-operators
      sourceNamespace: openshift-marketplace
      version: v1
    status: Created
  - resolving: my-operator.v1.0.1
    resource:
      group: rbac.authorization.k8s.io
      kind: RoleBinding
      manifest: >-
      ...
      name: my-operator.v1.0.1-my-operator-6d7cbc6f57
      sourceName: redhat-operators
      sourceNamespace: openshift-marketplace
      version: v1
    status: Created
    ...
```

**Additional resources**

- Allowing non-cluster administrators to install Operators

#### 2.4.1.2.5. Operator groups

An *Operator group*, defined by the **OperatorGroup** resource, provides multitenant configuration to OLM-installed Operators. An Operator group selects target namespaces in which to generate required RBAC access for its member Operators.

The set of target namespaces is provided by a comma-delimited string stored in the **olm.targetNamespaces** annotation of a cluster service version (CSV). This annotation is applied to the CSV instances of member Operators and is projected into their deployments.

**Additional resources**

- Operator groups.

### 2.4.2. Operator Lifecycle Manager architecture

This guide outlines the component architecture of Operator Lifecycle Manager (OLM) in OpenShift Container Platform.

#### 2.4.2.1. Component responsibilities

Operator Lifecycle Manager (OLM) is composed of two Operators: the OLM Operator and the Catalog Operator.

Each of these Operators is responsible for managing the custom resource definitions (CRDs) that are the basis for the OLM framework:

**Table 2.2. CRDs managed by OLM and Catalog Operators**

| Resource | Short name | Owner | Description |
|---|---|---|---|
| **ClusterServiceVersion** (CSV) | **csv** | OLM | Application metadata: name, version, icon, required resources, installation, and so on. |
| **InstallPlan** | **ip** | Catalog | Calculated list of resources to be created to automatically install or upgrade a CSV. |
| **CatalogSource** | **catsrc** | Catalog | A repository of CSVs, CRDs, and packages that define an application. |
| **Subscription** | **sub** | Catalog | Used to keep CSVs up to date by tracking a channel in a package. |
| **OperatorGroup** | **og** | OLM | Configures all Operators deployed in the same namespace as the **OperatorGroup** object to watch for their custom resource (CR) in a list of namespaces or cluster-wide. |

Each of these Operators is also responsible for creating the following resources:

**Table 2.3. Resources created by OLM and Catalog Operators**

| Resource | Owner |
|---|---|
| **Deployments** | OLM |
| **ServiceAccounts** | |
| **(Cluster)Roles** | |
| **(Cluster)RoleBindings** | |
| **CustomResourceDefinitions** (CRDs) | Catalog |

| Resource | Owner |
| --- | --- |
| **ClusterServiceVersions** | |

#### 2.4.2.2. OLM Operator

The OLM Operator is responsible for deploying applications defined by CSV resources after the required resources specified in the CSV are present in the cluster.

The OLM Operator is not concerned with the creation of the required resources; you can choose to manually create these resources using the CLI or using the Catalog Operator. This separation of concern allows users incremental buy-in in terms of how much of the OLM framework they choose to leverage for their application.

The OLM Operator uses the following workflow:

1. Watch for cluster service versions (CSVs) in a namespace and check that requirements are met.
2. If requirements are met, run the install strategy for the CSV.

**NOTE**

A CSV must be an active member of an Operator group for the install strategy to run.

#### 2.4.2.3. Catalog Operator

The Catalog Operator is responsible for resolving and installing cluster service versions (CSVs) and the required resources they specify. It is also responsible for watching catalog sources for updates to packages in channels and upgrading them, automatically if desired, to the latest available versions.

To track a package in a channel, you can create a **Subscription** object configuring the desired package, channel, and the **CatalogSource** object you want to use for pulling updates. When updates are found, an appropriate **InstallPlan** object is written into the namespace on behalf of the user.

The Catalog Operator uses the following workflow:

1. Connect to each catalog source in the cluster.
2. Watch for unresolved install plans created by a user, and if found:
    a. Find the CSV matching the name requested and add the CSV as a resolved resource.
    b. For each managed or required CRD, add the CRD as a resolved resource.
    c. For each required CRD, find the CSV that manages it.
3. Watch for resolved install plans and create all of the discovered resources for it, if approved by a user or automatically.
4. Watch for catalog sources and subscriptions and create install plans based on them.

#### 2.4.2.4. Catalog Registry

The Catalog Registry stores CSVs and CRDs for creation in a cluster and stores metadata about packages and channels.

A *package manifest* is an entry in the Catalog Registry that associates a package identity with sets of CSVs. Within a package, channels point to a particular CSV. Because CSVs explicitly reference the CSV that they replace, a package manifest provides the Catalog Operator with all of the information that is required to update a CSV to the latest version in a channel, stepping through each intermediate version.

### 2.4.3. Operator Lifecycle Manager workflow

This guide outlines the workflow of Operator Lifecycle Manager (OLM) in OpenShift Container Platform.

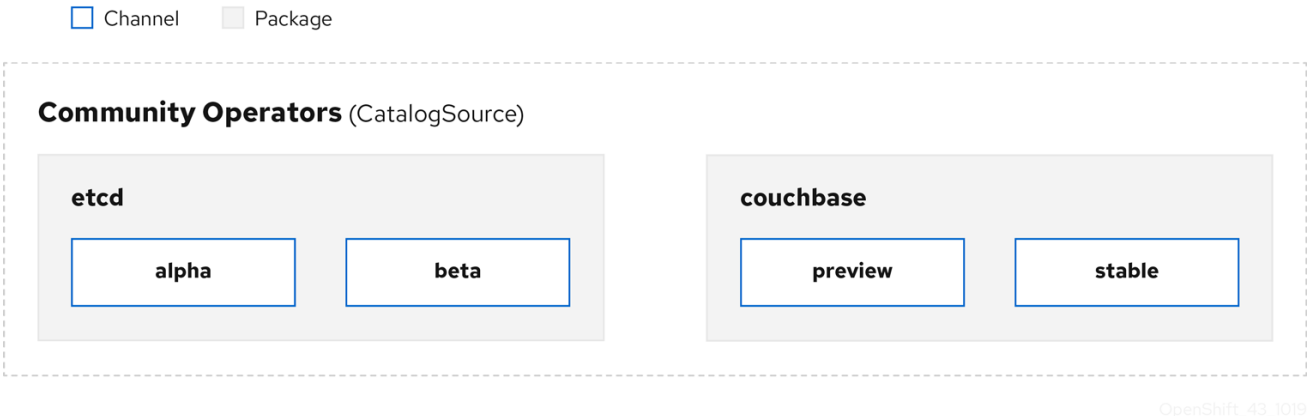
#### 2.4.3.1. Operator installation and upgrade workflow in OLM

In the Operator Lifecycle Manager (OLM) ecosystem, the following resources are used to resolve Operator installations and upgrades:

- **ClusterServiceVersion** (CSV)
- **CatalogSource**
- **Subscription**

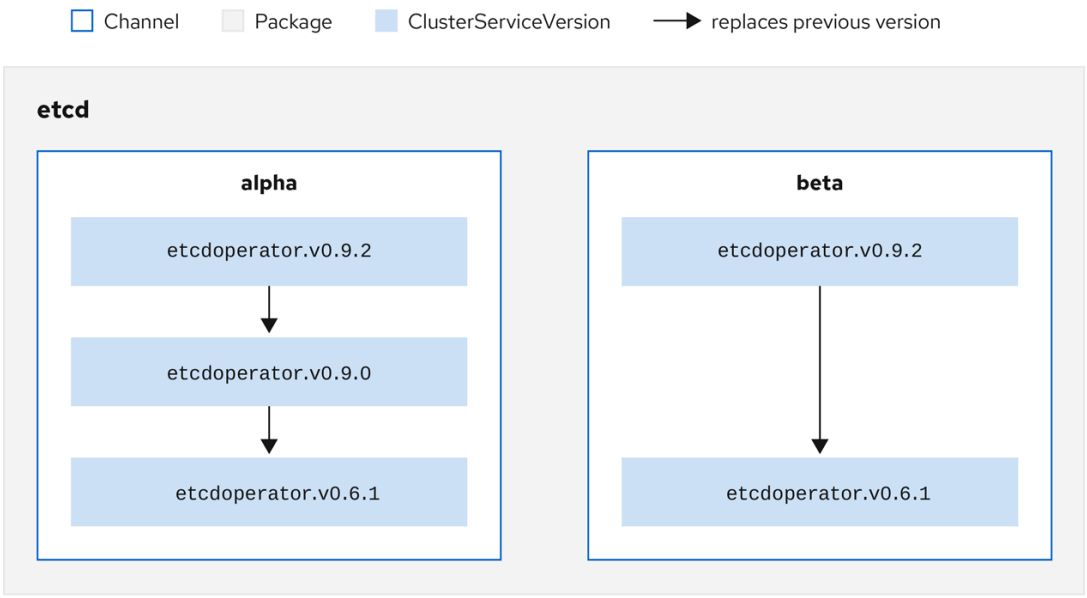
Operator metadata, defined in CSVs, can be stored in a collection called a catalog source. OLM uses catalog sources, which use the Operator Registry API, to query for available Operators as well as upgrades for installed Operators.

**Figure 2.3. Catalog source overview**




Within a catalog source, Operators are organized into *packages* and streams of updates called *channels*, which should be a familiar update pattern from OpenShift Container Platform or other software on a continuous release cycle like web browsers.

Figure 2.4. Packages and channels in a Catalog source



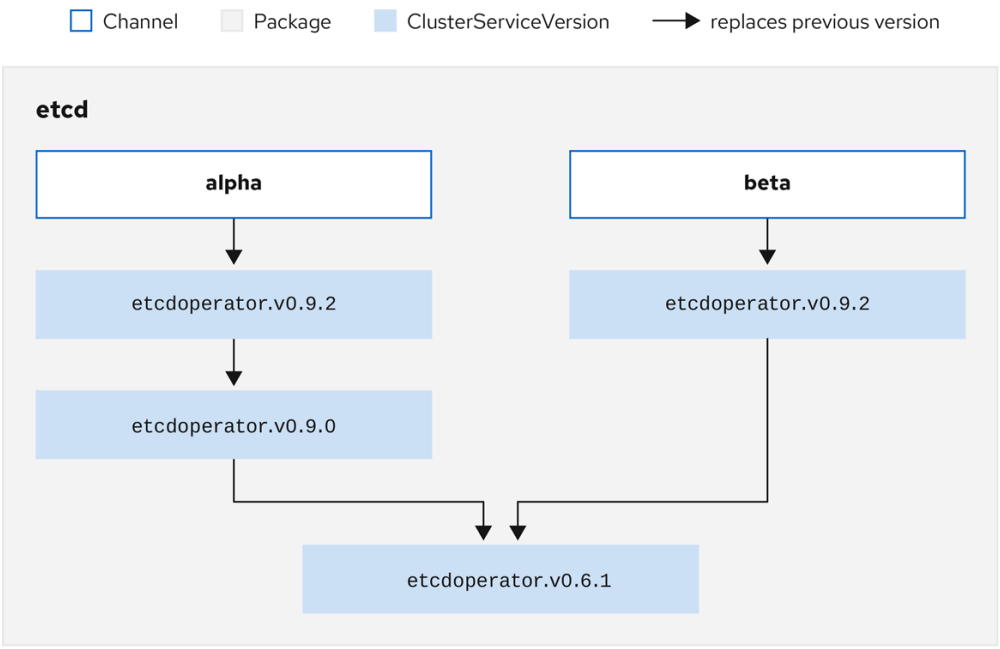

A user indicates a particular package and channel in a particular catalog source in a *subscription*, for example an **etcd** package and its **alpha** channel. If a subscription is made to a package that has not yet been installed in the namespace, the latest Operator for that package is installed.

NOTE

OLM deliberately avoids version comparisons, so the "latest" or "newest" Operator available from a given *catalog* → *channel* → *package* path does not necessarily need to be the highest version number. It should be thought of more as the *head* reference of a channel, similar to a Git repository.

Each CSV has a **replaces** parameter that indicates which Operator it replaces. This builds a graph of CSVs that can be queried by OLM, and updates can be shared between channels. Channels can be thought of as entry points into the graph of updates:

Figure 2.5. OLM graph of available channel updates




### Example channels in a package

```
packageName: example
channels:
- name: alpha
  currentCSV: example.v0.1.2
- name: beta
  currentCSV: example.v0.1.3
defaultChannel: alpha
```

For OLM to successfully query for updates, given a catalog source, package, channel, and CSV, a catalog must be able to return, unambiguously and deterministically, a single CSV that **replaces** the input CSV.

#### 2.4.3.1.1. Example upgrade path

For an example upgrade scenario, consider an installed Operator corresponding to CSV version **0.1.1**. OLM queries the catalog source and detects an upgrade in the subscribed channel with new CSV version **0.1.3** that replaces an older but not-installed CSV version **0.1.2**, which in turn replaces the older and installed CSV version **0.1.1**.

OLM walks back from the channel head to previous versions via the **replaces** field specified in the CSVs to determine the upgrade path **0.1.3 → 0.1.2 → 0.1.1**; the direction of the arrow indicates that the former replaces the latter. OLM upgrades the Operator one version at the time until it reaches the channel head.

For this given scenario, OLM installs Operator version **0.1.2** to replace the existing Operator version **0.1.1**. Then, it installs Operator version **0.1.3** to replace the previously installed Operator version **0.1.2**. At this point, the installed operator version **0.1.3** matches the channel head and the upgrade is completed.

#### 2.4.3.1.2. Skipping upgrades

The basic path for upgrades in OLM is:

- A catalog source is updated with one or more updates to an Operator.
- OLM traverses every version of the Operator until reaching the latest version the catalog source contains.

However, sometimes this is not a safe operation to perform. There will be cases where a published version of an Operator should never be installed on a cluster if it has not already, for example because a version introduces a serious vulnerability.

In those cases, OLM must consider two cluster states and provide an update graph that supports both:

- The "bad" intermediate Operator has been seen by the cluster and installed.
- The "bad" intermediate Operator has not yet been installed onto the cluster.

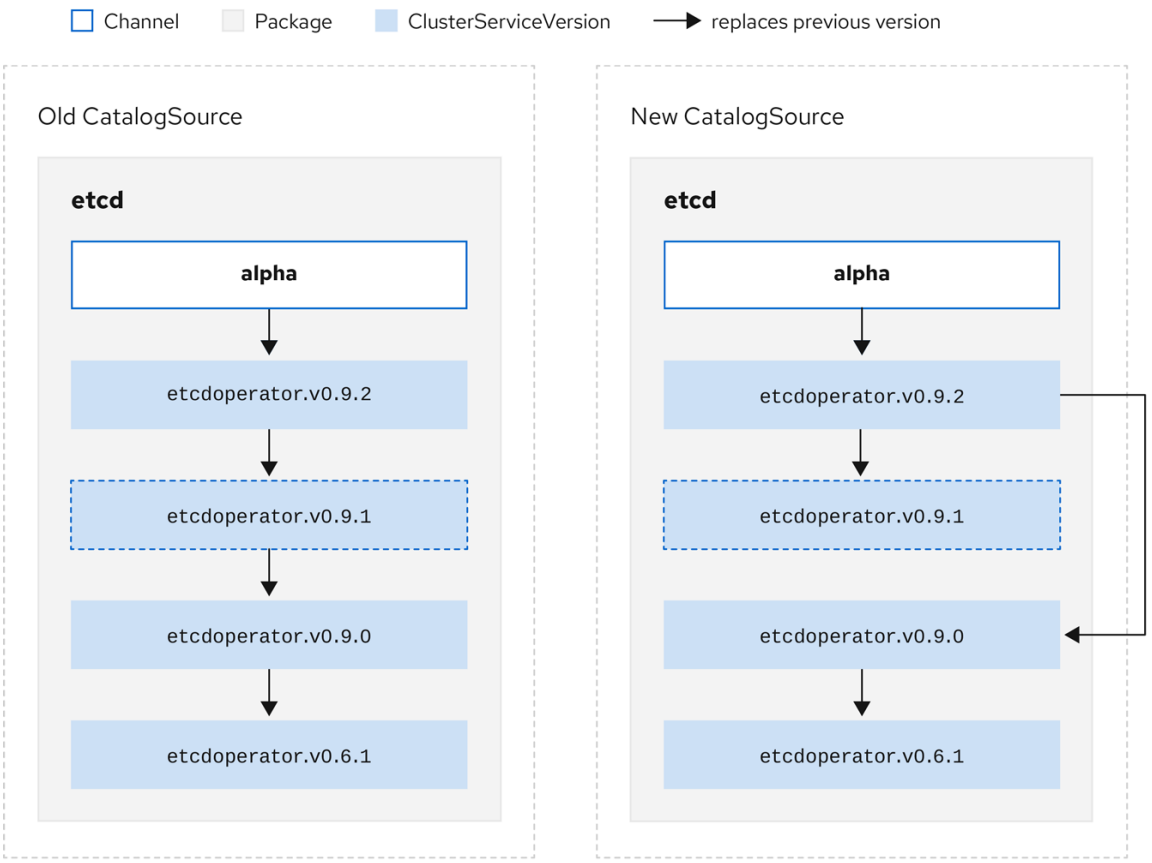
By shipping a new catalog and adding a *skipped* release, OLM is ensured that it can always get a single unique update regardless of the cluster state and whether it has seen the bad update yet.

### Example CSV with skipped release

```
apiVersion: operators.coreos.com/v1alpha1
kind: ClusterServiceVersion
metadata:
  name: etcdoperator.v0.9.2
  namespace: placeholder
  annotations:
spec:
    displayName: etcd
    description: Etcd Operator
    replaces: etcdoperator.v0.9.0
    skips:
    - etcdoperator.v0.9.1
```

Consider the following example of **Old CatalogSource** and **New CatalogSource**.

Figure 2.6. Skipping updates




This graph maintains that:

- Any Operator found in **Old CatalogSource** has a single replacement in **New CatalogSource**.
- Any Operator found in **New CatalogSource** has a single replacement in **New CatalogSource**.
- If the bad update has not yet been installed, it will never be.

#### 2.4.3.1.3. Replacing multiple Operators

Creating **New CatalogSource** as described requires publishing CSVs that **replace** one Operator, but can **skip** several. This can be accomplished using the **skipRange** annotation:

```
olm.skipRange: <semver_range>
```

where **<semver_range>** has the version range format supported by the semver library.

When searching catalogs for updates, if the head of a channel has a **skipRange** annotation and the currently installed Operator has a version field that falls in the range, OLM updates to the latest entry in the channel.

The order of precedence is:

1. Channel head in the source specified by **sourceName** on the subscription, if the other criteria for skipping are met.
2. The next Operator that replaces the current one, in the source specified by **sourceName**.

3. Channel head in another source that is visible to the subscription, if the other criteria for skipping are met.

4. The next Operator that replaces the current one in any source visible to the subscription.

### Example CSV with skipRange

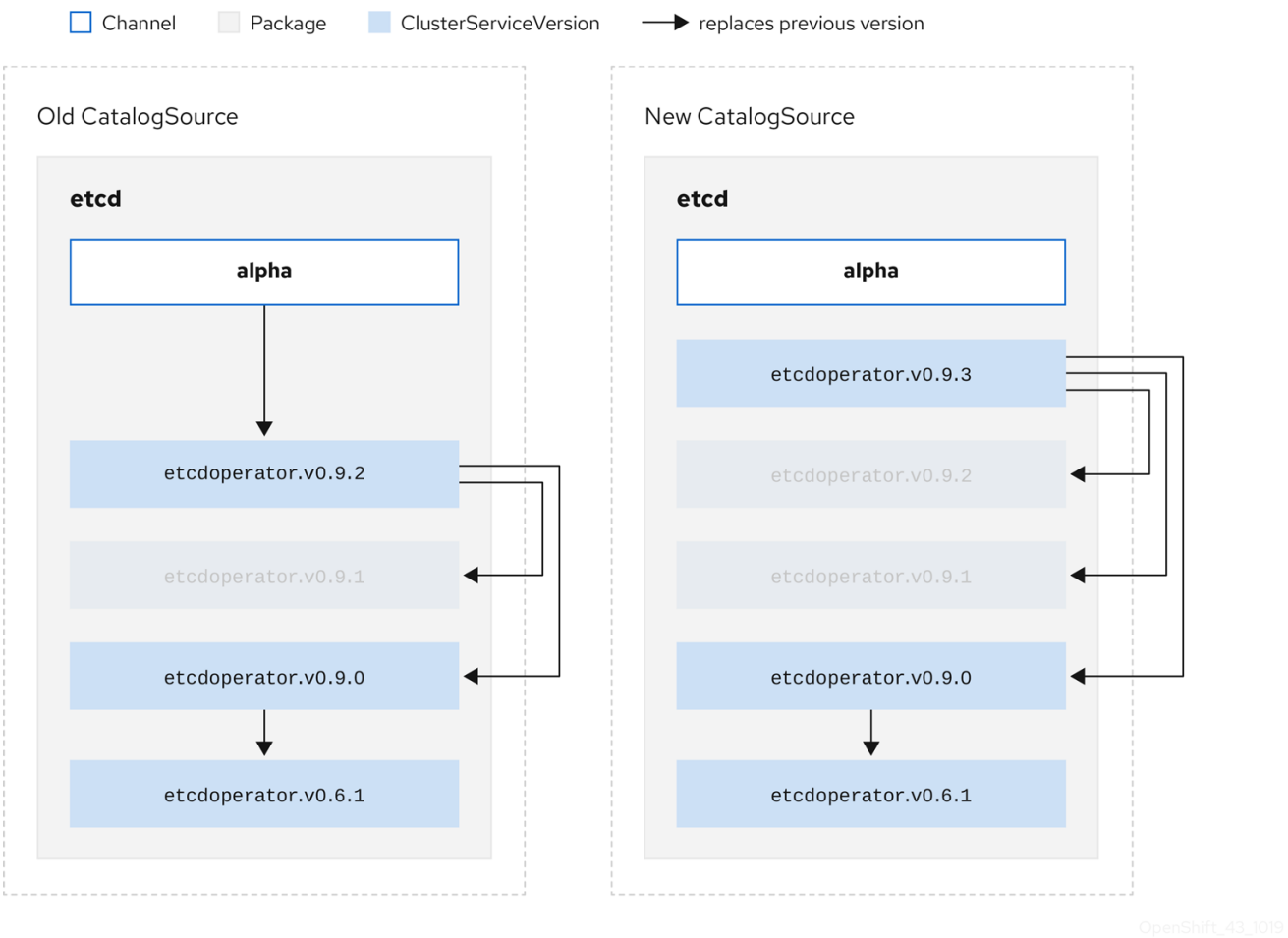
```
apiVersion: operators.coreos.com/v1alpha1
kind: ClusterServiceVersion
metadata:
  name: elasticsearch-operator.v4.1.2
  namespace: <namespace>
  annotations:
    olm.skipRange: '>=4.1.0 <4.1.2'
```

#### 2.4.3.1.4. Z-stream support

A *z-stream*, or patch release, must replace all previous z-stream releases for the same minor version. OLM does not consider major, minor, or patch versions, it just needs to build the correct graph in a catalog.

In other words, OLM must be able to take a graph as in **Old CatalogSource** and, similar to before, generate a graph as in **New CatalogSource**:

**Figure 2.7. Replacing several Operators**




This graph maintains that:

- Any Operator found in **Old CatalogSource** has a single replacement in **New CatalogSource**.
- Any Operator found in **New CatalogSource** has a single replacement in **New CatalogSource**.
- Any z-stream release in **Old CatalogSource** will update to the latest z-stream release in **New CatalogSource**.
- Unavailable releases can be considered "virtual" graph nodes; their content does not need to exist, the registry just needs to respond as if the graph looks like this.

### 2.4.4. Operator Lifecycle Manager dependency resolution

This guide outlines dependency resolution and custom resource definition (CRD) upgrade lifecycles with Operator Lifecycle Manager (OLM) in OpenShift Container Platform.

#### 2.4.4.1. About dependency resolution

OLM manages the dependency resolution and upgrade lifecycle of running Operators. In many ways, the problems OLM faces are similar to other operating system package managers like **yum** and **rpm**.

However, there is one constraint that similar systems do not generally have that OLM does: because Operators are always running, OLM attempts to ensure that you are never left with a set of Operators that do not work with each other.

This means that OLM must never do the following:

- Install a set of Operators that require APIs that cannot be provided.
- Update an Operator in a way that breaks another that depends upon it.

#### 2.4.4.2. Dependencies file

The dependencies of an Operator are listed in a **dependencies.yaml** file in the **metadata**/ folder of a bundle. This file is optional and currently only used to specify explicit Operator-version dependencies.

The dependency list contains a **type** field for each item to specify what kind of dependency this is. There are two supported types of Operator dependencies:

- **olm.package**: This type indicates a dependency for a specific Operator version. The dependency information must include the package name and the version of the package in semver format. For example, you can specify an exact version such as **0.5.2** or a range of versions such as **>0.5.1**.
- **olm.gvk**: With a **gvk** type, the author can specify a dependency with group/version/kind (GVK) information, similar to existing CRD and API-based usage in a CSV. This is a path to enable Operator authors to consolidate all dependencies, API or explicit versions, to be in the same place.

In the following example, dependencies are specified for a Prometheus Operator and etcd CRDs:

**Example dependencies.yaml file**

```
dependencies:
  - type: olm.package
    value:
      packageName: prometheus
```

```
      version: ">0.27.0"
  - type: olm.gvk
    value:
      group: etcd.database.coreos.com
      kind: EtcdCluster
      version: v1beta2
```

#### 2.4.4.3. Dependency preferences

There can be many options that equally satisfy a dependency of an Operator. The dependency resolver in Operator Lifecycle Manager (OLM) determines which option best fits the requirements of the requested Operator. As an Operator author or user, it can be important to understand how these choices are made so that dependency resolution is clear.

##### 2.4.4.3.1. Catalog priority

On OpenShift Container Platform cluster, OLM reads catalog sources to know which Operators are available for installation.

**Example CatalogSource object**

```
apiVersion: "operators.coreos.com/v1alpha1"
kind: "CatalogSource"
metadata:
  name: "my-operators"
  namespace: "operators"
spec:
  sourceType: grpc
  image: example.com/my/operator-index:v1
  displayName: "My Operators"
  priority: 100
```

A **CatalogSource** object has a **priority** field, which is used by the resolver to know how to prefer options for a dependency.

There are two rules that govern catalog preference:

- Options in higher-priority catalogs are preferred to options in lower-priority catalogs.
- Options in the same catalog as the dependent are preferred to any other catalogs.

##### 2.4.4.3.2. Channel ordering

An Operator package in a catalog is a collection of update channels that a user can subscribe to in a OpenShift Container Platform cluster. Channels can be used to provide a particular stream of updates for a minor release (**1.2**, **1.3**) or a release frequency (**stable**, **fast**).

It is likely that a dependency might be satisfied by Operators in the same package, but different channels. For example, version **1.2** of an Operator might exist in both the **stable** and **fast** channels.

Each package has a default channel, which is always preferred to non-default channels. If no option in the default channel can satisfy a dependency, options are considered from the remaining channels in lexicographic order of the channel name.

#### 2.4.4.3.3. Order within a channel

There are almost always multiple options to satisfy a dependency within a single channel. For example, Operators in one package and channel provide the same set of APIs.

When a user creates a subscription, they indicate which channel to receive updates from. This immediately reduces the search to just that one channel. But within the channel, it is likely that many Operators satisfy a dependency.

Within a channel, newer Operators that are higher up in the update graph are preferred. If the head of a channel satisfies a dependency, it will be tried first.

#### 2.4.4.3.4. Other constraints

In addition to the constraints supplied by package dependencies, OLM includes additional constraints to represent the desired user state and enforce resolution invariants.

##### 2.4.4.3.4.1. Subscription constraint

A subscription constraint filters the set of Operators that can satisfy a subscription. Subscriptions are user-supplied constraints for the dependency resolver. They declare the intent to either install a new Operator if it is not already on the cluster, or to keep an existing Operator updated.

##### 2.4.4.3.4.2. Package constraint

Within a namespace, no two Operators may come from the same package.

### 2.4.4.4. CRD upgrades

OLM upgrades a custom resource definition (CRD) immediately if it is owned by a singular cluster service version (CSV). If a CRD is owned by multiple CSVs, then the CRD is upgraded when it has satisfied all of the following backward compatible conditions:

- All existing serving versions in the current CRD are present in the new CRD.
- All existing instances, or custom resources, that are associated with the serving versions of the CRD are valid when validated against the validation schema of the new CRD.

**Additional resources**

- Adding a new CRD version
- Deprecating or removing a CRD version

### 2.4.4.5. Dependency best practices

When specifying dependencies, there are best practices you should consider.

**Depend on APIs or a specific version range of Operators**

Operators can add or remove APIs at any time; always specify an **olm.gvk** dependency on any APIs your Operators requires. The exception to this is if you are specifying **olm.package** constraints instead.

**Set a minimum version**

The Kubernetes documentation on API changes describes what changes are allowed for Kubernetes-style Operators. These versioning conventions allow an Operator to update an API without bumping the API version, as long as the API is backwards-compatible.
For Operator dependencies, this means that knowing the API version of a dependency might not be enough to ensure the dependent Operator works as intended.

For example:

- TestOperator v1.0.0 provides v1alpha1 API version of the **MyObject** resource.
- TestOperator v1.0.1 adds a new field **spec.newfield** to **MyObject**, but still at v1alpha1.

Your Operator might require the ability to write **spec.newfield** into the **MyObject** resource. An **olm.gvk** constraint alone is not enough for OLM to determine that you need TestOperator v1.0.1 and not TestOperator v1.0.0.

Whenever possible, if a specific Operator that provides an API is known ahead of time, specify an additional **olm.package** constraint to set a minimum.

#### Omit a maximum version or allow a very wide range

Because Operators provide cluster-scoped resources such as API services and CRDs, an Operator that specifies a small window for a dependency might unnecessarily constrain updates for other consumers of that dependency.
Whenever possible, do not set a maximum version. Alternatively, set a very wide semantic range to prevent conflicts with other Operators. For example, **>1.0.0 <2.0.0**.

Unlike with conventional package managers, Operator authors explicitly encode that updates are safe through channels in OLM. If an update is available for an existing subscription, it is assumed that the Operator author is indicating that it can update from the previous version. Setting a maximum version for a dependency overrides the update stream of the author by unnecessarily truncating it at a particular upper bound.

**NOTE**

Cluster administrators cannot override dependencies set by an Operator author.

However, maximum versions can and should be set if there are known incompatibilities that must be avoided. Specific versions can be omitted with the version range syntax, for example **> 1.0.0 !1.2.1**.

#### Additional resources

- Kubernetes documentation: Changing the API

### 2.4.4.6. Dependency caveats

When specifying dependencies, there are caveats you should consider.

#### No compound constraints (AND)

There is currently no method for specifying an AND relationship between constraints. In other words, there is no way to specify that one Operator depends on another Operator that both provides a given API and has version **>1.1.0**.
This means that when specifying a dependency such as:

```
dependencies:
- type: olm.package
  value:
    packageName: etcd
    version: ">3.1.0"
- type: olm.gvk
  value:
    group: etcd.database.coreos.com
    kind: EtcdCluster
    version: v1beta2
```

It would be possible for OLM to satisfy this with two Operators: one that provides EtcdCluster and one that has version **>3.1.0**. Whether that happens, or whether an Operator is selected that satisfies both constraints, depends on the ordering that potential options are visited. Dependency preferences and ordering options are well-defined and can be reasoned about, but to exercise caution, Operators should stick to one mechanism or the other.

**Cross-namespace compatibility**

OLM performs dependency resolution at the namespace scope. It is possible to get into an update deadlock if updating an Operator in one namespace would be an issue for an Operator in another namespace, and vice-versa.

### 2.4.4.7. Example dependency resolution scenarios

In the following examples, a *provider* is an Operator which "owns" a CRD or API service.

**Example: Deprecating dependent APIs**
A and B are APIs (CRDs):

- The provider of A depends on B.
- The provider of B has a subscription.
- The provider of B updates to provide C but deprecates B.

This results in:

- B no longer has a provider.
- A no longer works.

This is a case OLM prevents with its upgrade strategy.

**Example: Version deadlock**
A and B are APIs:

- The provider of A requires B.
- The provider of B requires A.
- The provider of A updates to (provide A2, require B2) and deprecate A.
- The provider of B updates to (provide B2, require A2) and deprecate B.

If OLM attempts to update A without simultaneously updating B, or vice-versa, it is unable to progress to new versions of the Operators, even though a new compatible set can be found.

This is another case OLM prevents with its upgrade strategy.

### 2.4.5. Operator groups

This guide outlines the use of Operator groups with Operator Lifecycle Manager (OLM) in OpenShift Container Platform.

#### 2.4.5.1. About Operator groups

An *Operator group*, defined by the **OperatorGroup** resource, provides multitenant configuration to OLM-installed Operators. An Operator group selects target namespaces in which to generate required RBAC access for its member Operators.

The set of target namespaces is provided by a comma-delimited string stored in the **olm.targetNamespaces** annotation of a cluster service version (CSV). This annotation is applied to the CSV instances of member Operators and is projected into their deployments.

#### 2.4.5.2. Operator group membership

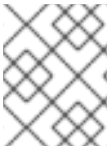
An Operator is considered a *member* of an Operator group if the following conditions are true:

- The CSV of the Operator exists in the same namespace as the Operator group.
- The install modes in the CSV of the Operator support the set of namespaces targeted by the Operator group.

An install mode in a CSV consists of an **InstallModeType** field and a boolean **Supported** field. The spec of a CSV can contain a set of install modes of four distinct **InstallModeTypes**:

**Table 2.4. Install modes and supported Operator groups**

| InstallModeType | Description |
|---|---|
| **OwnNamespace** | The Operator can be a member of an Operator group that selects its own namespace. |
| **SingleNamespace** | The Operator can be a member of an Operator group that selects one namespace. |
| **MultiNamespace** | The Operator can be a member of an Operator group that selects more than one namespace. |
| **AllNamespaces** | The Operator can be a member of an Operator group that selects all namespaces (target namespace set is the empty string **""**). |



NOTE

If the spec of a CSV omits an entry of **InstallModeType**, then that type is considered unsupported unless support can be inferred by an existing entry that implicitly supports it.

#### 2.4.5.3. Target namespace selection

You can explicitly name the target namespace for an Operator group using the **spec.targetNamespaces** parameter:

```
apiVersion: operators.coreos.com/v1
kind: OperatorGroup
metadata:
  name: my-group
  namespace: my-namespace
spec:
  targetNamespaces:
  - my-namespace
```

You can alternatively specify a namespace using a label selector with the **spec.selector** parameter:

```
apiVersion: operators.coreos.com/v1
kind: OperatorGroup
metadata:
  name: my-group
  namespace: my-namespace
spec:
  selector:
    cool.io/prod: "true"
```

IMPORTANT

Listing multiple namespaces via **spec.targetNamespaces** or use of a label selector via **spec.selector** is not recommended, as the support for more than one target namespace in an Operator group will likely be removed in a future release.

If both **spec.targetNamespaces** and **spec.selector** are defined, **spec.selector** is ignored. Alternatively, you can omit both **spec.selector** and **spec.targetNamespaces** to specify a *global* Operator group, which selects all namespaces:

```
apiVersion: operators.coreos.com/v1
kind: OperatorGroup
metadata:
  name: my-group
  namespace: my-namespace
```

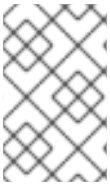
The resolved set of selected namespaces is shown in the **status.namespaces** parameter of an Opeator group. The **status.namespace** of a global Operator group contains the empty string ( **""**), which signals to a consuming Operator that it should watch all namespaces.

### 2.4.5.4. Operator group CSV annotations

Member CSVs of an Operator group have the following annotations:

| Annotation | Description |
|---|---|
| **olm.operatorGroup=<group_name>** | Contains the name of the Operator group. |

| Annotation | Description |
| --- | --- |
| **olm.operatorNamespace=<group_namespace>** | Contains the namespace of the Operator group. |
| **olm.targetNamespaces=<target_namespaces>** | Contains a comma-delimited string that lists the target namespace selection of the Operator group. |



NOTE

All annotations except **olm.targetNamespaces** are included with copied CSVs. Omitting the **olm.targetNamespaces** annotation on copied CSVs prevents the duplication of target namespaces between tenants.

#### 2.4.5.5. Provided APIs annotation

A *group/version/kind (GVK)* is a unique identifier for a Kubernetes API. Information about what GVKs are provided by an Operator group are shown in an **olm.providedAPIs** annotation. The value of the annotation is a string consisting of **<kind>.<version>.<group>** delimited with commas. The GVKs of CRDs and API services provided by all active member CSVs of an Operator group are included.

Review the following example of an **OperatorGroup** object with a single active member CSV that provides the **PackageManifest** resource:

```
apiVersion: operators.coreos.com/v1
kind: OperatorGroup
metadata:
  annotations:
    olm.providedAPIs: PackageManifest.v1alpha1.packages.apps.redhat.com
  name: olm-operators
  namespace: local
  ...
spec:
  selector: {}
  serviceAccount:
    metadata:
      creationTimestamp: null
  targetNamespaces:
  - local
status:
  lastUpdated: 2019-02-19T16:18:28Z
  namespaces:
  - local
```

#### 2.4.5.6. Role-based access control

When an Operator group is created, three cluster roles are generated. Each contains a single aggregation rule with a cluster role selector set to match a label, as shown below:

| Cluster role | Label to match |
| --- | --- |
| **<operatorgroup_name>-admin** | **olm.opgroup.permissions/aggregate-to-admin: <operatorgroup_name>** |
| **<operatorgroup_name>-edit** | **olm.opgroup.permissions/aggregate-to-edit: <operatorgroup_name>** |
| **<operatorgroup_name>-view** | **olm.opgroup.permissions/aggregate-to-view: <operatorgroup_name>** |

The following RBAC resources are generated when a CSV becomes an active member of an Operator group, as long as the CSV is watching all namespaces with the **AllNamespaces** install mode and is not in a failed state with reason **InterOperatorGroupOwnerConflict**:

- Cluster roles for each API resource from a CRD
- Cluster roles for each API resource from an API service
- Additional roles and role bindings

**Table 2.5. Cluster roles generated for each API resource from a CRD**

| Cluster role | Settings |
| --- | --- |
| **<kind>.<group>-<version>-admin** | Verbs on **<kind>**:<br>• *<br>Aggregation labels:<br>• **rbac.authorization.k8s.io/aggregate-to-admin: true**<br>• **olm.opgroup.permissions/aggregate-to-admin: <operatorgroup_name>** |

| Cluster role | Settings |
| --- | --- |
| **<kind>.<group>-<version>-edit** | Verbs on **<kind>**:<br>• **create**<br>• **update**<br>• **patch**<br>• **delete**<br>Aggregation labels:<br>• **rbac.authorization.k8s.io/aggregate-to-edit: true**<br>• **olm.opgroup.permissions/aggregate-to-edit: <operatorgroup_name>** |
| **<kind>.<group>-<version>-view** | Verbs on **<kind>**:<br>• **get**<br>• **list**<br>• **watch**<br>Aggregation labels:<br>• **rbac.authorization.k8s.io/aggregate-to-view: true**<br>• **olm.opgroup.permissions/aggregate-to-view: <operatorgroup_name>** |
| **<kind>.<group>-<version>-view-crdview** | Verbs on **apiextensions.k8s.io customresourcedefinitions <crd-name>**:<br>• **get**<br>Aggregation labels:<br>• **rbac.authorization.k8s.io/aggregate-to-view: true**<br>• **olm.opgroup.permissions/aggregate-to-view: <operatorgroup_name>** |

Table 2.6. Cluster roles generated for each API resource from an API service

| Cluster role | Settings |
| --- | --- |

| Cluster role | Settings |
| --- | --- |
| **<kind>.<group>-<version>-admin** | Verbs on **<kind>**:<br>• *****<br>Aggregation labels:<br>• **rbac.authorization.k8s.io/aggregate-to-admin: true**<br>• **olm.opgroup.permissions/aggregate-to-admin: <operatorgroup_name>** |
| **<kind>.<group>-<version>-edit** | Verbs on **<kind>**:<br>• **create**<br>• **update**<br>• **patch**<br>• **delete**<br>Aggregation labels:<br>• **rbac.authorization.k8s.io/aggregate-to-edit: true**<br>• **olm.opgroup.permissions/aggregate-to-edit: <operatorgroup_name>** |
| **<kind>.<group>-<version>-view** | Verbs on **<kind>**:<br>• **get**<br>• **list**<br>• **watch**<br>Aggregation labels:<br>• **rbac.authorization.k8s.io/aggregate-to-view: true**<br>• **olm.opgroup.permissions/aggregate-to-view: <operatorgroup_name>** |

Additional roles and role bindings

- If the CSV defines exactly one target namespace that contains *, then a cluster role and corresponding cluster role binding are generated for each permission defined in the **permissions** field of the CSV. All resources generated are given the **olm.owner: <csv_name>** and **olm.owner.namespace: <csv_namespace>** labels.

- If the CSV does *not* define exactly one target namespace that contains `*`, then all roles and role bindings in the Operator namespace with the **olm.owner: <csv_name>** and **olm.owner.namespace: <csv_namespace>** labels are copied into the target namespace.

#### 2.4.5.7. Copied CSVs

OLM creates copies of all active member CSVs of an Operator group in each of the target namespaces of that Operator group. The purpose of a copied CSV is to tell users of a target namespace that a specific Operator is configured to watch resources created there.

Copied CSVs have a status reason **Copied** and are updated to match the status of their source CSV. The **olm.targetNamespaces** annotation is stripped from copied CSVs before they are created on the cluster. Omitting the target namespace selection avoids the duplication of target namespaces between tenants.

Copied CSVs are deleted when their source CSV no longer exists or the Operator group that their source CSV belongs to no longer targets the namespace of the copied CSV.

#### 2.4.5.8. Static Operator groups

An Operator group is *static* if its **spec.staticProvidedAPIs** field is set to **true**. As a result, OLM does not modify the **olm.providedAPIs** annotation of an Operator group, which means that it can be set in advance. This is useful when a user wants to use an Operator group to prevent resource contention in a set of namespaces but does not have active member CSVs that provide the APIs for those resources.

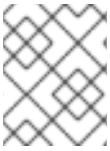
Below is an example of an Operator group that protects **Prometheus** resources in all namespaces with the **something.cool.io/cluster-monitoring: "true"** annotation:

```
apiVersion: operators.coreos.com/v1
kind: OperatorGroup
metadata:
  name: cluster-monitoring
  namespace: cluster-monitoring
  annotations:
    olm.providedAPIs:
Alertmanager.v1.monitoring.coreos.com,Prometheus.v1.monitoring.coreos.com,PrometheusRule.v1.mo
nitoring.coreos.com,ServiceMonitor.v1.monitoring.coreos.com
spec:
  staticProvidedAPIs: true
  selector:
    matchLabels:
      something.cool.io/cluster-monitoring: "true"
```

#### 2.4.5.9. Operator group intersection

Two Operator groups are said to have *intersecting provided APIs* if the intersection of their target namespace sets is not an empty set and the intersection of their provided API sets, defined by **olm.providedAPIs** annotations, is not an empty set.

A potential issue is that Operator groups with intersecting provided APIs can compete for the same resources in the set of intersecting namespaces.



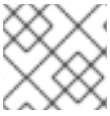
NOTE

When checking intersection rules, an Operator group namespace is always included as part of its selected target namespaces.

**Rules for intersection**

Each time an active member CSV synchronizes, OLM queries the cluster for the set of intersecting provided APIs between the Operator group of the CSV and all others. OLM then checks if that set is an empty set:

- If **true** and the CSV's provided APIs are a subset of the Operator group's:
  - Continue transitioning.
- If **true** and the CSV's provided APIs are *not* a subset of the Operator group's:
  - If the Operator group is static:
    - Clean up any deployments that belong to the CSV.
    - Transition the CSV to a failed state with status reason **CannotModifyStaticOperatorGroupProvidedAPIs**.
  - If the Operator group is *not* static:
    - Replace the Operator group's **olm.providedAPIs** annotation with the union of itself and the CSV's provided APIs.
- If **false** and the CSV's provided APIs are *not* a subset of the Operator group's:
  - Clean up any deployments that belong to the CSV.
  - Transition the CSV to a failed state with status reason **InterOperatorGroupOwnerConflict**.
- If **false** and the CSV's provided APIs are a subset of the Operator group's:
  - If the Operator group is static:
    - Clean up any deployments that belong to the CSV.
    - Transition the CSV to a failed state with status reason **CannotModifyStaticOperatorGroupProvidedAPIs**.
  - If the Operator group is *not* static:
    - Replace the Operator group's **olm.providedAPIs** annotation with the difference between itself and the CSV's provided APIs.



NOTE

Failure states caused by Operator groups are non-terminal.

The following actions are performed each time an Operator group synchronizes:

- The set of provided APIs from active member CSVs is calculated from the cluster. Note that copied CSVs are ignored.

- The cluster set is compared to **olm.providedAPIs**, and if **olm.providedAPIs** contains any extra APIs, then those APIs are pruned.
- All CSVs that provide the same APIs across all namespaces are requeued. This notifies conflicting CSVs in intersecting groups that their conflict has possibly been resolved, either through resizing or through deletion of the conflicting CSV.

#### 2.4.5.10. Limitations for multi-tenant Operator management

OpenShift Container Platform provides limited support for simultaneously installing different variations of an Operator on a cluster. Operators are control plane extensions. All tenants, or namespaces, share the same control plane of a cluster. Therefore, tenants in a multi-tenant environment also have to share Operators.

The Operator Lifecycle Manager (OLM) installs Operators multiple times in different namespaces. One constraint of this is that the Operator's API versions must be the same.

Different major versions of an Operator often have incompatible custom resource definitions (CRDs). This makes it difficult to quickly verify OLMs.

##### 2.4.5.10.1. Additional resources

- Allowing non-cluster administrators to install Operators

#### 2.4.5.11. Troubleshooting Operator groups

**Membership**

- If more than one Operator group exists in a single namespace, any CSV created in that namespace transitions to a failure state with the reason **TooManyOperatorGroups**. CSVs in a failed state for this reason transition to pending after the number of Operator groups in their namespaces reaches one.
- If the install modes of a CSV do not support the target namespace selection of the Operator group in its namespace, the CSV transitions to a failure state with the reason **UnsupportedOperatorGroup**. CSVs in a failed state for this reason transition to pending after either the target namespace selection of the Operator group changes to a supported configuration, or the install modes of the CSV are modified to support the target namespace selection.

### 2.4.6. Operator Lifecycle Manager metrics

#### 2.4.6.1. Exposed metrics

Operator Lifecycle Manager (OLM) exposes certain OLM-specific resources for use by the Prometheus-based OpenShift Container Platform cluster monitoring stack.

**Table 2.7. Metrics exposed by OLM**

| Name | Description |
|---|---|
| **catalog_source_count** | Number of catalog sources. |

| Name | Description |
|---|---|
| **csv_abnormal** | When reconciling a cluster service version (CSV), present whenever a CSV version is in any state other than **Succeeded**, for example when it is not installed. Includes the **name**, **namespace**, **phase**, **reason**, and **version** labels. A Prometheus alert is created when this metric is present. |
| **csv_count** | Number of CSVs successfully registered. |
| **csv_succeeded** | When reconciling a CSV, represents whether a CSV version is in a **Succeeded** state (value **1**) or not (value **0**). Includes the **name**, **namespace**, and **version** labels. |
| **csv_upgrade_count** | Monotonic count of CSV upgrades. |
| **install_plan_count** | Number of install plans. |
| **subscription_count** | Number of subscriptions. |
| **subscription_sync_total** | Monotonic count of subscription syncs. Includes the **channel**, **installed** CSV, and subscription **name** labels. |

### 2.4.7. Webhook management in Operator Lifecycle Manager

Webhooks allow Operator authors to intercept, modify, and accept or reject resources before they are saved to the object store and handled by the Operator controller. Operator Lifecycle Manager (OLM) can manage the lifecycle of these webhooks when they are shipped alongside your Operator.

See Generating a cluster service version (CSV) for details on how an Operator developer can define webhooks for their Operator, as well as considerations when running on OLM.

#### 2.4.7.1. Additional resources

- Types of webhook admission plug-ins
- Kubernetes documentation:
  - Validating admission webhooks
  - Mutating admission webhooks
  - Conversion webhooks

## 2.5. UNDERSTANDING OPERATORHUB

### 2.5.1. About OperatorHub

*OperatorHub* is the web console interface in OpenShift Container Platform that cluster administrators use to discover and install Operators. With one click, an Operator can be pulled from its off-cluster source, installed and subscribed on the cluster, and made ready for engineering teams to self-service manage the product across deployment environments using Operator Lifecycle Manager (OLM).

Cluster administrators can choose from catalogs grouped into the following categories:

| Category | Description |
|---|---|
| Red Hat Operators | Red Hat products packaged and shipped by Red Hat. Supported by Red Hat. |
| Certified Operators | Products from leading independent software vendors (ISVs). Red Hat partners with ISVs to package and ship. Supported by the ISV. |
| Red Hat Marketplace | Certified software that can be purchased from Red Hat Marketplace. |
| Community Operators | Optionally-visible software maintained by relevant representatives in the operator-framework/community-operators GitHub repository. No official support. |
| Custom Operators | Operators you add to the cluster yourself. If you have not added any custom Operators, the **Custom** category does not appear in the web console on your OperatorHub. |

Operators on OperatorHub are packaged to run on OLM. This includes a YAML file called a cluster service version (CSV) containing all of the CRDs, RBAC rules, deployments, and container images required to install and securely run the Operator. It also contains user-visible information like a description of its features and supported Kubernetes versions.

The Operator SDK can be used to assist developers packaging their Operators for use on OLM and OperatorHub. If you have a commercial application that you want to make accessible to your customers, get it included using the certification workflow provided on the Red Hat Partner Connect portal at connect.redhat.com.

### 2.5.2. OperatorHub architecture

The OperatorHub UI component is driven by the Marketplace Operator by default on OpenShift Container Platform in the **openshift-marketplace** namespace.

#### 2.5.2.1. OperatorHub custom resource

The Marketplace Operator manages an **OperatorHub** custom resource (CR) named **cluster** that manages the default **CatalogSource** objects provided with OperatorHub. You can modify this resource to enable or disable the default catalogs, which is useful when configuring OpenShift Container Platform in restricted network environments.

**Example OperatorHub custom resource**

```
apiVersion: config.openshift.io/v1
kind: OperatorHub
metadata:
  name: cluster
spec:
```

```
disableAllDefaultSources: true (1)
sources: [ (2)
  {
    name: "community-operators",
    disabled: false
  }
]
```

(1) **disableAllDefaultSources** is an override that controls availability of all default catalogs that are configured by default during an OpenShift Container Platform installation.

(2) Disable default catalogs individually by changing the **disabled** parameter value per source.

### 2.5.3. Additional resources

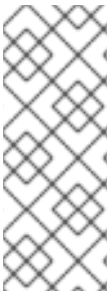
- Catalog source
- Getting started with the Operator SDK
- Generating a ClusterServiceVersion (CSV)
- Operator installation and upgrade workflow in OLM
- Red Hat Partner Connect
- Red Hat Marketplace

## 2.6. RED HAT-PROVIDED OPERATOR CATALOGS

### 2.6.1. About Operator catalogs

An Operator catalog is a repository of metadata that Operator Lifecycle Manager (OLM) can query to discover and install Operators and their dependencies on a cluster. OLM always installs Operators from the latest version of a catalog. As of OpenShift Container Platform 4.6, Red Hat-provided catalogs are distributed using *index images*.

An index image, based on the Operator Bundle Format, is a containerized snapshot of a catalog. It is an immutable artifact that contains the database of pointers to a set of Operator manifest content. A catalog can reference an index image to source its content for OLM on the cluster.

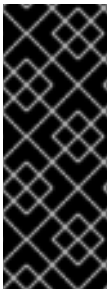


NOTE

Starting in OpenShift Container Platform 4.6, index images provided by Red Hat replace the App Registry catalog images, based on the deprecated Package Manifest Format, that are distributed for previous versions of OpenShift Container Platform 4. While App Registry catalog images are not distributed by Red Hat for OpenShift Container Platform 4.6 and later, custom catalog images based on the Package Manifest Format are still supported.

As catalogs are updated, the latest versions of Operators change, and older versions may be removed or altered. In addition, when OLM runs on an OpenShift Container Platform cluster in a restricted network environment, it is unable to access the catalogs directly from the Internet to pull the latest content.

As a cluster administrator, you can create your own custom index image, either based on a Red Hat-provided catalog or from scratch, which can be used to source the catalog content on the cluster. Creating and updating your own index image provides a method for customizing the set of Operators available on the cluster, while also avoiding the aforementioned restricted network environment issues.



**IMPORTANT**

When creating custom catalog images, previous versions of OpenShift Container Platform 4 required using the **oc adm catalog build** command, which has been deprecated for several releases. With the availability of Red Hat-provided index images starting in OpenShift Container Platform 4.6, catalog builders should start switching to using the **opm index** command to manage index images before the **oc adm catalog build** command is removed in a future release.

**Additional resources**

- Managing custom catalogs
- Using Operator Lifecycle Manager on restricted networks

### 2.6.2. About Red Hat-provided Operator catalogs

The following Operator catalogs are distributed by Red Hat:

| Catalog | Index image | Description |
|---|---|---|
| **redhat-operators** | **registry.redhat.io/redhat/redhat-operator-index:v4.6** | Red Hat products packaged and shipped by Red Hat. Supported by Red Hat. |
| **certified-operators** | **registry.redhat.io/redhat/certified-operator-index:v4.6** | Products from leading independent software vendors (ISVs). Red Hat partners with ISVs to package and ship. Supported by the ISV. |
| **redhat-marketplace** | **registry.redhat.io/redhat/redhat-marketplace-index:v4.6** | Certified software that can be purchased from Red Hat Marketplace. |
| **community-operators** | **registry.redhat.io/redhat/community-operator-index:v4.6** | Software maintained by relevant representatives in the operator-framework/community-operators GitHub repository. No official support. |

## 2.7. CRDS

### 2.7.1. Extending the Kubernetes API with custom resource definitions

This guide describes how cluster administrators can extend their OpenShift Container Platform cluster by creating and managing custom resource definitions (CRDs).

#### 2.7.1.1. Custom resource definitions

In the Kubernetes API, a *resource* is an endpoint that stores a collection of API objects of a certain kind. For example, the built-in **Pods** resource contains a collection of **Pod** objects.

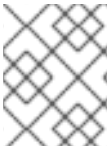
A *custom resource definition* (CRD) object defines a new, unique object type, called a *kind*, in the cluster and lets the Kubernetes API server handle its entire lifecycle.

*Custom resource* (CR) objects are created from CRDs that have been added to the cluster by a cluster administrator, allowing all cluster users to add the new resource type into projects.

When a cluster administrator adds a new CRD to the cluster, the Kubernetes API server reacts by creating a new RESTful resource path that can be accessed by the entire cluster or a single project (namespace) and begins serving the specified CR.

Cluster administrators that want to grant access to the CRD to other users can use cluster role aggregation to grant access to users with the **admin**, **edit**, or **view** default cluster roles. Cluster role aggregation allows the insertion of custom policy rules into these cluster roles. This behavior integrates the new resource into the RBAC policy of the cluster as if it was a built-in resource.

Operators in particular make use of CRDs by packaging them with any required RBAC policy and other software-specific logic. Cluster administrators can also add CRDs manually to the cluster outside of the lifecycle of an Operator, making them available to all users.



**NOTE**

While only cluster administrators can create CRDs, developers can create the CR from an existing CRD if they have read and write permission to it.

#### 2.7.1.2. Creating a custom resource definition

To create custom resource (CR) objects, cluster administrators must first create a custom resource definition (CRD).

**Prerequisites**

- Access to an OpenShift Container Platform cluster with **cluster-admin** user privileges.

**Procedure**

To create a CRD:

1. Create a YAML file that contains the following field types:

**Example YAML file for a CRD**

```
apiVersion: apiextensions.k8s.io/v1 1
kind: CustomResourceDefinition
metadata:
  name: crontabs.stable.example.com 2
```

```
spec:
  group: stable.example.com 3
  versions:
    name: v1 4
  scope: Namespaced 5
  names:
    plural: crontabs 6
    singular: crontab 7
    kind: CronTab 8
    shortNames:
    - ct 9
```

1. Use the **apiextensions.k8s.io/v1** API.
2. Specify a name for the definition. This must be in the **<plural-name>.<group>** format using the values from the **group** and **plural** fields.
3. Specify a group name for the API. An API group is a collection of objects that are logically related. For example, all batch objects like **Job** or **ScheduledJob** could be in the batch API group (such as **batch.api.example.com**). A good practice is to use a fully-qualified-domain name (FQDN) of your organization.
4. Specify a version name to be used in the URL. Each API group can exist in multiple versions, for example **v1alpha**, **v1beta**, **v1**.
5. Specify whether the custom objects are available to a project (**Namespaced**) or all projects in the cluster (**Cluster**).
6. Specify the plural name to use in the URL. The **plural** field is the same as a resource in an API URL.
7. Specify a singular name to use as an alias on the CLI and for display.
8. Specify the kind of objects that can be created. The type can be in CamelCase.
9. Specify a shorter string to match your resource on the CLI.

**NOTE**

By default, a CRD is cluster-scoped and available to all projects.

2. Create the CRD object:

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

A new RESTful API endpoint is created at:

```
/apis/<spec:group>/<spec:version>/<scope>/*/<names-plural>/...
```

For example, using the example file, the following endpoint is created:

```
/apis/stable.example.com/v1/namespaces/*/crontabs/...
```

You can now use this endpoint URL to create and manage CRs. The object kind is based on the **spec.kind** field of the CRD object you created.

### 2.7.1.3. Creating cluster roles for custom resource definitions

Cluster administrators can grant permissions to existing cluster-scoped custom resource definitions (CRDs). If you use the **admin**, **edit**, and **view** default cluster roles, you can take advantage of cluster role aggregation for their rules.

**IMPORTANT**

You must explicitly assign permissions to each of these roles. The roles with more permissions do not inherit rules from roles with fewer permissions. If you assign a rule to a role, you must also assign that verb to roles that have more permissions. For example, if you grant the **get crontabs** permission to the view role, you must also grant it to the **edit** and **admin** roles. The **admin** or **edit** role is usually assigned to the user that created a project through the project template.

**Prerequisites**

- Create a CRD.

**Procedure**

1. Create a cluster role definition file for the CRD. The cluster role definition is a YAML file that contains the rules that apply to each cluster role. A OpenShift Container Platform controller adds the rules that you specify to the default cluster roles.

**Example YAML file for a cluster role definition**

```
kind: ClusterRole
apiVersion: rbac.authorization.k8s.io/v1 (1)
metadata:
  name: aggregate-cron-tabs-admin-edit (2)
  labels:
    rbac.authorization.k8s.io/aggregate-to-admin: "true" (3)
    rbac.authorization.k8s.io/aggregate-to-edit: "true" (4)
rules:
- apiGroups: ["stable.example.com"] (5)
  resources: ["crontabs"] (6)
  verbs: ["get", "list", "watch", "create", "update", "patch", "delete", "deletecollection"] (7)
---
kind: ClusterRole
apiVersion: rbac.authorization.k8s.io/v1
metadata:
  name: aggregate-cron-tabs-view (8)
  labels:
    # Add these permissions to the "view" default role.
    rbac.authorization.k8s.io/aggregate-to-view: "true" (9)
    rbac.authorization.k8s.io/aggregate-to-cluster-reader: "true" (10)
rules:
```

```
- apiGroups: ["stable.example.com"] 11
  resources: ["crontabs"] 12
  verbs: ["get", "list", "watch"] 13
```

1 Use the **rbac.authorization.k8s.io/v1** API.

2 8 Specify a name for the definition.

3 Specify this label to grant permissions to the admin default role.

4 Specify this label to grant permissions to the edit default role.

5 11 Specify the group name of the CRD.

6 12 Specify the plural name of the CRD that these rules apply to.

7 13 Specify the verbs that represent the permissions that are granted to the role. For example, apply read and write permissions to the **admin** and **edit** roles and only read permission to the **view** role.

9 Specify this label to grant permissions to the **view** default role.

10 Specify this label to grant permissions to the **cluster-reader** default role.

2. Create the cluster role:

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

#### 2.7.1.4. Creating custom resources from a file

After a custom resource definitions (CRD) has been added to the cluster, custom resources (CRs) can be created with the CLI from a file using the CR specification.

**Prerequisites**

- CRD added to the cluster by a cluster administrator.

**Procedure**

1. Create a YAML file for the CR. In the following example definition, the **cronSpec** and **image** custom fields are set in a CR of **Kind: CronTab**. The **Kind** comes from the **spec.kind** field of the CRD object:

**Example YAML file for a CR**

```
apiVersion: "stable.example.com/v1" 1
kind: CronTab 2
metadata:
  name: my-new-cron-object 3
  finalizers: 4
  - finalizer.stable.example.com
```

```
spec: 5
  cronSpec: "* * * * /5"
  image: my-awesome-cron-image
```

1. Specify the group name and API version (name/version) from the CRD.
2. Specify the type in the CRD.
3. Specify a name for the object.
4. Specify the finalizers for the object, if any. Finalizers allow controllers to implement conditions that must be completed before the object can be deleted.
5. Specify conditions specific to the type of object.

2. After you create the file, create the object:

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

#### 2.7.1.5. Inspecting custom resources

You can inspect custom resource (CR) objects that exist in your cluster using the CLI.

**Prerequisites**

- A CR object exists in a namespace to which you have access.

**Procedure**

1. To get information on a specific kind of a CR, run:

```
$ oc get <kind>
```

For example:

```
$ oc get crontab
```

**Example output**

```
NAME                 KIND
my-new-cron-object   CronTab.v1.stable.example.com
```

Resource names are not case-sensitive, and you can use either the singular or plural forms defined in the CRD, as well as any short name. For example:

```
$ oc get crontabs
```

```
$ oc get crontab
```

```
$ oc get ct
```

2. You can also view the raw YAML data for a CR:

```
$ oc get <kind> -o yaml
```

For example:

```
$ oc get ct -o yaml
```

**Example output**

```
apiVersion: v1
items:
- apiVersion: stable.example.com/v1
  kind: CronTab
  metadata:
    clusterName: ""
    creationTimestamp: 2017-05-31T12:56:35Z
    deletionGracePeriodSeconds: null
    deletionTimestamp: null
    name: my-new-cron-object
    namespace: default
    resourceVersion: "285"
    selfLink: /apis/stable.example.com/v1/namespaces/default/crontabs/my-new-cron-object
    uid: 9423255b-4600-11e7-af6a-28d2447dc82b
  spec:
    cronSpec: '* * * * /5' 1
    image: my-awesome-cron-image 2
```

1 2 Custom data from the YAML that you used to create the object displays.

## 2.7.2. Managing resources from custom resource definitions

This guide describes how developers can manage custom resources (CRs) that come from custom resource definitions (CRDs).

### 2.7.2.1. Custom resource definitions

In the Kubernetes API, a *resource* is an endpoint that stores a collection of API objects of a certain kind. For example, the built-in **Pods** resource contains a collection of **Pod** objects.

A *custom resource definition* (CRD) object defines a new, unique object type, called a *kind*, in the cluster and lets the Kubernetes API server handle its entire lifecycle.

*Custom resource* (CR) objects are created from CRDs that have been added to the cluster by a cluster administrator, allowing all cluster users to add the new resource type into projects.

Operators in particular make use of CRDs by packaging them with any required RBAC policy and other software-specific logic. Cluster administrators can also add CRDs manually to the cluster outside of the lifecycle of an Operator, making them available to all users.

**NOTE**

While only cluster administrators can create CRDs, developers can create the CR from an existing CRD if they have read and write permission to it.

### 2.7.2.2. Creating custom resources from a file

After a custom resource definitions (CRD) has been added to the cluster, custom resources (CRs) can be created with the CLI from a file using the CR specification.

#### Prerequisites

- CRD added to the cluster by a cluster administrator.

#### Procedure

1. Create a YAML file for the CR. In the following example definition, the **cronSpec** and **image** custom fields are set in a CR of **Kind: CronTab**. The **Kind** comes from the **spec.kind** field of the CRD object:

   **Example YAML file for a CR**

```
apiVersion: "stable.example.com/v1" 1
kind: CronTab 2
metadata:
  name: my-new-cron-object 3
  finalizers: 4
  - finalizer.stable.example.com
spec: 5
  cronSpec: "* * * * /5"
  image: my-awesome-cron-image
```

   1. Specify the group name and API version (name/version) from the CRD.
   2. Specify the type in the CRD.
   3. Specify a name for the object.
   4. Specify the finalizers for the object, if any. Finalizers allow controllers to implement conditions that must be completed before the object can be deleted.
   5. Specify conditions specific to the type of object.

2. After you create the file, create the object:

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

### 2.7.2.3. Inspecting custom resources

You can inspect custom resource (CR) objects that exist in your cluster using the CLI.

#### Prerequisites

- A CR object exists in a namespace to which you have access.

**Procedure**

1. To get information on a specific kind of a CR, run:

```
$ oc get <kind>
```

For example:

```
$ oc get crontab
```

**Example output**

```
NAME                 KIND
my-new-cron-object   CronTab.v1.stable.example.com
```

Resource names are not case-sensitive, and you can use either the singular or plural forms defined in the CRD, as well as any short name. For example:

```
$ oc get crontabs
```

```
$ oc get crontab
```

```
$ oc get ct
```

2. You can also view the raw YAML data for a CR:

```
$ oc get <kind> -o yaml
```

For example:

```
$ oc get ct -o yaml
```

**Example output**

```
apiVersion: v1
items:
- apiVersion: stable.example.com/v1
  kind: CronTab
  metadata:
    clusterName: ""
    creationTimestamp: 2017-05-31T12:56:35Z
    deletionGracePeriodSeconds: null
    deletionTimestamp: null
    name: my-new-cron-object
    namespace: default
    resourceVersion: "285"
    selfLink: /apis/stable.example.com/v1/namespaces/default/crontabs/my-new-cron-object
    uid: 9423255b-4600-11e7-af6a-28d2447dc82b
```

```
spec:
  cronSpec: '* * * * /5' 1
  image: my-awesome-cron-image 2
```

1 2 Custom data from the YAML that you used to create the object displays.

# CHAPTER 3. USER TASKS

## 3.1. CREATING APPLICATIONS FROM INSTALLED OPERATORS

This guide walks developers through an example of creating applications from an installed Operator using the OpenShift Container Platform web console.

### 3.1.1. Creating an etcd cluster using an Operator

This procedure walks through creating a new etcd cluster using the etcd Operator, managed by Operator Lifecycle Manager (OLM).

**Prerequisites**

- Access to an OpenShift Container Platform 4.6 cluster.
- The etcd Operator already installed cluster-wide by an administrator.

**Procedure**

1. Create a new project in the OpenShift Container Platform web console for this procedure. This example uses a project called **my-etcd**.
2. Navigate to the **Operators → Installed Operators** page. The Operators that have been installed to the cluster by the cluster administrator and are available for use are shown here as a list of cluster service versions (CSVs). CSVs are used to launch and manage the software provided by the Operator.

   **TIP**

   You can get this list from the CLI using:

   ```
   $ oc get csv
   ```

3. On the **Installed Operators** page, click the etcd Operator to view more details and available actions.
   As shown under **Provided APIs**, this Operator makes available three new resource types, including one for an **etcd Cluster** (the **EtcdCluster** resource). These objects work similar to the built-in native Kubernetes ones, such as **Deployment** or **ReplicaSet**, but contain logic specific to managing etcd.
4. Create a new etcd cluster:
   a. In the **etcd Cluster** API box, click **Create instance**.
   b. The next screen allows you to make any modifications to the minimal starting template of an **EtcdCluster** object, such as the size of the cluster. For now, click **Create** to finalize. This triggers the Operator to start up the pods, services, and other components of the new etcd cluster.
5. Click on the **example** etcd cluster, then click the **Resources** tab to see that your project now contains a number of resources created and configured automatically by the Operator.

Verify that a Kubernetes service has been created that allows you to access the database from other pods in your project.

6. All users with the **edit** role in a given project can create, manage, and delete application instances (an etcd cluster, in this example) managed by Operators that have already been created in the project, in a self-service manner, just like a cloud service. If you want to enable additional users with this ability, project administrators can add the role using the following command:

```
$ oc policy add-role-to-user edit <user> -n <target_project>
```

You now have an etcd cluster that will react to failures and rebalance data as pods become unhealthy or are migrated between nodes in the cluster. Most importantly, cluster administrators or developers with proper access can now easily use the database with their applications.

## 3.2. INSTALLING OPERATORS IN YOUR NAMESPACE

If a cluster administrator has delegated Operator installation permissions to your account, you can install and subscribe an Operator to your namespace in a self-service manner.

### 3.2.1. Prerequisites

- A cluster administrator must add certain permissions to your OpenShift Container Platform user account to allow self-service Operator installation to a namespace. See Allowing non-cluster administrators to install Operators for details.

### 3.2.2. Operator installation with OperatorHub

OperatorHub is a user interface for discovering Operators; it works in conjunction with Operator Lifecycle Manager (OLM), which installs and manages Operators on a cluster.

As a user with the proper permissions, you can install an Operator from OperatorHub using the OpenShift Container Platform web console or CLI.

During installation, you must determine the following initial settings for the Operator:

**Installation Mode**

Choose a specific namespace in which to install the Operator.

**Update Channel**

If an Operator is available through multiple channels, you can choose which channel you want to subscribe to. For example, to deploy from the **stable** channel, if available, select it from the list.

**Approval Strategy**

You can choose automatic or manual updates.
If you choose automatic updates for an installed Operator, when a new version of that Operator is available in the selected channel, Operator Lifecycle Manager (OLM) automatically upgrades the running instance of your Operator without human intervention.

If you select manual updates, when a newer version of an Operator is available, OLM creates an update request. As a cluster administrator, you must then manually approve that update request to have the Operator updated to the new version.

- Understanding OperatorHub

### 3.2.3. Installing from OperatorHub using the web console

You can install and subscribe to an Operator from OperatorHub using the OpenShift Container Platform web console.

#### Prerequisites

- Access to an OpenShift Container Platform cluster using an account with Operator installation permissions.

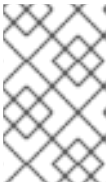
#### Procedure

1. Navigate in the web console to the **Operators → OperatorHub** page.
2. Scroll or type a keyword into the **Filter by keyword** box to find the Operator you want. For example, type **advanced** to find the Advanced Cluster Management for Kubernetes Operator. You can also filter options by **Infrastructure Features**. For example, select **Disconnected** if you want to see Operators that work in disconnected environments, also known as restricted network environments.
3. Select the Operator to display additional information.

NOTE

Choosing a Community Operator warns that Red Hat does not certify Community Operators; you must acknowledge the warning before continuing.

4. Read the information about the Operator and click **Install**.
5. On the **Install Operator** page:
   a. Choose a specific, single namespace in which to install the Operator. The Operator will only watch and be made available for use in this single namespace.
   b. Select an **Update Channel** (if more than one is available).
   c. Select **Automatic** or **Manual** approval strategy, as described earlier.
6. Click **Install** to make the Operator available to the selected namespaces on this OpenShift Container Platform cluster.
   a. If you selected a **Manual** approval strategy, the upgrade status of the subscription remains **Upgrading** until you review and approve the install plan.
   After approving on the **Install Plan** page, the subscription upgrade status moves to **Up to date**.
   b. If you selected an **Automatic** approval strategy, the upgrade status should resolve to **Up to date** without intervention.
7. After the upgrade status of the subscription is **Up to date**, select **Operators → Installed Operators** to verify that the cluster service version (CSV) of the installed Operator eventually shows up. The **Status** should ultimately resolve to **InstallSucceeded** in the relevant namespace.



NOTE

For the **All namespaces...** installation mode, the status resolves to **InstallSucceeded** in the **openshift-operators** namespace, but the status is **Copied** if you check in other namespaces.

If it does not:

a. Check the logs in any pods in the **openshift-operators** project (or other relevant namespace if **A specific namespace...** installation mode was selected) on the **Workloads → Pods** page that are reporting issues to troubleshoot further.

### 3.2.4. Installing from OperatorHub using the CLI

Instead of using the OpenShift Container Platform web console, you can install an Operator from OperatorHub using the CLI. Use the **oc** command to create or update a **Subscription** object.

#### Prerequisites

- Access to an OpenShift Container Platform cluster using an account with Operator installation permissions.
- Install the **oc** command to your local system.

#### Procedure

1. View the list of Operators available to the cluster from OperatorHub:

```
$ oc get packagemanifests -n openshift-marketplace
```

**Example output**

```
NAME                              CATALOG               AGE
3scale-operator                   Red Hat Operators     91m
advanced-cluster-management       Red Hat Operators     91m
amq7-cert-manager                 Red Hat Operators     91m
...
couchbase-enterprise-certified    Certified Operators   91m
crunchy-postgres-operator         Certified Operators   91m
mongodb-enterprise                Certified Operators   91m
...
etcd                              Community Operators   91m
jaeger                            Community Operators   91m
kubefed                           Community Operators   91m
...
```

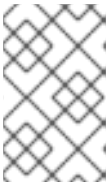
Note the catalog for your desired Operator.

2. Inspect your desired Operator to verify its supported install modes and available channels:

```
$ oc describe packagemanifests <operator_name> -n openshift-marketplace
```

3. An Operator group, defined by an **OperatorGroup** object, selects target namespaces in which to generate required RBAC access for all Operators in the same namespace as the Operator group.
The namespace to which you subscribe the Operator must have an Operator group that matches the install mode of the Operator, either the **AllNamespaces** or **SingleNamespace** mode. If the Operator you intend to install uses the **AllNamespaces**, then the **openshift-operators** namespace already has an appropriate Operator group in place.

   However, if the Operator uses the **SingleNamespace** mode and you do not already have an appropriate Operator group in place, you must create one.



NOTE

The web console version of this procedure handles the creation of the **OperatorGroup** and **Subscription** objects automatically behind the scenes for you when choosing **SingleNamespace** mode.

   a. Create an **OperatorGroup** object YAML file, for example **operatorgroup.yaml**:

**Example OperatorGroup object**

```
apiVersion: operators.coreos.com/v1
kind: OperatorGroup
metadata:
  name: <operatorgroup_name>
  namespace: <namespace>
spec:
  targetNamespaces:
  - <namespace>
```

   b. Create the **OperatorGroup** object:

```
$ oc apply -f operatorgroup.yaml
```

4. Create a **Subscription** object YAML file to subscribe a namespace to an Operator, for example **sub.yaml**:

**Example Subscription object**

```
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: <subscription_name>
  namespace: openshift-operators 1
spec:
  channel: <channel_name> 2
  name: <operator_name> 3
  source: redhat-operators 4
  sourceNamespace: openshift-marketplace 5
  config:
    env: 6
    - name: ARGS
      value: "-v=10"
```

```
envFrom: 7
- secretRef:
    name: license-secret
volumes: 8
- name: <volume_name>
  configMap:
    name: <configmap_name>
volumeMounts: 9
- mountPath: <directory_name>
  name: <volume_name>
tolerations: 10
- operator: "Exists"
resources: 11
  requests:
    memory: "64Mi"
    cpu: "250m"
  limits:
    memory: "128Mi"
    cpu: "500m"
nodeSelector: 12
  foo: bar
```

1. For **AllNamespaces** install mode usage, specify the **openshift-operators** namespace. Otherwise, specify the relevant single namespace for **SingleNamespace** install mode usage.
2. Name of the channel to subscribe to.
3. Name of the Operator to subscribe to.
4. Name of the catalog source that provides the Operator.
5. Namespace of the catalog source. Use **openshift-marketplace** for the default OperatorHub catalog sources.
6. The **env** parameter defines a list of Environment Variables that must exist in all containers in the pod created by OLM.
7. The **envFrom** parameter defines a list of sources to populate Environment Variables in the container.
8. The **volumes** parameter defines a list of Volumes that must exist on the pod created by OLM.
9. The **volumeMounts** parameter defines a list of VolumeMounts that must exist in all containers in the pod created by OLM. If a **volumeMount** references a **volume** that does not exist, OLM fails to deploy the Operator.
10. The **tolerations** parameter defines a list of Tolerations for the pod created by OLM.
11. The **resources** parameter defines resource constraints for all the containers in the pod created by OLM.
12. The **nodeSelector** parameter defines a **NodeSelector** for the pod created by OLM.

5. Create the **Subscription** object:

```
$ oc apply -f sub.yaml
```

At this point, OLM is now aware of the selected Operator. A cluster service version (CSV) for the Operator should appear in the target namespace, and APIs provided by the Operator should be available for creation.

### Additional resources

- Operator groups
- Channel names

## 3.2.5. Installing a specific version of an Operator

You can install a specific version of an Operator by setting the cluster service version (CSV) in a **Subscription** object.

### Prerequisites

- Access to an OpenShift Container Platform cluster using an account with Operator installation permissions
- OpenShift CLI (**oc**) installed

### Procedure

1. Create a **Subscription** object YAML file that subscribes a namespace to an Operator with a specific version by setting the **startingCSV** field. Set the **installPlanApproval** field to **Manual** to prevent the Operator from automatically upgrading if a later version exists in the catalog. For example, the following **sub.yaml** file can be used to install the Red Hat Quay Operator specifically to version 3.4.0:

#### Subscription with a specific starting Operator version

```
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: quay-operator
  namespace: quay
spec:
  channel: quay-v3.4
  installPlanApproval: Manual (1)
  name: quay-operator
  source: redhat-operators
  sourceNamespace: openshift-marketplace
  startingCSV: quay-operator.v3.4.0 (2)
```

(1) Set the approval strategy to **Manual** in case your specified version is superseded by a later version in the catalog. This plan prevents an automatic upgrade to a later version and requires manual approval before the starting CSV can complete the installation.

(2) Set a specific version of an Operator CSV.

2. Create the **Subscription** object:

```
$ oc apply -f sub.yaml
```

3. Manually approve the pending install plan to complete the Operator installation.

**Additional resources**

- Manually approving a pending Operator upgrade

# CHAPTER 4. ADMINISTRATOR TASKS

## 4.1. ADDING OPERATORS TO A CLUSTER

Cluster administrators can install Operators to an OpenShift Container Platform cluster by subscribing Operators to namespaces with OperatorHub.

### 4.1.1. Operator installation with OperatorHub

OperatorHub is a user interface for discovering Operators; it works in conjunction with Operator Lifecycle Manager (OLM), which installs and manages Operators on a cluster.

As a user with the proper permissions, you can install an Operator from OperatorHub using the OpenShift Container Platform web console or CLI.

During installation, you must determine the following initial settings for the Operator:

**Installation Mode**

Choose a specific namespace in which to install the Operator.

**Update Channel**

If an Operator is available through multiple channels, you can choose which channel you want to subscribe to. For example, to deploy from the **stable** channel, if available, select it from the list.

**Approval Strategy**

You can choose automatic or manual updates.
If you choose automatic updates for an installed Operator, when a new version of that Operator is available in the selected channel, Operator Lifecycle Manager (OLM) automatically upgrades the running instance of your Operator without human intervention.

If you select manual updates, when a newer version of an Operator is available, OLM creates an update request. As a cluster administrator, you must then manually approve that update request to have the Operator updated to the new version.

- Understanding OperatorHub

### 4.1.2. Installing from OperatorHub using the web console

You can install and subscribe to an Operator from OperatorHub using the OpenShift Container Platform web console.

**Prerequisites**

- Access to an OpenShift Container Platform cluster using an account with **cluster-admin** permissions.
- Access to an OpenShift Container Platform cluster using an account with Operator installation permissions.

**Procedure**

1. Navigate in the web console to the **Operators → OperatorHub** page.

2. Scroll or type a keyword into the **Filter by keyword** box to find the Operator you want. For example, type **advanced** to find the Advanced Cluster Management for Kubernetes Operator. You can also filter options by **Infrastructure Features**. For example, select **Disconnected** if you want to see Operators that work in disconnected environments, also known as restricted network environments.

3. Select the Operator to display additional information.

NOTE

Choosing a Community Operator warns that Red Hat does not certify Community Operators; you must acknowledge the warning before continuing.

4. Read the information about the Operator and click **Install**.

5. On the **Install Operator** page:

   a. Select one of the following:

      - **All namespaces on the cluster (default)**installs the Operator in the default **openshift-operators** namespace to watch and be made available to all namespaces in the cluster. This option is not always available.

      - **A specific namespace on the cluster**allows you to choose a specific, single namespace in which to install the Operator. The Operator will only watch and be made available for use in this single namespace.

   b. Choose a specific, single namespace in which to install the Operator. The Operator will only watch and be made available for use in this single namespace.

   c. Select an **Update Channel** (if more than one is available).

   d. Select **Automatic** or **Manual** approval strategy, as described earlier.

6. Click **Install** to make the Operator available to the selected namespaces on this OpenShift Container Platform cluster.

   a. If you selected a **Manual** approval strategy, the upgrade status of the subscription remains **Upgrading** until you review and approve the install plan.
   After approving on the **Install Plan** page, the subscription upgrade status moves to **Up to date**.

   b. If you selected an **Automatic** approval strategy, the upgrade status should resolve to **Up to date** without intervention.

7. After the upgrade status of the subscription is **Up to date**, select **Operators → Installed Operators** to verify that the cluster service version (CSV) of the installed Operator eventually shows up. The **Status** should ultimately resolve to **InstallSucceeded** in the relevant namespace.

NOTE

For the **All namespaces...** installation mode, the status resolves to **InstallSucceeded** in the **openshift-operators** namespace, but the status is **Copied** if you check in other namespaces.

If it does not:

a. Check the logs in any pods in the **openshift-operators** project (or other relevant namespace if **A specific namespace...** installation mode was selected) on the **Workloads → Pods** page that are reporting issues to troubleshoot further.

### 4.1.3. Installing from OperatorHub using the CLI

Instead of using the OpenShift Container Platform web console, you can install an Operator from OperatorHub using the CLI. Use the **oc** command to create or update a **Subscription** object.

#### Prerequisites

- Access to an OpenShift Container Platform cluster using an account with Operator installation permissions.
- Install the **oc** command to your local system.

#### Procedure

1. View the list of Operators available to the cluster from OperatorHub:

```
$ oc get packagemanifests -n openshift-marketplace
```

**Example output**

```
NAME                              CATALOG               AGE
3scale-operator                   Red Hat Operators     91m
advanced-cluster-management       Red Hat Operators     91m
amq7-cert-manager                 Red Hat Operators     91m
...
couchbase-enterprise-certified    Certified Operators   91m
crunchy-postgres-operator         Certified Operators   91m
mongodb-enterprise                Certified Operators   91m
...
etcd                              Community Operators   91m
jaeger                            Community Operators   91m
kubefed                           Community Operators   91m
...
```

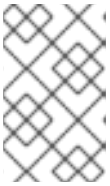
Note the catalog for your desired Operator.

2. Inspect your desired Operator to verify its supported install modes and available channels:

```
$ oc describe packagemanifests <operator_name> -n openshift-marketplace
```

3. An Operator group, defined by an **OperatorGroup** object, selects target namespaces in which to generate required RBAC access for all Operators in the same namespace as the Operator group.
The namespace to which you subscribe the Operator must have an Operator group that matches the install mode of the Operator, either the **AllNamespaces** or **SingleNamespace** mode. If the Operator you intend to install uses the **AllNamespaces**, then the **openshift-operators** namespace already has an appropriate Operator group in place.

   However, if the Operator uses the **SingleNamespace** mode and you do not already have an appropriate Operator group in place, you must create one.



NOTE

The web console version of this procedure handles the creation of the **OperatorGroup** and **Subscription** objects automatically behind the scenes for you when choosing **SingleNamespace** mode.

a. Create an **OperatorGroup** object YAML file, for example **operatorgroup.yaml**:

**Example OperatorGroup object**

```
apiVersion: operators.coreos.com/v1
kind: OperatorGroup
metadata:
  name: <operatorgroup_name>
  namespace: <namespace>
spec:
  targetNamespaces:
  - <namespace>
```

b. Create the **OperatorGroup** object:

```
$ oc apply -f operatorgroup.yaml
```

4. Create a **Subscription** object YAML file to subscribe a namespace to an Operator, for example **sub.yaml**:

**Example Subscription object**

```
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: <subscription_name>
  namespace: openshift-operators (1)
spec:
  channel: <channel_name> (2)
  name: <operator_name> (3)
  source: redhat-operators (4)
  sourceNamespace: openshift-marketplace (5)
  config:
    env: (6)
    - name: ARGS
      value: "-v=10"
    envFrom: (7)
    - secretRef:
        name: license-secret
    volumes: (8)
    - name: <volume_name>
      configMap:
        name: <configmap_name>
    volumeMounts: (9)
    - mountPath: <directory_name>
      name: <volume_name>
    tolerations: (10)
```

```
 - operator: "Exists"
 resources: 11
   requests:
     memory: "64Mi"
     cpu: "250m"
   limits:
     memory: "128Mi"
     cpu: "500m"
 nodeSelector: 12
   foo: bar
```

1. For **AllNamespaces** install mode usage, specify the **openshift-operators** namespace. Otherwise, specify the relevant single namespace for **SingleNamespace** install mode usage.
2. Name of the channel to subscribe to.
3. Name of the Operator to subscribe to.
4. Name of the catalog source that provides the Operator.
5. Namespace of the catalog source. Use **openshift-marketplace** for the default OperatorHub catalog sources.
6. The **env** parameter defines a list of Environment Variables that must exist in all containers in the pod created by OLM.
7. The **envFrom** parameter defines a list of sources to populate Environment Variables in the container.
8. The **volumes** parameter defines a list of Volumes that must exist on the pod created by OLM.
9. The **volumeMounts** parameter defines a list of VolumeMounts that must exist in all containers in the pod created by OLM. If a **volumeMount** references a **volume** that does not exist, OLM fails to deploy the Operator.
10. The **tolerations** parameter defines a list of Tolerations for the pod created by OLM.
11. The **resources** parameter defines resource constraints for all the containers in the pod created by OLM.
12. The **nodeSelector** parameter defines a **NodeSelector** for the pod created by OLM.

5. Create the **Subscription** object:

```
$ oc apply -f sub.yaml
```

At this point, OLM is now aware of the selected Operator. A cluster service version (CSV) for the Operator should appear in the target namespace, and APIs provided by the Operator should be available for creation.

### Additional resources

- About Operator groups

### 4.1.4. Installing a specific version of an Operator

You can install a specific version of an Operator by setting the cluster service version (CSV) in a **Subscription** object.

#### Prerequisites

- Access to an OpenShift Container Platform cluster using an account with Operator installation permissions
- OpenShift CLI (**oc**) installed

#### Procedure

1. Create a **Subscription** object YAML file that subscribes a namespace to an Operator with a specific version by setting the **startingCSV** field. Set the **installPlanApproval** field to **Manual** to prevent the Operator from automatically upgrading if a later version exists in the catalog. For example, the following **sub.yaml** file can be used to install the Red Hat Quay Operator specifically to version 3.4.0:

   **Subscription with a specific starting Operator version**

   ```
   apiVersion: operators.coreos.com/v1alpha1
   kind: Subscription
   metadata:
     name: quay-operator
     namespace: quay
   spec:
     channel: quay-v3.4
     installPlanApproval: Manual (1)
     name: quay-operator
     source: redhat-operators
     sourceNamespace: openshift-marketplace
     startingCSV: quay-operator.v3.4.0 (2)
   ```

   (1) Set the approval strategy to **Manual** in case your specified version is superseded by a later version in the catalog. This plan prevents an automatic upgrade to a later version and requires manual approval before the starting CSV can complete the installation.

   (2) Set a specific version of an Operator CSV.

2. Create the **Subscription** object:

   ```
   $ oc apply -f sub.yaml
   ```

3. Manually approve the pending install plan to complete the Operator installation.

#### Additional resources

- Manually approving a pending Operator upgrade

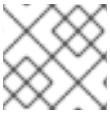
## 4.2. UPGRADING INSTALLED OPERATORS

As a cluster administrator, you can upgrade Operators that have been previously installed using Operator Lifecycle Manager (OLM) on your OpenShift Container Platform cluster.

### 4.2.1. Changing the update channel for an Operator

The subscription of an installed Operator specifies an update channel, which is used to track and receive updates for the Operator. To upgrade the Operator to start tracking and receiving updates from a newer channel, you can change the update channel in the subscription.

The names of update channels in a subscription can differ between Operators, but the naming scheme should follow a common convention within a given Operator. For example, channel names might follow a minor release update stream for the application provided by the Operator (**1.2**, **1.3**) or a release frequency (**stable**, **fast**).



NOTE

Installed Operators cannot change to a channel that is older than the current channel.

If the approval strategy in the subscription is set to **Automatic**, the upgrade process initiates as soon as a new Operator version is available in the selected channel. If the approval strategy is set to **Manual**, you must manually approve pending upgrades.

**Prerequisites**

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

**Procedure**

1. In the **Administrator** perspective of the OpenShift Container Platform web console, navigate to **Operators → Installed Operators**.
2. Click the name of the Operator you want to change the update channel for.
3. Click the **Subscription** tab.
4. Click the name of the update channel under **Channel**.
5. Click the newer update channel that you want to change to, then click **Save**.
6. For subscriptions with an **Automatic** approval strategy, the upgrade begins automatically. Navigate back to the **Operators → Installed Operators** page to monitor the progress of the upgrade. When complete, the status changes to **Succeeded** and **Up to date**.
   For subscriptions with a **Manual** approval strategy, you can manually approve the upgrade from the **Subscription** tab.

### 4.2.2. Manually approving a pending Operator upgrade

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

**Prerequisites**

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

**Procedure**

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

## 4.3. DELETING OPERATORS FROM A CLUSTER

The following describes how to delete Operators that were previously installed using Operator Lifecycle Manager (OLM) on your OpenShift Container Platform cluster.

### 4.3.1. Deleting Operators from a cluster using the web console

Cluster administrators can delete installed Operators from a selected namespace by using the web console.

**Prerequisites**

- Access to an OpenShift Container Platform cluster web console using an account with **cluster-admin** permissions.

**Procedure**

1. From the **Operators → Installed Operators** page, scroll or type a keyword into the **Filter by name** to find the Operator you want. Then, click on it.
2. On the right side of the **Operator Details** page, select **Uninstall Operator** from the **Actions** list. An **Uninstall Operator?** dialog box is displayed, reminding you that:

   **Removing the Operator will not remove any of its custom resource definitions or managed resources. If your Operator has deployed applications on the cluster or configured off-cluster resources, these will continue to run and need to be cleaned up manually.**

   This action removes the Operator as well as the Operator deployments and pods, if any. Any Operands, and resources managed by the Operator, including CRDs and CRs, are not removed. The web console enables dashboards and navigation items for some Operators. To remove these after uninstalling the Operator, you might need to manually delete the Operator CRDs.
3. Select **Uninstall**. This Operator stops running and no longer receives updates.

### 4.3.2. Deleting Operators from a cluster using the CLI

Cluster administrators can delete installed Operators from a selected namespace by using the CLI.

**Prerequisites**

- Access to an OpenShift Container Platform cluster using an account with **cluster-admin** permissions.
- **oc** command installed on workstation.

**Procedure**

1. Check the current version of the subscribed Operator (for example, **jaeger**) in the **currentCSV** field:

```
$ oc get subscription jaeger -n openshift-operators -o yaml | grep currentCSV
```

**Example output**

```
  currentCSV: jaeger-operator.v1.8.2
```

2. Delete the subscription (for example, **jaeger**):

```
$ oc delete subscription jaeger -n openshift-operators
```

**Example output**

```
subscription.operators.coreos.com "jaeger" deleted
```

3. Delete the CSV for the Operator in the target namespace using the **currentCSV** value from the previous step:

```
$ oc delete clusterserviceversion jaeger-operator.v1.8.2 -n openshift-operators
```

**Example output**

```
clusterserviceversion.operators.coreos.com "jaeger-operator.v1.8.2" deleted
```

### 4.3.3. Refreshing failing subscriptions

In Operator Lifecycle Manager (OLM), if you subscribe to an Operator that references images that are not accessible on your network, you can find jobs in the **openshift-marketplace** namespace that are failing with the following errors:

**Example output**

```
ImagePullBackOff for
Back-off pulling image "example.com/openshift4/ose-elasticsearch-operator-
bundle@sha256:6d2587129c846ec28d384540322b40b05833e7e00b25cca584e004af9a1d292e"
```

**Example output**

```
rpc error: code = Unknown desc = error pinging docker registry example.com: Get
"https://example.com/v2/": dial tcp: lookup example.com on 10.0.0.1:53: no such host
```

As a result, the subscription is stuck in this failing state and the Operator is unable to install or upgrade.

You can refresh a failing subscription by deleting the subscription, cluster service version (CSV), and other related objects. After recreating the subscription, OLM then reinstalls the correct version of the Operator.

### Prerequisites

- You have a failing subscription that is unable to pull an inaccessible bundle image.
- You have confirmed that the correct bundle image is accessible.

### Procedure

1. Get the names of the **Subscription** and **ClusterServiceVersion** objects from the namespace where the Operator is installed:

```
$ oc get sub,csv -n <namespace>
```

**Example output**

```
NAME                                         PACKAGE                SOURCE            CHANNEL
subscription.operators.coreos.com/elasticsearch-operator   elasticsearch-operator   redhat-operators   5.0

NAME                                                  DISPLAY                  VERSION    REPLACES   PHASE
clusterserviceversion.operators.coreos.com/elasticsearch-operator.5.0.0-65   OpenShift Elasticsearch Operator   5.0.0-65              Succeeded
```

2. Delete the subscription:

```
$ oc delete subscription <subscription_name> -n <namespace>
```

3. Delete the cluster service version:

```
$ oc delete csv <csv_name> -n <namespace>
```

4. Get the names of any failing jobs and related config maps in the **openshift-marketplace** namespace:

```
$ oc get job,configmap -n openshift-marketplace
```

**Example output**

```
NAME                                                                COMPLETIONS   DURATION   AGE
job.batch/1de9443b6324e629ddf31fed0a853a121275806170e34c926d69e53a7fcbccb   1/1           26s        9m30s

NAME                                                                DATA   AGE
configmap/1de9443b6324e629ddf31fed0a853a121275806170e34c926d69e53a7fcbccb   3      9m30s
```

5. Delete the job:

```
$ oc delete job <job_name> -n openshift-marketplace
```

This ensures pods that try to pull the inaccessible image are not recreated.

6. Delete the config map:

```
$ oc delete configmap <configmap_name> -n openshift-marketplace
```

7. Reinstall the Operator using OperatorHub in the web console.

**Verification**

- Check that the Operator has been reinstalled successfully:

```
$ oc get sub,csv,installplan -n <namespace>
```

## 4.4. CONFIGURING PROXY SUPPORT IN OPERATOR LIFECYCLE MANAGER

If a global proxy is configured on the OpenShift Container Platform cluster, Operator Lifecycle Manager (OLM) automatically configures Operators that it manages with the cluster-wide proxy. However, you can also configure installed Operators to override the global proxy or inject a custom CA certificate.

**Additional resources**

- Configuring the cluster-wide proxy
- Configuring a custom PKI (custom CA certificate)

### 4.4.1. Overriding proxy settings of an Operator

If a cluster-wide egress proxy is configured, Operators running with Operator Lifecycle Manager (OLM) inherit the cluster-wide proxy settings on their deployments. Cluster administrators can also override these proxy settings by configuring the subscription of an Operator.

**IMPORTANT**

Operators must handle setting environment variables for proxy settings in the pods for any managed Operands.

**Prerequisites**

- Access to an OpenShift Container Platform cluster using an account with **cluster-admin** permissions.

**Procedure**

1. Navigate in the web console to the **Operators → OperatorHub** page.
2. Select the Operator and click **Install**.

3. On the **Install Operator** page, modify the **Subscription** object to include one or more of the following environment variables in the **spec** section:

   - **HTTP_PROXY**
   - **HTTPS_PROXY**
   - **NO_PROXY**

   For example:

   **Subscription object with proxy setting overrides**

```
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: etcd-config-test
  namespace: openshift-operators
spec:
  config:
    env:
    - name: HTTP_PROXY
      value: test_http
    - name: HTTPS_PROXY
      value: test_https
    - name: NO_PROXY
      value: test
  channel: clusterwide-alpha
  installPlanApproval: Automatic
  name: etcd
  source: community-operators
  sourceNamespace: openshift-marketplace
  startingCSV: etcdoperator.v0.9.4-clusterwide
```

**NOTE**

These environment variables can also be unset using an empty value to remove any previously set cluster-wide or custom proxy settings.

   OLM handles these environment variables as a unit; if at least one of them is set, all three are considered overridden and the cluster-wide defaults are not used for the deployments of the subscribed Operator.

4. Click **Install** to make the Operator available to the selected namespaces.

5. After the CSV for the Operator appears in the relevant namespace, you can verify that custom proxy environment variables are set in the deployment. For example, using the CLI:

```
$ oc get deployment -n openshift-operators \
    etcd-operator -o yaml \
    | grep -i "PROXY" -A 2
```

   **Example output**

```
        - name: HTTP_PROXY
```

```
          value: test_http
        - name: HTTPS_PROXY
          value: test_https
        - name: NO_PROXY
          value: test
        image: quay.io/coreos/etcd-
operator@sha256:66a37fd61a06a43969854ee6d3e21088a98b93838e284a6086b13917f96b0
d9c
...
```

### 4.4.2. Injecting a custom CA certificate

When a cluster administrator adds a custom CA certificate to a cluster using a config map, the Cluster Network Operator merges the user-provided certificates and system CA certificates into a single bundle. You can inject this merged bundle into your Operator running on Operator Lifecycle Manager (OLM), which is useful if you have a man-in-the-middle HTTPS proxy.

#### Prerequisites

- Access to an OpenShift Container Platform cluster using an account with **cluster-admin** permissions.
- Custom CA certificate added to the cluster using a config map.
- Desired Operator installed and running on OLM.

#### Procedure

1. Create an empty config map in the namespace where the subscription for your Operator exists and include the following label:

```
apiVersion: v1
kind: ConfigMap
metadata:
  name: trusted-ca (1)
  labels:
    config.openshift.io/inject-trusted-cabundle: "true" (2)
```

(1) Name of the config map.

(2) Requests the Cluster Network Operator to inject the merged bundle.

After creating this config map, it is immediately populated with the certificate contents of the merged bundle.

2. Update your the **Subscription** object to include a **spec.config** section that mounts the **trusted-ca** config map as a volume to each container within a pod that requires a custom CA:

```
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: my-operator
spec:
  package: etcd
```

```
channel: alpha
config: 1
  selector:
    matchLabels:
      <labels_for_pods> 2
  volumes: 3
  - name: trusted-ca
    configMap:
      name: trusted-ca
      items:
        - key: ca-bundle.crt 4
          path: tls-ca-bundle.pem 5
  volumeMounts: 6
  - name: trusted-ca
    mountPath: /etc/pki/ca-trust/extracted/pem
    readOnly: true
```

1. Add a **config** section if it does not exist.
2. Specify labels to match pods that are owned by the Operator.
3. Create a **trusted-ca** volume.
4. **ca-bundle.crt** is required as the config map key.
5. **tls-ca-bundle.pem** is required as the config map path.
6. Create a **trusted-ca** volume mount.

## 4.5. VIEWING OPERATOR STATUS

Understanding the state of the system in Operator Lifecycle Manager (OLM) is important for making decisions about and debugging problems with installed Operators. OLM provides insight into subscriptions and related catalog sources regarding their state and actions performed. This helps users better understand the healthiness of their Operators.

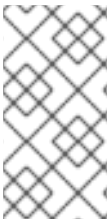
### 4.5.1. Operator subscription condition types

Subscriptions can report the following condition types:

**Table 4.1. Subscription condition types**

| Condition | Description |
|---|---|
| **CatalogSourcesUnhealthy** | Some or all of the catalog sources to be used in resolution are unhealthy. |
| **InstallPlanMissing** | An install plan for a subscription is missing. |
| **InstallPlanPending** | An install plan for a subscription is pending installation. |
| **InstallPlanFailed** | An install plan for a subscription has failed. |

| Condition | Description |
|---|---|



**NOTE**

Default OpenShift Container Platform cluster Operators are managed by the Cluster Version Operator (CVO) and they do not have a **Subscription** object. Application Operators are managed by Operator Lifecycle Manager (OLM) and they have a **Subscription** object.

**Additional resources**

- Refreshing failing subscriptions

### 4.5.2. Viewing Operator subscription status by using the CLI

You can view Operator subscription status by using the CLI.

**Prerequisites**

- You have access to the cluster as a user with the **cluster-admin** role.
- You have installed the OpenShift CLI (**oc**).

**Procedure**

1. List Operator subscriptions:

```
$ oc get subs -n <operator_namespace>
```

2. Use the **oc describe** command to inspect a **Subscription** resource:

```
$ oc describe sub <subscription_name> -n <operator_namespace>
```

3. In the command output, find the **Conditions** section for the status of Operator subscription condition types. In the following example, the **CatalogSourcesUnhealthy** condition type has a status of **false** because all available catalog sources are healthy:

**Example output**

```
Conditions:
  Last Transition Time:  2019-07-29T13:42:57Z
  Message:               all available catalogsources are healthy
  Reason:                AllCatalogSourcesHealthy
  Status:                False
  Type:                  CatalogSourcesUnhealthy
```

NOTE

Default OpenShift Container Platform cluster Operators are managed by the Cluster Version Operator (CVO) and they do not have a **Subscription** object. Application Operators are managed by Operator Lifecycle Manager (OLM) and they have a **Subscription** object.

### 4.5.3. Viewing Operator catalog source status by using the CLI

You can view the status of an Operator catalog source by using the CLI.

#### Prerequisites

- You have access to the cluster as a user with the **cluster-admin** role.
- You have installed the OpenShift CLI (**oc**).

#### Procedure

1. List the catalog sources in a namespace. For example, you can check the **openshift-marketplace** namespace, which is used for cluster-wide catalog sources:

```
$ oc get catalogsources -n openshift-marketplace
```

**Example output**

```
NAME                  DISPLAY               TYPE   PUBLISHER   AGE
certified-operators   Certified Operators   grpc   Red Hat     55m
community-operators   Community Operators   grpc   Red Hat     55m
example-catalog       Example Catalog       grpc   Example Org 2m25s
redhat-marketplace    Red Hat Marketplace   grpc   Red Hat     55m
redhat-operators      Red Hat Operators     grpc   Red Hat     55m
```

2. Use the **oc describe** command to get more details and status about a catalog source:

```
$ oc describe catalogsource example-catalog -n openshift-marketplace
```

**Example output**

```
Name:         example-catalog
Namespace:    openshift-marketplace
...
Status:
  Connection State:
    Address:              example-catalog.openshift-marketplace.svc:50051
    Last Connect:         2021-09-09T17:07:35Z
    Last Observed State:  TRANSIENT_FAILURE
  Registry Service:
    Created At:         2021-09-09T17:05:45Z
    Port:               50051
    Protocol:           grpc
    Service Name:       example-catalog
    Service Namespace:  openshift-marketplace
```

In the preceding example output, the last observed state is **TRANSIENT_FAILURE**. This state indicates that there is a problem establishing a connection for the catalog source.

3. List the pods in the namespace where your catalog source was created:

```
$ oc get pods -n openshift-marketplace
```

**Example output**

```
NAME                                  READY   STATUS             RESTARTS   AGE
certified-operators-cv9nn             1/1     Running            0          36m
community-operators-6v8lp             1/1     Running            0          36m
marketplace-operator-86bfc75f9b-jkgbc 1/1     Running            0          42m
example-catalog-bwt8z                 0/1     ImagePullBackOff   0          3m55s
redhat-marketplace-57p8c              1/1     Running            0          36m
redhat-operators-smxx8                1/1     Running            0          36m
```

When a catalog source is created in a namespace, a pod for the catalog source is created in that namespace. In the preceding example output, the status for the **example-catalog-bwt8z** pod is **ImagePullBackOff**. This status indicates that there is an issue pulling the catalog source's index image.

4. Use the **oc describe** command to inspect a pod for more detailed information:

```
$ oc describe pod example-catalog-bwt8z -n openshift-marketplace
```

**Example output**

```
Name:         example-catalog-bwt8z
Namespace:    openshift-marketplace
Priority:     0
Node:         ci-ln-jyryyg2-f76d1-ggdbq-worker-b-vsxjd/10.0.128.2
...
Events:
  Type     Reason          Age                From               Message
  ----     ------          ----               ----               -------
  Normal   Scheduled       48s                default-scheduler  Successfully assigned openshift-
marketplace/example-catalog-bwt8z to ci-ln-jyryyf2-f76d1-fgdbq-worker-b-vsxjd
  Normal   AddedInterface  47s                multus             Add eth0 [10.131.0.40/23] from
openshift-sdn
  Normal   BackOff         20s (x2 over 46s)  kubelet            Back-off pulling image
"quay.io/example-org/example-catalog:v1"
  Warning  Failed          20s (x2 over 46s)  kubelet            Error: ImagePullBackOff
  Normal   Pulling         8s (x3 over 47s)   kubelet            Pulling image "quay.io/example-
org/example-catalog:v1"
  Warning  Failed          8s (x3 over 47s)   kubelet            Failed to pull image
"quay.io/example-org/example-catalog:v1": rpc error: code = Unknown desc = reading
manifest v1 in quay.io/example-org/example-catalog: unauthorized: access to the requested
resource is not authorized
  Warning  Failed          8s (x3 over 47s)   kubelet            Error: ErrImagePull
```

In the preceding example output, the error messages indicate that the catalog source's index image is failing to pull successfully because of an authorization issue. For example, the index image might be stored in a registry that requires login credentials.

**Additional resources**

- Operator Lifecycle Manager concepts and resources → Catalog source
- gRPC documentation: States of Connectivity

## 4.6. ALLOWING NON-CLUSTER ADMINISTRATORS TO INSTALL OPERATORS

Operators can require wide privileges to run, and the required privileges can change between versions. Operator Lifecycle Manager (OLM) runs with **cluster-admin** privileges. By default, Operator authors can specify any set of permissions in the cluster service version (CSV) and OLM will consequently grant it to the Operator.

Cluster administrators should take measures to ensure that an Operator cannot achieve cluster-scoped privileges and that users cannot escalate privileges using OLM. One method for locking this down requires cluster administrators auditing Operators before they are added to the cluster. Cluster administrators are also provided tools for determining and constraining which actions are allowed during an Operator installation or upgrade using service accounts.

By associating an *Operator group* with a service account that has a set of privileges granted to it, cluster administrators can set policy on Operators to ensure they operate only within predetermined boundaries using RBAC rules. The Operator is unable to do anything that is not explicitly permitted by those rules.

This self-sufficient, limited scope installation of Operators by non-cluster administrators means that more of the Operator Framework tools can safely be made available to more users, providing a richer experience for building applications with Operators.

### 4.6.1. Understanding Operator installation policy

Using Operator Lifecycle Manager (OLM), cluster administrators can choose to specify a service account for an Operator group so that all Operators associated with the group are deployed and run against the privileges granted to the service account.

The **APIService** and **CustomResourceDefinition** resources are always created by OLM using the **cluster-admin** role. A service account associated with an Operator group should never be granted privileges to write these resources.

If the specified service account does not have adequate permissions for an Operator that is being installed or upgraded, useful and contextual information is added to the status of the respective resource(s) so that it is easy for the cluster administrator to troubleshoot and resolve the issue.

Any Operator tied to this Operator group is now confined to the permissions granted to the specified service account. If the Operator asks for permissions that are outside the scope of the service account, the install fails with appropriate errors.

#### 4.6.1.1. Installation scenarios

When determining whether an Operator can be installed or upgraded on a cluster, Operator Lifecycle Manager (OLM) considers the following scenarios:

- A cluster administrator creates a new Operator group and specifies a service account. All Operator(s) associated with this Operator group are installed and run against the privileges granted to the service account.

- A cluster administrator creates a new Operator group and does not specify any service account. OpenShift Container Platform maintains backward compatibility, so the default behavior remains and Operator installs and upgrades are permitted.
- For existing Operator groups that do not specify a service account, the default behavior remains and Operator installs and upgrades are permitted.
- A cluster administrator updates an existing Operator group and specifies a service account. OLM allows the existing Operator to continue to run with their current privileges. When such an existing Operator is going through an upgrade, it is reinstalled and run against the privileges granted to the service account like any new Operator.
- A service account specified by an Operator group changes by adding or removing permissions, or the existing service account is swapped with a new one. When existing Operators go through an upgrade, it is reinstalled and run against the privileges granted to the updated service account like any new Operator.
- A cluster administrator removes the service account from an Operator group. The default behavior remains and Operator installs and upgrades are permitted.

#### 4.6.1.2. Installation workflow

When an Operator group is tied to a service account and an Operator is installed or upgraded, Operator Lifecycle Manager (OLM) uses the following workflow:

1. The given **Subscription** object is picked up by OLM.
2. OLM fetches the Operator group tied to this subscription.
3. OLM determines that the Operator group has a service account specified.
4. OLM creates a client scoped to the service account and uses the scoped client to install the Operator. This ensures that any permission requested by the Operator is always confined to that of the service account in the Operator group.
5. OLM creates a new service account with the set of permissions specified in the CSV and assigns it to the Operator. The Operator runs as the assigned service account.

### 4.6.2. Scoping Operator installations

To provide scoping rules to Operator installations and upgrades on Operator Lifecycle Manager (OLM), associate a service account with an Operator group.

Using this example, a cluster administrator can confine a set of Operators to a designated namespace.

**Procedure**

1. Create a new namespace:

```
$ cat <<EOF | oc create -f -
apiVersion: v1
kind: Namespace
metadata:
  name: scoped
EOF
```

2. Allocate permissions that you want the Operator(s) to be confined to. This involves creating a new service account, relevant role(s), and role binding(s).

```
$ cat <<EOF | oc create -f -
apiVersion: v1
kind: ServiceAccount
metadata:
  name: scoped
  namespace: scoped
EOF
```

The following example grants the service account permissions to do anything in the designated namespace for simplicity. In a production environment, you should create a more fine-grained set of permissions:

```
$ cat <<EOF | oc create -f -
apiVersion: rbac.authorization.k8s.io/v1
kind: Role
metadata:
  name: scoped
  namespace: scoped
rules:
- apiGroups: ["*"]
  resources: ["*"]
  verbs: ["*"]
---
apiVersion: rbac.authorization.k8s.io/v1
kind: RoleBinding
metadata:
  name: scoped-bindings
  namespace: scoped
roleRef:
  apiGroup: rbac.authorization.k8s.io
  kind: Role
  name: scoped
subjects:
- kind: ServiceAccount
  name: scoped
  namespace: scoped
EOF
```

3. Create an **OperatorGroup** object in the designated namespace. This Operator group targets the designated namespace to ensure that its tenancy is confined to it.
In addition, Operator groups allow a user to specify a service account. Specify the service account created in the previous step:

```
$ cat <<EOF | oc create -f -
apiVersion: operators.coreos.com/v1
kind: OperatorGroup
metadata:
  name: scoped
  namespace: scoped
spec:
  serviceAccountName: scoped
```

```
  targetNamespaces:
  - scoped
EOF
```

Any Operator installed in the designated namespace is tied to this Operator group and therefore to the service account specified.

4. Create a **Subscription** object in the designated namespace to install an Operator:

```
$ cat <<EOF | oc create -f -
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: etcd
  namespace: scoped
spec:
  channel: singlenamespace-alpha
  name: etcd
  source: <catalog_source_name> 1
  sourceNamespace: <catalog_source_namespace> 2
EOF
```

1. Specify a catalog source that already exists in the designated namespace or one that is in the global catalog namespace.

2. Specify a namespace where the catalog source was created.

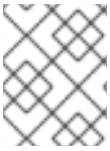
Any Operator tied to this Operator group is confined to the permissions granted to the specified service account. If the Operator requests permissions that are outside the scope of the service account, the installation fails with relevant errors.

#### 4.6.2.1. Fine-grained permissions

Operator Lifecycle Manager (OLM) uses the service account specified in an Operator group to create or update the following resources related to the Operator being installed:

- **ClusterServiceVersion**
- **Subscription**
- **Secret**
- **ServiceAccount**
- **Service**
- **ClusterRole** and **ClusterRoleBinding**
- **Role** and **RoleBinding**

In order to confine Operators to a designated namespace, cluster administrators can start by granting the following permissions to the service account:



**NOTE**

The following role is a generic example and additional rules might be required based on the specific Operator.

```
kind: Role
rules:
- apiGroups: ["operators.coreos.com"]
  resources: ["subscriptions", "clusterserviceversions"]
  verbs: ["get", "create", "update", "patch"]
- apiGroups: [""]
  resources: ["services", "serviceaccounts"]
  verbs: ["get", "create", "update", "patch"]
- apiGroups: ["rbac.authorization.k8s.io"]
  resources: ["roles", "rolebindings"]
  verbs: ["get", "create", "update", "patch"]
- apiGroups: ["apps"] 1
  resources: ["deployments"]
  verbs: ["list", "watch", "get", "create", "update", "patch", "delete"]
- apiGroups: [""] 2
  resources: ["pods"]
  verbs: ["list", "watch", "get", "create", "update", "patch", "delete"]
```

1 2 Add permissions to create other resources, such as deployments and pods shown here.

In addition, if any Operator specifies a pull secret, the following permissions must also be added:

```
kind: ClusterRole 1
rules:
- apiGroups: [""]
  resources: ["secrets"]
  verbs: ["get"]
---
kind: Role
rules:
- apiGroups: [""]
  resources: ["secrets"]
  verbs: ["create", "update", "patch"]
```

1 Required to get the secret from the OLM namespace.

### 4.6.3. Troubleshooting permission failures

If an Operator installation fails due to lack of permissions, identify the errors using the following procedure.

**Procedure**

1. Review the **Subscription** object. Its status has an object reference **installPlanRef** that points to the **InstallPlan** object that attempted to create the necessary **[Cluster]Role[Binding]** object(s) for the Operator:

```
apiVersion: operators.coreos.com/v1
kind: Subscription
metadata:
  name: etcd
  namespace: scoped
status:
  installPlanRef:
    apiVersion: operators.coreos.com/v1
    kind: InstallPlan
    name: install-4plp8
    namespace: scoped
    resourceVersion: "117359"
    uid: 2c1df80e-afea-11e9-bce3-5254009c9c23
```

2. Check the status of the **InstallPlan** object for any errors:

```
apiVersion: operators.coreos.com/v1
kind: InstallPlan
status:
  conditions:
  - lastTransitionTime: "2019-07-26T21:13:10Z"
    lastUpdateTime: "2019-07-26T21:13:10Z"
    message: 'error creating clusterrole etcdoperator.v0.9.4-clusterwide-dsfx4:
clusterroles.rbac.authorization.k8s.io
      is forbidden: User "system:serviceaccount:scoped:scoped" cannot create resource
      "clusterroles" in API group "rbac.authorization.k8s.io" at the cluster scope'
    reason: InstallComponentFailed
    status: "False"
    type: Installed
  phase: Failed
```

The error message tells you:

- The type of resource it failed to create, including the API group of the resource. In this case, it was **clusterroles** in the **rbac.authorization.k8s.io** group.
- The name of the resource.
- The type of error: **is forbidden** tells you that the user does not have enough permission to do the operation.
- The name of the user who attempted to create or update the resource. In this case, it refers to the service account specified in the Operator group.
- The scope of the operation: **cluster scope** or not.
  The user can add the missing permission to the service account and then iterate.

**NOTE**

Operator Lifecycle Manager (OLM) does not currently provide the complete list of errors on the first try.

## 4.7. MANAGING CUSTOM CATALOGS

This guide describes how to work with custom catalogs for Operators packaged using either the Bundle Format or the legacy Package Manifest Format on Operator Lifecycle Manager (OLM) in OpenShift Container Platform.

#### Additional resources

- Red Hat-provided Operator catalogs

### 4.7.1. Custom catalogs using the Bundle Format

#### 4.7.1.1. Prerequisites

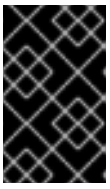
- Install the **opm** CLI.

#### 4.7.1.2. Creating an index image

You can create an index image using the **opm** CLI.

#### Prerequisites

- **opm** version 1.12.3+
- **podman** version 1.9.3+
- A bundle image built and pushed to a registry that supports Docker v2-2



**IMPORTANT**

The internal registry of the OpenShift Container Platform cluster cannot be used as the target registry because it does not support pushing without a tag, which is required during the mirroring process.

#### Procedure

1. Start a new index:

```
$ opm index add \
    --bundles <registry>/<namespace>/<bundle_image_name>:<tag> \ 1
    --tag <registry>/<namespace>/<index_image_name>:<tag> \ 2
    [--binary-image <registry_base_image>] 3
```

1. Comma-separated list of bundle images to add to the index.
2. The image tag that you want the index image to have.
3. Optional: An alternative registry base image to use for serving the catalog.

2. Push the index image to a registry.
   a. If required, authenticate with your target registry:

```
$ podman login <registry>
```

b. Push the index image:

```
$ podman push <registry>/<namespace>/test-catalog:latest
```

#### 4.7.1.3. Creating a catalog from an index image

You can create an Operator catalog from an index image and apply it to an OpenShift Container Platform cluster for use with Operator Lifecycle Manager (OLM).

**Prerequisites**

- An index image built and pushed to a registry.

**Procedure**

1. Create a **CatalogSource** object that references your index image.

   a. Modify the following to your specifications and save it as a **catalogSource.yaml** file:

```
apiVersion: operators.coreos.com/v1alpha1
kind: CatalogSource
metadata:
  name: my-operator-catalog
  namespace: openshift-marketplace (1)
spec:
  sourceType: grpc
  image: <registry>:<port>/<namespace>/redhat-operator-index:v4.6 (2)
  displayName: My Operator Catalog
  publisher: <publisher_name> (3)
  updateStrategy:
    registryPoll: (4)
      interval: 30m
```

   (1) If you want the catalog source to be available globally to users in all namespaces, specify the **openshift-marketplace** namespace. Otherwise, you can specify a different namespace for the catalog to be scoped and available only for that namespace.

   (2) Specify your index image.

   (3) Specify your name or an organization name publishing the catalog.

   (4) Catalog sources can automatically check for new versions to keep up to date.

   b. Use the file to create the **CatalogSource** object:

```
$ oc apply -f catalogSource.yaml
```

2. Verify the following resources are created successfully.

   a. Check the pods:

```
$ oc get pods -n openshift-marketplace
```

**Example output**

```
NAME                                READY   STATUS    RESTARTS  AGE
my-operator-catalog-6njx6           1/1     Running   0         28s
marketplace-operator-d9f549946-96sgr  1/1     Running   0         26h
```

b. Check the catalog source:

```
$ oc get catalogsource -n openshift-marketplace
```

**Example output**

```
NAME                  DISPLAY               TYPE PUBLISHER  AGE
my-operator-catalog   My Operator Catalog   grpc           5s
```

c. Check the package manifest:

```
$ oc get packagemanifest -n openshift-marketplace
```

**Example output**

```
NAME                     CATALOG               AGE
jaeger-product           My Operator Catalog   93s
```

You can now install the Operators from the **OperatorHub** page on your OpenShift Container Platform web console.

#### 4.7.1.4. Updating an index image

After configuring OperatorHub to use a catalog source that references a custom index image, cluster administrators can keep the available Operators on their cluster up to date by adding bundle images to the index image.

You can update an existing index image using the **opm index add** command.

**Prerequisites**

- **opm** version 1.12.3+
- **podman** version 1.9.3+
- An index image built and pushed to a registry.
- An existing catalog source referencing the index image.

**Procedure**

1. Update the existing index by adding bundle images:

```
$ opm index add \
   --bundles <registry>/<namespace>/<new_bundle_image>@sha256:<digest> \ 1
   --from-index <registry>/<namespace>/<existing_index_image>:<existing_tag> \ 2
```

```
--tag <registry>/<namespace>/<existing_index_image>:<updated_tag> \ 3
--pull-tool podman 4
```

1. The **--bundles** flag specifies a comma-separated list of additional bundle images to add to the index.
2. The **--from-index** flag specifies the previously pushed index.
3. The **--tag** flag specifies the image tag to apply to the updated index image.
4. The **--pull-tool** flag specifies the tool used to pull container images.

where:

**<registry>**
: Specifies the hostname of the registry, such as **quay.io** or **mirror.example.com**.

**<namespace>**
: Specifies the namespace of the registry, such as **ocs-dev** or **abc**.

**<new_bundle_image>**
: Specifies the new bundle image to add to the registry, such as **ocs-operator**.

**<digest>**
: Specifies the SHA image ID, or digest, of the bundle image, such as **c7f11097a628f092d8bad148406aa0e0951094a03445fd4bc0775431ef683a41**.

**<existing_index_image>**
: Specifies the previously pushed image, such as **abc-redhat-operator-index**.

**<existing_tag>**
: Specifies a previously pushed image tag, such as **4.6**.

**<updated_tag>**
: Specifies the image tag to apply to the updated index image, such as **4.6.1**.

### Example command

```
$ opm index add \
   --bundles quay.io/ocs-dev/ocs-operator@sha256:c7f11097a628f092d8bad148406aa0e0951094a03445fd4bc0775431ef683a41 \
   --from-index mirror.example.com/abc/abc-redhat-operator-index:4.6 \
   --tag mirror.example.com/abc/abc-redhat-operator-index:4.6.1 \
   --pull-tool podman
```

2. Push the updated index image:

```
$ podman push <registry>/<namespace>/<existing_index_image>:<updated_tag>
```

3. After Operator Lifecycle Manager (OLM) automatically polls the index image referenced in the catalog source at its regular interval, verify that the new packages are successfully added:

```
$ oc get packagemanifests -n openshift-marketplace
```

#### 4.7.1.5. Pruning an index image

An index image, based on the Operator Bundle Format, is a containerized snapshot of an Operator catalog. You can prune an index of all but a specified list of packages, which creates a copy of the source index containing only the Operators that you want.

**Prerequisites**

- **podman** version 1.9.3+
- **grpcurl** (third-party command-line tool)
- **opm** version 1.18.0+
- Access to a registry that supports Docker v2-2

**IMPORTANT**

The internal registry of the OpenShift Container Platform cluster cannot be used as the target registry because it does not support pushing without a tag, which is required during the mirroring process.

**Procedure**

1. Authenticate with your target registry:

```
$ podman login <target_registry>
```

2. Determine the list of packages you want to include in your pruned index.
   a. Run the source index image that you want to prune in a container. For example:

```
$ podman run -p50051:50051 \
    -it registry.redhat.io/redhat/redhat-operator-index:v4.6
```

**Example output**

```
Trying to pull registry.redhat.io/redhat/redhat-operator-index:v4.6...
Getting image source signatures
Copying blob ae8a0c23f5b1 done
...
INFO[0000] serving registry                 database=/database/index.db port=50051
```

   b. In a separate terminal session, use the **grpcurl** command to get a list of the packages provided by the index:

```
$ grpcurl -plaintext localhost:50051 api.Registry/ListPackages > packages.out
```

   c. Inspect the **packages.out** file and identify which package names from this list you want to keep in your pruned index. For example:

**Example snippets of packages list**

```
...
```

```
{
  "name": "advanced-cluster-management"
}
...
{
  "name": "jaeger-product"
}
...
{
{
  "name": "quay-operator"
}
...
```

d. In the terminal session where you executed the **podman run** command, press **Ctrl** and **C** to stop the container process.

3. Run the following command to prune the source index of all but the specified packages:

```
$ opm index prune \
   -f registry.redhat.io/redhat/redhat-operator-index:v4.6 \ 1
   -p advanced-cluster-management,jaeger-product,quay-operator \ 2
   [-i registry.redhat.io/openshift4/ose-operator-registry:v4.6] \ 3
   -t <target_registry>:<port>/<namespace>/redhat-operator-index:v4.6 4
```

1. Index to prune.
2. Comma-separated list of packages to keep.
3. Required only for IBM Power Systems and IBM Z images: Operator Registry base image with the tag that matches the target OpenShift Container Platform cluster major and minor version.
4. Custom tag for new index image being built.

4. Run the following command to push the new index image to your target registry:

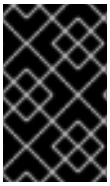
```
$ podman push <target_registry>:<port>/<namespace>/redhat-operator-index:v4.6
```

where **<namespace>** is any existing namespace on the registry.

## 4.7.2. Custom catalogs using the Package Manifest Format

### 4.7.2.1. Building a Package Manifest Format catalog image

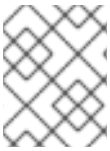
Cluster administrators can build a custom Operator catalog image based on the Package Manifest Format to be used by Operator Lifecycle Manager (OLM). The catalog image can be pushed to a container image registry that supports Docker v2-2. For a cluster on a restricted network, this registry can be a registry that the cluster has network access to, such as a mirror registry created during a restricted network cluster installation.



**IMPORTANT**

The internal registry of the OpenShift Container Platform cluster cannot be used as the target registry because it does not support pushing without a tag, which is required during the mirroring process.

For this example, the procedure assumes use of a mirror registry that has access to both your network and the Internet.



**NOTE**

Only the Linux version of the **oc** client can be used for this procedure, because the Windows and macOS versions do not provide the **oc adm catalog build** command.

**Prerequisites**

- Workstation with unrestricted network access
- **oc** version 4.3.5+ Linux client
- **podman** version 1.9.3+
- Access to mirror registry that supports Docker v2-2
- If you are working with private registries, set the **REG_CREDS** environment variable to the file path of your registry credentials for use in later steps. For example, for the **podman** CLI:

```
$ REG_CREDS=${XDG_RUNTIME_DIR}/containers/auth.json
```

- If you are working with private namespaces that your quay.io account has access to, you must set a Quay authentication token. Set the **AUTH_TOKEN** environment variable for use with the **--auth-token** flag by making a request against the login API using your quay.io credentials:

```
$ AUTH_TOKEN=$(curl -sH "Content-Type: application/json" \
    -XPOST https://quay.io/cnr/api/v1/users/login -d '
    {
        "user": {
            "username": "<quay_username>",
            "password": "<quay_password>"
        }
    }' | jq -r '.token')
```

**Procedure**

1. On the workstation with unrestricted network access, authenticate with the target mirror registry:

```
$ podman login <registry_host_name>
```

2. Authenticate with **registry.redhat.io** so that the base image can be pulled during the build:

```
$ podman login registry.redhat.io
```

3. Build a catalog image based on the **redhat-operators** catalog from Quay.io, tagging and pushing it to your mirror registry:

```
$ oc adm catalog build \
    --appregistry-org redhat-operators \ 1
    --from=registry.redhat.io/openshift4/ose-operator-registry:v4.6 \ 2
    --filter-by-os="linux/amd64" \ 3
    --to=<registry_host_name>:<port>/olm/redhat-operators:v1 \ 4
    [-a ${REG_CREDS}] \ 5
    [--insecure] \ 6
    [--auth-token "${AUTH_TOKEN}"] 7
```

1. Organization (namespace) to pull from an App Registry instance.
2. Set **--from** to the Operator Registry base image using the tag that matches the target OpenShift Container Platform cluster major and minor version.
3. Set **--filter-by-os** to the operating system and architecture to use for the base image, which must match the target OpenShift Container Platform cluster. Valid values are **linux/amd64**, **linux/ppc64le**, and **linux/s390x**.
4. Name your catalog image and include a tag, for example, **v1**.
5. Optional: If required, specify the location of your registry credentials file.
6. Optional: If you do not want to configure trust for the target registry, add the **--insecure** flag.
7. Optional: If other application registry catalogs are used that are not public, specify a Quay authentication token.

### Example output

```
INFO[0013] loading Bundles
dir=/var/folders/st/9cskxqs53ll3wdn434vw4cd80000gn/T/300666084/manifests-829192605
...
Pushed sha256:f73d42950021f9240389f99ddc5b0c7f1b533c054ba344654ff1edaf6bf827e3
to example_registry:5000/olm/redhat-operators:v1
```

Sometimes invalid manifests are accidentally introduced catalogs provided by Red Hat; when this happens, you might see some errors:

### Example output with errors

```
...
INFO[0014] directory
dir=/var/folders/st/9cskxqs53ll3wdn434vw4cd80000gn/T/300666084/manifests-829192605
file=4.2 load=package
W1114 19:42:37.876180   34665 builder.go:141] error building database: error loading
package into db: fuse-camel-k-operator.v7.5.0 specifies replacement that couldn't be found
Uploading ... 244.9kB/s
```

These errors are usually non-fatal, and if the Operator package mentioned does not contain an Operator you plan to install or a dependency of one, then they can be ignored.

**Additional resources**

- Mirroring images for a disconnected installation

#### 4.7.2.2. Mirroring a Package Manifest Format catalog image

Cluster administrators can mirror a custom Operator catalog image based on the Package Manifest Format into a registry and use a catalog source to load the content onto their cluster. For this example, the procedure uses a custom **redhat-operators** catalog image previously built and pushed to a supported registry.

**Prerequisites**

- Workstation with unrestricted network access
- A custom Operator catalog image based on the Package Manifest Format pushed to a supported registry
- **oc** version 4.3.5+
- **podman** version 1.9.3+
- Access to mirror registry that supports Docker v2-2

**IMPORTANT**

The internal registry of the OpenShift Container Platform cluster cannot be used as the target registry because it does not support pushing without a tag, which is required during the mirroring process.

- If you are working with private registries, set the **REG_CREDS** environment variable to the file path of your registry credentials for use in later steps. For example, for the **podman** CLI:

```
$ REG_CREDS=${XDG_RUNTIME_DIR}/containers/auth.json
```

**Procedure**

1. The **oc adm catalog mirror** command extracts the contents of your custom Operator catalog image to generate the manifests required for mirroring. You can choose to either:
   - Allow the default behavior of the command to automatically mirror all of the image content to your mirror registry after generating manifests, or
   - Add the **--manifests-only** flag to only generate the manifests required for mirroring, but do not actually mirror the image content to a registry yet. This can be useful for reviewing what will be mirrored, and it allows you to make any changes to the mapping list if you only require a subset of the content. You can then use that file with the **oc image mirror** command to mirror the modified list of images in a later step.

   On your workstation with unrestricted network access, run the following command:

```
$ oc adm catalog mirror \
    <registry_host_name>:<port>/olm/redhat-operators:v1 \ 1
    <registry_host_name>:<port> \ 2
    [-a ${REG_CREDS}] \ 3
    [--insecure] \ 4
    [--index-filter-by-os='<platform>/<arch>'] \ 5
    [--manifests-only] 6
```

1. Specify your Operator catalog image.
2. Specify the fully qualified domain name (FQDN) for the target registry.
3. Optional: If required, specify the location of your registry credentials file.
4. Optional: If you do not want to configure trust for the target registry, add the **--insecure** flag.
5. Optional: Specify which platform and architecture of the catalog image to select when multiple variants are available. Images are passed as **'<platform>/<arch>[/<variant>]'**. This does not apply to images referenced by the catalog image. Valid values are **linux/amd64**, **linux/ppc64le**, and **linux/s390x**.
6. Optional: Only generate the manifests required for mirroring and do not actually mirror the image content to a registry.

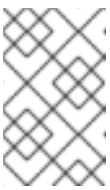
### Example output

```
using database path mapping: /:/tmp/190214037
wrote database to /tmp/190214037
using database at: /tmp/190214037/bundles.db 1
...
```

1. Temporary database generated by the command.

After running the command, a **manifests-<index_image_name>-<random_number>/** directory is created in the current directory and generates the following files:

- The **catalogSource.yaml** file is a basic definition for a **CatalogSource** object that is pre-populated with your catalog image tag and other relevant metadata. This file can be used as is or modified to add the catalog source to your cluster.
- The **imageContentSourcePolicy.yaml** file defines an **ImageContentSourcePolicy** object that can configure nodes to translate between the image references stored in Operator manifests and the mirrored registry.



**NOTE**

If your cluster uses an **ImageContentSourcePolicy** object to configure repository mirroring, you can use only global pull secrets for mirrored registries. You cannot add a pull secret to a project.

- The **mapping.txt** file contains all of the source images and where to map them in the target registry. This file is compatible with the **oc image mirror** command and can be used to further customize the mirroring configuration.

2. If you used the **--manifests-only** flag in the previous step and want to mirror only a subset of the content:

   a. Modify the list of images in your **mapping.txt** file to your specifications. If you are unsure of the exact names and versions of the subset of images you want to mirror, use the following steps to find them:

      i. Run the **sqlite3** tool against the temporary database that was generated by the **oc adm catalog mirror** command to retrieve a list of images matching a general search query. The output helps inform how you will later edit your **mapping.txt** file.
      For example, to retrieve a list of images that are similar to the string **clusterlogging.4.3**:

```
$ echo "select * from related_image \
    where operatorbundle_name like 'clusterlogging.4.3%';" \
    | sqlite3 -line /tmp/190214037/bundles.db 1
```

      1 Refer to the previous output of the **oc adm catalog mirror** command to find the path of the database file.

      **Example output**

```
image = registry.redhat.io/openshift4/ose-logging-
kibana5@sha256:aa4a8b2a00836d0e28aa6497ad90a3c116f135f382d8211e3c55f34f
b36dfe61
operatorbundle_name = clusterlogging.4.3.33-202008111029.p0

image = registry.redhat.io/openshift4/ose-oauth-
proxy@sha256:6b4db07f6e6c962fc96473d86c44532c93b146bbefe311d0c348117bf75
9c506
operatorbundle_name = clusterlogging.4.3.33-202008111029.p0
...
```

      ii. Use the results from the previous step to edit the **mapping.txt** file to only include the subset of images you want to mirror.
      For example, you can use the **image** values from the previous example output to find that the following matching lines exist in your **mapping.txt** file:

      **Matching image mappings in mapping.txt**

```
registry.redhat.io/openshift4/ose-logging-
kibana5@sha256:aa4a8b2a00836d0e28aa6497ad90a3c116f135f382d8211e3c55f34f
b36dfe61=<registry_host_name>:<port>/openshift4-ose-logging-kibana5:a767c8f0
registry.redhat.io/openshift4/ose-oauth-
proxy@sha256:6b4db07f6e6c962fc96473d86c44532c93b146bbefe311d0c348117bf75
9c506=<registry_host_name>:<port>/openshift4-ose-oauth-proxy:3754ea2b
```

      In this example, if you only want to mirror these images, you would then remove all other entries in the **mapping.txt** file and leave only the above two lines.

b. Still on your workstation with unrestricted network access, use your modified **mapping.txt** file to mirror the images to your registry using the **oc image mirror** command:

```
$ oc image mirror \
    [-a ${REG_CREDS}] \
    --filter-by-os='.*' \
    -f ./manifests-redhat-operators-<random_number>/mapping.txt
```

**WARNING**

If the **--filter-by-os** flag remains unset or set to any value other than **.***, the command filters out different architectures, which changes the digest of the manifest list, also known as a *multi-arch image*. The incorrect digest causes deployments of those images and Operators on disconnected clusters to fail.

3. Create the **ImageContentSourcePolicy** object:

```
$ oc create -f ./manifests-redhat-operators-
<random_number>/imageContentSourcePolicy.yaml
```

You can now create a **CatalogSource** object to reference your mirrored content.

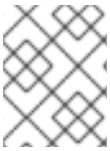
**Additional resources**

- Architecture and operating system support for Operators

### 4.7.2.3. Updating a Package Manifest Format catalog image

After a cluster administrator has configured OperatorHub to use custom Operator catalog images, administrators can keep their OpenShift Container Platform cluster up to date with the latest Operators by capturing updates made to App Registry catalogs provided by Red Hat. This is done by building and pushing a new Operator catalog image, then replacing the existing **spec.image** parameter in the **CatalogSource** object with the new image digest.

For this example, the procedure assumes a custom **redhat-operators** catalog image is already configured for use with OperatorHub.



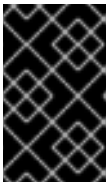
**NOTE**

Only the Linux version of the **oc** client can be used for this procedure, because the Windows and macOS versions do not provide the **oc adm catalog build** command.

**Prerequisites**

- Workstation with unrestricted network access
- **oc** version 4.3.5+ Linux client

- **podman** version 1.9.3+
- Access to mirror registry that supports Docker v2-2



**IMPORTANT**

The internal registry of the OpenShift Container Platform cluster cannot be used as the target registry because it does not support pushing without a tag, which is required during the mirroring process.

- OperatorHub configured to use custom catalog images
- If you are working with private registries, set the **REG_CREDS** environment variable to the file path of your registry credentials for use in later steps. For example, for the **podman** CLI:

```
$ REG_CREDS=${XDG_RUNTIME_DIR}/containers/auth.json
```

- If you are working with private namespaces that your quay.io account has access to, you must set a Quay authentication token. Set the **AUTH_TOKEN** environment variable for use with the **--auth-token** flag by making a request against the login API using your quay.io credentials:

```
$ AUTH_TOKEN=$(curl -sH "Content-Type: application/json" \
    -XPOST https://quay.io/cnr/api/v1/users/login -d '
    {
        "user": {
            "username": "<quay_username>",
            "password": "<quay_password>"
        }
    }' | jq -r '.token')
```

**Procedure**

1. On the workstation with unrestricted network access, authenticate with the target mirror registry:

```
$ podman login <registry_host_name>
```

2. Authenticate with **registry.redhat.io** so that the base image can be pulled during the build:

```
$ podman login registry.redhat.io
```

3. Build a new catalog image based on the **redhat-operators** catalog from Quay.io, tagging and pushing it to your mirror registry:

```
$ oc adm catalog build \
    --appregistry-org redhat-operators \ 1
    --from=registry.redhat.io/openshift4/ose-operator-registry:v4.6 \ 2
    --filter-by-os="linux/amd64" \ 3
    --to=<registry_host_name>:<port>/olm/redhat-operators:v2 \ 4
    [-a ${REG_CREDS}] \ 5
    [--insecure] \ 6
    [--auth-token "${AUTH_TOKEN}"] 7
```

1. Organization (namespace) to pull from an App Registry instance.
2. Set **--from** to the Operator Registry base image using the tag that matches the target OpenShift Container Platform cluster major and minor version.
3. Set **--filter-by-os** to the operating system and architecture to use for the base image, which must match the target OpenShift Container Platform cluster. Valid values are **linux/amd64**, **linux/ppc64le**, and **linux/s390x**.
4. Name your catalog image and include a tag, for example, **v2** because it is the updated catalog.
5. Optional: If required, specify the location of your registry credentials file.
6. Optional: If you do not want to configure trust for the target registry, add the **--insecure** flag.
7. Optional: If other application registry catalogs are used that are not public, specify a Quay authentication token.

### Example output

```
INFO[0013] loading Bundles
dir=/var/folders/st/9cskxqs53ll3wdn434vw4cd80000gn/T/300666084/manifests-829192605
...
Pushed sha256:f73d42950021f9240389f99ddc5b0c7f1b533c054ba344654ff1edaf6bf827e3
to example_registry:5000/olm/redhat-operators:v2
```

4. Mirror the contents of your catalog to your target registry. The following **oc adm catalog mirror** command extracts the contents of your custom Operator catalog image to generate the manifests required for mirroring and mirrors the images to your registry:

```
$ oc adm catalog mirror \
    <registry_host_name>:<port>/olm/redhat-operators:v2 \ 1
    <registry_host_name>:<port> \ 2
    [-a ${REG_CREDS}] \ 3
    [--insecure] \ 4
    [--index-filter-by-os='<platform>/<arch>'] 5
```

1. Specify your new Operator catalog image.
2. Specify the fully qualified domain name (FQDN) for the target registry.
3. Optional: If required, specify the location of your registry credentials file.
4. Optional: If you do not want to configure trust for the target registry, add the **--insecure** flag.
5. Optional: Specify which platform and architecture of the catalog image to select when multiple variants are available. Images are passed as **'<platform>/<arch>[/<variant>]'**. This does not apply to images referenced by the catalog image. Valid values are **linux/amd64**, **linux/ppc64le**, and **linux/s390x**.

5. Apply the newly generated manifests:

```
$ oc replace -f ./manifests-redhat-operators-<random_number>
```

**IMPORTANT**

It is possible that you do not need to apply the **imageContentSourcePolicy.yaml** manifest. Complete a **diff** of the files to determine if changes are necessary.

6. Update your **CatalogSource** object that references your catalog image.
   a. If you have your original **catalogsource.yaml** file for this **CatalogSource** object:
      i. Edit your **catalogsource.yaml** file to reference your new catalog image in the **spec.image** field:

```
apiVersion: operators.coreos.com/v1alpha1
kind: CatalogSource
metadata:
  name: my-operator-catalog
  namespace: openshift-marketplace
spec:
  sourceType: grpc
  image: <registry_host_name>:<port>/olm/redhat-operators:v2 1
  displayName: My Operator Catalog
  publisher: grpc
```

1 Specify your new Operator catalog image.

      ii. Use the updated file to replace the **CatalogSource** object:

```
$ oc replace -f catalogsource.yaml
```

   b. Alternatively, edit the catalog source using the following command and reference your new catalog image in the **spec.image** parameter:

```
$ oc edit catalogsource <catalog_source_name> -n openshift-marketplace
```

Updated Operators should now be available from the **OperatorHub** page on your OpenShift Container Platform cluster.

**Additional resources**

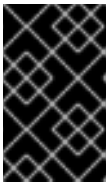
- Architecture and operating system support for Operators

### 4.7.2.4. Testing a Package Manifest Format catalog image

You can validate Operator catalog image content by running it as a container and querying its gRPC API. To further test the image, you can then resolve a subscription in Operator Lifecycle Manager (OLM) by referencing the image in a catalog source. For this example, the procedure uses a custom **redhat-operators** catalog image previously built and pushed to a supported registry.

### Prerequisites

- A custom Package Manifest Format catalog image pushed to a supported registry
- **podman** version 1.9.3+
- **oc** version 4.3.5+
- Access to mirror registry that supports Docker v2-2



**IMPORTANT**

The internal registry of the OpenShift Container Platform cluster cannot be used as the target registry because it does not support pushing without a tag, which is required during the mirroring process.

- **grpcurl**

### Procedure

1. Pull the Operator catalog image:

```
$ podman pull <registry_host_name>:<port>/olm/redhat-operators:v1
```

2. Run the image:

```
$ podman run -p 50051:50051 \
    -it <registry_host_name>:<port>/olm/redhat-operators:v1
```

3. Query the running image for available packages using **grpcurl**:

```
$ grpcurl -plaintext localhost:50051 api.Registry/ListPackages
```

#### Example output

```
{
  "name": "3scale-operator"
}
{
  "name": "amq-broker"
}
{
  "name": "amq-online"
}
```

4. Get the latest Operator bundle in a channel:

```
$  grpcurl -plaintext -d '{"pkgName":"kiali-ossm","channelName":"stable"}' localhost:50051
api.Registry/GetBundleForChannel
```

#### Example output

```
{
```

```
  "csvName": "kiali-operator.v1.0.7",
  "packageName": "kiali-ossm",
  "channelName": "stable",
...
```

5. Get the digest of the image:

```
$ podman inspect \
    --format='{{index .RepoDigests 0}}' \
    <registry_host_name>:<port>/olm/redhat-operators:v1
```

**Example output**

```
example_registry:5000/olm/redhat-
operators@sha256:f73d42950021f9240389f99ddc5b0c7f1b533c054ba344654ff1edaf6bf827e3
```

6. Assuming an Operator group exists in namespace **my-ns** that supports your Operator and its dependencies, create a **CatalogSource** object using the image digest. For example:

```
apiVersion: operators.coreos.com/v1alpha1
kind: CatalogSource
metadata:
  name: custom-redhat-operators
  namespace: my-ns
spec:
  sourceType: grpc
  image: example_registry:5000/olm/redhat-
operators@sha256:f73d42950021f9240389f99ddc5b0c7f1b533c054ba344654ff1edaf6bf827e3

  displayName: Red Hat Operators
```

7. Create a subscription that resolves the latest available **servicemeshoperator** and its dependencies from your catalog image:

```
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: servicemeshoperator
  namespace: my-ns
spec:
  source: custom-redhat-operators
  sourceNamespace: my-ns
  name: servicemeshoperator
  channel: "1.0"
```

### 4.7.3. Disabling the default OperatorHub sources

Operator catalogs that source content provided by Red Hat and community projects are configured for OperatorHub by default during an OpenShift Container Platform installation. As a cluster administrator, you can disable the set of default catalogs.

**Procedure**

- Disable the sources for the default catalogs by adding **disableAllDefaultSources: true** to the **OperatorHub** object:

```
$ oc patch OperatorHub cluster --type json \
    -p '[{"op": "add", "path": "/spec/disableAllDefaultSources", "value": true}]'
```

**TIP**

Alternatively, you can use the web console to manage catalog sources. From the **Administration → Cluster Settings → Global Configuration → OperatorHub** page, click the **Sources** tab, where you can create, delete, disable, and enable individual sources.

### 4.7.4. Removing custom catalogs

As a cluster administrator, you can remove custom Operator catalogs that have been previously added to your cluster by deleting the related catalog source.

**Procedure**

1. In the **Administrator** perspective of the web console, navigate to **Administration → Cluster Settings**.
2. Click the **Global Configuration** tab, and then click **OperatorHub**.
3. Click the **Sources** tab.
4. Select the **Options** menu  for the catalog that you want to remove, and then click **Delete CatalogSource**.

## 4.8. USING OPERATOR LIFECYCLE MANAGER ON RESTRICTED NETWORKS

For OpenShift Container Platform clusters that are installed on restricted networks, also known as *disconnected clusters*, Operator Lifecycle Manager (OLM) by default cannot access the Red Hat-provided OperatorHub sources hosted on remote registries because those remote sources require full Internet connectivity.

However, as a cluster administrator you can still enable your cluster to use OLM in a restricted network if you have a workstation that has full Internet access. The workstation, which requires full Internet access to pull the remote OperatorHub content, is used to prepare local mirrors of the remote sources, and push the content to a mirror registry.

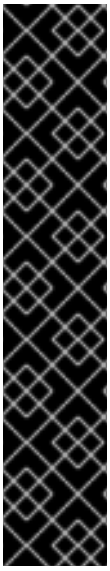
The mirror registry can be located on a bastion host, which requires connectivity to both your workstation and the disconnected cluster, or a completely disconnected, or *airgapped*, host, which requires removable media to physically move the mirrored content to the disconnected environment.

This guide describes the following process that is required to enable OLM in restricted networks:

- Disable the default remote OperatorHub sources for OLM.
- Use a workstation with full Internet access to create and push local mirrors of the OperatorHub content to a mirror registry.

- Configure OLM to install and manage Operators from local sources on the mirror registry instead of the default remote sources.

After enabling OLM in a restricted network, you can continue to use your unrestricted workstation to keep your local OperatorHub sources updated as newer versions of Operators are released.



**IMPORTANT**

While OLM can manage Operators from local sources, the ability for a given Operator to run successfully in a restricted network still depends on the Operator itself. The Operator must:

- List any related images, or other container images that the Operator might require to perform their functions, in the **relatedImages** parameter of its **ClusterServiceVersion** (CSV) object.
- Reference all specified images by a digest (SHA) and not by a tag.

See the following Red Hat Knowledgebase Article for a list of Red Hat Operators that support running in disconnected mode:

https://access.redhat.com/articles/4740011

**Additional resources**

- Red Hat-provided Operator catalogs
- Enabling your Operator for restricted network environments

### 4.8.1. Prerequisites

- Log in to your OpenShift Container Platform cluster as a user with **cluster-admin** privileges.
- If you want to prune the default catalog and selectively mirror only a subset of Operators, install the **opm** CLI.

**NOTE**

If you are using OLM in a restricted network on IBM Z, you must have at least 12 GB allocated to the directory where you place your registry.

### 4.8.2. Disabling the default OperatorHub sources

Operator catalogs that source content provided by Red Hat and community projects are configured for OperatorHub by default during an OpenShift Container Platform installation. In a restricted network environment, you must disable the default catalogs as a cluster administrator. You can then configure OperatorHub to use local catalog sources.

**Procedure**

- Disable the sources for the default catalogs by adding **disableAllDefaultSources: true** to the **OperatorHub** object:

```
$ oc patch OperatorHub cluster --type json \
    -p '[{"op": "add", "path": "/spec/disableAllDefaultSources", "value": true}]'
```

TIP

Alternatively, you can use the web console to manage catalog sources. From the **Administration → Cluster Settings → Global Configuration → OperatorHub** page, click the **Sources** tab, where you can create, delete, disable, and enable individual sources.

### 4.8.3. Pruning an index image

An index image, based on the Operator Bundle Format, is a containerized snapshot of an Operator catalog. You can prune an index of all but a specified list of packages, which creates a copy of the source index containing only the Operators that you want.

When configuring Operator Lifecycle Manager (OLM) to use mirrored content on restricted network OpenShift Container Platform clusters, use this pruning method if you want to only mirror a subset of Operators from the default catalogs.

For the steps in this procedure, the target registry is an existing mirror registry that is accessible by your workstation with unrestricted network access. This example also shows pruning the index image for the default **redhat-operators** catalog, but the process is the same for any index image.

#### Prerequisites

- Workstation with unrestricted network access
- **podman** version 1.9.3+
- **grpcurl** (third-party command-line tool)
- **opm** version 1.18.0+
- Access to a registry that supports Docker v2-2

IMPORTANT

The internal registry of the OpenShift Container Platform cluster cannot be used as the target registry because it does not support pushing without a tag, which is required during the mirroring process.

#### Procedure

1. Authenticate with **registry.redhat.io**:

```
$ podman login registry.redhat.io
```

2. Authenticate with your target registry:

```
$ podman login <target_registry>
```

3. Determine the list of packages you want to include in your pruned index.

   a. Run the source index image that you want to prune in a container. For example:

```
$ podman run -p50051:50051 \
    -it registry.redhat.io/redhat/redhat-operator-index:v4.6
```

**Example output**

```
Trying to pull registry.redhat.io/redhat/redhat-operator-index:v4.6...
Getting image source signatures
Copying blob ae8a0c23f5b1 done
...
INFO[0000] serving registry                 database=/database/index.db port=50051
```

b. In a separate terminal session, use the **grpcurl** command to get a list of the packages provided by the index:

```
$ grpcurl -plaintext localhost:50051 api.Registry/ListPackages > packages.out
```

c. Inspect the **packages.out** file and identify which package names from this list you want to keep in your pruned index. For example:

**Example snippets of packages list**

```
...
{
  "name": "advanced-cluster-management"
}
...
{
  "name": "jaeger-product"
}
...
{
{
  "name": "quay-operator"
}
...
```

d. In the terminal session where you executed the **podman run** command, press **Ctrl** and **C** to stop the container process.

4. Run the following command to prune the source index of all but the specified packages:

```
$ opm index prune \
    -f registry.redhat.io/redhat/redhat-operator-index:v4.6 \ 1
    -p advanced-cluster-management,jaeger-product,quay-operator \ 2
    [-i registry.redhat.io/openshift4/ose-operator-registry:v4.6] \ 3
    -t <target_registry>:<port>/<namespace>/redhat-operator-index:v4.6 4
```

1 Index to prune.

2 Comma-separated list of packages to keep.

3 Required only for IBM Power Systems and IBM Z images: Operator Registry base image with the tag that matches the target OpenShift Container Platform cluster major and minor version.

4 Custom tag for new index image being built.

5. Run the following command to push the new index image to your target registry:

```
$ podman push <target_registry>:<port>/<namespace>/redhat-operator-index:v4.6
```

where **<namespace>** is any existing namespace on the registry. For example, you might create an **olm-mirror** namespace to push all mirrored content to.

### 4.8.4. Mirroring an Operator catalog

You can mirror the Operator content of a Red Hat-provided catalog, or a custom catalog, into a container image registry using the **oc adm catalog mirror** command. The target registry must support Docker v2-2. For a cluster on a restricted network, this registry can be one that the cluster has network access to, such as a mirror registry created during a restricted network cluster installation.

**IMPORTANT**

The internal registry of the OpenShift Container Platform cluster cannot be used as the target registry because it does not support pushing without a tag, which is required during the mirroring process.

The **oc adm catalog mirror** command also automatically mirrors the index image that is specified during the mirroring process, whether it be a Red Hat-provided index image or your own custom-built index image, to the target registry. You can then use the mirrored index image to create a catalog source that allows Operator Lifecycle Manager (OLM) to load the mirrored catalog onto your OpenShift Container Platform cluster.

#### Prerequisites

- Workstation with unrestricted network access.
- **podman** version 1.9.3 or later.
- Access to mirror registry that supports Docker v2-2.
- Decide which namespace on your mirror registry you will use to store the mirrored Operator content. For example, you might create an **olm-mirror** namespace.
- If your mirror registry does not have Internet access, connect removable media to your workstation with unrestricted network access.
- If you are working with private registries, including **registry.redhat.io**, set the **REG_CREDS** environment variable to the file path of your registry credentials for use in later steps. For example, for the **podman** CLI:

```
$ REG_CREDS=${XDG_RUNTIME_DIR}/containers/auth.json
```

#### Procedure

1. If you want to mirror a Red Hat-provided catalog, run the following command on your workstation with unrestricted network access to authenticate with **registry.redhat.io**:

```
$ podman login registry.redhat.io
```

2. The **oc adm catalog mirror** command extracts the contents of an index image to generate the manifests required for mirroring. The default behavior of the command generates manifests, then automatically mirrors all of the image content from the index image, as well as the index image itself, to your mirror registry. Alternatively, if your mirror registry is on a completely disconnected, or *airgapped*, host, you can first mirror the content to removable media, move the media to the disconnected environment, then mirror the content from the media to the registry.

   - **Option A: If your mirror registry is on the same network** as your workstation with unrestricted network access, take the following actions on your workstation:

     a. If your mirror registry requires authentication, run the following command to log in to the registry:

     ```
     $ podman login <mirror_registry>
     ```

     b. Run the following command to mirror the content:

     ```
     $ oc adm catalog mirror \
       <index_image> \ 1
       <mirror_registry>:<port>/<namespace> \ 2
       [-a ${REG_CREDS}] \ 3
       [--insecure] \ 4
       [--index-filter-by-os='<platform>/<arch>'] \ 5
       [--manifests-only] 6
     ```

     1. Specify the index image for the catalog you want to mirror. For example, this might be a pruned index image that you created previously, or one of the source index images for the default catalogs, such as **registry.redhat.io/redhat/redhat-operator-index:v4.6**.

     2. Specify the fully qualified domain name (FQDN) for the target registry and namespace to mirror the Operator content to, where **<namespace>** is any existing namespace on the registry. For example, you might create an **olm-mirror** namespace to push all mirrored content to.

     3. Optional: If required, specify the location of your registry credentials file. **{REG_CREDS}** is required for **registry.redhat.io**.

     4. Optional: If you do not want to configure trust for the target registry, add the **--insecure** flag.

     5. Optional: Specify which platform and architecture of the index image to select when multiple variants are available. Images are passed as **'<platform>/<arch>[/<variant>]'**. This does not apply to images referenced by the index. Valid values are **linux/amd64**, **linux/ppc64le**, and **linux/s390x**.

     6. Optional: Generate only the manifests required for mirroring, and do not actually mirror the image content to a registry. This option can be useful for reviewing what will be mirrored, and it allows you to make any changes to the mapping list if you require only a subset of packages. You can then use the **mapping.txt** file with the **oc image mirror** command to mirror the modified list of images in a later step. This flag is intended for only advanced selective mirroring of content from the catalog; the **opm index prune** command, if you used it previously to prune the

index image, is suitable for most catalog management use cases.

**Example output**

```
src image has index label for database path: /database/index.db
using database path mapping: /database/index.db:/tmp/153048078
wrote database to /tmp/153048078 1
...
wrote mirroring manifests to manifests-redhat-operator-index-1614211642 2
```

1. Directory for the temporary **index.db** database generated by the command.
2. Be sure to record the manifests directory name that is generated. This directory name is used in a later step.

**NOTE**

Red Hat Quay does not support nested repositories. As a result, running the **oc adm catalog mirror** command will fail with a **401** unauthorized error. As a workaround, you can use the **--max-components=2** option when running the **oc adm catalog mirror** command to disable the creation of nested repositories. For more information on this workaround, see the Unauthorized error thrown while using catalog mirror command with Quay registry Knowledgebase Solution article.

- **Option B: If your mirror registry is on a disconnected host**, take the following actions.

  a. Run the following command on your workstation with unrestricted network access to mirror the content to local files:

```
$ oc adm catalog mirror \
    <index_image> \ 1
    file:///local/index \ 2
    [-a ${REG_CREDS}] \
    [--insecure]
```

1. Specify the index image for the catalog you want to mirror. For example, this might be a pruned index image that you created previously, or one of the source index images for the default catalogs, such as **registry.redhat.io/redhat/redhat-operator-index:v4.6**.
2. Mirrors content to local files in your current directory.

**Example output**

```
...
info: Mirroring completed in 5.93s (5.915MB/s)
wrote mirroring manifests to manifests-my-index-1614985528 1

To upload local images to a registry, run:
```

```
 oc adm catalog mirror file://local/index/myrepo/my-index:v1
REGISTRY/REPOSITORY 2
```

1. Be sure to record the manifests directory name that is generated. This directory name is used in a later step.
2. Record the expanded **file://** path that based on your provided index image. This path is used in a later step.

b. Copy the **v2/** directory that is generated in your current directory to removable media.

c. Physically remove the media and attach it to a host in the disconnected environment that has access to the mirror registry.

d. If your mirror registry requires authentication, run the following command on your host in the disconnected environment to log in to the registry:

```
$ podman login <mirror_registry>
```

e. Run the following command from the parent directory containing the **v2/** directory to upload the images from local files to the mirror registry:

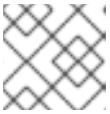
```
$ oc adm catalog mirror \
    file://local/index/<repo>/<index_image>:<tag> \ 1
    <mirror_registry>:<port>/<namespace> \ 2
    [-a ${REG_CREDS}] \
    [--insecure]
```

1. Specify the **file://** path from the previous command output.
2. Specify the fully qualified domain name (FQDN) for the target registry and namespace to mirror the Operator content to, where **<namespace>** is any existing namespace on the registry. For example, you might create an **olm-mirror** namespace to push all mirrored content to.

**NOTE**

Red Hat Quay does not support nested repositories. As a result, running the **oc adm catalog mirror** command will fail with a **401** unauthorized error. As a workaround, you can use the **--max-components=2** option when running the **oc adm catalog mirror** command to disable the creation of nested repositories. For more information on this workaround, see the Unauthorized error thrown while using catalog mirror command with Quay registry Knowledgebase Solution article.

3. After mirroring the content to your registry, inspect the manifests directory that is generated in your current directory.



**NOTE**

The manifests directory name is used in a later step.

If you mirrored content to a registry on the same network in the previous step, the directory name takes the following form:

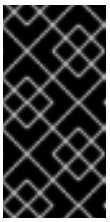
```
manifests-<index_image_name>-<random_number>
```

If you mirrored content to a registry on a disconnected host in the previous step, the directory name takes the following form:

```
manifests-index/<namespace>/<index_image_name>-<random_number>
```

The manifests directory contains the following files, some of which might require further modification:

- The **catalogSource.yaml** file is a basic definition for a **CatalogSource** object that is pre-populated with your index image tag and other relevant metadata. This file can be used as is or modified to add the catalog source to your cluster.



IMPORTANT

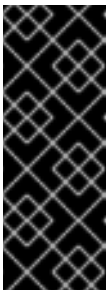
If you mirrored the content to local files, you must modify your **catalogSource.yaml** file to remove any backslash ( /) characters from the **metadata.name** field. Otherwise, when you attempt to create the object, it fails with an "invalid resource name" error.

- The **imageContentSourcePolicy.yaml** file defines an **ImageContentSourcePolicy** object that can configure nodes to translate between the image references stored in Operator manifests and the mirrored registry.

NOTE

If your cluster uses an **ImageContentSourcePolicy** object to configure repository mirroring, you can use only global pull secrets for mirrored registries. You cannot add a pull secret to a project.

- The **mapping.txt** file contains all of the source images and where to map them in the target registry. This file is compatible with the **oc image mirror** command and can be used to further customize the mirroring configuration.



IMPORTANT

If you used the **--manifests-only** flag during the mirroring process and want to further trim the subset of packages to be mirrored, see the steps in the "Mirroring a Package Manifest Format catalog image" procedure about modifying your **mapping.txt** file and using the file with the **oc image mirror** command. After following those further actions, you can continue this procedure.

4. On a host with access to the disconnected cluster, create the **ImageContentSourcePolicy** object by running the following command to specify the **imageContentSourcePolicy.yaml** file in your manifests directory:

```
$ oc create -f <path/to/manifests/dir>/imageContentSourcePolicy.yaml
```

where **<path/to/manifests/dir>** is the path to the manifests directory for your mirrored content.

You can now create a **CatalogSource** object to reference your mirrored index image and Operator content.

### Additional resources

- Mirroring images for a disconnected installation
- Architecture and operating system support for Operators
- Mirroring a Package Manifest Format catalog image

## 4.8.5. Creating a catalog from an index image

You can create an Operator catalog from an index image and apply it to an OpenShift Container Platform cluster for use with Operator Lifecycle Manager (OLM).

### Prerequisites

- An index image built and pushed to a registry.

### Procedure

1. Create a **CatalogSource** object that references your index image. If you used the **oc adm catalog mirror** command to mirror your catalog to a target registry, you can use the generated **catalogSource.yaml** file as a starting point.

   a. Modify the following to your specifications and save it as a **catalogSource.yaml** file:

```
apiVersion: operators.coreos.com/v1alpha1
kind: CatalogSource
metadata:
  name: my-operator-catalog (1)
  namespace: openshift-marketplace (2)
spec:
  sourceType: grpc
  image: <registry>:<port>/<namespace>/redhat-operator-index:v4.6 (3)
  displayName: My Operator Catalog
  publisher: <publisher_name> (4)
  updateStrategy:
    registryPoll: (5)
      interval: 30m
```

(1) If you mirrored content to local files before uploading to a registry, remove any backslash (/) characters from the **metadata.name** field to avoid an "invalid resource name" error when you create the object.

(2) If you want the catalog source to be available globally to users in all namespaces, specify the **openshift-marketplace** namespace. Otherwise, you can specify a different namespace for the catalog to be scoped and available only for that namespace.

(3) Specify your index image.

(4) Specify your name or an organization name publishing the catalog.

5 Catalog sources can automatically check for new versions to keep up to date.

b. Use the file to create the **CatalogSource** object:

```
$ oc apply -f catalogSource.yaml
```

2. Verify the following resources are created successfully.

a. Check the pods:

```
$ oc get pods -n openshift-marketplace
```

**Example output**

```
NAME                                  READY   STATUS    RESTARTS  AGE
my-operator-catalog-6njx6             1/1     Running   0         28s
marketplace-operator-d9f549946-96sgr  1/1     Running   0         26h
```

b. Check the catalog source:

```
$ oc get catalogsource -n openshift-marketplace
```

**Example output**

```
NAME                  DISPLAY               TYPE PUBLISHER  AGE
my-operator-catalog   My Operator Catalog   grpc           5s
```

c. Check the package manifest:

```
$ oc get packagemanifest -n openshift-marketplace
```

**Example output**

```
NAME                  CATALOG               AGE
jaeger-product          My Operator Catalog   93s
```

You can now install the Operators from the **OperatorHub** page on your OpenShift Container Platform web console.

### 4.8.6. Updating an index image

After configuring OperatorHub to use a catalog source that references a custom index image, cluster administrators can keep the available Operators on their cluster up to date by adding bundle images to the index image.

You can update an existing index image using the **opm index add** command. For restricted networks, the updated content must also be mirrored again to the cluster.

**Prerequisites**

- **opm** version 1.12.3+

- **podman** version 1.9.3+
- An index image built and pushed to a registry.
- An existing catalog source referencing the index image.

### Procedure

1. Update the existing index by adding bundle images:

```
$ opm index add \
   --bundles <registry>/<namespace>/<new_bundle_image>@sha256:<digest> \ 1
   --from-index <registry>/<namespace>/<existing_index_image>:<existing_tag> \ 2
   --tag <registry>/<namespace>/<existing_index_image>:<updated_tag> \ 3
   --pull-tool podman 4
```

1. The **--bundles** flag specifies a comma-separated list of additional bundle images to add to the index.
2. The **--from-index** flag specifies the previously pushed index.
3. The **--tag** flag specifies the image tag to apply to the updated index image.
4. The **--pull-tool** flag specifies the tool used to pull container images.

where:

**<registry>**
: Specifies the hostname of the registry, such as **quay.io** or **mirror.example.com**.

**<namespace>**
: Specifies the namespace of the registry, such as **ocs-dev** or **abc**.

**<new_bundle_image>**
: Specifies the new bundle image to add to the registry, such as **ocs-operator**.

**<digest>**
: Specifies the SHA image ID, or digest, of the bundle image, such as **c7f11097a628f092d8bad148406aa0e0951094a03445fd4bc0775431ef683a41**.

**<existing_index_image>**
: Specifies the previously pushed image, such as **abc-redhat-operator-index**.

**<existing_tag>**
: Specifies a previously pushed image tag, such as **4.6**.

**<updated_tag>**
: Specifies the image tag to apply to the updated index image, such as **4.6.1**.

#### Example command

```
$ opm index add \
   --bundles quay.io/ocs-dev/ocs-
operator@sha256:c7f11097a628f092d8bad148406aa0e0951094a03445fd4bc0775431ef683a
41 \
```

```
--from-index mirror.example.com/abc/abc-redhat-operator-index:4.6 \
--tag mirror.example.com/abc/abc-redhat-operator-index:4.6.1 \
--pull-tool podman
```

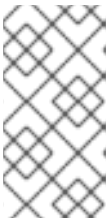
2. Push the updated index image:

```
$ podman push <registry>/<namespace>/<existing_index_image>:<updated_tag>
```

3. Follow the steps in the *Mirroring an Operator catalog* procedure again to mirror the updated content. However, when you get to the step about creating the **ImageContentSourcePolicy** (ICSP) object, use the **oc replace** command instead of the **oc create** command. For example:

```
$ oc replace -f ./manifests-redhat-operator-index-
<random_number>/imageContentSourcePolicy.yaml
```

This change is required because the object already exists and must be updated.



NOTE

Normally, the **oc apply** command can be used to update existing objects that were previously created using **oc apply**. However, due to a known issue regarding the size of the **metadata.annotations** field in ICSP objects, the **oc replace** command must be used for this step currently.

4. After Operator Lifecycle Manager (OLM) automatically polls the index image referenced in the catalog source at its regular interval, verify that the new packages are successfully added:

```
$ oc get packagemanifests -n openshift-marketplace
```

**Additional resources**

- Mirroring an Operator catalog

# CHAPTER 5. DEVELOPING OPERATORS

## 5.1. ABOUT THE OPERATOR SDK

The Operator Framework is an open source toolkit to manage Kubernetes native applications, called *Operators*, in an effective, automated, and scalable way. Operators take advantage of Kubernetes extensibility to deliver the automation advantages of cloud services, like provisioning, scaling, and backup and restore, while being able to run anywhere that Kubernetes can run.

Operators make it easy to manage complex, stateful applications on top of Kubernetes. However, writing an Operator today can be difficult because of challenges such as using low-level APIs, writing boilerplate, and a lack of modularity, which leads to duplication.

The Operator SDK, a component of the Operator Framework, provides a command-line interface (CLI) tool that Operator developers can use to build, test, and deploy an Operator.

**Why use the Operator SDK?**

The Operator SDK simplifies this process of building Kubernetes-native applications, which can require deep, application-specific operational knowledge. The Operator SDK not only lowers that barrier, but it also helps reduce the amount of boilerplate code required for many common management capabilities, such as metering or monitoring.

The Operator SDK is a framework that uses the controller-runtime library to make writing Operators easier by providing the following features:

- High-level APIs and abstractions to write the operational logic more intuitively
- Tools for scaffolding and code generation to quickly bootstrap a new project
- Integration with Operator Lifecycle Manager (OLM) to streamline packaging, installing, and running Operators on a cluster
- Extensions to cover common Operator use cases
- Metrics set up automatically in any generated Go-based Operator for use on clusters where the Prometheus Operator is deployed

Operator authors with cluster administrator access to a Kubernetes-based cluster, such as OpenShift Container Platform, can use the Operator SDK CLI to develop their own Operators based on Go, Ansible, or Helm. Kubebuilder is embedded into the Operator SDK as the scaffolding solution for Go-based Operators, which means existing Kubebuilder projects can be used as is with the Operator SDK and continue to work.

**NOTE**

OpenShift Container Platform 4.6 supports Operator SDK v0.19.4.

### 5.1.1. What are Operators?

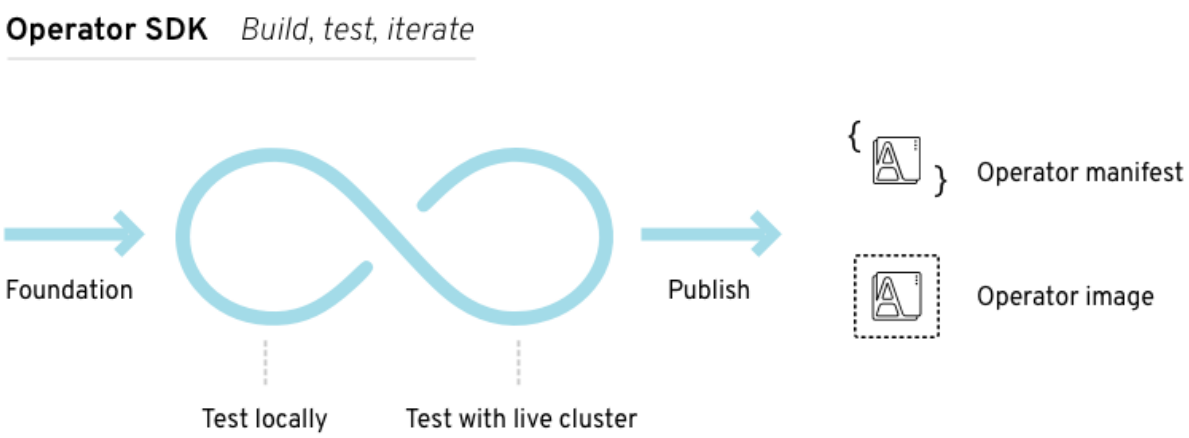
For an overview about basic Operator concepts and terminology, see Understanding Operators.

### 5.1.2. Development workflow

The Operator SDK provides the following workflow to develop a new Operator:

1. Create an Operator project by using the Operator SDK command-line interface (CLI).
2. Define new resource APIs by adding custom resource definitions (CRDs).
3. Specify resources to watch by using the Operator SDK API.
4. Define the Operator reconciling logic in a designated handler and use the Operator SDK API to interact with resources.
5. Use the Operator SDK CLI to build and generate the Operator deployment manifests.

**Figure 5.1. Operator SDK workflow**




At a high level, an Operator that uses the Operator SDK processes events for watched resources in an Operator author-defined handler and takes actions to reconcile the state of the application.

### 5.1.3. Additional resources

- Certified Operator Build Guide

## 5.2. INSTALLING THE OPERATOR SDK CLI

The Operator SDK provides a command-line interface (CLI) tool that Operator developers can use to build, test, and deploy an Operator. You can install the Operator SDK CLI on your workstation so that you are prepared to start authoring your own Operators.

OpenShift Container Platform 4.6 supports Operator SDK v0.19.4, which can be installed from upstream sources.

**NOTE**

Starting in OpenShift Container Platform 4.7, the Operator SDK is fully supported and available from official Red Hat product sources. See OpenShift Container Platform 4.7 release notes for more information.

### 5.2.1. Installing the Operator SDK CLI from from GitHub releases

You can download and install a pre-built release binary of the Operator SDK CLI from the project on GitHub.

**Prerequisites**

- Go v1.13+
- **docker** v17.03+, **podman** v1.9.3+, or **buildah** v1.7+
- OpenShift CLI (**oc**) v4.6+ installed
- Access to a cluster based on Kubernetes v1.12.0+
- Access to a container registry

**Procedure**

1. Set the release version variable:

```
$ RELEASE_VERSION=v0.19.4
```

2. Download the release binary.
   - For Linux:

```
$ curl -OJL https://github.com/operator-framework/operator-sdk/releases/download/${RELEASE_VERSION}/operator-sdk-${RELEASE_VERSION}-x86_64-linux-gnu
```

   - For macOS:

```
$ curl -OJL https://github.com/operator-framework/operator-sdk/releases/download/${RELEASE_VERSION}/operator-sdk-${RELEASE_VERSION}-x86_64-apple-darwin
```

3. Verify the downloaded release binary.
   a. Download the provided **.asc** file.
      - For Linux:

```
$ curl -OJL https://github.com/operator-framework/operator-sdk/releases/download/${RELEASE_VERSION}/operator-sdk-${RELEASE_VERSION}-x86_64-linux-gnu.asc
```

      - For macOS:

```
$ curl -OJL https://github.com/operator-framework/operator-sdk/releases/download/${RELEASE_VERSION}/operator-sdk-${RELEASE_VERSION}-x86_64-apple-darwin.asc
```

   b. Place the binary and corresponding **.asc** file into the same directory and run the following command to verify the binary:
      - For Linux:

```
$ gpg --verify operator-sdk-${RELEASE_VERSION}-x86_64-linux-gnu.asc
```

- For macOS:

```
$ gpg --verify operator-sdk-${RELEASE_VERSION}-x86_64-apple-darwin.asc
```

If you do not have the public key of the maintainer on your workstation, you will get the following error:

**Example output with error**

```
$ gpg: assuming signed data in 'operator-sdk-${RELEASE_VERSION}-x86_64-apple-darwin'
$ gpg: Signature made Fri Apr  5 20:03:22 2019 CEST
$ gpg:                using RSA key <key_id> 1
$ gpg: Can't check signature: No public key
```

1 RSA key string.

To download the key, run the following command, replacing **<key_id>** with the RSA key string provided in the output of the previous command:

```
$ gpg [--keyserver keys.gnupg.net] --recv-key "<key_id>" 1
```

1 If you do not have a key server configured, specify one with the **--keyserver** option.

4. Install the release binary in your **PATH**:

- For Linux:

```
$ chmod +x operator-sdk-${RELEASE_VERSION}-x86_64-linux-gnu
```

```
$ sudo cp operator-sdk-${RELEASE_VERSION}-x86_64-linux-gnu /usr/local/bin/operator-sdk
```

```
$ rm operator-sdk-${RELEASE_VERSION}-x86_64-linux-gnu
```

- For macOS:

```
$ chmod +x operator-sdk-${RELEASE_VERSION}-x86_64-apple-darwin
```

```
$ sudo cp operator-sdk-${RELEASE_VERSION}-x86_64-apple-darwin /usr/local/bin/operator-sdk
```

```
$ rm operator-sdk-${RELEASE_VERSION}-x86_64-apple-darwin
```

5. Verify that the CLI tool was installed correctly:

```
$ operator-sdk version
```

### 5.2.2. Installing the Operator SDK CLI from Homebrew

You can install the SDK CLI using Homebrew.

**Prerequisites**

- Homebrew
- **docker** v17.03+, **podman** v1.9.3+, or **buildah** v1.7+
- OpenShift CLI (**oc**) v4.6+ installed
- Access to a cluster based on Kubernetes v1.12.0+
- Access to a container registry

**Procedure**

1. Install the SDK CLI using the **brew** command:

```
$ brew install operator-sdk
```

2. Verify that the CLI tool was installed correctly:

```
$ operator-sdk version
```

### 5.2.3. Compiling and installing the Operator SDK CLI from source

You can obtain the Operator SDK source code to compile and install the SDK CLI.

**Prerequisites**

- Git
- Go v1.13+
- **docker** v17.03+, **podman** v1.9.3+, or **buildah** v1.7+
- OpenShift CLI (**oc**) v4.6+ installed
- Access to a cluster based on Kubernetes v1.12.0+
- Access to a container registry

**Procedure**

1. Clone the **operator-sdk** repository:

```
$ git clone https://github.com/operator-framework/operator-sdk
```

2. Change to the directory for the cloned repository:

```
$ cd operator-sdk
```

3. Check out the v0.19.4 release:

```
$ git checkout tags/v0.19.4 -b v0.19.4
```

4. Update dependencies:

```
$ make tidy
```

5. Compile and install the SDK CLI:

```
$ make install
```

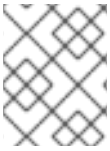
This installs the CLI binary **operator-sdk** in the **$GOPATH/bin/** directory.

6. Verify that the CLI tool was installed correctly:

```
$ operator-sdk version
```

## 5.3. CREATING GO-BASED OPERATORS

Operator developers can take advantage of Go programming language support in the Operator SDK to build an example Go-based Operator for Memcached, a distributed key-value store, and manage its lifecycle.



**NOTE**

Kubebuilder is embedded into the Operator SDK as the scaffolding solution for Go-based Operators.

### 5.3.1. Creating a Go-based Operator using the Operator SDK

The Operator SDK makes it easier to build Kubernetes native applications, a process that can require deep, application-specific operational knowledge. The SDK not only lowers that barrier, but it also helps reduce the amount of boilerplate code needed for many common management capabilities, such as metering or monitoring.

This procedure walks through an example of creating a simple Memcached Operator using tools and libraries provided by the SDK.

**Prerequisites**

- Operator SDK v0.19.4 CLI installed on the development workstation
- Operator Lifecycle Manager (OLM) installed on a Kubernetes-based cluster (v1.8 or above to support the **apps/v1beta2** API group), for example OpenShift Container Platform 4.6
- Access to the cluster using an account with **cluster-admin** permissions
- OpenShift CLI (**oc**) v4.6+ installed

**Procedure**

1. Create an Operator project:
   a. Create a directory for the project:

```
$ mkdir -p $HOME/projects/memcached-operator
```

b. Change to the directory:

```
$ cd $HOME/projects/memcached-operator
```

c. Activate support for Go modules:

```
$ export GO111MODULE=on
```

d. Run the **operator-sdk init** command to initialize the project:

```
$ operator-sdk init \
    --domain=example.com \
    --repo=github.com/example-inc/memcached-operator
```

NOTE

The **operator-sdk init** command uses the **go.kubebuilder.io/v2** plug-in by default.

2. Update your Operator to use supported images:

a. In the project root-level Dockerfile, change the default runner image reference from:

```
FROM gcr.io/distroless/static:nonroot
```

to:

```
FROM registry.access.redhat.com/ubi8/ubi-minimal:latest
```

b. Depending on the Go project version, your Dockerfile might contain a **USER 65532:65532** or **USER nonroot:nonroot** directive. In either case, remove the line, as it is not required by the supported runner image.

c. In the **config/default/manager_auth_proxy_patch.yaml** file, change the **image** value from:

```
gcr.io/kubebuilder/kube-rbac-proxy:<tag>
```

to use the supported image:

```
registry.redhat.io/openshift4/ose-kube-rbac-proxy:v4.6
```

3. Update the **test** target in your Makefile to install dependencies required during later builds by replacing the following lines:

**Example 5.1. Existing test target**

```
test: generate fmt vet manifests
	go test ./... -coverprofile cover.out
```

With the following lines:

**Example 5.2. Updated test target**

```
ENVTEST_ASSETS_DIR=$(shell pwd)/testbin
test: manifests generate fmt vet ## Run tests.
 mkdir -p ${ENVTEST_ASSETS_DIR}
 test -f ${ENVTEST_ASSETS_DIR}/setup-envtest.sh || curl -sSLo
${ENVTEST_ASSETS_DIR}/setup-envtest.sh
https://raw.githubusercontent.com/kubernetes-sigs/controller-runtime/v0.7.2/hack/setup-envtest.sh
 source ${ENVTEST_ASSETS_DIR}/setup-envtest.sh; fetch_envtest_tools
$(ENVTEST_ASSETS_DIR); setup_envtest_env $(ENVTEST_ASSETS_DIR); go test ./...
-coverprofile cover.out
```

4. Create a custom resource definition (CRD) API and controller:

   a. Run the following command to create an API with group **cache**, version **v1**, and kind **Memcached**:

   ```
   $ operator-sdk create api \
       --group=cache \
       --version=v1 \
       --kind=Memcached
   ```

   b. When prompted, enter **y** for creating both the resource and controller:

   ```
   Create Resource [y/n]
   y
   Create Controller [y/n]
   y
   ```

   **Example output**

   ```
   Writing scaffold for you to edit...
   api/v1/memcached_types.go
   controllers/memcached_controller.go
   ...
   ```

   This process generates the Memcached resource API at **api/v1/memcached_types.go** and the controller at **controllers/memcached_controller.go**.

   c. Modify the Go type definitions at **api/v1/memcached_types.go** to have the following **spec** and **status**:

   ```
   // MemcachedSpec defines the desired state of Memcached
   type MemcachedSpec struct {
    // +kubebuilder:validation:Minimum=0
    // Size is the size of the memcached deployment
    Size int32 `json:"size"`
   }

   // MemcachedStatus defines the observed state of Memcached
   ```

```
type MemcachedStatus struct {
 // Nodes are the names of the memcached pods
 Nodes []string `json:"nodes"`
}
```

d. Add the **+kubebuilder:subresource:status** marker to add a **status** subresource to the CRD manifest:

```
// Memcached is the Schema for the memcacheds API
// +kubebuilder:subresource:status (1)
type Memcached struct {
 metav1.TypeMeta   `json:",inline"`
 metav1.ObjectMeta `json:"metadata,omitempty"`

 Spec   MemcachedSpec   `json:"spec,omitempty"`
 Status MemcachedStatus `json:"status,omitempty"`
}
```

(1) Add this line.

This enables the controller to update the CR status without changing the rest of the CR object.

e. Update the generated code for the resource type:

```
$ make generate
```

**TIP**

After you modify a ***_types.go** file, you must run the **make generate** command to update the generated code for that resource type.

The above Makefile target invokes the **controller-gen** utility to update the **api/v1/zz_generated.deepcopy.go** file. This ensures your API Go type definitions implement the **runtime.Object** interface that all **Kind** types must implement.

5. Generate and update CRD manifests:

```
$ make manifests
```

This Makefile target invokes the **controller-gen** utility to generate the CRD manifests in the **config/crd/bases/cache.example.com_memcacheds.yaml** file.

a. Optional: Add custom validation to your CRD.
OpenAPI v3.0 schemas are added to CRD manifests in the **spec.validation** block when the manifests are generated. This validation block allows Kubernetes to validate the properties in a **Memcached** custom resource (CR) when it is created or updated.

As an Operator author, you can use annotation-like, single-line comments called Kubebuilder *markers* to configure custom validations for your API. These markers must always have a **+kubebuilder:validation** prefix. For example, adding an enum-type specification can be done by adding the following marker:

```
// +kubebuilder:validation:Enum=Lion;Wolf;Dragon
type Alias string
```

Usage of markers in API code is discussed in the Kubebuilder Generating CRDs and Markers for Config/Code Generation documentation. A full list of OpenAPIv3 validation markers is also available in the Kubebuilder CRD Validation documentation.

If you add any custom validations, run the following command to update the OpenAPI validation section for the CRD:

```
$ make manifests
```

6. After creating a new API and controller, you can implement the controller logic. For this example, replace the generated controller file **controllers/memcached_controller.go** with following example implementation:

**Example 5.3. Example memcached_controller.go**

```
/*
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distributed under the License is distributed on an "AS IS" BASIS,
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limitations under the License.
*/

package controllers

import (
 "context"
 "reflect"

 "github.com/go-logr/logr"
 appsv1 "k8s.io/api/apps/v1"
 corev1 "k8s.io/api/core/v1"
 "k8s.io/apimachinery/pkg/api/errors"
 metav1 "k8s.io/apimachinery/pkg/apis/meta/v1"
 "k8s.io/apimachinery/pkg/runtime"
 "k8s.io/apimachinery/pkg/types"
 ctrl "sigs.k8s.io/controller-runtime"
 "sigs.k8s.io/controller-runtime/pkg/client"

 cachev1 "github.com/example-inc/memcached-operator/api/v1"
)

// MemcachedReconciler reconciles a Memcached object
type MemcachedReconciler struct {
 client.Client
 Log    logr.Logger
 Scheme *runtime.Scheme
```

```
}

//
+kubebuilder:rbac:groups=cache.example.com,resources=memcacheds,verbs=get;list;watch
;create;update;patch;delete
//
+kubebuilder:rbac:groups=cache.example.com,resources=memcacheds/status,verbs=get;up
date;patch
//
+kubebuilder:rbac:groups=apps,resources=deployments,verbs=get;list;watch;create;update;
patch;delete
// +kubebuilder:rbac:groups=core,resources=pods,verbs=get;list;

func (r *MemcachedReconciler) Reconcile(req ctrl.Request) (ctrl.Result, error) {
 ctx := context.Background()
 log := r.Log.WithValues("memcached", req.NamespacedName)

 // Fetch the Memcached instance
 memcached := &cachev1.Memcached{}
 err := r.Get(ctx, req.NamespacedName, memcached)
 if err != nil {
  if errors.IsNotFound(err) {
   // Request object not found, could have been deleted after reconcile request.
   // Owned objects are automatically garbage collected. For additional cleanup logic use
finalizers.
   // Return and don't requeue
   log.Info("Memcached resource not found. Ignoring since object must be deleted")
   return ctrl.Result{}, nil
  }
  // Error reading the object - requeue the request.
  log.Error(err, "Failed to get Memcached")
  return ctrl.Result{}, err
 }

 // Check if the deployment already exists, if not create a new one
 found := &appsv1.Deployment{}
 err = r.Get(ctx, types.NamespacedName{Name: memcached.Name, Namespace:
memcached.Namespace}, found)
 if err != nil && errors.IsNotFound(err) {
  // Define a new deployment
  dep := r.deploymentForMemcached(memcached)
  log.Info("Creating a new Deployment", "Deployment.Namespace", dep.Namespace,
"Deployment.Name", dep.Name)
  err = r.Create(ctx, dep)
  if err != nil {
   log.Error(err, "Failed to create new Deployment", "Deployment.Namespace",
dep.Namespace, "Deployment.Name", dep.Name)
   return ctrl.Result{}, err
  }
  // Deployment created successfully - return and requeue
  return ctrl.Result{Requeue: true}, nil
 } else if err != nil {
  log.Error(err, "Failed to get Deployment")
  return ctrl.Result{}, err
 }
```

```
 // Ensure the deployment size is the same as the spec
 size := memcached.Spec.Size
 if *found.Spec.Replicas != size {
  found.Spec.Replicas = &size
  err = r.Update(ctx, found)
  if err != nil {
   log.Error(err, "Failed to update Deployment", "Deployment.Namespace",
found.Namespace, "Deployment.Name", found.Name)
   return ctrl.Result{}, err
  }
  // Spec updated - return and requeue
  return ctrl.Result{Requeue: true}, nil
 }

 // Update the Memcached status with the pod names
 // List the pods for this memcached's deployment
 podList := &corev1.PodList{}
 listOpts := []client.ListOption{
  client.InNamespace(memcached.Namespace),
  client.MatchingLabels(labelsForMemcached(memcached.Name)),
 }
 if err = r.List(ctx, podList, listOpts...); err != nil {
  log.Error(err, "Failed to list pods", "Memcached.Namespace", memcached.Namespace,
"Memcached.Name", memcached.Name)
  return ctrl.Result{}, err
 }
 podNames := getPodNames(podList.Items)

 // Update status.Nodes if needed
 if !reflect.DeepEqual(podNames, memcached.Status.Nodes) {
  memcached.Status.Nodes = podNames
  err := r.Status().Update(ctx, memcached)
  if err != nil {
   log.Error(err, "Failed to update Memcached status")
   return ctrl.Result{}, err
  }
 }

 return ctrl.Result{}, nil
}

// deploymentForMemcached returns a memcached Deployment object
func (r *MemcachedReconciler) deploymentForMemcached(m *cachev1.Memcached)
*appsv1.Deployment {
 ls := labelsForMemcached(m.Name)
 replicas := m.Spec.Size

 dep := &appsv1.Deployment{
  ObjectMeta: metav1.ObjectMeta{
   Name:      m.Name,
   Namespace: m.Namespace,
  },
  Spec: appsv1.DeploymentSpec{
   Replicas: &replicas,
   Selector: &metav1.LabelSelector{
    MatchLabels: ls,
```

```
    },
    Template: corev1.PodTemplateSpec{
     ObjectMeta: metav1.ObjectMeta{
      Labels: ls,
     },
     Spec: corev1.PodSpec{
      Containers: []corev1.Container{{
       Image:   "memcached:1.4.36-alpine",
       Name:    "memcached",
       Command: []string{"memcached", "-m=64", "-o", "modern", "-v"},
       Ports: []corev1.ContainerPort{{
        ContainerPort: 11211,
        Name:          "memcached",
       }},
      }},
     },
    },
   },
  }
  // Set Memcached instance as the owner and controller
  ctrl.SetControllerReference(m, dep, r.Scheme)
  return dep
}

// labelsForMemcached returns the labels for selecting the resources
// belonging to the given memcached CR name.
func labelsForMemcached(name string) map[string]string {
 return map[string]string{"app": "memcached", "memcached_cr": name}
}

// getPodNames returns the pod names of the array of pods passed in
func getPodNames(pods []corev1.Pod) []string {
 var podNames []string
 for _, pod := range pods {
  podNames = append(podNames, pod.Name)
 }
 return podNames
}

func (r *MemcachedReconciler) SetupWithManager(mgr ctrl.Manager) error {
 return ctrl.NewControllerManagedBy(mgr).
  For(&cachev1.Memcached{}).
  Owns(&appsv1.Deployment{}).
  Complete(r)
}
```

The example controller runs the following reconciliation logic for each **Memcached** CR:

- Create a Memcached deployment if it does not exist.
- Ensure that the deployment size is the same as specified by the **Memcached** CR spec.
- Update the **Memcached** CR status with the names of the **memcached** pods.

The next two sub-steps inspect how the controller watches resources and how the reconcile loop is triggered. You can skip these steps to go directly to building and running the Operator.

a. Inspect the controller implementation at the **controllers/memcached_controller.go** file to see how the controller watches resources.
The **SetupWithManager()** function specifies how the controller is built to watch a CR and other resources that are owned and managed by that controller:

**Example 5.4. SetupWithManager() function**

```
import (
 ...
 appsv1 "k8s.io/api/apps/v1"
 ...
)

func (r *MemcachedReconciler) SetupWithManager(mgr ctrl.Manager) error {
 return ctrl.NewControllerManagedBy(mgr).
  For(&cachev1.Memcached{}).
  Owns(&appsv1.Deployment{}).
  Complete(r)
}
```

**NewControllerManagedBy()** provides a controller builder that allows various controller configurations.

**For(&cachev1.Memcached{})** specifies the **Memcached** type as the primary resource to watch. For each Add, Update, or Delete event for a **Memcached** type, the reconcile loop is sent a reconcile **Request** argument, which consists of a namespace and name key, for that **Memcached** object.

**Owns(&appsv1.Deployment{})** specifies the **Deployment** type as the secondary resource to watch. For each **Deployment** type Add, Update, or Delete event, the event handler maps each event to a reconcile request for the owner of the deployment. In this case, the owner is the **Memcached** object for which the deployment was created.

b. Every controller has a reconciler object with a **Reconcile()** method that implements the reconcile loop. The reconcile loop is passed the **Request** argument, which is a namespace and name key used to find the primary resource object, **Memcached**, from the cache:

**Example 5.5. Reconcile loop**

```
import (
 ctrl "sigs.k8s.io/controller-runtime"

 cachev1 "github.com/example-inc/memcached-operator/api/v1"
 ...
)

func (r *MemcachedReconciler) Reconcile(ctx context.Context, req ctrl.Request)
(ctrl.Result, error) {
  // Lookup the Memcached instance for this reconcile request
  memcached := &cachev1.Memcached{}
```

```
    err := r.Get(ctx, req.NamespacedName, memcached)
    ...
}
```

Based on the return value of the **Reconcile()** function, the reconcile **Request** might be requeued, and the loop might be triggered again:

**Example 5.6. Requeue logic**

```
// Reconcile successful - don't requeue
return reconcile.Result{}, nil
// Reconcile failed due to error - requeue
return reconcile.Result{}, err
// Requeue for any reason other than error
return reconcile.Result{Requeue: true}, nil
```

You can set the **Result.RequeueAfter** to requeue the request after a grace period:

**Example 5.7. Requeue after grace period**

```
import "time"

// Reconcile for any reason other than an error after 5 seconds
return ctrl.Result{RequeueAfter: time.Second*5}, nil
```

**NOTE**

You can return **Result** with **RequeueAfter** set to periodically reconcile a CR.

For more on reconcilers, clients, and interacting with resource events, see the Controller Runtime Client API documentation.

**Additional resources**

- For more information about OpenAPI v3.0 validation schemas in CRDs, refer to the Kubernetes documentation.

### 5.3.2. Running the Operator

There are two ways you can use the Operator SDK CLI to build and run your Operator:

- Run locally outside the cluster as a Go program.
- Run as a deployment on the cluster.

**Prerequisites**

- You have a Go-based Operator project as described in Creating a Go-based Operator using the Operator SDK.

#### 5.3.2.1. Running locally outside the cluster

You can run your Operator project as a Go program outside of the cluster. This method is useful for development purposes to speed up deployment and testing.

**Procedure**

- Run the following command to install the custom resource definitions (CRDs) in the cluster configured in your ~/**.kube**/**config** file and run the Operator as a Go program locally:

```
$ make install run
```

**Example 5.8. Example output**

```
...
2021-01-10T21:09:29.016-0700 INFO controller-runtime.metrics metrics server is starting
to listen {"addr": ":8080"}
2021-01-10T21:09:29.017-0700 INFO setup starting manager
2021-01-10T21:09:29.017-0700 INFO controller-runtime.manager starting metrics server
{"path": "/metrics"}
2021-01-10T21:09:29.018-0700 INFO controller-runtime.manager.controller.memcached
Starting EventSource {"reconciler group": "cache.example.com", "reconciler kind":
"Memcached", "source": "kind source: /, Kind="}
2021-01-10T21:09:29.218-0700 INFO controller-runtime.manager.controller.memcached
Starting Controller {"reconciler group": "cache.example.com", "reconciler kind":
"Memcached"}
2021-01-10T21:09:29.218-0700 INFO controller-runtime.manager.controller.memcached
Starting workers {"reconciler group": "cache.example.com", "reconciler kind":
"Memcached", "worker count": 1}
```

#### 5.3.2.2. Running as a deployment

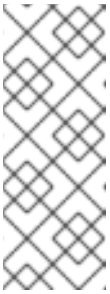
After creating your Go-based Operator project, you can build and run your Operator as a deployment inside a cluster.

**Procedure**

1. Run the following **make** commands to build and push the Operator image. Modify the **IMG** argument in the following steps to reference a repository that you have access to. You can obtain an account for storing containers at repository sites such as Quay.io.

   a. Build the image:

```
$ make docker-build IMG=<registry>/<user>/<image_name>:<tag>
```



NOTE

The Dockerfile generated by the SDK for the Operator explicitly references **GOARCH=amd64** for **go build**. This can be amended to **GOARCH=$TARGETARCH** for non-AMD64 architectures. Docker will automatically set the environment variable to the value specified by **–platform**. With Buildah, the **–build-arg** will need to be used for the purpose. For more information, see Multiple Architectures.

b. Push the image to a repository:

```
$ make docker-push IMG=<registry>/<user>/<image_name>:<tag>
```

NOTE

The name and tag of the image, for example **IMG=<registry>/<user>/<image_name>:<tag>**, in both the commands can also be set in your Makefile. Modify the **IMG ?= controller:latest** value to set your default image name.

2. Run the following command to deploy the Operator:

```
$ make deploy IMG=<registry>/<user>/<image_name>:<tag>
```

By default, this command creates a namespace with the name of your Operator project in the form **<project_name>-system** and is used for the deployment. This command also installs the RBAC manifests from **config/rbac**.

3. Verify that the Operator is running:

```
$ oc get deployment -n <project_name>-system
```

**Example output**

```
NAME                                    READY   UP-TO-DATE   AVAILABLE   AGE
<project_name>-controller-manager       1/1     1            1           8m
```

### 5.3.3. Creating a custom resource

After your Operator is installed, you can test it by creating a custom resource (CR) that is now provided on the cluster by the Operator.

**Prerequisites**

- Example Memcached Operator, which provides the **Memcached** CR, installed on a cluster

**Procedure**

1. Change to the namespace where your Operator is installed. For example, if you deployed the Operator using the **make deploy** command:

```
$ oc project memcached-operator-system
```

2. Edit the sample **Memcached** CR manifest at **config/samples/cache_v1_memcached.yaml** to contain the following specification:

```
apiVersion: cache.example.com/v1
kind: Memcached
metadata:
  name: memcached-sample
...
spec:
...
  size: 3
```

3. Create the CR:

```
$ oc apply -f config/samples/cache_v1_memcached.yaml
```

4. Ensure that the **Memcached** Operator creates the deployment for the sample CR with the correct size:

```
$ oc get deployments
```

**Example output**

```
NAME                                  READY   UP-TO-DATE   AVAILABLE   AGE
memcached-operator-controller-manager   1/1     1            1           8m
memcached-sample                      3/3     3            3           1m
```

5. Check the pods and CR status to confirm the status is updated with the Memcached pod names.

   a. Check the pods:

```
$ oc get pods
```

**Example output**

```
NAME                                  READY     STATUS    RESTARTS   AGE
memcached-sample-6fd7c98d8-7dqdr      1/1       Running   0          1m
memcached-sample-6fd7c98d8-g5k7v      1/1       Running   0          1m
memcached-sample-6fd7c98d8-m7vn7      1/1       Running   0          1m
```

   b. Check the CR status:

```
$ oc get memcached/memcached-sample -o yaml
```

**Example output**

```
apiVersion: cache.example.com/v1
kind: Memcached
metadata:
...
  name: memcached-sample
...
```

```
spec:
  size: 3
status:
  nodes:
  - memcached-sample-6fd7c98d8-7dqdr
  - memcached-sample-6fd7c98d8-g5k7v
  - memcached-sample-6fd7c98d8-m7vn7
```

6. Update the deployment size.

   a. Update **config/samples/cache_v1_memcached.yaml** file to change the **spec.size** field in the **Memcached** CR from **3** to **5**:

   ```
   $ oc patch memcached memcached-sample \
     -p '{"spec":{"size": 5}}' \
     --type=merge
   ```

   b. Confirm that the Operator changes the deployment size:

   ```
   $ oc get deployments
   ```

   **Example output**

   ```
   NAME                                  READY   UP-TO-DATE   AVAILABLE   AGE
   memcached-operator-controller-manager   1/1     1            1           10m
   memcached-sample                        5/5     5            5           3m
   ```

### 5.3.4. Additional resources

- See Appendices to learn about the project directory structures created by the Operator SDK.
- Operator Development Guide for Red Hat Partners

## 5.4. CREATING ANSIBLE-BASED OPERATORS

This guide outlines Ansible support in the Operator SDK and walks Operator authors through examples building and running Ansible-based Operators with the **operator-sdk** CLI tool that use Ansible playbooks and modules.

### 5.4.1. Ansible support in the Operator SDK

The Operator Framework is an open source toolkit to manage Kubernetes native applications, called *Operators*, in an effective, automated, and scalable way. This framework includes the Operator SDK, which assists developers in bootstrapping and building an Operator based on their expertise without requiring knowledge of Kubernetes API complexities.

One of the Operator SDK options for generating an Operator project includes leveraging existing Ansible playbooks and modules to deploy Kubernetes resources as a unified application, without having to write any Go code.

#### 5.4.1.1. Custom resource files

Operators use the Kubernetes extension mechanism, custom resource definitions (CRDs), so your custom resource (CR) looks and acts just like the built-in, native Kubernetes objects.

The CR file format is a Kubernetes resource file. The object has mandatory and optional fields:

**Table 5.1. Custom resource fields**

| Field | Description |
|---|---|
| **apiVersion** | Version of the CR to be created. |
| **kind** | Kind of the CR to be created. |
| **metadata** | Kubernetes-specific metadata to be created. |
| **spec** (optional) | Key-value list of variables which are passed to Ansible. This field is empty by default. |
| **status** | Summarizes the current state of the object. For Ansible-based Operators, the **status** subresource is enabled for CRDs and managed by the **operator_sdk.util.k8s_status** Ansible module by default, which includes **condition** information to the CR **status**. |
| **annotations** | Kubernetes-specific annotations to be appended to the CR. |

The following list of CR annotations modify the behavior of the Operator:

**Table 5.2. Ansible-based Operator annotations**

| Annotation | Description |
|---|---|
| **ansible.operator-sdk/reconcile-period** | Specifies the reconciliation interval for the CR. This value is parsed using the standard Golang package **time**. Specifically, **ParseDuration** is used which applies the default suffix of **s**, giving the value in seconds. |

### Example Ansible-based Operator annotation

```
apiVersion: "test1.example.com/v1alpha1"
kind: "Test1"
metadata:
  name: "example"
annotations:
  ansible.operator-sdk/reconcile-period: "30s"
```

### 5.4.1.2. watches.yaml file

A *group/version/kind (GVK)* is a unique identifier for a Kubernetes API. The **watches.yaml** file contains a list of mappings from custom resources (CRs), identified by its GVK, to an Ansible role or playbook. The Operator expects this mapping file in a predefined location at **/opt/ansible/watches.yaml**.

**Table 5.3. watches.yaml file mappings**

| Field | Description |
|---|---|
| **group** | Group of CR to watch. |
| **version** | Version of CR to watch. |
| **kind** | Kind of CR to watch |
| **role** (default) | Path to the Ansible role added to the container. For example, if your **roles** directory is at **/opt/ansible/roles/** and your role is named **busybox**, this value would be **/opt/ansible/roles/busybox**. This field is mutually exclusive with the **playbook** field. |
| **playbook** | Path to the Ansible playbook added to the container. This playbook is expected to be a way to call roles. This field is mutually exclusive with the **role** field. |
| **reconcilePeriod** (optional) | The reconciliation interval, how often the role or playbook is run, for a given CR. |
| **manageStatus** (optional) | When set to **true** (default), the Operator manages the status of the CR generically. When set to **false**, the status of the CR is managed elsewhere, by the specified role or playbook or in a separate controller. |

### Example **watches.yaml** file

```
- version: v1alpha1 (1)
  group: test1.example.com
  kind: Test1
  role: /opt/ansible/roles/Test1

- version: v1alpha1 (2)
  group: test2.example.com
  kind: Test2
  playbook: /opt/ansible/playbook.yml

- version: v1alpha1 (3)
  group: test3.example.com
  kind: Test3
  playbook: /opt/ansible/test3.yml
  reconcilePeriod: 0
  manageStatus: false
```

1. Simple example mapping **Test1** to the **test1** role.
2. Simple example mapping **Test2** to a playbook.
3. More complex example for the **Test3** kind. Disables re-queuing and managing the CR status in the playbook.

#### 5.4.1.2.1. Advanced options

Advanced features can be enabled by adding them to your **watches.yaml** file per GVK. They can go below the **group**, **version**, **kind** and **playbook** or **role** fields.

Some features can be overridden per resource using an annotation on that CR. The options that can be overridden have the annotation specified below.

**Table 5.4. Advanced watches.yaml file options**

| Feature | YAML key | Description | Annotation for override | Default value |
|---|---|---|---|---|
| Reconcile period | **reconcilePeriod** | Time between reconcile runs for a particular CR. | **ansible.operator-sdk/reconcile-period** | **1m** |
| Manage status | **manageStatus** | Allows the Operator to manage the **conditions** section of each CR **status** section. | | **true** |
| Watch dependent resources | **watchDependentResources** | Allows the Operator to dynamically watch resources that are created by Ansible. | | **true** |
| Watch cluster-scoped resources | **watchClusterScopedResources** | Allows the Operator to watch cluster-scoped resources that are created by Ansible. | | **false** |
| Max runner artifacts | **maxRunnerArtifacts** | Manages the number of artifact directories that Ansible Runner keeps in the Operator container for each individual resource. | **ansible.operator-sdk/max-runner-artifacts** | **20** |

#### Example watches.yml file with advanced options

```
- version: v1alpha1
  group: app.example.com
  kind: AppService
  playbook: /opt/ansible/playbook.yml
  maxRunnerArtifacts: 30
  reconcilePeriod: 5s
  manageStatus: False
  watchDependentResources: False
```

### 5.4.1.3. Extra variables sent to Ansible

Extra variables can be sent to Ansible, which are then managed by the Operator. The **spec** section of the custom resource (CR) passes along the key-value pairs as extra variables. This is equivalent to extra variables passed in to the **ansible-playbook** command.

The Operator also passes along additional variables under the **meta** field for the name of the CR and the namespace of the CR.

For the following CR example:

```
apiVersion: "app.example.com/v1alpha1"
kind: "Database"
metadata:
  name: "example"
spec:
  message: "Hello world 2"
  newParameter: "newParam"
```

The structure passed to Ansible as extra variables is:

```
{ "meta": {
        "name": "<cr_name>",
        "namespace": "<cr_namespace>",
  },
  "message": "Hello world 2",
  "new_parameter": "newParam",
  "_app_example_com_database": {
     <full_crd>
   },
}
```

The **message** and **newParameter** fields are set in the top level as extra variables, and **meta** provides the relevant metadata for the CR as defined in the Operator. The **meta** fields can be accessed using dot notation in Ansible, for example:

```
- debug:
    msg: "name: {{ meta.name }}, {{ meta.namespace }}"
```

#### 5.4.1.4. Ansible Runner directory

Ansible Runner keeps information about Ansible runs in the container. This is located at **/tmp/ansible-operator/runner/<group>/<version>/<kind>/<namespace>/<name>**.

**Additional resources**

- To learn more about the **runner** directory, see the Ansible Runner documentation.

### 5.4.2. Building an Ansible-based Operator using the Operator SDK

This procedure walks through an example of building a simple Memcached Operator powered by Ansible playbooks and modules using tools and libraries provided by the Operator SDK.

**Prerequisites**

- Operator SDK v0.19.4 CLI installed on the development workstation

- Access to a Kubernetes-based cluster v1.11.3+ (for example OpenShift Container Platform 4.6) using an account with **cluster-admin** permissions
- OpenShift CLI (**oc**) v4.6+ installed
- **ansible** v2.9.0+
- **ansible-runner** v1.1.0+
- **ansible-runner-http** v1.0.0+

**Procedure**

1. **Create a new Operator project.** A namespace-scoped Operator watches and manages resources in a single namespace. Namespace-scoped Operators are preferred because of their flexibility. They enable decoupled upgrades, namespace isolation for failures and monitoring, and differing API definitions.
   To create a new Ansible-based, namespace-scoped **memcached-operator** project and change to the new directory, use the following commands:

   ```
   $ operator-sdk new memcached-operator \
       --api-version=cache.example.com/v1alpha1 \
       --kind=Memcached \
       --type=ansible
   ```

   ```
   $ cd memcached-operator
   ```

   This creates the **memcached-operator** project specifically for watching the **Memcached** resource with API version **example.com/v1apha1** and kind **Memcached**.

2. **Customize the Operator logic.**
   For this example, the **memcached-operator** executes the following reconciliation logic for each **Memcached** custom resource (CR):

   - Create a **memcached** deployment if it does not exist.
   - Ensure that the deployment size is the same as specified by the **Memcached** CR.

   By default, the **memcached-operator** watches **Memcached** resource events as shown in the **watches.yaml** file and executes the Ansible role **Memcached**:

   ```
   - version: v1alpha1
     group: cache.example.com
     kind: Memcached
   ```

   You can optionally customize the following logic in the **watches.yaml** file:

   a. Specifying a **role** option configures the Operator to use this specified path when launching **ansible-runner** with an Ansible role. By default, the **operator-sdk new** command fills in an absolute path to where your role should go:

      ```
      - version: v1alpha1
        group: cache.example.com
        kind: Memcached
        role: /opt/ansible/roles/memcached
      ```

b. Specifying a **playbook** option in the **watches.yaml** file configures the Operator to use this specified path when launching **ansible-runner** with an Ansible playbook:

```
- version: v1alpha1
  group: cache.example.com
  kind: Memcached
  playbook: /opt/ansible/playbook.yaml
```

3. **Build the Memcached Ansible role.**
Modify the generated Ansible role under the **roles/memcached/** directory. This Ansible role controls the logic that is executed when a resource is modified.

a. **Define the Memcached spec.**
Defining the spec for an Ansible-based Operator can be done entirely in Ansible. The Ansible Operator passes all key-value pairs listed in the CR spec field along to Ansible as variables. The names of all variables in the spec field are converted to snake case (lowercase with an underscore) by the Operator before running Ansible. For example, **serviceAccount** in the spec becomes **service_account** in Ansible.

**TIP**

You should perform some type validation in Ansible on the variables to ensure that your application is receiving expected input.

In case the user does not set the **spec** field, set a default by modifying the **roles/memcached/defaults/main.yml** file:

```
size: 1
```

b. **Define the Memcached deployment.**
With the **Memcached** spec now defined, you can define what Ansible is actually executed on resource changes. Because this is an Ansible role, the default behavior executes the tasks in the **roles/memcached/tasks/main.yml** file.

The goal is for Ansible to create a deployment if it does not exist, which runs the **memcached:1.4.36-alpine** image. Ansible 2.7+ supports the k8s Ansible module, which this example leverages to control the deployment definition.

Modify the **roles/memcached/tasks/main.yml** to match the following:

```
- name: start memcached
  k8s:
    definition:
      kind: Deployment
      apiVersion: apps/v1
      metadata:
        name: '{{ meta.name }}-memcached'
        namespace: '{{ meta.namespace }}'
      spec:
        replicas: "{{size}}"
        selector:
          matchLabels:
            app: memcached
        template:
```

```
    metadata:
      labels:
        app: memcached
    spec:
      containers:
      - name: memcached
        command:
        - memcached
        - -m=64
        - -o
        - modern
        - -v
        image: "docker.io/memcached:1.4.36-alpine"
        ports:
          - containerPort: 11211
```

**NOTE**

This example used the **size** variable to control the number of replicas of the **Memcached** deployment. This example sets the default to **1**, but any user can create a CR that overwrites the default.

4. **Deploy the CRD.**
   Before running the Operator, Kubernetes needs to know about the new custom resource definition (CRD) that the Operator will be watching. Deploy the **Memcached** CRD:

```
$ oc create -f deploy/crds/cache.example.com_memcacheds_crd.yaml
```

5. **Build and run the Operator.**
   There are two ways to build and run the Operator:

   - As a pod inside a Kubernetes cluster.
   - As a Go program outside the cluster using the **operator-sdk up** command.

   Choose one of the following methods:

   a. **Run as a pod**inside a Kubernetes cluster. This is the preferred method for production use.

      i. Build the **memcached-operator** image and push it to a registry:

```
$ operator-sdk build quay.io/example/memcached-operator:v0.0.1
```

```
$ podman push quay.io/example/memcached-operator:v0.0.1
```

      ii. Deployment manifests are generated in the **deploy/operator.yaml** file. The deployment image in this file needs to be modified from the placeholder **REPLACE_IMAGE** to the previous built image. To do this, run:

```
$ sed -i 's|REPLACE_IMAGE|quay.io/example/memcached-operator:v0.0.1|g'
deploy/operator.yaml
```

      iii. Deploy the **memcached-operator** manifests:

```
$ oc create -f deploy/service_account.yaml
```

```
$ oc create -f deploy/role.yaml
```

```
$ oc create -f deploy/role_binding.yaml
```

```
$ oc create -f deploy/operator.yaml
```

iv. Verify that the **memcached-operator** deployment is up and running:

```
$ oc get deployment
```

```
NAME                 DESIRED   CURRENT   UP-TO-DATE   AVAILABLE   AGE
memcached-operator   1         1         1            1           1m
```

b. **Run outside the cluster.** This method is preferred during the development cycle to speed up deployment and testing.
Ensure that Ansible Runner and Ansible Runner HTTP Plug-in are installed or else you will see unexpected errors from Ansible Runner when a CR is created.

It is also important that the role path referenced in the **watches.yaml** file exists on your machine. Because normally a container is used where the role is put on disk, the role must be manually copied to the configured Ansible roles path (for example **/etc/ansible/roles**).

i. To run the Operator locally with the default Kubernetes configuration file present at **$HOME/.kube/config**:

```
$ operator-sdk run --local
```

To run the Operator locally with a provided Kubernetes configuration file:

```
$ operator-sdk run --local --kubeconfig=config
```

6. **Create a Memcached CR.**

a. Modify the **deploy/crds/cache_v1alpha1_memcached_cr.yaml** file as shown and create a **Memcached** CR:

```
$ cat deploy/crds/cache_v1alpha1_memcached_cr.yaml
```

**Example output**

```
apiVersion: "cache.example.com/v1alpha1"
kind: "Memcached"
metadata:
  name: "example-memcached"
spec:
  size: 3
```

```
$ oc apply -f deploy/crds/cache_v1alpha1_memcached_cr.yaml
```

b. Ensure that the **memcached-operator** creates the deployment for the CR:

```
$ oc get deployment
```

**Example output**

```
NAME                 DESIRED   CURRENT   UP-TO-DATE   AVAILABLE   AGE
memcached-operator       1         1         1            1          2m
example-memcached        3         3         3            3          1m
```

c. Check the pods to confirm three replicas were created:

```
$ oc get pods
```

```
NAME                                  READY     STATUS    RESTARTS   AGE
example-memcached-6fd7c98d8-7dqdr     1/1       Running   0          1m
example-memcached-6fd7c98d8-g5k7v     1/1       Running   0          1m
example-memcached-6fd7c98d8-m7vn7     1/1       Running   0          1m
memcached-operator-7cc7cfdf86-vvjqk   1/1       Running   0          2m
```

7. **Update the size.**

a. Change the **spec.size** field in the **memcached** CR from **3** to **4** and apply the change:

```
$ cat deploy/crds/cache_v1alpha1_memcached_cr.yaml
```

**Example output**

```
apiVersion: "cache.example.com/v1alpha1"
kind: "Memcached"
metadata:
  name: "example-memcached"
spec:
  size: 4
```

```
$ oc apply -f deploy/crds/cache_v1alpha1_memcached_cr.yaml
```

b. Confirm that the Operator changes the deployment size:

```
$ oc get deployment
```

**Example output**

```
NAME                 DESIRED   CURRENT   UP-TO-DATE   AVAILABLE   AGE
example-memcached    4         4         4            4           5m
```

8. **Clean up the resources:**

```
$ oc delete -f deploy/crds/cache_v1alpha1_memcached_cr.yaml
```

```
$ oc delete -f deploy/operator.yaml
```

```
$ oc delete -f deploy/role_binding.yaml
```

```
$ oc delete -f deploy/role.yaml
```

```
$ oc delete -f deploy/service_account.yaml
```

```
$ oc delete -f deploy/crds/cache_v1alpha1_memcached_crd.yaml
```

### 5.4.3. Managing application lifecycle using the k8s Ansible module

To manage the lifecycle of your application on Kubernetes using Ansible, you can use the **k8s** Ansible module. This Ansible module allows a developer to either leverage their existing Kubernetes resource files (written in YAML) or express the lifecycle management in native Ansible.

One of the biggest benefits of using Ansible in conjunction with existing Kubernetes resource files is the ability to use Jinja templating so that you can customize resources with the simplicity of a few variables in Ansible.

This section goes into detail on usage of the **k8s** Ansible module. To get started, install the module on your local workstation and test it using a playbook before moving on to using it within an Operator.

#### 5.4.3.1. Installing the k8s Ansible module

To install the **k8s** Ansible module on your local workstation:

**Procedure**

1. Install Ansible 2.9+:

```
$ sudo yum install ansible
```

2. Install the OpenShift python client package using **pip**:

```
$ sudo pip install openshift
```

```
$ sudo pip install kubernetes
```

#### 5.4.3.2. Testing the k8s Ansible module locally

Sometimes, it is beneficial for a developer to run the Ansible code from their local machine as opposed to running and rebuilding the Operator each time.

**Procedure**

1. Install the **community.kubernetes** collection:

```
$ ansible-galaxy collection install community.kubernetes
```

2. Initialize a new Ansible-based Operator project:

```
$ operator-sdk new --type ansible \
    --kind Test1 \
    --api-version test1.example.com/v1alpha1 test1-operator
```

**Example output**

```
Create test1-operator/tmp/init/galaxy-init.sh
Create test1-operator/tmp/build/Dockerfile
Create test1-operator/tmp/build/test-framework/Dockerfile
Create test1-operator/tmp/build/go-test.sh
Rendering Ansible Galaxy role [test1-operator/roles/test1]...
Cleaning up test1-operator/tmp/init
Create test1-operator/watches.yaml
Create test1-operator/deploy/rbac.yaml
Create test1-operator/deploy/crd.yaml
Create test1-operator/deploy/cr.yaml
Create test1-operator/deploy/operator.yaml
Run git init ...
Initialized empty Git repository in /home/user/go/src/github.com/user/opsdk/test1-
operator/.git/
Run git init done
```

```
$ cd test1-operator
```

3. Modify the **roles/test1/tasks/main.yml** file with the Ansible logic that you want. This example creates and deletes a namespace with the switch of a variable.

```
- name: set test namespace to "{{ state }}"
  community.kubernetes.k8s:
    api_version: v1
    kind: Namespace
    state: "{{ state }}"
    name: test
  ignore_errors: true (1)
```

(1) Setting **ignore_errors: true** ensures that deleting a nonexistent project does not fail.

4. Modify the **roles/test1/defaults/main.yml** file to set **state** to **present** by default:

```
state: present
```

5. Create an Ansible playbook **playbook.yml** in the top-level directory, which includes the **test1** role:

```
- hosts: localhost
  roles:
    - test1
```

6. Run the playbook:

```
$ ansible-playbook playbook.yml
```

**Example output**

```
 [WARNING]: provided hosts list is empty, only localhost is available. Note that the implicit
localhost does not match 'all'

PLAY [localhost] ***************************************************************************

PROCEDURE [Gathering Facts]
*********************************************************************
ok: [localhost]

Task [test1 : set test namespace to present]
changed: [localhost]

PLAY RECAP *********************************************************************************
localhost                  : ok=2    changed=1    unreachable=0    failed=0
```

7. Check that the namespace was created:

```
$ oc get namespace
```

**Example output**

```
NAME          STATUS    AGE
default       Active    28d
kube-public   Active    28d
kube-system   Active    28d
test          Active    3s
```

8. Rerun the playbook setting **state** to **absent**:

```
$ ansible-playbook playbook.yml --extra-vars state=absent
```

**Example output**

```
 [WARNING]: provided hosts list is empty, only localhost is available. Note that the implicit
localhost does not match 'all'

PLAY [localhost] ***************************************************************************

PROCEDURE [Gathering Facts]
*********************************************************************
ok: [localhost]

Task [test1 : set test namespace to absent]
changed: [localhost]

PLAY RECAP *********************************************************************************
localhost                  : ok=2    changed=1    unreachable=0    failed=0
```

9. Check that the namespace was deleted:

```
$ oc get namespace
```

Example output

```
NAME          STATUS    AGE
default       Active    28d
kube-public   Active    28d
kube-system   Active    28d
```

#### 5.4.3.3. Testing the k8s Ansible module inside an Operator

After you are familiar with using the **k8s** Ansible module locally, you can trigger the same Ansible logic inside of an Operator when a custom resource (CR) changes. This example maps an Ansible role to a specific Kubernetes resource that the Operator watches. This mapping is done in the **watches.yaml** file.

##### 5.4.3.3.1. Testing an Ansible-based Operator locally

After getting comfortable testing Ansible workflows locally, you can test the logic inside of an Ansible-based Operator running locally.

To do so, use the **operator-sdk run --local** command from the top-level directory of your Operator project. This command reads from the **watches.yaml** file and uses the ~/**.kube**/**config** file to communicate with a Kubernetes cluster just as the **k8s** Ansible module does.

Procedure

1. Because the **run --local** command reads from the **watches.yaml** file, there are options available to the Operator author. If **role** is left alone (by default, /**opt**/**ansible**/**roles**/**<name>**) you must copy the role over to the /**opt**/**ansible**/**roles**/ directory from the Operator directly.
   This is cumbersome because changes are not reflected from the current directory. Instead, change the **role** field to point to the current directory and comment out the existing line:

```
- version: v1alpha1
  group: test1.example.com
  kind: Test1
  #  role: /opt/ansible/roles/Test1
  role: /home/user/test1-operator/Test1
```

2. Create a custom resource definition (CRD) and proper role-based access control (RBAC) definitions for the custom resource (CR) **Test1**. The **operator-sdk** command autogenerates these files inside of the **deploy**/ directory:

```
$ oc create -f deploy/crds/test1_v1alpha1_test1_crd.yaml
```

```
$ oc create -f deploy/service_account.yaml
```

```
$ oc create -f deploy/role.yaml
```

```
$ oc create -f deploy/role_binding.yaml
```

3. Run the **run --local** command:

```
$ operator-sdk run --local
```

**Example output**

```
[...]
INFO[0000] Starting to serve on 127.0.0.1:8888
INFO[0000] Watching test1.example.com/v1alpha1, Test1, default
```

4. Now that the Operator is watching the resource **Test1** for events, the creation of a CR triggers your Ansible role to execute. View the **deploy/cr.yaml** file:

```
apiVersion: "test1.example.com/v1alpha1"
kind: "Test1"
metadata:
  name: "example"
```

Because the **spec** field is not set, Ansible is invoked with no extra variables. The next section covers how extra variables are passed from a CR to Ansible. This is why it is important to set reasonable defaults for the Operator.

5. Create a CR instance of **Test1** with the default variable **state** set to **present**:

```
$ oc create -f deploy/cr.yaml
```

6. Check that the namespace **test** was created:

```
$ oc get namespace
```

**Example output**

```
NAME          STATUS    AGE
default       Active    28d
kube-public   Active    28d
kube-system   Active    28d
test          Active    3s
```

7. Modify the **deploy/cr.yaml** file to set the **state** field to **absent**:

```
apiVersion: "test1.example.com/v1alpha1"
kind: "Test1"
metadata:
  name: "example"
spec:
  state: "absent"
```

8. Apply the changes and confirm that the namespace is deleted:

```
$ oc apply -f deploy/cr.yaml
```

```
$ oc get namespace
```

**Example output**

```
NAME          STATUS    AGE
```

```
default       Active    28d
kube-public   Active    28d
kube-system   Active    28d
```

#### 5.4.3.3.2. Testing an Ansible-based Operator on a cluster

After getting familiar running Ansible logic inside of an Ansible-based Operator locally, you can test the Operator inside of a pod on a Kubernetes cluster, such as OpenShift Container Platform. Running as a pod on a cluster is preferred for production use.

**Procedure**

1. Build the **test1-operator** image and push it to a registry:

```
$ operator-sdk build quay.io/example/test1-operator:v0.0.1
```

```
$ podman push quay.io/example/test1-operator:v0.0.1
```

2. Deployment manifests are generated in the **deploy/operator.yaml** file. The deployment image in this file must be modified from the placeholder **REPLACE_IMAGE** to the previously-built image. To do so, run the following command:

```
$ sed -i 's|REPLACE_IMAGE|quay.io/example/test1-operator:v0.0.1|g' deploy/operator.yaml
```

   If you are performing these steps on macOS, use the following command instead:

```
$ sed -i "" 's|REPLACE_IMAGE|quay.io/example/test1-operator:v0.0.1|g'
deploy/operator.yaml
```

3. Deploy the **test1-operator**:

```
$ oc create -f deploy/crds/test1_v1alpha1_test1_crd.yaml 1
```

   1 Only required if the CRD does not exist already.

```
$ oc create -f deploy/service_account.yaml
```

```
$ oc create -f deploy/role.yaml
```

```
$ oc create -f deploy/role_binding.yaml
```

```
$ oc create -f deploy/operator.yaml
```

4. Verify that the **test1-operator** is up and running:

```
$ oc get deployment
```

**Example output**

```
NAME                 DESIRED   CURRENT   UP-TO-DATE   AVAILABLE   AGE
test1-operator       1         1         1            1           1m
```

5. You can now view the Ansible logs for the **test1-operator**:

```
$ oc logs deployment/test1-operator
```

### 5.4.4. Managing custom resource status using the operator_sdk.util Ansible collection

Ansible-based Operators automatically update custom resource (CR) **status** subresources with generic information about the previous Ansible run. This includes the number of successful and failed tasks and relevant error messages as shown:

```
status:
  conditions:
    - ansibleResult:
      changed: 3
      completion: 2018-12-03T13:45:57.13329
      failures: 1
      ok: 6
      skipped: 0
    lastTransitionTime: 2018-12-03T13:45:57Z
    message: 'Status code was -1 and not [200]: Request failed: <urlopen error [Errno
      113] No route to host>'
    reason: Failed
    status: "True"
    type: Failure
  - lastTransitionTime: 2018-12-03T13:46:13Z
    message: Running reconciliation
    reason: Running
    status: "True"
    type: Running
```

Ansible-based Operators also allow Operator authors to supply custom status values with the **k8s_status** Ansible module, which is included in the **operator_sdk.util** collection. This allows the author to update the **status** from within Ansible with any key-value pair as desired.

By default, Ansible-based Operators always include the generic Ansible run output as shown above. If you would prefer your application did *not* update the status with Ansible output, you can track the status manually from your application.

#### Procedure

1. To track CR status manually from your application, update the **watches.yaml** file with a **manageStatus** field set to **false**:

```
- version: v1
  group: api.example.com
  kind: Test1
  role: Test1
  manageStatus: false
```

2. Use the **operator_sdk.util.k8s_status** Ansible module to update the subresource. For example, to update with key **test1** and value **test2**, **operator_sdk.util** can be used as shown:

```
- operator_sdk.util.k8s_status:
    api_version: app.example.com/v1
    kind: Test1
    name: "{{ meta.name }}"
    namespace: "{{ meta.namespace }}"
    status:
      test1: test2
```

Collections can also be declared in the **meta/main.yml** for the role, which is included for new scaffolded Ansible Operators:

```
collections:
  - operator_sdk.util
```

Declaring collections in the role meta allows you to invoke the **k8s_status** module directly:

```
k8s_status:
  <snip>
  status:
    test1: test2
```

**Additional resources**

- For more details about user-driven status management from Ansible-based Operators, see the Ansible-based Operator Status Proposal for Operator SDK.

### 5.4.5. Additional resources

- See Appendices to learn about the project directory structures created by the Operator SDK.
- Reaching for the Stars with Ansible Operator - Red Hat OpenShift Blog
- Operator Development Guide for Red Hat Partners

## 5.5. CREATING HELM-BASED OPERATORS

This guide outlines Helm chart support in the Operator SDK and walks Operator authors through an example of building and running an Nginx Operator with the **operator-sdk** CLI tool that uses an existing Helm chart.

### 5.5.1. Helm chart support in the Operator SDK

The Operator Framework is an open source toolkit to manage Kubernetes native applications, called *Operators*, in an effective, automated, and scalable way. This framework includes the Operator SDK, which assists developers in bootstrapping and building an Operator based on their expertise without requiring knowledge of Kubernetes API complexities.

One of the Operator SDK options for generating an Operator project includes leveraging an existing Helm chart to deploy Kubernetes resources as a unified application, without having to write any Go code. Such Helm-based Operators are designed to excel at stateless applications that require very little logic when rolled out, because changes should be applied to the Kubernetes objects that are generated as part of the chart. This may sound limiting, but can be sufficient for a surprising amount of use-cases as shown by the proliferation of Helm charts built by the Kubernetes community.

The main function of an Operator is to read from a custom object that represents your application instance and have its desired state match what is running. In the case of a Helm-based Operator, the **spec** field of the object is a list of configuration options that are typically described in the Helm **values.yaml** file. Instead of setting these values with flags using the Helm CLI (for example, **helm install -f values.yaml**), you can express them within a custom resource (CR), which, as a native Kubernetes object, enables the benefits of RBAC applied to it and an audit trail.

For an example of a simple CR called **Tomcat**:

```
apiVersion: apache.org/v1alpha1
kind: Tomcat
metadata:
  name: example-app
spec:
  replicaCount: 2
```

The **replicaCount** value, **2** in this case, is propagated into the template of the chart where the following is used:

```
{{ .Values.replicaCount }}
```

After an Operator is built and deployed, you can deploy a new instance of an app by creating a new instance of a CR, or list the different instances running in all environments using the **oc** command:

```
$ oc get Tomcats --all-namespaces
```

There is no requirement use the Helm CLI or install Tiller; Helm-based Operators import code from the Helm project. All you have to do is have an instance of the Operator running and register the CR with a custom resource definition (CRD). Because it obeys RBAC, you can more easily prevent production changes.

### 5.5.2. Building a Helm-based Operator using the Operator SDK

This procedure walks through an example of building a simple Nginx Operator powered by a Helm chart using tools and libraries provided by the Operator SDK.

#### TIP

It is best practice to build a new Operator for each chart. This can allow for more native-behaving Kubernetes APIs (for example, **oc get Nginx**) and flexibility if you ever want to write a fully-fledged Operator in Go, migrating away from a Helm-based Operator.

#### Prerequisites

- Operator SDK v0.19.4 CLI installed on the development workstation
- Access to a Kubernetes-based cluster v1.11.3+ (for example OpenShift Container Platform 4.6) using an account with **cluster-admin** permissions
- OpenShift CLI (**oc**) v4.6+ installed

#### Procedure

1. **Create a new Operator project.** A namespace-scoped Operator watches and manages

resources in a single namespace. Namespace-scoped Operators are preferred because of their flexibility. They enable decoupled upgrades, namespace isolation for failures and monitoring, and differing API definitions.
To create a new Helm-based, namespace-scoped **nginx-operator** project, use the following command:

```
$ operator-sdk new nginx-operator \
  --api-version=example.com/v1alpha1 \
  --kind=Nginx \
  --type=helm
```

```
$ cd nginx-operator
```

This creates the **nginx-operator** project specifically for watching the Nginx resource with API version **example.com/v1apha1** and kind **Nginx**.

2. **Customize the Operator logic.**
For this example, the **nginx-operator** executes the following reconciliation logic for each **Nginx** custom resource (CR):

- Create an Nginx deployment if it does not exist.
- Create an Nginx service if it does not exist.
- Create an Nginx ingress if it is enabled and does not exist.
- Ensure that the deployment, service, and optional ingress match the desired configuration (for example, replica count, image, service type) as specified by the Nginx CR.

By default, the **nginx-operator** watches **Nginx** resource events as shown in the **watches.yaml** file and executes Helm releases using the specified chart:

```
- version: v1alpha1
  group: example.com
  kind: Nginx
  chart: /opt/helm/helm-charts/nginx
```

a. **Review the Nginx Helm chart.**
When a Helm Operator project is created, the Operator SDK creates an example Helm chart that contains a set of templates for a simple Nginx release.

For this example, templates are available for deployment, service, and ingress resources, along with a **NOTES.txt** template, which Helm chart developers use to convey helpful information about a release.

If you are not already familiar with Helm Charts, review the Helm Chart developer documentation.

b. **Understand the Nginx CR spec.**
Helm uses a concept called values to provide customizations to the defaults of a Helm chart, which are defined in the **values.yaml** file.

Override these defaults by setting the desired values in the CR spec. You can use the number of replicas as an example:

i. First, inspect the **helm-charts/nginx/values.yaml** file to find that the chart has a value called **replicaCount** and it is set to **1** by default. To have 2 Nginx instances in your deployment, your CR spec must contain **replicaCount: 2**.
Update the **deploy/crds/example.com_v1alpha1_nginx_cr.yaml** file to look like the following:

```
apiVersion: example.com/v1alpha1
kind: Nginx
metadata:
  name: example-nginx
spec:
  replicaCount: 2
```

ii. Similarly, the default service port is set to **80**. To instead use **8080**, update the **deploy/crds/example.com_v1alpha1_nginx_cr.yaml** file again by adding the service port override:

```
apiVersion: example.com/v1alpha1
kind: Nginx
metadata:
  name: example-nginx
spec:
  replicaCount: 2
  service:
    port: 8080
```

The Helm Operator applies the entire spec as if it was the contents of a values file, just like the **helm install -f ./overrides.yaml** command works.

3. **Deploy the CRD.**
Before running the Operator, Kubernetes must know about the new custom resource definition (CRD) that the Operator will be watching. Deploy the following CRD:

```
$ oc create -f deploy/crds/example_v1alpha1_nginx_crd.yaml
```

4. **Build and run the Operator.**
There are two ways to build and run the Operator:

- As a pod inside a Kubernetes cluster.
- As a Go program outside the cluster using the **operator-sdk up** command.

Choose one of the following methods:

a. **Run as a pod** inside a Kubernetes cluster. This is the preferred method for production use.

i. Build the **nginx-operator** image and push it to a registry:

```
$ operator-sdk build quay.io/example/nginx-operator:v0.0.1
```

```
$ podman push quay.io/example/nginx-operator:v0.0.1
```

ii. Deployment manifests are generated in the **deploy/operator.yaml** file. The deployment

ii. Deployment manifests are generated in the **deploy/operator.yaml** file. The deployment image in this file needs to be modified from the placeholder **REPLACE_IMAGE** to the previous built image. To do this, run:

```
$ sed -i 's|REPLACE_IMAGE|quay.io/example/nginx-operator:v0.0.1|g'
deploy/operator.yaml
```

iii. Deploy the **nginx-operator** manifests:

```
$ oc create -f deploy/service_account.yaml
```

```
$ oc create -f deploy/role.yaml
```

```
$ oc create -f deploy/role_binding.yaml
```

```
$ oc create -f deploy/operator.yaml
```

iv. Verify that the **nginx-operator** deployment is up and running:

```
$ oc get deployment
```

**Example output**

```
NAME             DESIRED   CURRENT   UP-TO-DATE   AVAILABLE   AGE
nginx-operator     1         1         1            1          1m
```

b. **Run outside the cluster.** This method is preferred during the development cycle to speed up deployment and testing.
It is important that the chart path referenced in the **watches.yaml** file exists on your machine. By default, the **watches.yaml** file is scaffolded to work with an Operator image built with the **operator-sdk build** command. When developing and testing your Operator with the **operator-sdk run --local** command, the SDK looks in your local file system for this path.

i. Create a symlink at this location to point to the path of your Helm chart:

```
$ sudo mkdir -p /opt/helm/helm-charts
```

```
$ sudo ln -s $PWD/helm-charts/nginx /opt/helm/helm-charts/nginx
```

ii. To run the Operator locally with the default Kubernetes configuration file present at **$HOME/.kube/config**:

```
$ operator-sdk run --local
```

To run the Operator locally with a provided Kubernetes configuration file:

```
$ operator-sdk run --local --kubeconfig=<path_to_config>
```

5. **Deploy the Nginx CR.**
Apply the **Nginx** CR that you modified earlier:

```
$ oc apply -f deploy/crds/example.com_v1alpha1_nginx_cr.yaml
```

Ensure that the **nginx-operator** creates the deployment for the CR:

```
$ oc get deployment
```

**Example output**

```
NAME                                     DESIRED   CURRENT   UP-TO-DATE   AVAILABLE   AGE
example-nginx-b9phnoz9spckcrua7ihrbkrt1   2         2         2            2           1m
```

Check the pods to confirm two replicas were created:

```
$ oc get pods
```

**Example output**

```
NAME                                                READY     STATUS    RESTARTS   AGE
example-nginx-b9phnoz9spckcrua7ihrbkrt1-f8f9c875d-fjcr9   1/1       Running   0          1m
example-nginx-b9phnoz9spckcrua7ihrbkrt1-f8f9c875d-ljbzl   1/1       Running   0          1m
```

Check that the service port is set to **8080**:

```
$ oc get service
```

**Example output**

```
NAME                                     TYPE        CLUSTER-IP   EXTERNAL-IP   PORT(S)    AGE
example-nginx-b9phnoz9spckcrua7ihrbkrt1   ClusterIP   10.96.26.3   <none>        8080/TCP
1m
```

6. **Update the replicaCount and remove the port.**
Change the **spec.replicaCount** field from **2** to **3**, remove the **spec.service** field, and apply the change:

```
$ cat deploy/crds/example.com_v1alpha1_nginx_cr.yaml
```

**Example output**

```
apiVersion: "example.com/v1alpha1"
kind: "Nginx"
metadata:
  name: "example-nginx"
spec:
  replicaCount: 3
```

```
$ oc apply -f deploy/crds/example.com_v1alpha1_nginx_cr.yaml
```

Confirm that the Operator changes the deployment size:

```
$ oc get deployment
```

**Example output**

```
NAME                                    DESIRED   CURRENT   UP-TO-DATE   AVAILABLE   AGE
example-nginx-b9phnoz9spckcrua7ihrbkrt1   3         3         3            3           1m
```

Check that the service port is set to the default **80**:

```
$ oc get service
```

**Example output**

```
NAME                                    TYPE        CLUSTER-IP   EXTERNAL-IP   PORT(S)   AGE
example-nginx-b9phnoz9spckcrua7ihrbkrt1   ClusterIP   10.96.26.3   <none>        80/TCP
1m
```

7. **Clean up the resources:**

```
$ oc delete -f deploy/crds/example.com_v1alpha1_nginx_cr.yaml
```

```
$ oc delete -f deploy/operator.yaml
```

```
$ oc delete -f deploy/role_binding.yaml
```

```
$ oc delete -f deploy/role.yaml
```

```
$ oc delete -f deploy/service_account.yaml
```

```
$ oc delete -f deploy/crds/example_v1alpha1_nginx_crd.yaml
```

### 5.5.3. Additional resources

- See Appendices to learn about the project directory structures created by the Operator SDK.
- Operator Development Guide for Red Hat Partners

## 5.6. GENERATING A CLUSTER SERVICE VERSION (CSV)

A *cluster service version* (CSV), defined by a **ClusterServiceVersion** object, is a YAML manifest created from Operator metadata that assists Operator Lifecycle Manager (OLM) in running the Operator in a cluster. It is the metadata that accompanies an Operator container image, used to populate user interfaces with information such as its logo, description, and version. It is also a source of technical information that is required to run the Operator, like the RBAC rules it requires and which custom resources (CRs) it manages or depends on.

The Operator SDK includes the **generate csv** subcommand to generate a CSV for the current Operator project customized using information contained in manually-defined YAML manifests and Operator source files.

A CSV-generating command removes the responsibility of Operator authors having in-depth OLM knowledge in order for their Operator to interact with OLM or publish metadata to the Catalog Registry. Further, because the CSV spec will likely change over time as new Kubernetes and OLM features are implemented, the Operator SDK is equipped to easily extend its update system to handle new CSV features going forward.

The CSV version is the same as the Operator version, and a new CSV is generated when upgrading Operator versions. Operator authors can use the **--csv-version** flag to have their Operator state encapsulated in a CSV with the supplied semantic version:

```
$ operator-sdk generate csv --csv-version <version>
```

This action is idempotent and only updates the CSV file when a new version is supplied, or a YAML manifest or source file is changed. Operator authors should not have to directly modify most fields in a CSV manifest. Those that require modification are defined in this guide. For example, the CSV version must be included in **metadata.name**.

### 5.6.1. How CSV generation works

The **deploy**/ directory of an Operator project is the standard location for all manifests required to deploy an Operator. The Operator SDK can use data from manifests in **deploy**/ to write a cluster service version (CSV).

The following command:

```
$ operator-sdk generate csv --csv-version <version>
```

writes a CSV YAML file to the **deploy**/**olm-catalog**/ directory by default.

Exactly three types of manifests are required to generate a CSV:

- **operator.yaml**
- ***_{crd,cr}.yaml**
- RBAC role files, for example **role.yaml**

Operator authors may have different versioning requirements for these files and can configure which specific files are included in the **deploy**/**olm-catalog**/**csv-config.yaml** file.

**Workflow**

Depending on whether an existing CSV is detected, and assuming all configuration defaults are used, the **generate csv** subcommand either:

- Creates a new CSV, with the same location and naming convention as exists currently, using available data in YAML manifests and source files.
    a. The update mechanism checks for an existing CSV in **deploy**/. When one is not found, it creates a **ClusterServiceVersion** object, referred to here as a *cache*, and populates fields easily derived from Operator metadata, such as Kubernetes API **ObjectMeta**.
    b. The update mechanism searches **deploy**/ for manifests that contain data a CSV uses, such as a **Deployment** resource, and sets the appropriate CSV fields in the cache with this data.
    c. After the search completes, every cache field populated is written back to a CSV YAML file.

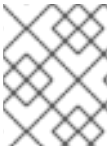
or:

- Updates an existing CSV at the currently pre-defined location, using available data in YAML manifests and source files.

  a. The update mechanism checks for an existing CSV in **deploy**/. When one is found, the CSV YAML file contents are marshaled into a CSV cache.

  b. The update mechanism searches **deploy**/ for manifests that contain data a CSV uses, such as a **Deployment** resource, and sets the appropriate CSV fields in the cache with this data.

  c. After the search completes, every cache field populated is written back to a CSV YAML file.



NOTE

Individual YAML fields are overwritten and not the entire file, as descriptions and other non-generated parts of a CSV should be preserved.

### 5.6.2. CSV composition configuration

Operator authors can configure CSV composition by populating several fields in the **deploy/olm-catalog/csv-config.yaml** file:

| Field | Description |
|---|---|
| **operator-path** (string) | The Operator resource manifest file path. Default: **deploy/operator.yaml**. |
| **crd-cr-path-list** (string(, string)*) | A list of CRD and CR manifest file paths. Default: **[deploy/crds/*_{crd,cr}.yaml]**. |
| **rbac-path-list** (string(, string)*) | A list of RBAC role manifest file paths. Default: **[deploy/role.yaml]**. |

### 5.6.3. Manually-defined CSV fields

Many CSV fields cannot be populated using generated, generic manifests that are not specific to Operator SDK. These fields are mostly human-written metadata about the Operator and various custom resource definitions (CRDs).

Operator authors must directly modify their cluster service version (CSV) YAML file, adding personalized data to the following required fields. The Operator SDK gives a warning during CSV generation when a lack of data in any of the required fields is detected.

The following tables detail which manually-defined CSV fields are required and which are optional.

**Table 5.5. Required**

| Field | Description |
|---|---|
| **metadata.name** | A unique name for this CSV. Operator version should be included in the name to ensure uniqueness, for example **app-operator.v0.1.1**. |

| Field | Description |
|---|---|
| **metadata.capabilities** | The capability level according to the Operator maturity model. Options include **Basic Install**, **Seamless Upgrades**, **Full Lifecycle**, **Deep Insights**, and **Auto Pilot**. |
| **spec.displayName** | A public name to identify the Operator. |
| **spec.description** | A short description of the functionality of the Operator. |
| **spec.keywords** | Keywords describing the Operator. |
| **spec.maintainers** | Human or organizational entities maintaining the Operator, with a **name** and **email**. |
| **spec.provider** | The provider of the Operator (usually an organization), with a **name**. |
| **spec.labels** | Key-value pairs to be used by Operator internals. |
| **spec.version** | Semantic version of the Operator, for example **0.1.1**. |
| **spec.customresourcedefinitions** | Any CRDs the Operator uses. This field is populated automatically by the Operator SDK if any CRD YAML files are present in **deploy/**. However, several fields not in the CRD manifest spec require user input:<br>• **description**: description of the CRD.<br>• **resources**: any Kubernetes resources leveraged by the CRD, for example **Pod** and **StatefulSet** objects.<br>• **specDescriptors**: UI hints for inputs and outputs of the Operator. |

Table 5.6. Optional

| Field | Description |
|---|---|
| **spec.replaces** | The name of the CSV being replaced by this CSV. |
| **spec.links** | URLs (for example, websites and documentation) pertaining to the Operator or application being managed, each with a **name** and **url**. |
| **spec.selector** | Selectors by which the Operator can pair resources in a cluster. |
| **spec.icon** | A base64-encoded icon unique to the Operator, set in a **base64data** field with a **mediatype**. |
| **spec.maturity** | The level of maturity the software has achieved at this version. Options include **planning**, **pre-alpha**, **alpha**, **beta**, **stable**, **mature**, **inactive**, and **deprecated**. |

Further details on what data each field above should hold are found in the CSV spec.

NOTE

Several YAML fields currently requiring user intervention can potentially be parsed from Operator code.

**Additional resources**

- Operator maturity model

#### 5.6.3.1. Operator metadata annotations

Operator developers can manually define certain annotations in the metadata of a cluster service version (CSV) to enable features or highlight capabilities in user interfaces (UIs), such as OperatorHub.

The following table lists Operator metadata annotations that can be manually defined using **metadata.annotations** fields.

**Table 5.7. Annotations**

| Field | Description |
|---|---|
| **alm-examples** | Provide custom resource definition (CRD) templates with a minimum set of configuration. Compatible UIs pre-fill this template for users to further customize. |
| **operatorframework.io/initialization-resource** | Specify a single required custom resource that must be created at the time that the Operator is installed. Must include a template that contains a complete YAML definition. |
| **operatorframework.io/suggested-namespace** | Set a suggested namespace where the Operator should be deployed. |

| Field | Description |
| --- | --- |
| **operators.openshift.io/infrastructure-features** | Infrastructure features supported by the Operator. Users can view and filter by these features when discovering Operators through OperatorHub in the web console. Valid, case-sensitive values:<br>• **disconnected**: Operator supports being mirrored into disconnected catalogs, including all dependencies, and does not require Internet access. All related images required for mirroring are listed by the Operator.<br>• **cnf**: Operator provides a Cloud-native Network Functions (CNF) Kubernetes plug-in.<br>• **cni**: Operator provides a Container Network Interface (CNI) Kubernetes plug-in.<br>• **csi**: Operator provides a Container Storage Interface (CSI) Kubernetes plug-in.<br>• **fips**: Operator accepts the FIPS mode of the underlying platform and works on nodes that are booted into FIPS mode.<br>  <br>IMPORTANT<br>The use of FIPS Validated / Modules in Process cryptographic libraries is only supported on OpenShift Container Platform deployments on the **x86_64** architecture.<br>• **proxy-aware**: Operator supports running on a cluster behind a proxy. Operator accepts the standard proxy environment variables **HTTP_PROXY** and **HTTPS_PROXY**, which Operator Lifecycle Manager (OLM) provides to the Operator automatically when the cluster is configured to use a proxy. Required environment variables are passed down to Operands for managed workloads. |
| **operators.openshift.io/valid-subscription** | Free-form array for listing any specific subscriptions that are required to use the Operator. For example, **'["3Scale Commercial License", "Red Hat Managed Integration"]'**. |
| **operators.operatorframework.io/internal-objects** | Hides CRDs in the UI that are not meant for user manipulation. |

Example use cases

#### Operator supports disconnected and proxy-aware

```
operators.openshift.io/infrastructure-features: '["disconnected", "proxy-aware"]'
```

#### Operator requires an OpenShift Container Platform license

```
operators.openshift.io/valid-subscription: '["OpenShift Container Platform"]'
```

#### Operator requires a 3scale license

```
operators.openshift.io/valid-subscription: '["3Scale Commercial License", "Red Hat Managed Integration"]'
```

#### Operator supports disconnected and proxy-aware, and requires an OpenShift Container Platform license

```
operators.openshift.io/infrastructure-features: '["disconnected", "proxy-aware"]'
operators.openshift.io/valid-subscription: '["OpenShift Container Platform"]'
```

#### Additional resources

- CRD templates
- Initializing required custom resources
- Setting a suggested namespace
- Enabling your Operator for restricted network environments (disconnected mode)
- Hiding internal objects
- Support for FIPS crytography

### 5.6.4. Generating a CSV

#### Prerequisites

- An Operator project generated using the Operator SDK

#### Procedure

1. In your Operator project, configure your CSV composition by modifying the **deploy/olm-catalog/csv-config.yaml** file, if desired.
2. Generate the CSV:

```
$ operator-sdk generate csv --csv-version <version>
```

3. In the new CSV generated in the **deploy/olm-catalog/** directory, ensure all required, manually-defined fields are set appropriately.

### 5.6.5. Enabling your Operator for restricted network environments

As an Operator author, your Operator must meet additional requirements to run properly in a restricted network, or disconnected, environment.

### Operator requirements for supporting disconnected mode

- In the cluster service version (CSV) of your Operator:
  - List any *related images*, or other container images that your Operator might require to perform their functions.
  - Reference all specified images by a digest (SHA) and not by a tag.
- All dependencies of your Operator must also support running in a disconnected mode.
- Your Operator must not require any off-cluster resources.

For the CSV requirements, you can make the following changes as the Operator author.

### Prerequisites

- An Operator project with a CSV.

### Procedure

1. Use SHA references to related images in two places in the CSV for your Operator:
   a. Update **spec.relatedImages**:

```
...
spec:
  relatedImages: 1
    - name: etcd-operator 2
      image: quay.io/etcd-
operator/operator@sha256:d134a9865524c29fcf75bbc4469013bc38d8a15cb5f41acfddb6
b9e492f556e4 3
    - name: etcd-image
      image: quay.io/etcd-
operator/etcd@sha256:13348c15263bd8838ec1d5fc4550ede9860fcbb0f843e48cbccec07
810eebb68
...
```

1. Create a **relatedImages** section and set the list of related images.
2. Specify a unique identifier for the image.
3. Specify each image by a digest (SHA), not by an image tag.

   b. Update the **env** section in the deployment when declaring environment variables that inject the image that the Operator should use:

```
spec:
  install:
    spec:
      deployments:
      - name: etcd-operator-v3.1.1
```

```
    spec:
      replicas: 1
      selector:
        matchLabels:
          name: etcd-operator
      strategy:
        type: Recreate
      template:
        metadata:
          labels:
            name: etcd-operator
        spec:
          containers:
          - args:
            - /opt/etcd/bin/etcd_operator_run.sh
            env:
            - name: WATCH_NAMESPACE
              valueFrom:
                fieldRef:
                  fieldPath: metadata.annotations['olm.targetNamespaces']
            - name: ETCD_OPERATOR_DEFAULT_ETCD_IMAGE (1)
              value: quay.io/etcd-
operator/etcd@sha256:13348c15263bd8838ec1d5fc4550ede9860fcbb0f843e48cbccec07
810eebb68 (2)
            - name: ETCD_LOG_LEVEL
              value: INFO
            image: quay.io/etcd-
operator/operator@sha256:d134a9865524c29fcf75bbc4469013bc38d8a15cb5f41acfddb6
b9e492f556e4 (3)
            imagePullPolicy: IfNotPresent
            livenessProbe:
              httpGet:
                path: /healthy
                port: 8080
              initialDelaySeconds: 10
              periodSeconds: 30
            name: etcd-operator
            readinessProbe:
              httpGet:
                path: /ready
                port: 8080
              initialDelaySeconds: 10
              periodSeconds: 30
            resources: {}
          serviceAccountName: etcd-operator
    strategy: deployment
```

1. Inject the images referenced by the Operator by using environment variables.
2. Specify each image by a digest (SHA), not by an image tag.
3. Also reference the Operator container image by a digest (SHA), not by an image tag.

NOTE

When configuring probes, the **timeoutSeconds** value must be lower than the **periodSeconds** value. The **timeoutSeconds** default value is **1**. The **periodSeconds** default value is **10**.

2. Add the **disconnected** annotation, which indicates that the Operator works in a disconnected environment:

```
metadata:
  annotations:
    operators.openshift.io/infrastructure-features: '["disconnected"]'
```

Operators can be filtered in OperatorHub by this infrastructure feature.

### 5.6.6. Enabling your Operator for multiple architectures and operating systems

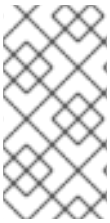
Operator Lifecycle Manager (OLM) assumes that all Operators run on Linux hosts. However, as an Operator author, you can specify whether your Operator supports managing workloads on other architectures, if worker nodes are available in the OpenShift Container Platform cluster.

If your Operator supports variants other than AMD64 and Linux, you can add labels to the cluster service version (CSV) that provides the Operator to list the supported variants. Labels indicating supported architectures and operating systems are defined by the following:

```
labels:
    operatorframework.io/arch.<arch>: supported (1)
    operatorframework.io/os.<os>: supported (2)
```

(1) Set **<arch>** to a supported string.

(2) Set **<os>** to a supported string.



NOTE

Only the labels on the channel head of the default channel are considered for filtering package manifests by label. This means, for example, that providing an additional architecture for an Operator in the non-default channel is possible, but that architecture is not available for filtering in the **PackageManifest** API.

If a CSV does not include an **os** label, it is treated as if it has the following Linux support label by default:

```
labels:
    operatorframework.io/os.linux: supported
```

If a CSV does not include an **arch** label, it is treated as if it has the following AMD64 support label by default:

```
labels:
    operatorframework.io/arch.amd64: supported
```

If an Operator supports multiple node architectures or operating systems, you can add multiple labels, as well.

**Prerequisites**

- An Operator project with a CSV.
- To support listing multiple architectures and operating systems, your Operator image referenced in the CSV must be a manifest list image.
- For the Operator to work properly in restricted network, or disconnected, environments, the image referenced must also be specified using a digest (SHA) and not by a tag.

**Procedure**

- Add a label in the **metadata.labels** of your CSV for each supported architecture and operating system that your Operator supports:

```
labels:
  operatorframework.io/arch.s390x: supported
  operatorframework.io/os.zos: supported
  operatorframework.io/os.linux: supported 1
  operatorframework.io/arch.amd64: supported 2
```

1 2 After you add a new architecture or operating system, you must also now include the default **os.linux** and **arch.amd64** variants explicitly.

**Additional resources**

- See the Image Manifest V 2, Schema 2 specification for more information on manifest lists.

### 5.6.6.1. Architecture and operating system support for Operators

The following strings are supported in Operator Lifecycle Manager (OLM) on OpenShift Container Platform when labeling or filtering Operators that support multiple architectures and operating systems:

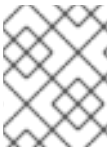
**Table 5.8. Architectures supported on OpenShift Container Platform**

| Architecture | String |
|---|---|
| AMD64 | **amd64** |
| 64-bit PowerPC little-endian | **ppc64le** |
| IBM Z | **s390x** |

**Table 5.9. Operating systems supported on OpenShift Container Platform**

| Operating system | String |
|---|---|
| Linux | **linux** |

| Operating system | String |
| --- | --- |
| z/OS | **zos** |



NOTE

Different versions of OpenShift Container Platform and other Kubernetes-based distributions might support a different set of architectures and operating systems.

### 5.6.7. Setting a suggested namespace

Some Operators must be deployed in a specific namespace, or with ancillary resources in specific namespaces, in order to work properly. If resolved from a subscription, Operator Lifecycle Manager (OLM) defaults the namespaced resources of an Operator to the namespace of its subscription.

As an Operator author, you can instead express a desired target namespace as part of your cluster service version (CSV) to maintain control over the final namespaces of the resources installed for their Operators. When adding the Operator to a cluster using OperatorHub, this enables the web console to autopopulate the suggested namespace for the cluster administrator during the installation process.

**Procedure**

- In your CSV, set the **operatorframework.io/suggested-namespace** annotation to your suggested namespace:

```
metadata:
  annotations:
    operatorframework.io/suggested-namespace: <namespace> 1
```

1 Set your suggested namespace.

### 5.6.8. Defining webhooks

Webhooks allow Operator authors to intercept, modify, and accept or reject resources before they are saved to the object store and handled by the Operator controller. Operator Lifecycle Manager (OLM) can manage the lifecycle of these webhooks when they are shipped alongside your Operator.

The cluster service version (CSV) resource of an Operator can include a **webhookdefinitions** section to define the following types of webhooks:

- Admission webhooks (validating and mutating)
- Conversion webhooks

**Procedure**

- Add a **webhookdefinitions** section to the **spec** section of the CSV of your Operator and include any webhook definitions using a **type** of **ValidatingAdmissionWebhook**, **MutatingAdmissionWebhook**, or **ConversionWebhook**. The following example contains all three types of webhooks:

  **CSV containing webhooks**

```
apiVersion: operators.coreos.com/v1alpha1
kind: ClusterServiceVersion
metadata:
  name: webhook-operator.v0.0.1
spec:
  customresourcedefinitions:
    owned:
    - kind: WebhookTest
      name: webhooktests.webhook.operators.coreos.io 1
      version: v1
  install:
    spec:
      deployments:
      - name: webhook-operator-webhook
        ...
        ...
        ...
    strategy: deployment
  installModes:
  - supported: false
    type: OwnNamespace
  - supported: false
    type: SingleNamespace
  - supported: false
    type: MultiNamespace
  - supported: true
    type: AllNamespaces
  webhookdefinitions:
  - type: ValidatingAdmissionWebhook 2
    admissionReviewVersions:
    - v1beta1
    - v1
    containerPort: 443
    targetPort: 4343
    deploymentName: webhook-operator-webhook
    failurePolicy: Fail
    generateName: vwebhooktest.kb.io
    rules:
    - apiGroups:
      - webhook.operators.coreos.io
      apiVersions:
      - v1
      operations:
      - CREATE
      - UPDATE
      resources:
      - webhooktests
    sideEffects: None
    webhookPath: /validate-webhook-operators-coreos-io-v1-webhooktest
  - type: MutatingAdmissionWebhook 3
    admissionReviewVersions:
    - v1beta1
    - v1
    containerPort: 443
    targetPort: 4343
```

```
    deploymentName: webhook-operator-webhook
    failurePolicy: Fail
    generateName: mwebhooktest.kb.io
    rules:
    - apiGroups:
      - webhook.operators.coreos.io
      apiVersions:
      - v1
      operations:
      - CREATE
      - UPDATE
      resources:
      - webhooktests
    sideEffects: None
    webhookPath: /mutate-webhook-operators-coreos-io-v1-webhooktest
  - type: ConversionWebhook (4)
    admissionReviewVersions:
    - v1beta1
    - v1
    containerPort: 443
    targetPort: 4343
    deploymentName: webhook-operator-webhook
    generateName: cwebhooktest.kb.io
    sideEffects: None
    webhookPath: /convert
    conversionCRDs:
    - webhooktests.webhook.operators.coreos.io (5)
...
```

(1) The CRDs targeted by the conversion webhook must exist here.

(2) A validating admission webhook.

(3) A mutating admission webhook.

(4) A conversion webhook.

(5) The **spec.PreserveUnknownFields** property of each CRD must be set to **false** or **nil**.

**Additional resources**

- Types of webhook admission plug-ins
- Kubernetes documentation:
  - Validating admission webhooks
  - Mutating admission webhooks
  - Conversion webhooks

#### 5.6.8.1. Webhook considerations for OLM

When deploying an Operator with webhooks using Operator Lifecycle Manager (OLM), you must define the following:

- The **type** field must be set to either **ValidatingAdmissionWebhook**, **MutatingAdmissionWebhook**, or **ConversionWebhook**, or the CSV will be placed in a failed phase.
- The CSV must contain a deployment whose name is equivalent to the value supplied in the **deploymentName** field of the **webhookdefinition**.

When the webhook is created, OLM ensures that the webhook only acts upon namespaces that match the Operator group that the Operator is deployed in.

**Certificate authority constraints**
OLM is configured to provide each deployment with a single certificate authority (CA). The logic that generates and mounts the CA into the deployment was originally used by the API service lifecycle logic. As a result:

- The TLS certificate file is mounted to the deployment at **/apiserver.local.config/certificates/apiserver.crt**.
- The TLS key file is mounted to the deployment at **/apiserver.local.config/certificates/apiserver.key**.

**Admission webhook rules constraints**
To prevent an Operator from configuring the cluster into an unrecoverable state, OLM places the CSV in the failed phase if the rules defined in an admission webhook intercept any of the following requests:

- Requests that target all groups
- Requests that target the **operators.coreos.com** group
- Requests that target the **ValidatingWebhookConfigurations** or **MutatingWebhookConfigurations** resources

**Conversion webhook constraints**
OLM places the CSV in the failed phase if a conversion webhook definition does not adhere to the following constraints:

- CSVs featuring a conversion webhook can only support the **AllNamespaces** install mode.
- The CRD targeted by the conversion webhook must have its **spec.preserveUnknownFields** field set to **false** or **nil**.
- The conversion webhook defined in the CSV must target an owned CRD.
- There can only be one conversion webhook on the entire cluster for a given CRD.

## 5.6.9. Understanding your custom resource definitions (CRDs)

There are two types of custom resource definitions (CRDs) that your Operator can use: ones that are *owned* by it and ones that it depends on, which are *required*.

### 5.6.9.1. Owned CRDs

The custom resource definitions (CRDs) owned by your Operator are the most important part of your CSV. This establishes the link between your Operator and the required RBAC rules, dependency management, and other Kubernetes concepts.

It is common for your Operator to use multiple CRDs to link together concepts, such as top-level database configuration in one object and a representation of replica sets in another. Each one should be listed out in the CSV file.

Table 5.10. Owned CRD fields

| Field | Description | Required/optional |
|---|---|---|
| **Name** | The full name of your CRD. | Required |
| **Version** | The version of that object API. | Required |
| **Kind** | The machine readable name of your CRD. | Required |
| **DisplayName** | A human readable version of your CRD name, for example **MongoDB Standalone**. | Required |
| **Description** | A short description of how this CRD is used by the Operator or a description of the functionality provided by the CRD. | Required |
| **Group** | The API group that this CRD belongs to, for example **database.example.com**. | Optional |
| **Resources** | Your CRDs own one or more types of Kubernetes objects. These are listed in the **resources** section to inform your users of the objects they might need to troubleshoot or how to connect to the application, such as the service or ingress rule that exposes a database.<br><br>It is recommended to only list out the objects that are important to a human, not an exhaustive list of everything you orchestrate. For example, do not list config maps that store internal state that are not meant to be modified by a user. | Optional |

| Field | Description | Required/optional |
|---|---|---|
| **SpecDescriptors**, **StatusDescriptors**, and **ActionDescriptors** | These descriptors are a way to hint UIs with certain inputs or outputs of your Operator that are most important to an end user. If your CRD contains the name of a secret or config map that the user must provide, you can specify that here. These items are linked and highlighted in compatible UIs.<br><br>There are three types of descriptors:<br><br>• **SpecDescriptors**: A reference to fields in the **spec** block of an object.<br>• **StatusDescriptors**: A reference to fields in the **status** block of an object.<br>• **ActionDescriptors**: A reference to actions that can be performed on an object.<br><br>All descriptors accept the following fields:<br><br>• **DisplayName**: A human readable name for the **Spec**, **Status**, or **Action**.<br>• **Description**: A short description of the**Spec**, **Status**, or **Action** and how it is used by the Operator.<br>• **Path**: A dot-delimited path of the field on the object that this descriptor describes.<br>• **X-Descriptors**: Used to determine which "capabilities" this descriptor has and which UI component to use. See the **openshift/console** project for a canonical list of React UI X-Descriptors for OpenShift Container Platform.<br><br>Also see the **openshift/console** project for more information on Descriptors in general. | Optional |

The following example depicts a **MongoDB Standalone** CRD that requires some user input in the form of a secret and config map, and orchestrates services, stateful sets, pods and config maps:

### Example owned CRD

```
- displayName: MongoDB Standalone
  group: mongodb.com
  kind: MongoDbStandalone
  name: mongodbstandalones.mongodb.com
  resources:
    - kind: Service
      name: ''
      version: v1
    - kind: StatefulSet
      name: ''
      version: v1beta2
```

```
    - kind: Pod
      name: ''
      version: v1
    - kind: ConfigMap
      name: ''
      version: v1
  specDescriptors:
    - description: Credentials for Ops Manager or Cloud Manager.
      displayName: Credentials
      path: credentials
      x-descriptors:
        - 'urn:alm:descriptor:com.tectonic.ui:selector:core:v1:Secret'
    - description: Project this deployment belongs to.
      displayName: Project
      path: project
      x-descriptors:
        - 'urn:alm:descriptor:com.tectonic.ui:selector:core:v1:ConfigMap'
    - description: MongoDB version to be installed.
      displayName: Version
      path: version
      x-descriptors:
        - 'urn:alm:descriptor:com.tectonic.ui:label'
  statusDescriptors:
    - description: The status of each of the pods for the MongoDB cluster.
      displayName: Pod Status
      path: pods
      x-descriptors:
        - 'urn:alm:descriptor:com.tectonic.ui:podStatuses'
  version: v1
  description: >-
    MongoDB Deployment consisting of only one host. No replication of
    data.
```

#### 5.6.9.2. Required CRDs

Relying on other required CRDs is completely optional and only exists to reduce the scope of individual Operators and provide a way to compose multiple Operators together to solve an end-to-end use case.

An example of this is an Operator that might set up an application and install an etcd cluster (from an etcd Operator) to use for distributed locking and a Postgres database (from a Postgres Operator) for data storage.

Operator Lifecycle Manager (OLM) checks against the available CRDs and Operators in the cluster to fulfill these requirements. If suitable versions are found, the Operators are started within the desired namespace and a service account created for each Operator to create, watch, and modify the Kubernetes resources required.

**Table 5.11. Required CRD fields**

| Field | Description | Required/optional |
|---|---|---|
| **Name** | The full name of the CRD you require. | Required |
| **Version** | The version of that object API. | Required |

| Field | Description | Required/optional |
|---|---|---|
| **Kind** | The Kubernetes object kind. | Required |
| **DisplayName** | A human readable version of the CRD. | Required |
| **Description** | A summary of how the component fits in your larger architecture. | Required |

### Example required CRD

```
required:
- name: etcdclusters.etcd.database.coreos.com
  version: v1beta2
  kind: EtcdCluster
  displayName: etcd Cluster
  description: Represents a cluster of etcd nodes.
```

#### 5.6.9.3. CRD upgrades

OLM upgrades a custom resource definition (CRD) immediately if it is owned by a singular cluster service version (CSV). If a CRD is owned by multiple CSVs, then the CRD is upgraded when it has satisfied all of the following backward compatible conditions:

- All existing serving versions in the current CRD are present in the new CRD.
- All existing instances, or custom resources, that are associated with the serving versions of the CRD are valid when validated against the validation schema of the new CRD.

##### 5.6.9.3.1. Adding a new CRD version

### Procedure

To add a new version of a CRD to your Operator:

1. Add a new entry in the CRD resource under the **versions** section of your CSV.
   For example, if the current CRD has a version **v1alpha1** and you want to add a new version **v1beta1** and mark it as the new storage version, add a new entry for **v1beta1**:

```
versions:
  - name: v1alpha1
    served: true
    storage: false
  - name: v1beta1 (1)
    served: true
    storage: true
```

(1) New entry.

2. Ensure the referencing version of the CRD in the **owned** section of your CSV is updated if the CSV intends to use the new version:

```
customresourcedefinitions:
  owned:
  - name: cluster.example.com
    version: v1beta1 (1)
    kind: cluster
    displayName: Cluster
```

(1) Update the **version**.

3. Push the updated CRD and CSV to your bundle.

#### 5.6.9.3.2. Deprecating or removing a CRD version

Operator Lifecycle Manager (OLM) does not allow a serving version of a custom resource definition (CRD) to be removed right away. Instead, a deprecated version of the CRD must be first disabled by setting the **served** field in the CRD to **false**. Then, the non-serving version can be removed on the subsequent CRD upgrade.

### Procedure

To deprecate and remove a specific version of a CRD:

1. Mark the deprecated version as non-serving to indicate this version is no longer in use and may be removed in a subsequent upgrade. For example:

```
versions:
  - name: v1alpha1
    served: false (1)
    storage: true
```

(1) Set to **false**.

2. Switch the **storage** version to a serving version if the version to be deprecated is currently the **storage** version. For example:

```
versions:
  - name: v1alpha1
    served: false
    storage: false (1)
  - name: v1beta1
    served: true
    storage: true (2)
```

(1) (2) Update the **storage** fields accordingly.

NOTE

In order to remove a specific version that is or was the **storage** version from a CRD, that version must be removed from the **storedVersion** in the status of the CRD. OLM will attempt to do this for you if it detects a stored version no longer exists in the new CRD.

3. Upgrade the CRD with the above changes.

4. In subsequent upgrade cycles, the non-serving version can be removed completely from the CRD. For example:

```
versions:
  - name: v1beta1
    served: true
    storage: true
```

5. Ensure the referencing CRD version in the **owned** section of your CSV is updated accordingly if that version is removed from the CRD.

#### 5.6.9.4. CRD templates

Users of your Operator must be made aware of which options are required versus optional. You can provide templates for each of your custom resource definitions (CRDs) with a minimum set of configuration as an annotation named **alm-examples**. Compatible UIs will pre-fill this template for users to further customize.

The annotation consists of a list of the kind, for example, the CRD name and the corresponding **metadata** and **spec** of the Kubernetes object.

The following full example provides templates for **EtcdCluster**, **EtcdBackup** and **EtcdRestore**:

```
metadata:
  annotations:
    alm-examples: >-
      [{"apiVersion":"etcd.database.coreos.com/v1beta2","kind":"EtcdCluster","metadata":
{"name":"example","namespace":"default"},"spec":{"size":3,"version":"3.2.13"}},
{"apiVersion":"etcd.database.coreos.com/v1beta2","kind":"EtcdRestore","metadata":
{"name":"example-etcd-cluster"},"spec":{"etcdCluster":{"name":"example-etcd-
cluster"},"backupStorageType":"S3","s3":{"path":"<full-s3-path>","awsSecret":"<aws-secret>"}}},
{"apiVersion":"etcd.database.coreos.com/v1beta2","kind":"EtcdBackup","metadata":
{"name":"example-etcd-cluster-backup"},"spec":{"etcdEndpoints":["<etcd-cluster-
endpoints>"],"storageType":"S3","s3":{"path":"<full-s3-path>","awsSecret":"<aws-secret>"}}}]
```

#### 5.6.9.5. Hiding internal objects

It is common practice for Operators to use custom resource definitions (CRDs) internally to accomplish a task. These objects are not meant for users to manipulate and can be confusing to users of the Operator. For example, a database Operator might have a **Replication** CRD that is created whenever a user creates a Database object with **replication: true**.

As an Operator author, you can hide any CRDs in the user interface that are not meant for user manipulation by adding the **operators.operatorframework.io/internal-objects** annotation to the cluster service version (CSV) of your Operator.

**Procedure**

1. Before marking one of your CRDs as internal, ensure that any debugging information or configuration that might be required to manage the application is reflected on the status or **spec** block of your CR, if applicable to your Operator.

2. Add the **operators.operatorframework.io/internal-objects** annotation to the CSV of your Operator to specify any internal objects to hide in the user interface:

**Internal object annotation**

```
apiVersion: operators.coreos.com/v1alpha1
kind: ClusterServiceVersion
metadata:
  name: my-operator-v1.2.3
  annotations:
    operators.operatorframework.io/internal-objects:
'["my.internal.crd1.io","my.internal.crd2.io"]' (1)
...
```

(1) Set any internal CRDs as an array of strings.

### 5.6.9.6. Initializing required custom resources

An Operator might require the user to instantiate a custom resource before the Operator can be fully functional. However, it can be challenging for a user to determine what is required or how to define the resource.

As an Operator developer, you can specify a single required custom resource that must be created at the time that the Operator is installed by adding the **operatorframework.io/initialization-resource** annotation to the cluster service version (CSV). The annotation must include a template that contains a complete YAML definition that is required to initialize the resource during installation.

If this annotation is defined, after installing the Operator from the OpenShift Container Platform web console, the user is prompted to create the resource using the template provided in the CSV.

**Procedure**

- Add the **operatorframework.io/initialization-resource** annotation to the CSV of your Operator to specify a required custom resource. For example, the following annotation requires the creation of a **StorageCluster** resource and provides a full YAML definition:

**Initialization resource annotation**

```
apiVersion: operators.coreos.com/v1alpha1
kind: ClusterServiceVersion
metadata:
  name: my-operator-v1.2.3
  annotations:
    operatorframework.io/initialization-resource: |-
        {
            "apiVersion": "ocs.openshift.io/v1",
            "kind": "StorageCluster",
            "metadata": {
                "name": "example-storagecluster"
            },
            "spec": {
                "manageNodes": false,
                "monPVCTemplate": {
                    "spec": {
```

```
                    "accessModes": [
                      "ReadWriteOnce"
                    ],
                    "resources": {
                      "requests": {
                        "storage": "10Gi"
                      }
                    },
                    "storageClassName": "gp2"
                  }
                },
                "storageDeviceSets": [
                  {
                    "count": 3,
                    "dataPVCTemplate": {
                      "spec": {
                        "accessModes": [
                          "ReadWriteOnce"
                        ],
                        "resources": {
                          "requests": {
                            "storage": "1Ti"
                          }
                        },
                        "storageClassName": "gp2",
                        "volumeMode": "Block"
                      }
                    },
                    "name": "example-deviceset",
                    "placement": {},
                    "portable": true,
                    "resources": {}
                  }
                ]
              }
            }
...
```

## 5.6.10. Understanding your API services

As with CRDs, there are two types of API services that your Operator may use: *owned* and *required*.

### 5.6.10.1. Owned API services

When a CSV owns an API service, it is responsible for describing the deployment of the extension **api-server** that backs it and the group/version/kind (GVK) it provides.

An API service is uniquely identified by the group/version it provides and can be listed multiple times to denote the different kinds it is expected to provide.

**Table 5.12. Owned API service fields**

| Field | Description | Required/optional |
|---|---|---|
| **Group** | Group that the API service provides, for example **database.example.com**. | Required |
| **Version** | Version of the API service, for example **v1alpha1**. | Required |
| **Kind** | A kind that the API service is expected to provide. | Required |
| **Name** | The plural name for the API service provided. | Required |
| **DeploymentName** | Name of the deployment defined by your CSV that corresponds to your API service (required for owned API services). During the CSV pending phase, the OLM Operator searches the **InstallStrategy** of your CSV for a **Deployment** spec with a matching name, and if not found, does not transition the CSV to the "Install Ready" phase. | Required |
| **DisplayName** | A human readable version of your API service name, for example **MongoDB Standalone**. | Required |
| **Description** | A short description of how this API service is used by the Operator or a description of the functionality provided by the API service. | Required |
| **Resources** | Your API services own one or more types of Kubernetes objects. These are listed in the resources section to inform your users of the objects they might need to troubleshoot or how to connect to the application, such as the service or ingress rule that exposes a database.<br><br>It is recommended to only list out the objects that are important to a human, not an exhaustive list of everything you orchestrate. For example, do not list config maps that store internal state that are not meant to be modified by a user. | Optional |
| **SpecDescriptors**, **StatusDescriptors**, and **ActionDescriptors** | Essentially the same as for owned CRDs. | Optional |

#### 5.6.10.1.1. API service resource creation

Operator Lifecycle Manager (OLM) is responsible for creating or replacing the service and API service resources for each unique owned API service:

- Service pod selectors are copied from the CSV deployment matching the **DeploymentName** field of the API service description.
- A new CA key/certificate pair is generated for each installation and the base64-encoded CA bundle is embedded in the respective API service resource.

#### 5.6.10.1.2. API service serving certificates

OLM handles generating a serving key/certificate pair whenever an owned API service is being installed. The serving certificate has a common name (CN) containing the hostname of the generated **Service** resource and is signed by the private key of the CA bundle embedded in the corresponding API service resource.

The certificate is stored as a type **kubernetes.io/tls** secret in the deployment namespace, and a volume named **apiservice-cert** is automatically appended to the volumes section of the deployment in the CSV matching the **DeploymentName** field of the API service description.

If one does not already exist, a volume mount with a matching name is also appended to all containers of that deployment. This allows users to define a volume mount with the expected name to accommodate any custom path requirements. The path of the generated volume mount defaults to **/apiserver.local.config/certificates** and any existing volume mounts with the same path are replaced.

### 5.6.10.2. Required API services

OLM ensures all required CSVs have an API service that is available and all expected GVKs are discoverable before attempting installation. This allows a CSV to rely on specific kinds provided by API services it does not own.

**Table 5.13. Required API service fields**

| Field | Description | Required/optional |
|---|---|---|
| **Group** | Group that the API service provides, for example **database.example.com**. | Required |
| **Version** | Version of the API service, for example **v1alpha1**. | Required |
| **Kind** | A kind that the API service is expected to provide. | Required |
| **DisplayName** | A human readable version of your API service name, for example **MongoDB Standalone**. | Required |
| **Description** | A short description of how this API service is used by the Operator or a description of the functionality provided by the API service. | Required |

## 5.7. WORKING WITH BUNDLE IMAGES

You can use the Operator SDK to package Operators using the Bundle Format.

### 5.7.1. Building a bundle image

You can build, push, and validate an Operator bundle image using the Operator SDK.

**Prerequisites**

- Operator SDK version 0.19.4

- **podman** version 1.9.3+
- An Operator project generated using the Operator SDK
- Access to a registry that supports Docker v2-2

**IMPORTANT**

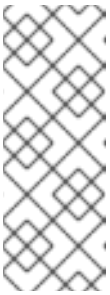
The internal registry of the OpenShift Container Platform cluster cannot be used as the target registry because it does not support pushing without a tag, which is required during the mirroring process.

**Procedure**

1. Run the following **make** commands in your Operator project directory to build and push your Operator image. Modify the **IMG** argument in the following steps to reference a repository that you have access to. You can obtain an account for storing containers at repository sites such as Quay.io.

   a. Build the image:

   ```
   $ make docker-build IMG=<registry>/<user>/<operator_image_name>:<tag>
   ```

   **NOTE**

   The Dockerfile generated by the SDK for the Operator explicitly references **GOARCH=amd64** for **go build**. This can be amended to **GOARCH=$TARGETARCH** for non-AMD64 architectures. Docker will automatically set the environment variable to the value specified by **–platform**. With Buildah, the **–build-arg** will need to be used for the purpose. For more information, see Multiple Architectures.

   b. Push the image to a repository:

   ```
   $ make docker-push IMG=<registry>/<user>/<operator_image_name>:<tag>
   ```

2. Update your **Makefile** by setting the **IMG** URL to your Operator image name and tag that you pushed:

   ```
   $ # Image URL to use all building/pushing image targets
   IMG ?= <registry>/<user>/<operator_image_name>:<tag>
   ```

   This value is used for subsequent operations.

3. Create your Operator bundle manifest by running the **make bundle** command, which invokes several commands, including the Operator SDK **generate bundle** and **bundle validate** subcommands:

   ```
   $ make bundle
   ```

   Bundle manifests for an Operator describe how to display, create, and manage an application. The **make bundle** command creates the following files and directories in your Operator project:

- A bundle manifests directory named **bundle/manifests** that contains a **ClusterServiceVersion** object
- A bundle metadata directory named **bundle/metadata**
- All custom resource definitions (CRDs) in a **config/crd** directory
- A Dockerfile **bundle.Dockerfile**

These files are then automatically validated by using **operator-sdk bundle validate** to ensure the on-disk bundle representation is correct.

4. Build and push your bundle image by running the following commands. OLM consumes Operator bundles using an index image, which reference one or more bundle images.

   a. Build the bundle image. Set **BUNDLE_IMG** with the details for the registry, user namespace, and image tag where you intend to push the image:

   ```
   $ make bundle-build BUNDLE_IMG=<registry>/<user>/<bundle_image_name>:<tag>
   ```

   b. Push the bundle image:

   ```
   $ docker push <registry>/<user>/<bundle_image_name>:<tag>
   ```

### 5.7.2. Additional resources

- See Operator Framework packaging formats for details on the Bundle Format.
- See Managing custom catalogs for details on adding bundle images to index images by using the **opm** command.
- See Operator Lifecycle Manager workflow for details on how upgrades work for installed Operators.

## 5.8. VALIDATING OPERATORS USING THE SCORECARD

Operator authors should validate that their Operator is packaged correctly and free of syntax errors. As an Operator author, you can use the Operator SDK scorecard tool to validate your Operator packaging and run tests.

**NOTE**

OpenShift Container Platform 4.6 supports Operator SDK v0.19.4.

### 5.8.1. About the scorecard tool

To validate an Operator, the scorecard tool provided by the Operator SDK begins by creating all resources required by any related custom resources (CRs) and the Operator. The scorecard then creates a proxy container in the deployment of the Operator which is used to record calls to the API server and run some of the tests. The tests performed also examine some of the parameters in the CRs.

### 5.8.2. Scorecard configuration

The scorecard tool uses a configuration file that allows you to configure internal plug-ins, as well as several global configuration options.

#### 5.8.2.1. Configuration file

The default location for the scorecard tool configuration is the **<project_dir>/.osdk-scorecard.***. The following is an example of a YAML-formatted configuration file:

**Scorecard configuration file**

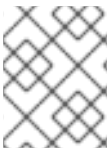
```
scorecard:
  output: json
  plugins:
    - basic: 1
        cr-manifest:
          - "deploy/crds/cache.example.com_v1alpha1_memcached_cr.yaml"
          - "deploy/crds/cache.example.com_v1alpha1_memcachedrs_cr.yaml"
    - olm: 2
        cr-manifest:
          - "deploy/crds/cache.example.com_v1alpha1_memcached_cr.yaml"
          - "deploy/crds/cache.example.com_v1alpha1_memcachedrs_cr.yaml"
        csv-path: "deploy/olm-catalog/memcached-operator/0.0.3/memcached-
operator.v0.0.3.clusterserviceversion.yaml"
```

1. **basic** tests configured to test two custom resources (CRs).
2. **olm** tests configured to test two CRs.

Configuration methods for global options take the following priority, highest to lowest:

Command arguments (if available) → configuration file → default

The configuration file must be in YAML format. As the configuration file might be extended to allow configuration of all **operator-sdk** subcommands in the future, the scorecard configuration must be under a **scorecard** subsection.



**NOTE**

Configuration file support is provided by the **viper** package. For more info on how **viper** configuration works, see the README.

#### 5.8.2.2. Command arguments

While most of the scorecard tool configuration is done using a configuration file, you can also use the following arguments:

**Table 5.14. Scorecard tool arguments**

| Flag | Type | Description |
|---|---|---|
| **--bundle**, **-b** | string | The path to a bundle directory used for the bundle validation test. |

| Flag | Type | Description |
|---|---|---|
| **--config** | string | The path to the scorecard configuration file. The default is **<project_dir>/.osdk-scorecard**. The file type and extension must be **.yaml**. If a configuration file is not provided or found at the default location, the scorecard exits with an error. |
| **--output**, **-o** | string | Output format. Valid options are **text** and **json**. The default format is **text**, which is designed to be a human readable format. The **json** format uses the JSON schema output format used for plug-ins defined later. |
| **--kubeconfig**, **-o** | string | The path to the **kubeconfig** file. It sets the**kubeconfig** for internal plug-ins. |
| **--version** | string | The version of scorecard to run. The default and only valid option is **v1alpha2**. |
| **--selector**, **-l** | string | The label selector to filter tests on. |
| **--list**, **-L** | bool | If **true**, only print the test names that would be run based on selector filtering. |

#### 5.8.2.3. Configuration file options

The scorecard configuration file provides the following options:

**Table 5.15. Scorecard configuration file options**

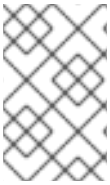
| Option | Type | Description |
|---|---|---|
| **bundle** | string | Equivalent of the **--bundle** flag. Operator Lifecycle Manager (OLM) bundle directory path, when specified, runs bundle validation. |
| **output** | string | Equivalent of the **--output** flag. If this option is defined by both the configuration file and the flag, the flag value takes priority. |
| **kubeconfig** | string | Equivalent of the **--kubeconfig** flag. If this option is defined by both the configuration file and the flag, the flag value takes priority. |
| **plugins** | array | An array of plug-in names. |

##### 5.8.2.3.1. Basic and OLM plug-ins

The scorecard supports the internal **basic** and **olm** plug-ins, which are configured by a **plugins** section in the configuration file.

Table 5.16. Plug-in options

| Option | Type | Description |
|---|---|---|
| **cr-manifest** | []string | The path(s) for CRs being tested. Required if **olm-deployed** is unset or **false**. |
| **csv-path** | string | The path to the cluster service version (CSV) for the Operator. Required for OLM tests or if **olm-deployed** is set to **true**. |
| **olm-deployed** | bool | Indicates that the CSV and relevant CRDs have been deployed onto the cluster by OLM. |
| **kubeconfig** | string | The path to the **kubeconfig** file. If both the global **kubeconfig** and this field are set, this field is used for the plug-in. |
| **namespace** | string | The namespace to run the plug-ins in. If unset, the default specified by the **kubeconfig** file is used. |
| **init-timeout** | int | Time in seconds until a timeout during initialization of the Operator. |
| **crds-dir** | string | The path to the directory containing CRDs that must be deployed to the cluster. |
| **namespaced-manifest** | string | The manifest file with all resources that run within a namespace. By default, the scorecard combines the **service_account.yaml**, **role.yaml**, **role_binding.yaml**, and **operator.yaml** files from the **deploy** directory into a temporary manifest to use as the namespaced manifest. |
| **global-manifest** | string | The manifest containing required resources that run globally (not namespaced). By default, the scorecard combines all CRDs in the **crds-dir** directory into a temporary manifest to use as the global manifest. |



NOTE

Currently, using the scorecard with a CSV does not permit multiple CR manifests to be set through the CLI, configuration file, or CSV annotations. You must tear down your Operator in the cluster, re-deploy, and re-run the scorecard for each CR that is tested.

Additional resources

- You can either set **cr-manifest** or your CSV **metadata.annotations['alm-examples']** to provide CRs to the scorecard, but not both. See CRD templates for details.

### 5.8.3. Tests performed

By default, the scorecard tool has a set of internal tests it can run available across two internal plug-ins. If multiple CRs are specified for a plug-in, the test environment is fully cleaned up after each CR so that each CR gets a clean testing environment.

Each test has a short name that uniquely identifies the test. This is useful when selecting a specific test or tests to run. For example:

```
$ operator-sdk scorecard -o text --selector=test=checkspectest
```

```
$ operator-sdk scorecard -o text --selector='test in (checkspectest,checkstatustest)'
```

#### 5.8.3.1. Basic plug-in

The following basic Operator tests are available from the **basic** plug-in:

**Table 5.17. basic plug-in tests**

| Test | Description | Short name |
|---|---|---|
| Spec Block Exists | This test checks the custom resources (CRs) created in the cluster to make sure that all CRs have a **spec** block. This test has a maximum score of **1**. | **checkspectest** |
| Status Block Exists | This test checks the CRs created in the cluster to make sure that all CRs have a **status** block. This test has a maximum score of **1**. | **checkstatustest** |
| Writing Into CRs Has An Effect | This test reads the scorecard proxy logs to verify that the Operator is making **PUT** or **POST**, or both, requests to the API server, indicating that it is modifying resources. This test has a maximum score of **1**. | **writingintocrshaseffecttest** |

#### 5.8.3.2. OLM plug-in

The following Operator Lifecycle Manager (OLM) integration tests are available from the **olm** plug-in:

**Table 5.18. olm plug-in tests**

| Test | Description | Short name |
|---|---|---|
| OLM Bundle Validation | This test validates the OLM bundle manifests found in the bundle directory as specified by the bundle flag. If the bundle contents contain errors, then the test result output includes the validator log as well as error messages from the validation library. | **bundlevalidationtest** |

| Test | Description | Short name |
|---|---|---|
| Provided APIs Have Validation | This test verifies that the CRDs for the provided CRs contain a validation section and that there is validation for each **spec** and **status** field detected in the CR. This test has a maximum score equal to the number of CRs provided by the **cr-manifest** option. | **crdshavevalidationtest** |
| Owned CRDs Have Resources Listed | This test makes sure that the CRDs for each CR provided by the **cr-manifest** option have a**resources** subsection in the **owned** CRDs section of the CSV. If the test detects used resources that are not listed in the **resources** section, it lists them in the suggestions at the end of the test. This test has a maximum score equal to the number of CRs provided by the **cr-manifest** option. | **crdshaveresourcestest** |
| Spec Fields With Descriptors | This test verifies that every field in the **spec** sections of custom resources have a corresponding descriptor listed in the CSV. This test has a maximum score equal to the total number of fields in the **spec** sections of each custom resource passed in by the **cr-manifest** option. | **specdescriptorstest** |
| Status Fields With Descriptors | This test verifies that every field in the **status** sections of custom resources have a corresponding descriptor listed in the CSV. This test has a maximum score equal to the total number of fields in the **status** sections of each custom resource passed in by the **cr-manifest** option. | **statusdescriptorstest** |

#### Additional resources

- Owned CRDs

### 5.8.4. Running the scorecard

#### Prerequisites

The following prerequisites for the Operator project are checked by the scorecard tool:

- Access to a cluster running Kubernetes 1.11.3 or later.
- If you want to use the scorecard to check the integration of your Operator project with Operator Lifecycle Manager (OLM), then a cluster service version (CSV) file is also required. This is a requirement when the **olm-deployed** option is used.
- For Operators that were not generated using the Operator SDK (non-SDK Operators):
  - Resource manifests for installing and configuring the Operator and custom resources (CRs).
  - Configuration getter that supports reading from the **KUBECONFIG** environment variable, such as the **clientcmd** or **controller-runtime** configuration getters. This is required for the scorecard proxy to work correctly.

**Procedure**

1. Define a **.osdk-scorecard.yaml** configuration file in your Operator project.
2. Create the namespace defined in the RBAC files (**role_binding**).
3. Run the scorecard from the root directory of your Operator project:

```
$ operator-sdk scorecard
```

The scorecard return code is **1** if any of the executed texts did not pass and **0** if all selected tests passed.

### 5.8.5. Running the scorecard with an OLM-managed Operator

The scorecard can be run using a cluster service version (CSV), providing a way to test cluster-ready and non-Operator SDK Operators.

**Procedure**

1. The scorecard requires a proxy container in the deployment pod of the Operator to read Operator logs. A few modifications to your CSV and creation of one extra object are required to run the proxy *before* deploying your Operator with Operator Lifecycle Manager (OLM).
This step can be performed manually or automated using bash functions. Choose one of the following methods.

   - **Manual method:**

     a. Create a proxy server secret containing a local **kubeconfig** file`.

        i. Generate a user name using the namespaced owner reference of the scorecard proxy.

```
$ echo
'{"apiVersion":"","kind":"","name":"scorecard","uid":"","Namespace":"'<namespace>
'"}' | base64 -w 0 (1)
```

(1) Replace **<namespace>** with the namespace your Operator will deploy in.

        ii. Write a **Config** manifest **scorecard-config.yaml** using the following template, replacing **<username>** with the base64 user name generated in the previous step:

```
apiVersion: v1
kind: Config
clusters:
- cluster:
    insecure-skip-tls-verify: true
    server: http://<username>@localhost:8889
  name: proxy-server
contexts:
- context:
    cluster: proxy-server
    user: admin/proxy-server
  name: <namespace>/proxy-server
current-context: <namespace>/proxy-server
```

```
preferences: {}
users:
- name: admin/proxy-server
  user:
    username: <username>
    password: unused
```

iii. Encode the **Config** as base64:

```
$ cat scorecard-config.yaml | base64 -w 0
```

iv. Create a **Secret** manifest **scorecard-secret.yaml**:

```
apiVersion: v1
kind: Secret
metadata:
  name: scorecard-kubeconfig
  namespace: <namespace> (1)
data:
  kubeconfig: <kubeconfig_base64> (2)
```

(1) Replace **<namespace>** with the namespace your Operator will deploy in.

(2) Replace **<kubeconfig_base64>** with the **Config** encoded as base64.

v. Apply the secret:

```
$ oc apply -f scorecard-secret.yaml
```

vi. Insert a volume referring to the secret into the deployment for the Operator:

```
spec:
  install:
    spec:
      deployments:
      - name: memcached-operator
        spec:
          ...
          template:
            ...
            spec:
              containers:
              ...
              volumes:
              - name: scorecard-kubeconfig (1)
                secret:
                  secretName: scorecard-kubeconfig
                  items:
                  - key: kubeconfig
                    path: config
```

(1) Scorecard **kubeconfig** volume.

b. Insert a volume mount and **KUBECONFIG** environment variable into each container in the deployment of your Operator:

```
spec:
  install:
    spec:
      deployments:
      - name: memcached-operator
        spec:
          ...
          template:
            ...
            spec:
              containers:
              - name: container1
                ...
                volumeMounts:
                - name: scorecard-kubeconfig (1)
                  mountPath: /scorecard-secret
                env:
                - name: KUBECONFIG (2)
                  value: /scorecard-secret/config
              - name: container2 (3)
                ...
```

(1) Scorecard **kubeconfig** volume mount.

(2) Scorecard **kubeconfig** environment variable.

(3) Repeat the same for this and all other containers.

c. Insert the scorecard proxy container into the deployment of your Operator:

```
spec:
  install:
    spec:
      deployments:
      - name: memcached-operator
        spec:
          ...
          template:
            ...
            spec:
              containers:
              ...
              - name: scorecard-proxy (1)
                command:
                - scorecard-proxy
                env:
                - name: WATCH_NAMESPACE
                  valueFrom:
                    fieldRef:
                      apiVersion: v1
                      fieldPath: metadata.namespace
```

```
        image: quay.io/operator-framework/scorecard-proxy:master
        imagePullPolicy: Always
        ports:
        - name: proxy
          containerPort: 8889
```

1 Scorecard proxy container.

- **Automated method:**
  The **community-operators** repository has several bash functions that can perform the previous steps in the procedure for you.

  a. Run the following **curl** command:

  ```
  $ curl -Lo csv-manifest-modifiers.sh \
      https://raw.githubusercontent.com/operator-framework/community-operators/master/scripts/lib/file
  ```

  b. Source the **csv-manifest-modifiers.sh** file:

  ```
  $ . ./csv-manifest-modifiers.sh
  ```

  c. Create the **kubeconfig** secret file:

  ```
  $ create_kubeconfig_secret_file scorecard-secret.yaml "<namespace>" 1
  ```

  1 Replace **<namespace>** with the namespace your Operator will deploy in.

  d. Apply the secret:

  ```
  $ oc apply -f scorecard-secret.yaml
  ```

  e. Insert the **kubeconfig** volume:

  ```
  $ insert_kubeconfig_volume "<csv_file>" 1
  ```

  1 Replace **<csv_file>** with the path to your CSV manifest.

  f. Insert the **kubeconfig** secret mount:

  ```
  $ insert_kubeconfig_secret_mount "<csv_file>"
  ```

  g. Insert the proxy container:

  ```
  $ insert_proxy_container "<csv_file>" "quay.io/operator-framework/scorecard-proxy:master"
  ```

2. After inserting the proxy container, follow the steps in the *Getting started with the Operator SDK* guide to bundle your CSV and custom resource definitions (CRDs) and deploy your Operator on OLM.

3. After your Operator has been deployed on OLM, define a **.osdk-scorecard.yaml** configuration file in your Operator project and ensure both the **csv-path: <csv_manifest_path>** and **olm-deployed** options are set.

4. Run the scorecard with both the **csv-path: <csv_manifest_path>** and **olm-deployed** options set in your scorecard configuration file:

```
$ operator-sdk scorecard
```

## 5.9. CONFIGURING BUILT-IN MONITORING WITH PROMETHEUS

This guide describes the built-in monitoring support provided by the Operator SDK using the Prometheus Operator and details usage for Operator authors.

### 5.9.1. Prometheus Operator support

Prometheus is an open-source systems monitoring and alerting toolkit. The Prometheus Operator creates, configures, and manages Prometheus clusters running on Kubernetes-based clusters, such as OpenShift Container Platform.

Helper functions exist in the Operator SDK by default to automatically set up metrics in any generated Go-based Operator for use on clusters where the Prometheus Operator is deployed.

### 5.9.2. Metrics helper

In Go-based Operators generated using the Operator SDK, the following function exposes general metrics about the running program:

```
func ExposeMetricsPort(ctx context.Context, port int32) (*v1.Service, error)
```

These metrics are inherited from the **controller-runtime** library API. By default, the metrics are served on **0.0.0.0:8383/metrics**.

A **Service** object is created with the metrics port exposed, which can be then accessed by Prometheus. The **Service** object is garbage collected when the leader pod's **root** owner is deleted.

The following example is present in the **cmd/manager/main.go** file in all Operators generated using the Operator SDK:

```
import(
    "github.com/operator-framework/operator-sdk/pkg/metrics"
    "machine.openshift.io/controller-runtime/pkg/manager"
)

var (
    // Change the below variables to serve metrics on a different host or port.
    metricsHost       = "0.0.0.0" 1
    metricsPort int32 = 8383 2
)
...
func main() {
    ...
    // Pass metrics address to controller-runtime manager
    mgr, err := manager.New(cfg, manager.Options{
```

```
        Namespace:          namespace,
        MetricsBindAddress: fmt.Sprintf("%s:%d", metricsHost, metricsPort),
    })

    ...
    // Create Service object to expose the metrics port.
    _, err = metrics.ExposeMetricsPort(ctx, metricsPort)
    if err != nil {
        // handle error
        log.Info(err.Error())
    }
    ...
}
```

1. The host that the metrics are exposed on.
2. The port that the metrics are exposed on.

#### 5.9.2.1. Modifying the metrics port

Operator authors can modify the port that metrics are exposed on.

**Prerequisites**

- Go-based Operator generated using the Operator SDK
- Kubernetes-based cluster with the Prometheus Operator deployed

**Procedure**

- In the **cmd/manager/main.go** file of the generated Operator, change the value of **metricsPort** in the following line:

```
var metricsPort int32 = 8383
```

### 5.9.3. Service monitors

A **ServiceMonitor** is a custom resource provided by the Prometheus Operator that discovers the **Endpoints** in **Service** objects and configures Prometheus to monitor those pods.

In Go-based Operators generated using the Operator SDK, the **GenerateServiceMonitor()** helper function can take a **Service** object and generate a **ServiceMonitor** object based on it.

**Additional resources**

- See the Prometheus Operator documentation for more information about the **ServiceMonitor** custom resource definition (CRD).

#### 5.9.3.1. Creating service monitors

Operator authors can add service target discovery of created monitoring services using the **metrics.CreateServiceMonitor()** helper function, which accepts the newly created service.

**Prerequisites**

- Go-based Operator generated using the Operator SDK
- Kubernetes-based cluster with the Prometheus Operator deployed

**Procedure**

- Add the **metrics.CreateServiceMonitor()** helper function to your Operator code:

```
import(
    "k8s.io/api/core/v1"
    "github.com/operator-framework/operator-sdk/pkg/metrics"
    "machine.openshift.io/controller-runtime/pkg/client/config"
)
func main() {

    ...
    // Populate below with the Service(s) for which you want to create ServiceMonitors.
    services := []*v1.Service{}
    // Create one ServiceMonitor per application per namespace.
    // Change the below value to name of the Namespace you want the ServiceMonitor to be
created in.
    ns := "default"
    // restConfig is used for talking to the Kubernetes apiserver
    restConfig := config.GetConfig()

    // Pass the Service(s) to the helper function, which in turn returns the array of
ServiceMonitor objects.
    serviceMonitors, err := metrics.CreateServiceMonitors(restConfig, ns, services)
    if err != nil {
        // Handle errors here.
    }
    ...
}
```

## 5.10. CONFIGURING LEADER ELECTION

During the lifecycle of an Operator, it is possible that there may be more than one instance running at any given time, for example when rolling out an upgrade for the Operator. In such a scenario, it is necessary to avoid contention between multiple Operator instances using leader election. This ensures only one leader instance handles the reconciliation while the other instances are inactive but ready to take over when the leader steps down.

There are two different leader election implementations to choose from, each with its own trade-off:

**Leader-for-life**

The leader pod only gives up leadership, using garbage collection, when it is deleted. This implementation precludes the possibility of two instances mistakenly running as leaders, a state also known as split brain. However, this method can be subject to a delay in electing a new leader. For example, when the leader pod is on an unresponsive or partitioned node, the **pod-eviction-timeout** dictates long how it takes for the leader pod to be deleted from the node and step down, with a default of **5m**. See the Leader-for-life Go documentation for more.

**Leader-with-lease**

The leader pod periodically renews the leader lease and gives up leadership when it cannot renew the lease. This implementation allows for a faster transition to a new leader when the existing leader is isolated, but there is a possibility of split brain in certain situations. See the Leader-with-lease Go documentation for more.

By default, the Operator SDK enables the Leader-for-life implementation. Consult the related Go documentation for both approaches to consider the trade-offs that make sense for your use case.

### 5.10.1. Operator leader election examples

The following examples illustrate how to use the two leader election options for an Operator, Leader-for-life and Leader-with-lease.

#### 5.10.1.1. Leader-for-life election

With the Leader-for-life election implementation, a call to **leader.Become()** blocks the Operator as it retries until it can become the leader by creating the config map named **memcached-operator-lock**:

```
import (
  ...
  "github.com/operator-framework/operator-sdk/pkg/leader"
)

func main() {
  ...
  err = leader.Become(context.TODO(), "memcached-operator-lock")
  if err != nil {
    log.Error(err, "Failed to retry for leader lock")
    os.Exit(1)
  }
  ...
}
```

If the Operator is not running inside a cluster, **leader.Become()** simply returns without error to skip the leader election since it cannot detect the name of the Operator.

#### 5.10.1.2. Leader-with-lease election

The Leader-with-lease implementation can be enabled using the Manager Options for leader election:

```
import (
  ...
  "sigs.k8s.io/controller-runtime/pkg/manager"
)

func main() {
  ...
  opts := manager.Options{
    ...
    LeaderElection: true,
    LeaderElectionID: "memcached-operator-lock"
  }
  mgr, err := manager.New(cfg, opts)
  ...
}
```

When the Operator is not running in a cluster, the Manager returns an error when starting because it cannot detect the namespace of the Operator in order to create the config map for leader election. You can override this namespace by setting the **LeaderElectionNamespace** option for the Manager.

## 5.11. OPERATOR SDK CLI REFERENCE

This guide documents the Operator SDK CLI commands and their syntax:

```
$ operator-sdk <command> [<subcommand>] [<argument>] [<flags>]
```

### 5.11.1. alpha

The **operator-sdk alpha** command is used to run an alpha subcommand.

#### 5.11.1.1. scorecard

The **alpha scorecard** subcommand runs the scorecard tool to validate an Operator bundle and provide suggestions for improvements. The command takes one argument, either a bundle image or directory containing manifests and metadata. If the argument holds an image tag, the image must be present remotely.

Table 5.19. **scorecard** flags

| Flag | Description |
|---|---|
| **-c**, **--config** (string) | Path to scorecard configuration file. |
| **-h**, **--help** | Help output for the **scorecard** command. |
| **--kubeconfig** (string) | Path to **kubeconfig** file. |
| **-L**, **--list** | List which tests are available to run. |
| **-n**, **--namespace** (string) | Namespace in which to run the test images. Default: **default**. |
| **-o**, **--output** (string) | Output format for results. Available values are **text**, and **json**. Default: **text**. |
| **-l**, **--selector** (string) | Label selector to determine which tests are run. |
| **-s**, **--service-account** (string) | Service account to use for tests. Default: **default**. |
| **-x**, **--skip-cleanup** | Disable resource cleanup after tests are run. |
| **-w**, **--wait-time <duration>** | Seconds to wait for tests to complete, for example **35s**. Default: **30s**. |

### 5.11.2. build

The **operator-sdk build** command compiles the code and builds the executables. After **build** completes, the image is built using a local container engine. It must then be pushed to a remote registry.

**Table 5.20. build arguments**

| Argument | Description |
|---|---|
| **<image>** | The container image to be built, for example **quay.io/example/operator:v0.0.1**. |

**Table 5.21. build flags**

| Flag | Description |
|---|---|
| **--go-build-args** (string) | Extra Go build arguments. |
| **--image-build-args** (string) | Extra image build arguments as one string. |
| **--image-builder** (string) | Tool to build OCI images. Available options are: **docker**, **podman**, or **buildah**. Default: **docker**. |
| **-h, --help** | Usage help output. |

### 5.11.3. bundle

The **operator-sdk bundle** command manages Operator bundle metadata.

#### 5.11.3.1. validate

The **bundle validate** subcommand validates an Operator bundle.

**Table 5.22. bundle validate flags**

| Flag | Description |
|---|---|
| **-h**, **--help** | Help output for the **bundle validate** subcommand. |
| **-b**, **--image-builder** (string) | Tool to pull and unpack bundle images. Only used when validating a bundle image. Available options are **docker**, **podman**, or **none**. Default: **docker**. |

### 5.11.4. cleanup

The **operator-sdk cleanup** command destroys and removes resources that were created for an Operator that was deployed with the **run** command.

#### 5.11.4.1. packagemanifests

**cleanup packagemanifests** subcommand destroys an Operator that was deployed with OLM by using the **run packagemanifests** command.

Table 5.23. **packagemanifests** arguments

| Arguments | Description |
|---|---|
| **--include** (string) | The file path to Kubernetes resource manifests, such as role and subscription objects. These supplement or override the defaults generated by **run** or **cleanup**. |
| **--install-mode** (string) | The **OperatorGroup** is created with the specified**InstallMode**. Format: **InstallModeType[=ns1,ns2[, ...]]`** |
| **--kubeconfig** (string) | The file path to a Kubernetes configuration file. Default: The location specified by **$KUBECONFIG**, or to default file rules if not set. |
| **--olm-namespace** (string) | The namespace where the OLM is installed. Default: **olm**. |
| **--operator-namespace** (string) | The namespace where the Operator resources are created. The namespace must already exist in the cluster, or be defined in a manifest that is passed to **--include**. |
| **--operator-version** | The version of the Operator to be deployed. |
| **--timeout <duration>** | The time to wait for the command to complete before it fails. Default: **2m0s**. |
| **-h, --help** | Usage help output. |

### 5.11.5. completion

The **operator-sdk completion** command generates shell completions to make issuing CLI commands quicker and easier.

Table 5.24. **completion** subcommands

| Subcommand | Description |
|---|---|
| **bash** | Generate bash completions. |
| **zsh** | Generate zsh completions. |

Table 5.25. **completion** flags

| Flag | Description |
|---|---|
| **-h, --help** | Usage help output. |

For example:

```
$ operator-sdk completion bash
```

**Example output**

```
# bash completion for operator-sdk                  -*- shell-script -*-
...
# ex: ts=4 sw=4 et filetype=sh
```

### 5.11.6. create

The **operator-sdk create** command is used to create, or *scaffold*, a Kubernetes API.

#### 5.11.6.1. api

The **create api** subcommand scaffolds a Kubernetes API. The subcommand must be run in a project that was initialized with the **init** command.

**Table 5.26. create api flags**

| Flag | Description |
|---|---|
| **-h**, **--help** | Help output for the **run bundle** subcommand. |

#### 5.11.6.2. webhook

The **create webhook** subcommand scaffolds a webhook for an API resource. The subcommand must be run in a project that was initialized with the **init** command.

**Table 5.27. create webhook flags**

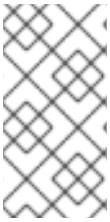
| Flag | Description |
|---|---|
| **-h**, **--help** | Help output for the **run bundle** subcommand. |

### 5.11.7. generate

The **operator-sdk generate** command invokes a specific generator to generate code as needed.

#### 5.11.7.1. bundle

The **generate bundle** subcommand generates a set of bundle manifests, metadata, and a **bundle.Dockerfile** file for your Operator project.



NOTE

Typically, you run the **generate kustomize manifests** subcommand first to generate the input Kustomize bases that are used by the **generate bundle** subcommand. However, you can use the **make bundle** command in an initialized project to automate running these commands in sequence.

Table 5.28. **generate bundle** flags

| Flag | Description |
|---|---|
| **--channels** (string) | Comma-separated list of channels to which the bundle belongs. The default value is **alpha**. |
| **--crds-dir** (string) | Root directory for **CustomResoureDefinition** manifests. |
| **--default-channel** (string) | The default channel for the bundle. |
| **--deploy-dir** (string) | Root directory for Operator manifests, such as deployments and RBAC. This directory is different from the directory passed to the **--input-dir** flag. |
| **-h**, **--help** | Help for **generate bundle** |
| **--input-dir** (string) | Directory from which to read an existing bundle. This directory is the parent of your bundle **manifests** directory and is different from the**--deploy-dir** directory. |
| **--kustomize-dir** (string) | Directory containing Kustomize bases and a **kustomization.yaml** file for bundle manifests. The default path is **config/manifests**. |
| **--manifests** | Generate bundle manifests. |
| **--metadata** | Generate bundle metadata and Dockerfile. |
| **--operator-name** (string) | Name of the Operator of the bundle. |
| **--output-dir** (string) | Directory to write the bundle to. |
| **--overwrite** | Overwrite the bundle metadata and Dockerfile if they exist. The default value is **true**. |
| **-q**, **--quiet** | Run in quiet mode. |
| **--stdout** | Write bundle manifest to standard out. |
| **--version** (string) | Semantic version of the Operator in the generated bundle. Set only when creating a new bundle or upgrading the Operator. |

#### 5.11.7.2. kustomize

The **generate kustomize** subcommand contains subcommands that generate Kustomize data for the Operator.

##### 5.11.7.2.1. manifests

The **generate kustomize manifests** subcommand generates or regenerates Kustomize bases and a **kustomization.yaml** file in the **config/manifests** directory, which are used to build bundle manifests by other Operator SDK commands. This command interactively asks for UI metadata, an important component of manifest bases, by default unless a base already exists or you set the **--interactive=false** flag.

Table 5.29. **generate kustomize manifests** flags

| Flag | Description |
|---|---|
| **--apis-dir** (string) | Root directory for API type definitions. |
| **-h**, **--help** | Help for **generate kustomize manifests**. |
| **--input-dir** (string) | Directory containing existing Kustomize files. |
| **--interactive** | When set to **false**, if no Kustomize base exists, an interactive command prompt is presented to accept custom metadata. |
| **--operator-name** (string) | Name of the Operator. |
| **--output-dir** (string) | Directory where to write Kustomize files. |
| **-q**, **--quiet** | Run in quiet mode. |

#### 5.11.7.3. packagemanifests

Running **generate packagemanifests** subcommand is the first step to publishing your Operator to a catalog, deploying it with OLM or both. This command generates a set of manifests in a versioned directory and a package manifest file for your Operator. You must run **generate kustomize manifests** first to regenerate Kustomize bases consumed by this command.

Table 5.30. **generate packagemanifests** flags

| Flag | Description |
|---|---|
| **--channel** (string) | The channel name for the generated package. |
| **--crds-dir** (string) | The root directory for custom resource definition (CRD) manifests. |
| **--default-channel** | Use the channel passed to **--channel** as the default channel of package manifest file. |

| Flag | Description |
|---|---|
| **--deploy-dir** (string) | The root directory for Operator manifests such as deployments and RBAC, for example, **deploy**. This directory is different from that passed to **--input-dir**. |
| **--from-version** (string) | The semantic version of the Operator, from which it is being upgraded. |
| **-h**, **--help** | Help for **generate kustomize manifests**. |
| **--input-dir** (string) | The directory to read existing package manifests from. This directory is the parent of individual versioned package directories, and different from **--deploy-dir**. |
| **--kustomize-dir** (string) | The directory containing Kustomize bases and a **kustomization.yaml** for **operator-framework** manifests. Default: **config/manifests**. |
| **--operator-name** (string) | The name of the packaged Operator. |
| **--output-dir** (string) | The directory in which to write package manifests. |
| **-q**, **--quiet** | Run in quiet mode. |
| **--stdout** | Write package to **stdout**. |
| **--update-crds** | Update custom resource definition (CRD) manifests in this package. Default: **true**. |
| **-v, --version** (string) | The semantic version of the packaged Operator. |

### 5.11.8. init

The **operator-sdk init** command initializes an Operator project and generates, or *scaffolds*, a default project directory layout for the given plug-in.

This command writes the following files:

- Boilerplate license file
- **PROJECT** file with the domain and repository
- **Makefile** to build the project
- **go.mod** file with project dependencies
- **kustomization.yaml** file for customizing manifests
- Patch file for customizing images for manager manifests
- Patch file for enabling Prometheus metrics

- **main.go** file to run

Table 5.31. **init** flags

| Flag | Description |
|---|---|
| **--help, -h** | Help output for the **init** command. |
| **--plugins** (string) | Name and optionally version of the plug-in to initialize the project with. Available plug-ins are **ansible.sdk.operatorframework.io/v1**, **go.kubebuilder.io/v2**, **go.kubebuilder.io/v3**, and **helm.sdk.operatorframework.io/v1**. |
| **--project-version** | Project version. Available values are **2** and **3-alpha**, which is the default. |

### 5.11.9. new

The **operator-sdk new** command creates a new Operator application and generates (or *scaffolds*) a default project directory layout based on the input **<project_name>**.

Table 5.32. **new** arguments

| Argument | Description |
|---|---|
| **<project_name>** | Name of the new project. |

Table 5.33. **new** flags

| Flag | Description |
|---|---|
| **--api-version** | Kubernetes API version in the format **<group_name>/<version>**, for example **app.example.com/v1alpha1**. |
| **--crd-version** | CRD version to generate. Default: **v1**. |
| **--generate-playbook** | Generate an Ansible playbook skeleton. Used with **ansible** type. |
| **--helm-chart <string>** | Initialize Helm Operator with existing Helm chart: **<url>**, **<repo>/<name>**, or local path. |
| **--helm-chart-repo <string>** | Chart repository URL for the requested Helm chart. |
| **--helm-chart-version <string>** | Specific version of the Helm chart. Used only with the **helm** type. Default: latest version. |
| **--help, -h** | Usage and help output. |
| **--kind <string>** | CRD kind, for example **AppService**. |

| Flag | Description |
|---|---|
| **--skip-generation** | Skip generation of deepcopy and OpenAPI code and OpenAPI CRD specs. |
| **--type** | Type of Operator to initialize: **ansible** or **helm**. |

NOTE

Starting with Operator SDK v0.12.0, the **--dep-manager** flag and support for **dep**-based projects have been removed. Go projects are now scaffolded to use Go modules.

### Example usage for Go project

```
$ mkdir $GOPATH/src/github.com/example.com/
```

```
$ cd $GOPATH/src/github.com/example.com/
```

```
$ operator-sdk new app-operator
```

### Example usage for Ansible project

```
$ operator-sdk new app-operator \
    --type=ansible \
    --api-version=app.example.com/v1alpha1 \
    --kind=AppService
```

## 5.11.10. olm

The **operator-sdk olm** command manages the Operator Lifecycle Manager (OLM) installation in your cluster.

### 5.11.10.1. install

**olm install** subcommand installs OLM in your cluster.

Table 5.34. **install** arguments

| Argument | Description |
|---|---|
| **--olm-namespace** string | The namespace where OLM is installed. Default: **olm**. |
| **--timeout <duration>** | The time to wait for the command to complete before it fails. Default: **2m0s**. |
| **--version** string | The version of OLM resources to be installed. Default: **latest**. |
| **-h, --help** | Usage help output. |

#### 5.11.10.2. status

**olm status** subcommand gets the status of the Operator Lifecycle Manager (OLM) installation in your cluster.

Table 5.35. **status** arguments

| Argument | Description |
|---|---|
| **--olm-namespace** string | The namespace from where OLM is installed. Default: **olm**. |
| **--timeout <duration>** | The time to wait for the command to complete before it fails. Default: **2m0s**. |
| **--version** string | The version of the OLM that is installed on your cluster. If unset, **operator-sdk** attempts to auto-discover the version. |
| **-h, --help** | Usage help output. |

#### 5.11.10.3. uninstall

**olm uninstall** subcommand uninstalls OLM from your cluster.

Table 5.36. **uninstall** arguments

| Argument | Description |
|---|---|
| **--olm-namespace** (string) | The namespace from where OLM is to be uninstalled. Default: **olm**. |
| **--timeout <duration>** | The time to wait for the command to complete before it fails. Default: **2m0s**. |
| **--version** (string) | The version of OLM resources to be uninstalled. |
| **-h, --help** | Usage help output. |

### 5.11.11. run

The **operator-sdk run** command provides options that can launch the Operator in various environments.

#### 5.11.11.1. packagemanifests

**run packagemanifests** subcommand deploys an Operator's package manifests with Operator Lifecycle Manager (OLM). The command argument must be set to a valid package manifest root directory, for example, **<project_root>/packagemanifests**.

Table 5.37. **packagemanifests** arguments

| Arguments | Description |
|---|---|
| **--include** (string) | The file path to Kubernetes resource manifests, such as role and subscription objects. These supplement or override the defaults generated by **run** or **cleanup**. |
| **--install-mode** (string) | The **OperatorGroup** is created with the specified**InstallMode**. Format: **InstallModeType[=ns1,ns2[, ...]]**. |
| **--kubeconfig** (string) | The file path to a Kubernetes configuration file. Default: The location specified by **$KUBECONFIG**, or to default file rules if the environment variable not set. |
| **--olm-namespace** (string) | The namespace where OLM is installed. Default: **olm**. |
| **--operator-namespace** (string) | The namespace where the Operator resources are created. The namespace must already exist in the cluster, or be defined in a manifest that is passed to **--include**. |
| **--operator-version** (string) | The version of the Operator to deploy. |
| **--timeout <duration>** | The time to wait for the command to complete before it fails. Default: **2m0s**. |
| **-h, --help** | Usage help output. |

## 5.12. APPENDICES

### 5.12.1. Operator project scaffolding layout

The **operator-sdk** CLI generates a number of packages for each Operator project. The following sections describes a basic rundown of each generated file and directory.

#### 5.12.1.1. Ansible-based projects

Ansible-based Operator projects generated using the **operator-sdk new --type ansible** command contain the following directories and files:

| File/folders | Purpose |
|---|---|
| **molecule**/ | Contains the files that are used for testing the Ansible roles. |
| **roles**/ | Contains the Helm chart used while creating the project. |
| **build**/ | Contains the Dockerfile and build scripts used to build the Operator. |

| File/folders | Purpose |
|---|---|
| **deploy/** | Contains various YAML manifests for registering CRDs, setting up RBAC, and deploying the Operator as a deployment. |
| **requirements.yml** | Contains the Ansible content that needs to be installed. |
| **watches.yaml** | Contains group, version, kind and role. |

#### 5.12.1.2. Helm-based projects

Helm-based Operator projects generated using the **operator-sdk new --type helm** command contain the following directories and files:

| File/folders | Purpose |
|---|---|
| **deploy/** | Contains various YAML manifests for registering CRDs, setting up RBAC, and deploying the Operator as a Deployment. |
| **helm-charts/<kind>** | Contains a Helm chart initialized using the equivalent of the **helm create** command. |
| **build/** | Contains the Dockerfile and build scripts used to build the Operator. |
| **watches.yaml** | Contains group, version, kind and Helm chart location. |

# CHAPTER 6. RED HAT OPERATORS

## 6.1. CLOUD CREDENTIAL OPERATOR

### Purpose

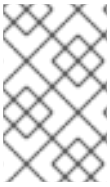
The Cloud Credential Operator (CCO) manages cloud provider credentials as Kubernetes custom resource definitions (CRDs). The CCO syncs on **credentialsRequest** custom resources (CRs) to allow OpenShift Container Platform components to request cloud provider credentials with the specific permissions that are required for the cluster to run.

By setting different values for the **credentialsMode** parameter in the **install-config.yaml** file, the CCO can be configured to operate in several different modes. If no mode is specified, or the **credentialsMode** parameter is set to an empty string ( **""**), the CCO operates in its default mode.

### Default behavior

For platforms where multiple modes are supported (AWS, Azure, and GCP), when the CCO operates in its default mode, it checks the provided credentials dynamically to determine for which mode they are sufficient to process **credentialsRequest** CRs.

By default, the CCO determines whether the credentials are sufficient for mint mode, which is the preferred mode of operation, and uses those credentials to create appropriate credentials for components in the cluster. If the credentials are not sufficient for mint mode, it determines whether they are sufficient for passthrough mode. If the credentials are not sufficient for passthrough mode, the CCO cannot adequately process **credentialsRequest** CRs.



NOTE

The CCO cannot verify whether Azure credentials are sufficient for passthrough mode. If Azure credentials are insufficient for mint mode, the CCO operates with the assumption that the credentials are sufficient for passthrough mode.

If the provided credentials are determined to be insufficient during installation, the installation fails. For AWS, the installer fails early in the process and indicates which required permissions are missing. Other providers might not provide specific information about the cause of the error until errors are encountered.

If the credentials are changed after a successful installation and the CCO determines that the new credentials are insufficient, the CCO puts conditions on any new **credentialsRequest** CRs to indicate that it cannot process them because of the insufficient credentials.

To resolve insufficient credentials issues, provide a credential with sufficient permissions. If an error occurred during installation, try installing again. For issues with new **credentialsRequest** CRs, wait for the CCO to try to process the CR again. As an alternative, you can manually create IAM for AWS, Azure, or GCP. For details, see the *Manually creating IAM* section of the installation content for AWS, Azure, or GCP.

### Modes

By setting different values for the **credentialsMode** parameter in the **install-config.yaml** file, the CCO can be configured to operate in *mint*, *passthrough*, or *manual* mode. These options provide transparency and flexibility in how the CCO uses cloud credentials to process **credentialsRequest** CRs in the cluster, and allow the CCO to be configured to suit the security requirements of your organization. Not all CCO modes are supported for all cloud providers.

### Mint mode

Mint mode is supported for AWS, Azure, and GCP.

Mint mode is the default and recommended best practice setting for the CCO to use. In this mode, the CCO uses the provided admin-level cloud credential to run the cluster.

If the credential is not removed after installation, it is stored and used by the CCO to process **credentialsRequest** CRs for components in the cluster and create new credentials for each with only the specific permissions that are required. The continuous reconciliation of cloud credentials in mint mode allows actions that require additional credentials or permissions, such as upgrading, to proceed.

The requirement that mint mode stores the admin-level credential in the cluster **kube-system** namespace might not suit the security requirements of every organization.

When using the CCO in mint mode, ensure that the credential you provide meets the requirements of the cloud on which you are running or installing OpenShift Container Platform. If the provided credentials are not sufficient for mint mode, the CCO cannot create an IAM user.

**Table 6.1. Mint mode credential requirements**

| Cloud | Permissions |
|---|---|
| AWS | • **iam:CreateAccessKey**<br>• **iam:CreateUser**<br>• **iam:DeleteAccessKey**<br>• **iam:DeleteUser**<br>• **iam:DeleteUserPolicy**<br>• **iam:GetUser**<br>• **iam:GetUserPolicy**<br>• **iam:ListAccessKeys**<br>• **iam:PutUserPolicy**<br>• **iam:TagUser**<br>• **iam:SimulatePrincipalPolicy** |
| Azure | Service principal with the permissions specified in the *Creating a service principal* section of the *Configuring an Azure account* content. |

| Cloud | Permissions |
| --- | --- |
| GCP | • **resourcemanager.projects.get**<br>• **serviceusage.services.list**<br>• **iam.serviceAccountKeys.create**<br>• **iam.serviceAccountKeys.delete**<br>• **iam.serviceAccounts.create**<br>• **iam.serviceAccounts.delete**<br>• **iam.serviceAccounts.get**<br>• **iam.roles.get**<br>• **resourcemanager.projects.getIamPolicy**<br>• **resourcemanager.projects.setIamPolicy** |

### Mint mode with removal or rotation of the admin-level credential

Mint mode with removal or rotation of the admin-level credential is supported for AWS in OpenShift Container Platform version 4.4 and later.

This option requires the presence of the admin-level credential during installation, but the credential is not stored in the cluster permanently and does not need to be long-lived.

After installing OpenShift Container Platform in mint mode, you can remove the admin-level credential Secret from the cluster. If you remove the Secret, the CCO uses a previously minted read-only credential that allows it to verify whether all **credentialsRequest** CRs have their required permissions. Once removed, the associated credential can be destroyed on the underlying cloud if desired.

The admin-level credential is not required unless something that requires an admin-level credential needs to be changed, for instance during an upgrade. Prior to each upgrade, you must reinstate the credential Secret with the admin-level credential. If the credential is not present, the upgrade might be blocked.

#### Passthrough mode

Passthrough mode is supported for AWS, Azure, GCP, Red Hat OpenStack Platform (RHOSP), Red Hat Virtualization (RHV), and VMware vSphere.

In passthrough mode, the CCO passes the provided cloud credential to the components that request cloud credentials. The credential must have permissions to perform the installation and complete the operations that are required by components in the cluster, but does not need to be able to create new credentials. The CCO does not attempt to create additional limited-scoped credentials in passthrough mode.

### Passthrough mode permissions requirements

When using the CCO in passthrough mode, ensure that the credential you provide meets the requirements of the cloud on which you are running or installing OpenShift Container Platform. If the provided credentials the CCO passes to a component that creates a **credentialsRequest** CR are not sufficient, that component will report an error when it tries to call an API that it does not have permissions for.

The credential you provide for passthrough mode in AWS, Azure, or GCP must have all the requested permissions for all **credentialsRequest** CRs that are required by the version of OpenShift Container Platform you are running or installing. To locate the **credentialsRequest** CRs that are required for your cloud provider, see the *Manually creating IAM* section of the installation content for AWS, Azure, or GCP.

To install an OpenShift Container Platform cluster on Red Hat OpenStack Platform (RHOSP), the CCO requires a credential with the permissions of a **member** user role.

To install an OpenShift Container Platform cluster on Red Hat Virtualization (RHV), the CCO requires a credential with the following privileges:

- **DiskOperator**
- **DiskCreator**
- **UserTemplateBasedVm**
- **TemplateOwner**
- **TemplateCreator**
- **ClusterAdmin** on the specific cluster that is targeted for OpenShift Container Platform deployment

To install an OpenShift Container Platform cluster on VMware vSphere, the CCO requires a credential with the following vSphere privileges:

**Table 6.2. Required vSphere privileges**

| Category | Privileges |
|---|---|
| Datastore | *Allocate space* |
| Folder | *Create folder*, *Delete folder* |
| vSphere Tagging | All privileges |
| Network | *Assign network* |
| Resource | *Assign virtual machine to resource pool* |
| Profile-driven storage | All privileges |
| vApp | All privileges |
| Virtual machine | All privileges |

### Passthrough mode credential maintenance

If **credentialsRequest** CRs change over time as the cluster is upgraded, you must manually update the passthrough mode credential to meet the requirements. To avoid credentials issues during an upgrade, check the **credentialsRequest** CRs in the release image for the new version of OpenShift Container

Platform before upgrading. To locate the **credentialsRequest** CRs that are required for your cloud provider, see the *Manually creating IAM* section of the installation content for AWS, Azure, or GCP.

### Reducing permissions after installation

When using passthrough mode, each component has the same permissions used by all other components. If you do not reduce the permissions after installing, all components have the broad permissions that are required to run the installer.

After installation, you can reduce the permissions on your credential to only those that are required to run the cluster, as defined by the **credentialsRequest** CRs in the release image for the version of OpenShift Container Platform that you are using.

To locate the **credentialsRequest** CRs that are required for AWS, Azure, or GCP and learn how to change the permissions the CCO uses, see the *Manually creating IAM* section of the installation content for AWS, Azure, or GCP.

#### Manual mode

Manual mode is supported for AWS.

In manual mode, a user manages cloud credentials instead of the CCO. To use this mode, you must examine the **credentialsRequest** CRs in the release image for the version of OpenShift Container Platform that you are running or installing, create corresponding credentials in the underlying cloud provider, and create Kubernetes Secrets in the correct namespaces to satisfy all **credentialsRequest** CRs for the cluster's cloud provider.

Using manual mode allows each cluster component to have only the permissions it requires, without storing an admin-level credential in the cluster. This mode also does not require connectivity to the AWS public IAM endpoint. However, you must manually reconcile permissions with new release images for every upgrade.

For information about configuring AWS to use manual mode, see *Manually creating IAM for AWS*.

#### Disabled CCO

Disabled CCO is supported for Azure and GCP.

To manually manage credentials for Azure or GCP, you must disable the CCO. Disabling the CCO has many of the same configuration and maintenance requirements as running the CCO in manual mode, but is accomplished by a different process. For more information, see the *Manually creating IAM* section of the installation content for Azure or GCP.

### Project

openshift-cloud-credential-operator

### CRDs

- **credentialsrequests.cloudcredential.openshift.io**
  - Scope: Namespaced
  - CR: **credentialsrequest**
  - Validation: Yes

### Configuration objects

No configuration required.

## 6.2. CLUSTER AUTHENTICATION OPERATOR

### Purpose

The Cluster Authentication Operator installs and maintains the **Authentication** custom resource in a cluster and can be viewed with:

```
$ oc get clusteroperator authentication -o yaml
```

### Project

cluster-authentication-operator

## 6.3. CLUSTER AUTOSCALER OPERATOR

### Purpose

The Cluster Autoscaler Operator manages deployments of the OpenShift Cluster Autoscaler using the **cluster-api** provider.

### Project

cluster-autoscaler-operator

### CRDs

- **ClusterAutoscaler**: This is a singleton resource, which controls the configuration autoscaler instance for the cluster. The Operator only responds to the **ClusterAutoscaler** resource named **default** in the managed namespace, the value of the **WATCH_NAMESPACE** environment variable.
- **MachineAutoscaler**: This resource targets a node group and manages the annotations to enable and configure autoscaling for that group, the **min** and **max** size. Currently only **MachineSet** objects can be targeted.

## 6.4. CLUSTER IMAGE REGISTRY OPERATOR

### Purpose

The Cluster Image Registry Operator manages a singleton instance of the OpenShift Container Platform registry. It manages all configuration of the registry, including creating storage.

On initial start up, the Operator creates a default **image-registry** resource instance based on the configuration detected in the cluster. This indicates what cloud storage type to use based on the cloud provider.

If insufficient information is available to define a complete **image-registry** resource, then an incomplete resource is defined and the Operator updates the resource status with information about what is missing.

The Cluster Image Registry Operator runs in the **openshift-image-registry** namespace and it also manages the registry instance in that location. All configuration and workload resources for the registry reside in that namespace.

### Project

cluster-image-registry-operator

## 6.5. CLUSTER MONITORING OPERATOR

### Purpose
The Cluster Monitoring Operator manages and updates the Prometheus-based cluster monitoring stack deployed on top of OpenShift Container Platform.

### Project
openshift-monitoring

### CRDs

- **alertmanagers.monitoring.coreos.com**
  - Scope: Namespaced
  - CR: **alertmanager**
  - Validation: Yes
- **prometheuses.monitoring.coreos.com**
  - Scope: Namespaced
  - CR: **prometheus**
  - Validation: Yes
- **prometheusrules.monitoring.coreos.com**
  - Scope: Namespaced
  - CR: **prometheusrule**
  - Validation: Yes
- **servicemonitors.monitoring.coreos.com**
  - Scope: Namespaced
  - CR: **servicemonitor**
  - Validation: Yes

### Configuration objects

```
$ oc -n openshift-monitoring edit cm cluster-monitoring-config
```

## 6.6. CLUSTER NETWORK OPERATOR

### Purpose
The Cluster Network Operator installs and upgrades the networking components on an OpenShift Container Platform cluster.

## 6.7. OPENSHIFT CONTROLLER MANAGER OPERATOR

### Purpose
The OpenShift Controller Manager Operator installs and maintains the **OpenShiftControllerManager** custom resource in a cluster and can be viewed with:

```
$ oc get clusteroperator openshift-controller-manager -o yaml
```

The custom resource definitino (CRD) **openshiftcontrollermanagers.operator.openshift.io** can be viewed in a cluster with:

```
$ oc get crd openshiftcontrollermanagers.operator.openshift.io -o yaml
```

### Project

cluster-openshift-controller-manager-operator

## 6.8. CLUSTER SAMPLES OPERATOR

### Purpose

The Cluster Samples Operator manages the sample image streams and templates stored in the **openshift** namespace.

On initial start up, the Operator creates the default samples configuration resource to initiate the creation of the image streams and templates. The configuration object is a cluster scoped object with the key **cluster** and type **configs.samples**.

The image streams are the Red Hat Enterprise Linux CoreOS (RHCOS)-based OpenShift Container Platform image streams pointing to images on **registry.redhat.io**. Similarly, the templates are those categorized as OpenShift Container Platform templates.

The Cluster Samples Operator deployment is contained within the **openshift-cluster-samples-operator** namespace. On start up, the install pull secret is used by the image stream import logic in the internal registry and API server to authenticate with **registry.redhat.io**. An administrator can create any additional secrets in the **openshift** namespace if they change the registry used for the sample image streams. If created, those secrets contain the content of a **config.json** for **docker** needed to facilitate image import.

The image for the Cluster Samples Operator contains image stream and template definitions for the associated OpenShift Container Platform release. After the Cluster Samples Operator creates a sample, it adds an annotation that denotes the OpenShift Container Platform version that it is compatible with. The Operator uses this annotation to ensure that each sample matches the compatible release version. Samples outside of its inventory are ignored, as are skipped samples.

Modifications to any samples that are managed by the Operator are allowed as long as the version annotation is not modified or deleted. However, on an upgrade, as the version annotation will change, those modifications can get replaced as the sample will be updated with the newer version. The Jenkins images are part of the image payload from the installation and are tagged into the image streams directly.

The samples resource includes a finalizer, which cleans up the following upon its deletion:

- Operator-managed image streams
- Operator-managed templates
- Operator-generated configuration resources
- Cluster status resources

Upon deletion of the samples resource, the Cluster Samples Operator recreates the resource using the default configuration.

**Project**
cluster-samples-operator

## 6.9. CLUSTER STORAGE OPERATOR

**Purpose**
The Cluster Storage Operator sets OpenShift Container Platform cluster-wide storage defaults. It ensures a default storage class exists for OpenShift Container Platform clusters.

**Project**
cluster-storage-operator

**Configuration**
No configuration is required.

**Notes**

- The Cluster Storage Operator supports Amazon Web Services (AWS) and Red Hat OpenStack Platform (RHOSP).
- The created storage class can be made non-default by editing its annotation, but the storage class cannot be deleted as long as the Operator runs.

## 6.10. CLUSTER VERSION OPERATOR

**Purpose**
Cluster Operators manage specific areas of cluster functionality. The Cluster Version Operator (CVO) manages the lifecycle of cluster Operators, many of which are installed in OpenShift Container Platform by default.

The CVO also checks with the OpenShift Update Service to see the valid updates and update paths based on current component versions and information in the graph.

**Project**
cluster-version-operator

**Additional resources**

- Operators in OpenShift Container Platform

## 6.11. CONSOLE OPERATOR

**Purpose**
The Console Operator installs and maintains the OpenShift Container Platform web console on a cluster.

**Project**
console-operator

## 6.12. DNS OPERATOR

**Purpose**
The DNS Operator deploys and manages CoreDNS to provide a name resolution service to pods that enables DNS-based Kubernetes Service discovery in OpenShift Container Platform.

The Operator creates a working default deployment based on the cluster's configuration.

- The default cluster domain is **cluster.local**.
- Configuration of the CoreDNS Corefile or Kubernetes plug-in is not yet supported.

The DNS Operator manages CoreDNS as a Kubernetes daemon set exposed as a service with a static IP. CoreDNS runs on all nodes in the cluster.

### Project
cluster-dns-operator

## 6.13. ETCD CLUSTER OPERATOR

### Purpose
The etcd cluster Operator automates etcd cluster scaling, enables etcd monitoring and metrics, and simplifies disaster recovery procedures.

### Project
cluster-etcd-operator

### CRDs

- **etcds.operator.openshift.io**
  - Scope: Cluster
  - CR: **etcd**
  - Validation: Yes

### Configuration objects

```
$ oc edit etcd cluster
```

## 6.14. INGRESS OPERATOR

### Purpose
The Ingress Operator configures and manages the OpenShift Container Platform router.

### Project
openshift-ingress-operator

### CRDs

- **clusteringresses.ingress.openshift.io**
  - Scope: Namespaced
  - CR: **clusteringresses**
  - Validation: No

### Configuration objects

- Cluster config

- Type Name: **clusteringresses.ingress.openshift.io**
- Instance Name: **default**
- View Command:

```
$ oc get clusteringresses.ingress.openshift.io -n openshift-ingress-operator default -o yaml
```

### Notes

The Ingress Operator sets up the router in the **openshift-ingress** project and creates the deployment for the router:

```
$ oc get deployment -n openshift-ingress
```

The Ingress Operator uses the **clusterNetwork[].cidr** from the **network/cluster** status to determine what mode (IPv4, IPv6, or dual stack) the managed ingress controller (router) should operate in. For example, if **clusterNetwork** contains only a v6 **cidr**, then the ingress controller operate in IPv6-only mode.

In the following example, ingress controllers managed by the Ingress Operator will run in IPv4-only mode because only one cluster network exists and the network is an IPv4 **cidr**:

```
$ oc get network/cluster -o jsonpath='{.status.clusterNetwork[*]}'
```

### Example output

```
map[cidr:10.128.0.0/14 hostPrefix:23]
```

## 6.15. KUBERNETES API SERVER OPERATOR

### Purpose

The Kubernetes API Server Operator manages and updates the Kubernetes API server deployed on top of OpenShift Container Platform. The Operator is based on the OpenShift library-go framework and it is installed using the Cluster Version Operator (CVO).

### Project

openshift-kube-apiserver-operator

### CRDs

- **kubeapiservers.operator.openshift.io**
  - Scope: Cluster
  - CR: **kubeapiserver**
  - Validation: Yes

### Configuration objects

```
$ oc edit kubeapiserver
```

## 6.16. KUBERNETES CONTROLLER MANAGER OPERATOR

### Purpose

The Kubernetes Controller Manager Operator manages and updates the Kubernetes Controller Manager deployed on top of OpenShift Container Platform. The Operator is based on OpenShift **library-go** framework and it is installed via the Cluster Version Operator (CVO).

It contains the following components:

- Operator
- Bootstrap manifest renderer
- Installer based on static pods
- Configuration observer

By default, the Operator exposes Prometheus metrics through the **metrics** service.

### Project

cluster-kube-controller-manager-operator

## 6.17. KUBERNETES SCHEDULER OPERATOR

### Purpose

The Kubernetes Scheduler Operator manages and updates the Kubernetes Scheduler deployed on top of OpenShift Container Platform. The Operator is based on the OpenShift Container Platform **library-go** framework and it is installed with the Cluster Version Operator (CVO).

The Kubernetes Scheduler Operator contains the following components:

- Operator
- Bootstrap manifest renderer
- Installer based on static pods
- Configuration observer

By default, the Operator exposes Prometheus metrics through the metrics service.

### Project

cluster-kube-scheduler-operator

### Configuration

The configuration for the Kubernetes Scheduler is the result of merging:

- a default configuration.
- an observed configuration from the spec **schedulers.config.openshift.io**.

All of these are sparse configurations, invalidated JSON snippets which are merged in order to form a valid configuration at the end.

## 6.18. MACHINE API OPERATOR

### Purpose
The Machine API Operator manages the lifecycle of specific purpose custom resource definitions (CRD), controllers, and RBAC objects that extend the Kubernetes API. This declares the desired state of machines in a cluster.

### Project
machine-api-operator

### CRDs

- **MachineSet**
- **Machine**
- **MachineHealthCheck**

## 6.19. MACHINE CONFIG OPERATOR

### Purpose
The Machine Config Operator manages and applies configuration and updates of the base operating system and container runtime, including everything between the kernel and kubelet.

There are four components:

- **machine-config-server**: Provides Ignition configuration to new machines joining the cluster.
- **machine-config-controller**: Coordinates the upgrade of machines to the desired configurations defined by a **MachineConfig** object. Options are provided to control the upgrade for sets of machines individually.
- **machine-config-daemon**: Applies new machine configuration during update. Validates and verifies the state of the machine to the requested machine configuration.
- **machine-config**: Provides a complete source of machine configuration at installation, first start up, and updates for a machine.

### Project
openshift-machine-config-operator

## 6.20. MARKETPLACE OPERATOR

### Purpose
The Marketplace Operator is a conduit to bring off-cluster Operators to your cluster.

### Project
operator-marketplace

## 6.21. NODE TUNING OPERATOR

### Purpose
The Node Tuning Operator helps you manage node-level tuning by orchestrating the Tuned daemon. 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.

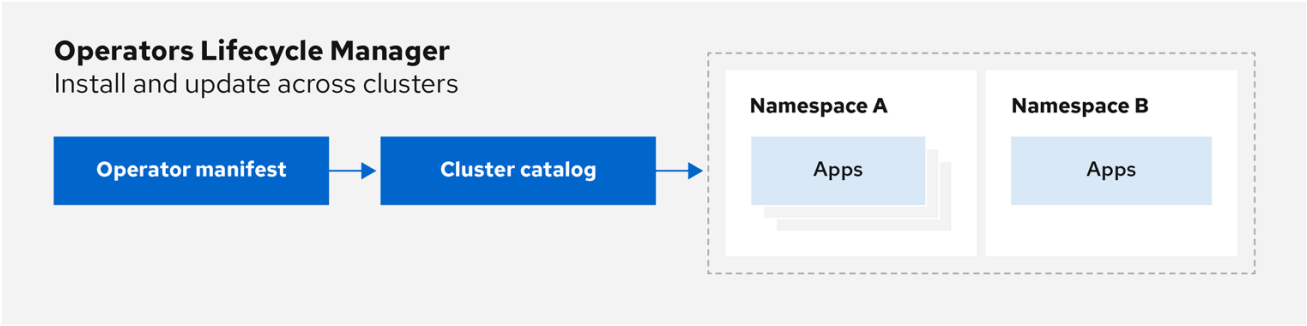
The Node Tuning Operator is part of a standard OpenShift Container Platform installation in version 4.1 and later.

### Project
cluster-node-tuning-operator

## 6.22. OPERATOR LIFECYCLE MANAGER OPERATORS

### Purpose
*Operator Lifecycle Manager* (OLM) helps users install, update, and manage the lifecycle of Kubernetes native applications (Operators) and their associated services running across their OpenShift Container Platform clusters. It is part of the Operator Framework, an open source toolkit designed to manage Operators in an effective, automated, and scalable way.

**Figure 6.1. Operator Lifecycle Manager workflow**




OpenShift_43_1019

OLM runs by default in OpenShift Container Platform 4.6, which aids cluster administrators in installing, upgrading, and granting access to Operators running on their cluster. The OpenShift Container Platform web console provides management screens for cluster administrators to install Operators, as well as grant specific projects access to use the catalog of Operators available on the cluster.

For developers, a self-service experience allows provisioning and configuring instances of databases, monitoring, and big data services without having to be subject matter experts, because the Operator has that knowledge baked into it.

### CRDs
Operator Lifecycle Manager (OLM) is composed of two Operators: the OLM Operator and the Catalog Operator.

Each of these Operators is responsible for managing the custom resource definitions (CRDs) that are the basis for the OLM framework:

**Table 6.3. CRDs managed by OLM and Catalog Operators**

| Resource | Short name | Owner | Description |
|---|---|---|---|
| **ClusterServiceVersion** (CSV) | **csv** | OLM | Application metadata: name, version, icon, required resources, installation, and so on. |
| **InstallPlan** | **ip** | Catalog | Calculated list of resources to be created to automatically install or upgrade a CSV. |
| **CatalogSource** | **catsrc** | Catalog | A repository of CSVs, CRDs, and packages that define an application. |
| **Subscription** | **sub** | Catalog | Used to keep CSVs up to date by tracking a channel in a package. |
| **OperatorGroup** | **og** | OLM | Configures all Operators deployed in the same namespace as the **OperatorGroup** object to watch for their custom resource (CR) in a list of namespaces or cluster-wide. |

Each of these Operators is also responsible for creating the following resources:

**Table 6.4. Resources created by OLM and Catalog Operators**

| Resource | Owner |
|---|---|
| **Deployments** | OLM |
| **ServiceAccounts** | |
| **(Cluster)Roles** | |
| **(Cluster)RoleBindings** | |
| **CustomResourceDefinitions** (CRDs) | Catalog |
| **ClusterServiceVersions** | |

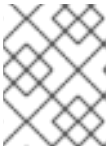
### OLM Operator

The OLM Operator is responsible for deploying applications defined by CSV resources after the required resources specified in the CSV are present in the cluster.

The OLM Operator is not concerned with the creation of the required resources; you can choose to manually create these resources using the CLI or using the Catalog Operator. This separation of concern allows users incremental buy-in in terms of how much of the OLM framework they choose to leverage for their application.

The OLM Operator uses the following workflow:

1. Watch for cluster service versions (CSVs) in a namespace and check that requirements are met.
2. If requirements are met, run the install strategy for the CSV.



**NOTE**

A CSV must be an active member of an Operator group for the install strategy to run.

### Catalog Operator

The Catalog Operator is responsible for resolving and installing cluster service versions (CSVs) and the required resources they specify. It is also responsible for watching catalog sources for updates to packages in channels and upgrading them, automatically if desired, to the latest available versions.

To track a package in a channel, you can create a **Subscription** object configuring the desired package, channel, and the **CatalogSource** object you want to use for pulling updates. When updates are found, an appropriate **InstallPlan** object is written into the namespace on behalf of the user.

The Catalog Operator uses the following workflow:

1. Connect to each catalog source in the cluster.
2. Watch for unresolved install plans created by a user, and if found:
   a. Find the CSV matching the name requested and add the CSV as a resolved resource.
   b. For each managed or required CRD, add the CRD as a resolved resource.
   c. For each required CRD, find the CSV that manages it.
3. Watch for resolved install plans and create all of the discovered resources for it, if approved by a user or automatically.
4. Watch for catalog sources and subscriptions and create install plans based on them.

### Catalog Registry

The Catalog Registry stores CSVs and CRDs for creation in a cluster and stores metadata about packages and channels.

A *package manifest* is an entry in the Catalog Registry that associates a package identity with sets of CSVs. Within a package, channels point to a particular CSV. Because CSVs explicitly reference the CSV that they replace, a package manifest provides the Catalog Operator with all of the information that is required to update a CSV to the latest version in a channel, stepping through each intermediate version.

### Additional resources

- Understanding Operator Lifecycle Manager (OLM)

## 6.23. OPENSHIFT API SERVER OPERATOR

### Purpose

The OpenShift API Server Operator installs and maintains the **openshift-apiserver** on a cluster.

### Project

openshift-apiserver-operator

### CRDs

- **openshiftapiservers.operator.openshift.io**
  - Scope: Cluster
  - CR: **openshiftapiserver**
  - Validation: Yes

## 6.24. PROMETHEUS OPERATOR

### Purpose

The Prometheus Operator for Kubernetes provides easy monitoring definitions for Kubernetes services and deployment and management of Prometheus instances.

Once installed, the Prometheus Operator provides the following features:

- Create and Destroy: Easily launch a Prometheus instance for your Kubernetes namespace, a specific application or team easily using the Operator.
- Simple Configuration: Configure the fundamentals of Prometheus like versions, persistence, retention policies, and replicas from a native Kubernetes resource.
- Target Services via Labels: Automatically generate monitoring target configurations based on familiar Kubernetes label queries; no need to learn a Prometheus specific configuration language.

### Project

prometheus-operator

## 6.25. WINDOWS MACHINE CONFIG OPERATOR

### Purpose

The Windows Machine Config Operator (WMCO) orchestrates the process of deploying and managing Windows workloads on a cluster. The WMCO configures Windows machines into compute nodes, enabling Windows container workloads to run in OpenShift Container Platform clusters. This is done by creating a machine set that uses a Windows image with the Docker-formatted container runtime installed. The WMCO completes all necessary steps to configure the underlying Windows VM so that it can join the cluster as a compute node.

### Project

windows-machine-config-operator