OpenShift Container Platform 4.12

Specialized hardware and driver enablement

Learn about hardware enablement on OpenShift Container Platform

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Abstract

This document provides an overview of hardware enablement in OpenShift Container Platform.

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CHAPTER 1. ABOUT SPECIALIZED HARDWARE AND DRIVER ENABLEMENT

The Driver Toolkit (DTK) is a container image in the OpenShift Container Platform payload which is meant to be used as a base image on which to build driver containers. The Driver Toolkit image contains the kernel packages commonly required as dependencies to build or install kernel modules as well as a few tools needed in driver containers. The version of these packages will match the kernel version running on the RHCOS nodes in the corresponding OpenShift Container Platform release.

Driver containers are container images used for building and deploying out-of-tree kernel modules and drivers on container operating systems such as Red Hat Enterprise Linux CoreOS (RHCOS). Kernel modules and drivers are software libraries running with a high level of privilege in the operating system kernel. They extend the kernel functionalities or provide the hardware-specific code required to control new devices. Examples include hardware devices like field-programmable gate arrays (FPGA) or graphics processing units (GPU), and software-defined storage solutions, which all require kernel modules on client machines. Driver containers are the first layer of the software stack used to enable these technologies on OpenShift Container Platform deployments.

CHAPTER 2. DRIVER TOOLKIT

Learn about the Driver Toolkit and how you can use it as a base image for driver containers for enabling special software and hardware devices on OpenShift Container Platform deployments.

2.1. ABOUT THE DRIVER TOOLKIT

Background

The Driver Toolkit is a container image in the OpenShift Container Platform payload used as a base image on which you can build driver containers. The Driver Toolkit image includes the kernel packages commonly required as dependencies to build or install kernel modules, as well as a few tools needed in driver containers. The version of these packages will match the kernel version running on the Red Hat Enterprise Linux CoreOS (RHCOS) nodes in the corresponding OpenShift Container Platform release.

Driver containers are container images used for building and deploying out-of-tree kernel modules and drivers on container operating systems like RHCOS. Kernel modules and drivers are software libraries running with a high level of privilege in the operating system kernel. They extend the kernel functionalities or provide the hardware-specific code required to control new devices. Examples include hardware devices like Field Programmable Gate Arrays (FPGA) or GPUs, and software-defined storage (SDS) solutions, such as Lustre parallel file systems, which require kernel modules on client machines. Driver containers are the first layer of the software stack used to enable these technologies on Kubernetes.

The list of kernel packages in the Driver Toolkit includes the following and their dependencies:

- **kernel-core**
- **kernel-devel**
- **kernel-headers**
- **kernel-modules**
- **kernel-modules-extra**

In addition, the Driver Toolkit also includes the corresponding real-time kernel packages:

- **kernel-rt-core**
- **kernel-rt-devel**
- **kernel-rt-modules**
- **kernel-rt-modules-extra**

The Driver Toolkit also has several tools that are commonly needed to build and install kernel modules, including:

- **elfutils-libelf-devel**
- **kmod**
- **binutilskabi-dw**
- **kernel-abi-whitelists**

- dependencies for the above

Purpose
Prior to the Driver Toolkit's existence, users would install kernel packages in a pod or build config on OpenShift Container Platform using entitled builds or by installing from the kernel RPMs in the hosts **machine-os-content**. The Driver Toolkit simplifies the process by removing the entitlement step, and avoids the privileged operation of accessing the machine-os-content in a pod. The Driver Toolkit can also be used by partners who have access to pre-released OpenShift Container Platform versions to prebuild driver-containers for their hardware devices for future OpenShift Container Platform releases.

The Driver Toolkit is also used by the Kernel Module Management (KMM), which is currently available as a community Operator on OperatorHub. KMM supports out-of-tree and third-party kernel drivers and the support software for the underlying operating system. Users can create modules for KMM to build and deploy a driver container, as well as support software like a device plugin, or metrics. Modules can include a build config to build a driver container-based on the Driver Toolkit, or KMM can deploy a prebuilt driver container.

2.2. PULLING THE DRIVER TOOLKIT CONTAINER IMAGE

The **driver-toolkit** image is available from the Container images section of the Red Hat Ecosystem Catalog and in the OpenShift Container Platform release payload. The image corresponding to the most recent minor release of OpenShift Container Platform will be tagged with the version number in the catalog. The image URL for a specific release can be found using the **oc adm** CLI command.

2.2.1. Pulling the Driver Toolkit container image from registry.redhat.io

Instructions for pulling the **driver-toolkit** image from **registry.redhat.io** with **podman** or in OpenShift Container Platform can be found on the Red Hat Ecosystem Catalog . The driver-toolkit image for the latest minor release are tagged with the minor release version on **registry.redhat.io**, for example: **registry.redhat.io/openshift4/driver-toolkit-rhel8:v4.12**.

2.2.2. Finding the Driver Toolkit image URL in the payload

Prerequisites

- You obtained the image pull secret from the Red Hat OpenShift Cluster Manager .
- You installed the OpenShift CLI (**oc**).

Procedure

1. Use the **oc adm** command to extract the image URL of the **driver-toolkit** corresponding to a certain release:
   - For an x86 image, enter the following command:

     ```
     $ oc adm release info quay.io/openshift-release-dev/ocp-release:4.12.z-x86_64 --image-for=driver-toolkit
     ```

   - For an ARM image, enter the following command:

     ```
     $ oc adm release info quay.io/openshift-release-dev/ocp-release:4.12.z-aarch64 --image-for=driver-toolkit
     ```

Example output

```
quay.io/openshift-release-dev/ocp-v4.0-art-dev@sha256:0fd84aee79606178b6561ac71f8540f404d518ae5deff45f6d6ac8f02636c7f4
```

2. Obtain this image by using a valid pull secret, such as the pull secret required to install OpenShift Container Platform:

```
$ podman pull --authfile=path/to/pullsecret.json quay.io/openshift-release-dev/ocp-v4.0-art-dev@sha256:<SHA>
```

2.3. USING THE DRIVER TOOLKIT

As an example, the Driver Toolkit can be used as the base image for building a very simple kernel module called **simple-kmod**.

NOTE

The Driver Toolkit includes the necessary dependencies, **openssl**, **mokutil**, and **keyutils**, needed to sign a kernel module. However, in this example, the **simple-kmod** kernel module is not signed and therefore cannot be loaded on systems with **Secure Boot** enabled.

2.3.1. Build and run the simple-kmod driver container on a cluster

Prerequisites

- You have a running OpenShift Container Platform cluster.
- You set the Image Registry Operator state to **Managed** for your cluster.
- You installed the OpenShift CLI (**oc**).
- You are logged into the OpenShift CLI as a user with **cluster-admin** privileges.

Procedure

Create a namespace. For example:

```
$ oc new-project simple-kmod-demo
```

1. The YAML defines an **ImageStream** for storing the **simple-kmod** driver container image, and a **BuildConfig** for building the container. Save this YAML as **0000-buildconfig.yaml.template**.

```
apiVersion: image.openshift.io/v1
kind: ImageStream
metadata:
  labels:
    app: simple-kmod-driver-container
  name: simple-kmod-driver-container
  namespace: simple-kmod-demo
spec: {}
---
```

```
apiVersion: build.openshift.io/v1
kind: BuildConfig
metadata:
  labels:
    app: simple-kmod-driver-build
  name: simple-kmod-driver-build
  namespace: simple-kmod-demo
spec:
  nodeSelector:
    node-role.kubernetes.io/worker: ""
  runPolicy: "Serial"
  triggers:
    - type: "ConfigChange"
    - type: "ImageChange"
  source:
    dockerfile: |
      ARG DTK
      FROM ${DTK} as builder

      ARG KVER

      WORKDIR /build/

      RUN git clone https://github.com/openshift-psap/simple-kmod.git

      WORKDIR /build/simple-kmod

      RUN make all install KVER=${KVER}

      FROM registry.redhat.io/ubi8/ubi-minimal

      ARG KVER

      # Required for installing `modprobe`
      RUN microdnf install kmod

      COPY --from=builder /lib/modules/${KVER}/simple-kmod.ko /lib/modules/${KVER}/
      COPY --from=builder /lib/modules/${KVER}/simple-procfs-kmod.ko
/lib/modules/${KVER}/
      RUN depmod ${KVER}
  strategy:
    dockerStrategy:
      buildArgs:
        - name: KMODVER
          value: DEMO
          # $ oc adm release info quay.io/openshift-release-dev/ocp-release:<cluster version>-
x86_64 --image-for=driver-toolkit
        - name: DTK
          value: quay.io/openshift-release-dev/ocp-v4.0-art-
dev@sha256:34864ccd2f4b6e385705a730864c04a40908e57acede44457a783d739e377cae
        - name: KVER
          value: 4.18.0-372.26.1.el8_6.x86_64
  output:
    to:
      kind: ImageStreamTag
      name: simple-kmod-driver-container:demo
```

2. Substitute the correct driver toolkit image for the OpenShift Container Platform version you are running in place of “DRIVER_TOOLKIT_IMAGE” with the following commands.

```
$ OCP_VERSION=$(oc get clusterversion/version -ojsonpath={.status.desired.version})
```

```
$ DRIVER_TOOLKIT_IMAGE=$(oc adm release info $OCP_VERSION --image-for=driver-toolkit)
```

```
$ sed "s#DRIVER_TOOLKIT_IMAGE#${DRIVER_TOOLKIT_IMAGE}#" 0000-buildconfig.yaml.template > 0000-buildconfig.yaml
```

3. Create the image stream and build config with

```
$ oc create -f 0000-buildconfig.yaml
```

4. After the builder pod completes successfully, deploy the driver container image as a **DaemonSet**.

   a. The driver container must run with the privileged security context in order to load the kernel modules on the host. The following YAML file contains the RBAC rules and the **DaemonSet** for running the driver container. Save this YAML as **1000-drivercontainer.yaml**.

```
apiVersion: v1
kind: ServiceAccount
metadata:
  name: simple-kmod-driver-container
---
apiVersion: rbac.authorization.k8s.io/v1
kind: Role
metadata:
  name: simple-kmod-driver-container
rules:
- apiGroups:
  - security.openshift.io
  resources:
  - securitycontextconstraints
  verbs:
  - use
  resourceNames:
  - privileged
---
apiVersion: rbac.authorization.k8s.io/v1
kind: RoleBinding
metadata:
  name: simple-kmod-driver-container
roleRef:
  apiGroup: rbac.authorization.k8s.io
  kind: Role
  name: simple-kmod-driver-container
subjects:
- kind: ServiceAccount
  name: simple-kmod-driver-container
userNames:
- system:serviceaccount:simple-kmod-demo:simple-kmod-driver-container
```

```
---
apiVersion: apps/v1
kind: DaemonSet
metadata:
  name: simple-kmod-driver-container
spec:
  selector:
    matchLabels:
      app: simple-kmod-driver-container
  template:
    metadata:
      labels:
        app: simple-kmod-driver-container
    spec:
      serviceAccount: simple-kmod-driver-container
      serviceAccountName: simple-kmod-driver-container
      containers:
      - image: image-registry.openshift-image-registry.svc:5000/simple-kmod-
demo/simple-kmod-driver-container:demo
        name: simple-kmod-driver-container
        imagePullPolicy: Always
        command: [sleep, infinity]
        lifecycle:
          postStart:
            exec:
              command: ["modprobe", "-v", "-a" , "simple-kmod", "simple-procfs-kmod"]
          preStop:
            exec:
              command: ["modprobe", "-r", "-a" , "simple-kmod", "simple-procfs-kmod"]
        securityContext:
          privileged: true
      nodeSelector:
        node-role.kubernetes.io/worker: ""
```

b. Create the RBAC rules and daemon set:

```
$ oc create -f 1000-drivercontainer.yaml
```

5. After the pods are running on the worker nodes, verify that the **simple_kmod** kernel module is loaded successfully on the host machines with **lsmod**.

a. Verify that the pods are running:

```
$ oc get pod -n simple-kmod-demo
```

Example output

```
NAME                                READY   STATUS      RESTARTS   AGE
simple-kmod-driver-build-1-build    0/1     Completed   0          6m
simple-kmod-driver-container-b22fd  1/1     Running     0          40s
simple-kmod-driver-container-jz9vn  1/1     Running     0          40s
simple-kmod-driver-container-p45cc  1/1     Running     0          40s
```

b. Execute the **lsmod** command in the driver container pod:

```
$ oc exec -it pod/simple-kmod-driver-container-p45cc -- lsmod | grep simple
```

Example output

```
simple_procfs_kmod     16384  0
simple_kmod            16384  0
```

2.4. ADDITIONAL RESOURCES

- For more information about configuring registry storage for your cluster, see Image Registry Operator in OpenShift Container Platform.

CHAPTER 3. NODE FEATURE DISCOVERY OPERATOR

Learn about the Node Feature Discovery (NFD) Operator and how you can use it to expose node-level information by orchestrating Node Feature Discovery, a Kubernetes add-on for detecting hardware features and system configuration.

The Node Feature Discovery Operator (NFD) manages the detection of hardware features and configuration in an OpenShift Container Platform cluster by labeling the nodes with hardware-specific information. NFD labels the host with node-specific attributes, such as PCI cards, kernel, operating system version, and so on.

The NFD Operator can be found on the Operator Hub by searching for “Node Feature Discovery”.

3.1. INSTALLING THE NODE FEATURE DISCOVERY OPERATOR

The Node Feature Discovery (NFD) Operator orchestrates all resources needed to run the NFD daemon set. As a cluster administrator, you can install the NFD Operator by using the OpenShift Container Platform CLI or the web console.

3.1.1. Installing the NFD Operator using the CLI

As a cluster administrator, you can install the NFD Operator using the CLI.

Prerequisites

- An OpenShift Container Platform cluster
- Install the OpenShift CLI (**oc**).
- Log in as a user with **cluster-admin** privileges.

Procedure

1. Create a namespace for the NFD Operator.
   a. Create the following **Namespace** custom resource (CR) that defines the **openshift-nfd** namespace, and then save the YAML in the **nfd-namespace.yaml** file. Set **cluster-monitoring** to **"true"**.

```
apiVersion: v1
kind: Namespace
metadata:
  name: openshift-nfd
  labels:
    name: openshift-nfd
    openshift.io/cluster-monitoring: "true"
```

   b. Create the namespace by running the following command:

```
$ oc create -f nfd-namespace.yaml
```

2. Install the NFD Operator in the namespace you created in the previous step by creating the following objects:
   a. Create the following **OperatorGroup** CR and save the YAML in the **nfd**

a. Create the following **OperatorGroup** CR and save the YAML in the **nfd-operatorgroup.yaml** file:

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

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

```
$ oc create -f nfd-operatorgroup.yaml
```

c. Create the following **Subscription** CR and save the YAML in the **nfd-sub.yaml** file:

Example Subscription

```
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: nfd
  namespace: openshift-nfd
spec:
  channel: "stable"
  installPlanApproval: Automatic
  name: nfd
  source: redhat-operators
  sourceNamespace: openshift-marketplace
```

d. Create the subscription object by running the following command:

```
$ oc create -f nfd-sub.yaml
```

e. Change to the **openshift-nfd** project:

```
$ oc project openshift-nfd
```

Verification

- To verify that the Operator deployment is successful, run:

```
$ oc get pods
```

Example output

```
NAME                                  READY   STATUS    RESTARTS   AGE
nfd-controller-manager-7f86ccfb58-vgr4x   2/2     Running   0          10m
```

A successful deployment shows a **Running** status.

3.1.2. Installing the NFD Operator using the web console

As a cluster administrator, you can install the NFD Operator using the web console.

Procedure

1. In the OpenShift Container Platform web console, click **Operators → OperatorHub**.
2. Choose **Node Feature Discovery** from the list of available Operators, and then click **Install**.
3. On the **Install Operator** page, select **A specific namespace on the cluster**, and then click **Install**. You do not need to create a namespace because it is created for you.

Verification

To verify that the NFD Operator installed successfully:

1. Navigate to the **Operators → Installed Operators** page.
2. Ensure that **Node Feature Discovery** is listed in the **openshift-nfd** project with a **Status** of **InstallSucceeded**.

NOTE

During installation an Operator might display a **Failed** status. If the installation later succeeds with an **InstallSucceeded** message, you can ignore the **Failed** message.

Troubleshooting

If the Operator does not appear as installed, troubleshoot further:

1. Navigate to the **Operators → Installed Operators** page and inspect the **Operator Subscriptions** and **Install Plans** tabs for any failure or errors under **Status**.
2. Navigate to the **Workloads → Pods** page and check the logs for pods in the **openshift-nfd** project.

3.2. USING THE NODE FEATURE DISCOVERY OPERATOR

The Node Feature Discovery (NFD) Operator orchestrates all resources needed to run the Node-Feature-Discovery daemon set by watching for a **NodeFeatureDiscovery** custom resource (CR). Based on the **NodeFeatureDiscovery** CR, the Operator creates the operand (NFD) components in the selected namespace. You can edit the CR to use another namespace, image, image pull policy, and **nfd-worker-conf** config map, among other options.

As a cluster administrator, you can create a **NodeFeatureDiscovery** CR by using the OpenShift CLI (**oc**) or the web console.

3.2.1. Creating a NodeFeatureDiscovery CR by using the CLI

As a cluster administrator, you can create a **NodeFeatureDiscovery** CR instance by using the OpenShift CLI (**oc**).

Prerequisites

- You have access to an OpenShift Container Platform cluster
- You installed the OpenShift CLI (**oc**).
- You logged in as a user with **cluster-admin** privileges.
- You installed the NFD Operator.

Procedure

1. Create a **NodeFeatureDiscovery** CR:

Example NodeFeatureDiscovery CR

```
apiVersion: nfd.openshift.io/v1
kind: NodeFeatureDiscovery
metadata:
  name: nfd-instance
  namespace: openshift-nfd
spec:
  instance: "" # instance is empty by default
  topologyupdater: false # False by default
  operand:
    image: registry.redhat.io/openshift4/ose-node-feature-discovery:v4.12
    imagePullPolicy: Always
  workerConfig:
    configData: |
      core:
      #  labelWhiteList:
      #  noPublish: false
        sleepInterval: 60s
      #  sources: [all]
      #  klog:
      #    addDirHeader: false
      #    alsologtostderr: false
      #    logBacktraceAt:
      #    logtostderr: true
      #    skipHeaders: false
      #    stderrthreshold: 2
      #    v: 0
      #    vmodule:
      ##   NOTE: the following options are not dynamically run-time configurable
      ##         and require a nfd-worker restart to take effect after being changed
      #    logDir:
      #    logFile:
      #    logFileMaxSize: 1800
      #    skipLogHeaders: false
      sources:
        cpu:
          cpuid:
      #     NOTE: whitelist has priority over blacklist
            attributeBlacklist:
              - "BMI1"
              - "BMI2"
              - "CLMUL"
              - "CMOV"
```

```
            - "CX16"
            - "ERMS"
            - "F16C"
            - "HTT"
            - "LZCNT"
            - "MMX"
            - "MMXEXT"
            - "NX"
            - "POPCNT"
            - "RDRAND"
            - "RDSEED"
            - "RDTSCP"
            - "SGX"
            - "SSE"
            - "SSE2"
            - "SSE3"
            - "SSE4.1"
            - "SSE4.2"
            - "SSSE3"
          attributeWhitelist:
      kernel:
        kconfigFile: "/path/to/kconfig"
        configOpts:
          - "NO_HZ"
          - "X86"
          - "DMI"
      pci:
        deviceClassWhitelist:
          - "0200"
          - "03"
          - "12"
        deviceLabelFields:
          - "class"
  customConfig:
    configData: |
        - name: "more.kernel.features"
          matchOn:
          - loadedKMod: ["example_kmod3"]
```

2. Create the **NodeFeatureDiscovery** CR by running the following command:

```
$ oc apply -f <filename>
```

Verification

1. Check that the **NodeFeatureDiscovery** CR was created by running the following command:

```
$ oc get pods
```

Example output

```
NAME                                  READY   STATUS    RESTARTS   AGE
nfd-controller-manager-7f86ccfb58-vgr4x   2/2     Running   0          11m
nfd-master-hcn64                      1/1     Running   0          60s
```

```
nfd-master-lnnxx                1/1     Running   0          60s
nfd-master-mp6hr                 1/1     Running   0          60s
nfd-worker-vgcz9                 1/1     Running   0          60s
nfd-worker-xqbws                 1/1     Running   0          60s
```

A successful deployment shows a **Running** status.

3.2.2. Creating a NodeFeatureDiscovery CR by using the CLI in a disconnected environment

As a cluster administrator, you can create a **NodeFeatureDiscovery** CR instance by using the OpenShift CLI (**oc**).

Prerequisites

- You have access to an OpenShift Container Platform cluster
- You installed the OpenShift CLI (**oc**).
- You logged in as a user with **cluster-admin** privileges.
- You installed the NFD Operator.
- You have access to a mirror registry with the required images.
- You installed the **skopeo** CLI tool.

Procedure

1. Determine the digest of the registry image:
   a. Run the following command:

```
$ skopeo inspect docker://registry.redhat.io/openshift4/ose-node-feature-discovery:
<openshift_version>
```

Example command

```
$ skopeo inspect docker://registry.redhat.io/openshift4/ose-node-feature-discovery:v4.12
```

   b. Inspect the output to identify the image digest:

Example output

```
{
  ...
  "Digest":
"sha256:1234567890abcdef1234567890abcdef1234567890abcdef1234567890abcdef",
  ...
}
```

2. Use the **skopeo** CLI tool to copy the image from **registry.redhat.io** to your mirror registry, by running the following command:

```
skopeo copy docker://registry.redhat.io/openshift4/ose-node-feature-discovery@<image_digest> docker://<mirror_registry>/openshift4/ose-node-feature-discovery@<image_digest>
```

Example command

```
skopeo copy docker://registry.redhat.io/openshift4/ose-node-feature-discovery@sha256:1234567890abcdef1234567890abcdef1234567890abcdef1234567890abcdef docker://<your-mirror-registry>/openshift4/ose-node-feature-discovery@sha256:1234567890abcdef1234567890abcdef1234567890abcdef1234567890abcdef
```

3. Create a **NodeFeatureDiscovery** CR:

Example **NodeFeatureDiscovery** CR

```
apiVersion: nfd.openshift.io/v1
kind: NodeFeatureDiscovery
metadata:
  name: nfd-instance
spec:
  operand:
    image: <mirror_registry>/openshift4/ose-node-feature-discovery@<image_digest>
    imagePullPolicy: Always
  workerConfig:
    configData: |
      core:
      #  labelWhiteList:
      #  noPublish: false
        sleepInterval: 60s
      #  sources: [all]
      #  klog:
      #    addDirHeader: false
      #    alsologtostderr: false
      #    logBacktraceAt:
      #    logtostderr: true
      #    skipHeaders: false
      #    stderrthreshold: 2
      #    v: 0
      #    vmodule:
      ##   NOTE: the following options are not dynamically run-time configurable
      ##         and require a nfd-worker restart to take effect after being changed
      #    logDir:
      #    logFile:
      #    logFileMaxSize: 1800
      #    skipLogHeaders: false
      sources:
        cpu:
          cpuid:
      #     NOTE: whitelist has priority over blacklist
            attributeBlacklist:
              - "BMI1"
              - "BMI2"
              - "CLMUL"
              - "CMOV"
```

```
            - "CX16"
            - "ERMS"
            - "F16C"
            - "HTT"
            - "LZCNT"
            - "MMX"
            - "MMXEXT"
            - "NX"
            - "POPCNT"
            - "RDRAND"
            - "RDSEED"
            - "RDTSCP"
            - "SGX"
            - "SSE"
            - "SSE2"
            - "SSE3"
            - "SSE4.1"
            - "SSE4.2"
            - "SSSE3"
          attributeWhitelist:
      kernel:
        kconfigFile: "/path/to/kconfig"
        configOpts:
          - "NO_HZ"
          - "X86"
          - "DMI"
      pci:
        deviceClassWhitelist:
          - "0200"
          - "03"
          - "12"
        deviceLabelFields:
          - "class"
  customConfig:
    configData: |
        - name: "more.kernel.features"
          matchOn:
          - loadedKMod: ["example_kmod3"]
```

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

```
$ oc apply -f <filename>
```

Verification

1. Check the status of the **NodeFeatureDiscovery** CR by running the following command:

```
$ oc get nodefeaturediscovery nfd-instance -o yaml
```

2. Check that the pods are running without **ImagePullBackOff** errors by running the following command:

```
$ oc get pods -n <nfd_namespace>
```

3.2.3. Creating a NodeFeatureDiscovery CR by using the web console

As a cluster administrator, you can create a **NodeFeatureDiscovery** CR by using the OpenShift Container Platform web console.

Prerequisites

- You have access to an OpenShift Container Platform cluster
- You logged in as a user with **cluster-admin** privileges.
- You installed the NFD Operator.

Procedure

1. Navigate to the **Operators → Installed Operators** page.
2. In the **Node Feature Discovery** section, under **Provided APIs**, click **Create instance**.
3. Edit the values of the **NodeFeatureDiscovery** CR.
4. Click **Create**.

3.3. CONFIGURING THE NODE FEATURE DISCOVERY OPERATOR

3.3.1. core

The **core** section contains common configuration settings that are not specific to any particular feature source.

core.sleepInterval
core.sleepInterval specifies the interval between consecutive passes of feature detection or re-detection, and thus also the interval between node re-labeling. A non-positive value implies infinite sleep interval; no re-detection or re-labeling is done.

This value is overridden by the deprecated **--sleep-interval** command-line flag, if specified.

Example usage

```
core:
  sleepInterval: 60s 1
```

The default value is **60s**.

core.sources
core.sources specifies the list of enabled feature sources. A special value **all** enables all feature sources.

This value is overridden by the deprecated **--sources** command-line flag, if specified.

Default: **[all]**

Example usage

```
core:
  sources:
    - system
    - custom
```

core.labelWhiteList
core.labelWhiteList specifies a regular expression for filtering feature labels based on the label name. Non-matching labels are not published.

The regular expression is only matched against the basename part of the label, the part of the name after '/'. The label prefix, or namespace, is omitted.

This value is overridden by the deprecated **--label-whitelist** command-line flag, if specified.

Default: **null**

Example usage

```
core:
  labelWhiteList: '^cpu-cpuid'
```

core.noPublish
Setting **core.noPublish** to **true** disables all communication with the **nfd-master**. It is effectively a dry run flag; **nfd-worker** runs feature detection normally, but no labeling requests are sent to **nfd-master**.

This value is overridden by the **--no-publish** command-line flag, if specified.

Example:

Example usage

```
core:
  noPublish: true (1)
```

The default value is **false**.

core.klog
The following options specify the logger configuration, most of which can be dynamically adjusted at run-time.

The logger options can also be specified using command-line flags, which take precedence over any corresponding config file options.

core.klog.addDirHeader
If set to **true**, **core.klog.addDirHeader** adds the file directory to the header of the log messages.

Default: **false**

Run-time configurable: yes

core.klog.alsologtostderr
Log to standard error as well as files.

Default: **false**

Run-time configurable: yes

core.klog.logBacktraceAt
When logging hits line file:N, emit a stack trace.

Default: **empty**

Run-time configurable: yes

core.klog.logDir
If non-empty, write log files in this directory.

Default: **empty**

Run-time configurable: no

core.klog.logFile
If not empty, use this log file.

Default: **empty**

Run-time configurable: no

core.klog.logFileMaxSize
core.klog.logFileMaxSize defines the maximum size a log file can grow to. Unit is megabytes. If the value is **0**, the maximum file size is unlimited.

Default: **1800**

Run-time configurable: no

core.klog.logtostderr
Log to standard error instead of files

Default: **true**

Run-time configurable: yes

core.klog.skipHeaders
If **core.klog.skipHeaders** is set to **true**, avoid header prefixes in the log messages.

Default: **false**

Run-time configurable: yes

core.klog.skipLogHeaders
If **core.klog.skipLogHeaders** is set to **true**, avoid headers when opening log files.

Default: **false**

Run-time configurable: no

core.klog.stderrthreshold
Logs at or above this threshold go to stderr.

Default: **2**

Run-time configurable: yes

core.klog.v
core.klog.v is the number for the log level verbosity.

Default: **0**

Run-time configurable: yes

core.klog.vmodule
core.klog.vmodule is a comma-separated list of **pattern=N** settings for file-filtered logging.

Default: **empty**

Run-time configurable: yes

3.3.2. sources

The **sources** section contains feature source specific configuration parameters.

sources.cpu.cpuid.attributeBlacklist
Prevent publishing **cpuid** features listed in this option.

This value is overridden by **sources.cpu.cpuid.attributeWhitelist**, if specified.

Default: **[BMI1, BMI2, CLMUL, CMOV, CX16, ERMS, F16C, HTT, LZCNT, MMX, MMXEXT, NX, POPCNT, RDRAND, RDSEED, RDTSCP, SGX, SGXLC, SSE, SSE2, SSE3, SSE4.1, SSE4.2, SSSE3]**

Example usage

```
sources:
  cpu:
    cpuid:
      attributeBlacklist: [MMX, MMXEXT]
```

sources.cpu.cpuid.attributeWhitelist
Only publish the **cpuid** features listed in this option.

sources.cpu.cpuid.attributeWhitelist takes precedence over **sources.cpu.cpuid.attributeBlacklist**.

Default: **empty**

Example usage

```
sources:
  cpu:
    cpuid:
      attributeWhitelist: [AVX512BW, AVX512CD, AVX512DQ, AVX512F, AVX512VL]
```

sources.kernel.kconfigFile
sources.kernel.kconfigFile is the path of the kernel config file. If empty, NFD runs a search in the well-known standard locations.

Default: **empty**

Example usage

```
sources:
  kernel:
    kconfigFile: "/path/to/kconfig"
```

sources.kernel.configOpts
sources.kernel.configOpts represents kernel configuration options to publish as feature labels.

Default: **[NO_HZ, NO_HZ_IDLE, NO_HZ_FULL, PREEMPT]**

Example usage

```
sources:
  kernel:
    configOpts: [NO_HZ, X86, DMI]
```

sources.pci.deviceClassWhitelist
sources.pci.deviceClassWhitelist is a list of PCI device class IDs for which to publish a label. It can be specified as a main class only (for example, **03**) or full class-subclass combination (for example **0300**). The former implies that all subclasses are accepted. The format of the labels can be further configured with **deviceLabelFields**.

Default: **["03", "0b40", "12"]**

Example usage

```
sources:
  pci:
    deviceClassWhitelist: ["0200", "03"]
```

sources.pci.deviceLabelFields
sources.pci.deviceLabelFields is the set of PCI ID fields to use when constructing the name of the feature label. Valid fields are **class**, **vendor**, **device**, **subsystem_vendor** and **subsystem_device**.

Default: **[class, vendor]**

Example usage

```
sources:
  pci:
    deviceLabelFields: [class, vendor, device]
```

With the example config above, NFD would publish labels such as **feature.node.kubernetes.io/pci-<class-id>_<vendor-id>_<device-id>.present=true**

sources.usb.deviceClassWhitelist
sources.usb.deviceClassWhitelist is a list of USB device class IDs for which to publish a feature label. The format of the labels can be further configured with **deviceLabelFields**.

Default: **["0e", "ef", "fe", "ff"]**

Example usage

```
sources:
  usb:
    deviceClassWhitelist: ["ef", "ff"]
```

sources.usb.deviceLabelFields
sources.usb.deviceLabelFields is the set of USB ID fields from which to compose the name of the feature label. Valid fields are **class**, **vendor**, and **device**.

Default: **[class, vendor, device]**

Example usage

```
sources:
  pci:
    deviceLabelFields: [class, vendor]
```

With the example config above, NFD would publish labels like: **feature.node.kubernetes.io/usb-<class-id>_<vendor-id>.present=true**.

sources.custom
sources.custom is the list of rules to process in the custom feature source to create user-specific labels.

Default: **empty**

Example usage

```
source:
  custom:
  - name: "my.custom.feature"
    matchOn:
    - loadedKMod: ["e1000e"]
    - pciId:
        class: ["0200"]
        vendor: ["8086"]
```

3.4. ABOUT THE NODEFEATURERULE CUSTOM RESOURCE

NodeFeatureRule objects are a **NodeFeatureDiscovery** custom resource designed for rule-based custom labeling of nodes. Some use cases include application-specific labeling or distribution by hardware vendors to create specific labels for their devices.

NodeFeatureRule objects provide a method to create vendor- or application-specific labels and taints. It uses a flexible rule-based mechanism for creating labels and optionally taints based on node features.

3.5. USING THE NODEFEATURERULE CUSTOM RESOURCE

Create a **NodeFeatureRule** object to label nodes if a set of rules match the conditions.

Procedure

1. Create a custom resource file named **nodefeaturerule.yaml** that contains the following text:

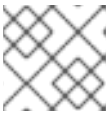
```
apiVersion: nfd.openshift.io/v1
kind: NodeFeatureRule
metadata:
  name: example-rule
spec:
  rules:
    - name: "example rule"
      labels:
        "example-custom-feature": "true"
      # Label is created if all of the rules below match
      matchFeatures:
        # Match if "veth" kernel module is loaded
        - feature: kernel.loadedmodule
          matchExpressions:
            veth: {op: Exists}
        # Match if any PCI device with vendor 8086 exists in the system
        - feature: pci.device
          matchExpressions:
            vendor: {op: In, value: ["8086"]}
```

This custom resource specifies that labelling occurs when the **veth** module is loaded and any PCI device with vendor code **8086** exists in the cluster.

2. Apply the **nodefeaturerule.yaml** file to your cluster by running the following command:

```
$ oc apply -f https://raw.githubusercontent.com/kubernetes-sigs/node-feature-discovery/v0.13.6/examples/nodefeaturerule.yaml
```

The example applies the feature label on nodes with the **veth** module loaded and any PCI device with vendor code **8086** exists.



NOTE

A relabeling delay of up to 1 minute might occur.

3.6. USING THE NFD TOPOLOGY UPDATER

The Node Feature Discovery (NFD) Topology Updater is a daemon responsible for examining allocated resources on a worker node. It accounts for resources that are available to be allocated to new pod on a per-zone basis, where a zone can be a Non-Uniform Memory Access (NUMA) node. The NFD Topology Updater communicates the information to nfd-master, which creates a **NodeResourceTopology** custom resource (CR) corresponding to all of the worker nodes in the cluster. One instance of the NFD Topology Updater runs on each node of the cluster.

To enable the Topology Updater workers in NFD, set the **topologyupdater** variable to **true** in the **NodeFeatureDiscovery** CR, as described in the section **Using the Node Feature Discovery Operator**.

3.6.1. NodeResourceTopology CR

When run with NFD Topology Updater, NFD creates custom resource instances corresponding to the node resource hardware topology, such as:

```
apiVersion: topology.node.k8s.io/v1alpha1
kind: NodeResourceTopology
```

```
metadata:
  name: node1
topologyPolicies: ["SingleNUMANodeContainerLevel"]
zones:
  - name: node-0
    type: Node
    resources:
      - name: cpu
        capacity: 20
        allocatable: 16
        available: 10
      - name: vendor/nic1
        capacity: 3
        allocatable: 3
        available: 3
  - name: node-1
    type: Node
    resources:
      - name: cpu
        capacity: 30
        allocatable: 30
        available: 15
      - name: vendor/nic2
        capacity: 6
        allocatable: 6
        available: 6
  - name: node-2
    type: Node
    resources:
      - name: cpu
        capacity: 30
        allocatable: 30
        available: 15
      - name: vendor/nic1
        capacity: 3
        allocatable: 3
        available: 3
```

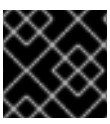
3.6.2. NFD Topology Updater command-line flags

To view available command-line flags, run the **nfd-topology-updater -help** command. For example, in a podman container, run the following command:

```
$ podman run gcr.io/k8s-staging-nfd/node-feature-discovery:master nfd-topology-updater -help
```

-ca-file
The **-ca-file** flag is one of the three flags, together with the **-cert-file** and `-key-file`flags, that controls the mutual TLS authentication on the NFD Topology Updater. This flag specifies the TLS root certificate that is used for verifying the authenticity of nfd-master.

Default: empty



IMPORTANT

The **-ca-file** flag must be specified together with the **-cert-file** and **-key-file** flags.

Example

```
$ nfd-topology-updater -ca-file=/opt/nfd/ca.crt -cert-file=/opt/nfd/updater.crt -key-
file=/opt/nfd/updater.key
```

-cert-file
The **-cert-file** flag is one of the three flags, together with the **-ca-file** and **-key-file flags**, that controls mutual TLS authentication on the NFD Topology Updater. This flag specifies the TLS certificate presented for authenticating outgoing requests.

Default: empty

IMPORTANT

The **-cert-file** flag must be specified together with the **-ca-file** and **-key-file** flags.

Example

```
$ nfd-topology-updater -cert-file=/opt/nfd/updater.crt -key-file=/opt/nfd/updater.key -ca-
file=/opt/nfd/ca.crt
```

-h, -help
Print usage and exit.

-key-file
The **-key-file** flag is one of the three flags, together with the **-ca-file** and **-cert-file** flags, that controls the mutual TLS authentication on the NFD Topology Updater. This flag specifies the private key corresponding the given certificate file, or **-cert-file**, that is used for authenticating outgoing requests.

Default: empty

IMPORTANT

The **-key-file** flag must be specified together with the **-ca-file** and **-cert-file** flags.

Example

```
$ nfd-topology-updater -key-file=/opt/nfd/updater.key -cert-file=/opt/nfd/updater.crt -ca-
file=/opt/nfd/ca.crt
```

-kubelet-config-file
The **-kubelet-config-file** specifies the path to the Kubelet's configuration file.

Default: **/host-var/lib/kubelet/config.yaml**

Example

```
$ nfd-topology-updater -kubelet-config-file=/var/lib/kubelet/config.yaml
```

-no-publish

The **-no-publish** flag disables all communication with the nfd-master, making it a dry run flag for nfd-topology-updater. NFD Topology Updater runs resource hardware topology detection normally, but no CR requests are sent to nfd-master.

Default: **false**

Example

```
$ nfd-topology-updater -no-publish
```

3.6.2.1. -oneshot

The **-oneshot** flag causes the NFD Topology Updater to exit after one pass of resource hardware topology detection.

Default: **false**

Example

```
$ nfd-topology-updater -oneshot -no-publish
```

-podresources-socket
The **-podresources-socket** flag specifies the path to the Unix socket where kubelet exports a gRPC service to enable discovery of in-use CPUs and devices, and to provide metadata for them.

Default: **/host-var/liblib/kubelet/pod-resources/kubelet.sock**

Example

```
$ nfd-topology-updater -podresources-socket=/var/lib/kubelet/pod-resources/kubelet.sock
```

-server
The **-server** flag specifies the address of the nfd-master endpoint to connect to.

Default: **localhost:8080**

Example

```
$ nfd-topology-updater -server=nfd-master.nfd.svc.cluster.local:443
```

-server-name-override
The **-server-name-override** flag specifies the common name (CN) which to expect from the nfd-master TLS certificate. This flag is mostly intended for development and debugging purposes.

Default: empty

Example

```
$ nfd-topology-updater -server-name-override=localhost
```

-sleep-interval

The **-sleep-interval** flag specifies the interval between resource hardware topology re-examination and custom resource updates. A non-positive value implies infinite sleep interval and no re-detection is done.

Default: **60s**

Example

```
$ nfd-topology-updater -sleep-interval=1h
```

-version
Print version and exit.

-watch-namespace
The **-watch-namespace** flag specifies the namespace to ensure that resource hardware topology examination only happens for the pods running in the specified namespace. Pods that are not running in the specified namespace are not considered during resource accounting. This is particularly useful for testing and debugging purposes. A * value means that all of the pods across all namespaces are considered during the accounting process.

Default: *

Example

```
$ nfd-topology-updater -watch-namespace=rte
```

CHAPTER 4. KERNEL MODULE MANAGEMENT OPERATOR

Learn about the Kernel Module Management (KMM) Operator and how you can use it to deploy out-of-tree kernel modules and device plugins on OpenShift Container Platform clusters.

4.1. ABOUT THE KERNEL MODULE MANAGEMENT OPERATOR

The Kernel Module Management (KMM) Operator manages, builds, signs, and deploys out-of-tree kernel modules and device plugins on OpenShift Container Platform clusters.

KMM adds a new **Module** CRD which describes an out-of-tree kernel module and its associated device plugin. You can use **Module** resources to configure how to load the module, define **ModuleLoader** images for kernel versions, and include instructions for building and signing modules for specific kernel versions.

KMM is designed to accommodate multiple kernel versions at once for any kernel module, allowing for seamless node upgrades and reduced application downtime.

4.2. INSTALLING THE KERNEL MODULE MANAGEMENT OPERATOR

As a cluster administrator, you can install the Kernel Module Management (KMM) Operator by using the OpenShift CLI or the web console.

The KMM Operator is supported on OpenShift Container Platform 4.12 and later. Installing KMM on version 4.11 does not require specific additional steps. For details on installing KMM on version 4.10 and earlier, see the section "Installing the Kernel Module Management Operator on earlier versions of OpenShift Container Platform".

4.2.1. Installing the Kernel Module Management Operator using the web console

As a cluster administrator, you can install the Kernel Module Management (KMM) Operator using the OpenShift Container Platform web console.

Procedure

1. Log in to the OpenShift Container Platform web console.
2. Install the Kernel Module Management Operator:
    a. In the OpenShift Container Platform web console, click **Operators → OperatorHub**.
    b. Select **Kernel Module Management Operator** from the list of available Operators, and then click **Install**.
    c. On the **Install Operator** page, select the **Installation mode** as **A specific namespace on the cluster**.
    d. From the **Installed Namespace** list, select the **openshift-kmm** namespace.
    e. Click **Install**.

Verification

To verify that KMM Operator installed successfully:

1. Navigate to the **Operators → Installed Operators** page.
2. Ensure that **Kernel Module Management Operator** is listed in the **openshift-kmm** project with a **Status** of **InstallSucceeded**.

NOTE

During installation, an Operator might display a **Failed** status. If the installation later succeeds with an **InstallSucceeded** message, you can ignore the **Failed** message.

Troubleshooting

1. To troubleshoot issues with Operator installation:
   a. Navigate to the **Operators → Installed Operators** page and inspect the **Operator Subscriptions** and **Install Plans** tabs for any failure or errors under **Status**.
   b. Navigate to the **Workloads → Pods** page and check the logs for pods in the **openshift-kmm** project.

4.2.2. Installing the Kernel Module Management Operator by using the CLI

As a cluster administrator, you can install the Kernel Module Management (KMM) Operator by using the OpenShift CLI.

Prerequisites

- You have a running OpenShift Container Platform cluster.
- You installed the OpenShift CLI (**oc**).
- You are logged into the OpenShift CLI as a user with **cluster-admin** privileges.

Procedure

1. Install KMM in the **openshift-kmm** namespace:
   a. Create the following **Namespace** CR and save the YAML file, for example, **kmm-namespace.yaml**:

```
apiVersion: v1
kind: Namespace
metadata:
  name: openshift-kmm
```

   b. Create the following **OperatorGroup** CR and save the YAML file, for example, **kmm-op-group.yaml**:

```
apiVersion: operators.coreos.com/v1
kind: OperatorGroup
metadata:
  name: kernel-module-management
  namespace: openshift-kmm
```

c. Create the following **Subscription** CR and save the YAML file, for example, **kmm-sub.yaml**:

```
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: kernel-module-management
  namespace: openshift-kmm
spec:
  channel: release-1.0
  installPlanApproval: Automatic
  name: kernel-module-management
  source: redhat-operators
  sourceNamespace: openshift-marketplace
  startingCSV: kernel-module-management.v1.0.0
```

d. Create the subscription object by running the following command:

```
$ oc create -f kmm-sub.yaml
```

Verification

- To verify that the Operator deployment is successful, run the following command:

```
$ oc get -n openshift-kmm deployments.apps kmm-operator-controller-manager
```

Example output

```
NAME                              READY UP-TO-DATE  AVAILABLE AGE
kmm-operator-controller-manager   1/1   1           1         97s
```

The Operator is available.

4.2.3. Installing the Kernel Module Management Operator on earlier versions of OpenShift Container Platform

The KMM Operator is supported on OpenShift Container Platform 4.12 and later. For version 4.10 and earlier, you must create a new **SecurityContextConstraint** object and bind it to the Operator's **ServiceAccount**. As a cluster administrator, you can install the Kernel Module Management (KMM) Operator by using the OpenShift CLI.

Prerequisites

- You have a running OpenShift Container Platform cluster.
- You installed the OpenShift CLI (**oc**).
- You are logged into the OpenShift CLI as a user with **cluster-admin** privileges.

Procedure

1. Install KMM in the **openshift-kmm** namespace:

   a. Create the following **Namespace** CR and save the YAML file, for example, **kmm**

a. Create the following **Namespace** CR and save the YAML file, for example, **kmm-namespace.yaml** file:

```
apiVersion: v1
kind: Namespace
metadata:
  name: openshift-kmm
```

b. Create the following **SecurityContextConstraint** object and save the YAML file, for example, **kmm-security-constraint.yaml**:

```
allowHostDirVolumePlugin: false
allowHostIPC: false
allowHostNetwork: false
allowHostPID: false
allowHostPorts: false
allowPrivilegeEscalation: false
allowPrivilegedContainer: false
allowedCapabilities:
  - NET_BIND_SERVICE
apiVersion: security.openshift.io/v1
defaultAddCapabilities: null
fsGroup:
  type: MustRunAs
groups: []
kind: SecurityContextConstraints
metadata:
  name: restricted-v2
priority: null
readOnlyRootFilesystem: false
requiredDropCapabilities:
  - ALL
runAsUser:
  type: MustRunAsRange
seLinuxContext:
  type: MustRunAs
seccompProfiles:
  - runtime/default
supplementalGroups:
  type: RunAsAny
users: []
volumes:
  - configMap
  - downwardAPI
  - emptyDir
  - persistentVolumeClaim
  - projected
  - secret
```

c. Bind the **SecurityContextConstraint** object to the Operator's **ServiceAccount** by running the following commands:

```
$ oc apply -f kmm-security-constraint.yaml
```

```
$ oc adm policy add-scc-to-user kmm-security-constraint -z kmm-operator-controller-manager -n openshift-kmm
```

d. Create the following **OperatorGroup** CR and save the YAML file, for example, **kmm-op-group.yaml**:

```
apiVersion: operators.coreos.com/v1
kind: OperatorGroup
metadata:
  name: kernel-module-management
  namespace: openshift-kmm
```

e. Create the following **Subscription** CR and save the YAML file, for example, **kmm-sub.yaml**:

```
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: kernel-module-management
  namespace: openshift-kmm
spec:
  channel: release-1.0
  installPlanApproval: Automatic
  name: kernel-module-management
  source: redhat-operators
  sourceNamespace: openshift-marketplace
  startingCSV: kernel-module-management.v1.0.0
```

f. Create the subscription object by running the following command:

```
$ oc create -f kmm-sub.yaml
```

Verification

- To verify that the Operator deployment is successful, run the following command:

```
$ oc get -n openshift-kmm deployments.apps kmm-operator-controller-manager
```

Example output

```
NAME                              READY UP-TO-DATE  AVAILABLE AGE
kmm-operator-controller-manager   1/1   1           1         97s
```

The Operator is available.

4.3. KERNEL MODULE DEPLOYMENT

For each **Module** resource, Kernel Module Management (KMM) can create a number of **DaemonSet** resources:

- One ModuleLoader **DaemonSet** per compatible kernel version running in the cluster.

- One device plugin **DaemonSet**, if configured.

The module loader daemon set resources run ModuleLoader images to load kernel modules. A module loader image is an OCI image that contains the **.ko** files and both the **modprobe** and **sleep** binaries.

When the module loader pod is created, the pod runs **modprobe** to insert the specified module into the kernel. It then enters a sleep state until it is terminated. When that happens, the **ExecPreStop** hook runs **modprobe -r** to unload the kernel module.

If the **.spec.devicePlugin** attribute is configured in a **Module** resource, then KMM creates a device plugin daemon set in the cluster. That daemon set targets:

- Nodes that match the **.spec.selector** of the **Module** resource.
- Nodes with the kernel module loaded (where the module loader pod is in the **Ready** condition).

4.3.1. The Module custom resource definition

The **Module** custom resource definition (CRD) represents a kernel module that can be loaded on all or select nodes in the cluster, through a module loader image. A **Module** custom resource (CR) specifies one or more kernel versions with which it is compatible, and a node selector.

The compatible versions for a **Module** resource are listed under **.spec.moduleLoader.container.kernelMappings**. A kernel mapping can either match a **literal** version, or use **regexp** to match many of them at the same time.

The reconciliation loop for the **Module** resource runs the following steps:

1. List all nodes matching **.spec.selector**.
2. Build a set of all kernel versions running on those nodes.
3. For each kernel version:
    a. Go through **.spec.moduleLoader.container.kernelMappings** and find the appropriate container image name. If the kernel mapping has **build** or **sign** defined and the container image does not already exist, run the build, the signing job, or both, as needed.
    b. Create a module loader daemon set with the container image determined in the previous step.
    c. If **.spec.devicePlugin** is defined, create a device plugin daemon set using the configuration specified under **.spec.devicePlugin.container**.
4. Run **garbage-collect** on:
    a. Existing daemon set resources targeting kernel versions that are not run by any node in the cluster.
    b. Successful build jobs.
    c. Successful signing jobs.

4.3.2. Security and permissions

IMPORTANT

Loading kernel modules is a highly sensitive operation. After they are loaded, kernel modules have all possible permissions to do any kind of operation on the node.

4.3.2.1. ServiceAccounts and SecurityContextConstraints

Kernel Module Management (KMM) creates a privileged workload to load the kernel modules on nodes. That workload needs **ServiceAccounts** allowed to use the **privileged SecurityContextConstraint** (SCC) resource.

The authorization model for that workload depends on the namespace of the **Module** resource, as well as its spec.

- If the **.spec.moduleLoader.serviceAccountName** or **.spec.devicePlugin.serviceAccountName** fields are set, they are always used.
- If those fields are not set, then:
  - If the **Module** resource is created in the operator's namespace (**openshift-kmm** by default), then KMM uses its default, powerful **ServiceAccounts** to run the daemon sets.
  - If the **Module** resource is created in any other namespace, then KMM runs the daemon sets as the namespace's **default ServiceAccount**. The **Module** resource cannot run a privileged workload unless you manually enable it to use the **privileged** SCC.

IMPORTANT

openshift-kmm is a trusted namespace.

When setting up RBAC permissions, remember that any user or **ServiceAccount** creating a **Module** resource in the **openshift-kmm** namespace results in KMM automatically running privileged workloads on potentially all nodes in the cluster.

To allow any **ServiceAccount** to use the **privileged** SCC and therefore to run module loader or device plugin pods, use the following command:

```
$ oc adm policy add-scc-to-user privileged -z "${serviceAccountName}" [ -n "${namespace}" ]
```

4.3.2.2. Pod security standards

OpenShift runs a synchronization mechanism that sets the namespace Pod Security level automatically based on the security contexts in use. No action is needed.

Additional resources

- Understanding and managing pod security admission .

4.3.3. Example Module CR

The following is an annotated **Module** example:

```
apiVersion: kmm.sigs.x-k8s.io/v1beta1
```

```
kind: Module
metadata:
  name: <my_kmod>
spec:
  moduleLoader:
    container:
      modprobe:
        moduleName: <my_kmod> 1
        dirName: /opt 2
        firmwarePath: /firmware 3
        parameters: 4
          - param=1
      kernelMappings: 5
        - literal: 6.0.15-300.fc37.x86_64
          containerImage: some.registry/org/my-kmod:6.0.15-300.fc37.x86_64
        - regexp: '^.+\fc37\.x86_64$' 6
          containerImage: "some.other.registry/org/<my_kmod>:${KERNEL_FULL_VERSION}"
        - regexp: '^.+$' 7
          containerImage: "some.registry/org/<my_kmod>:${KERNEL_FULL_VERSION}"
          build:
            buildArgs: 8
              - name: ARG_NAME
                value: <some_value>
            secrets:
              - name: <some_kubernetes_secret> 9
            baseImageRegistryTLS: 10
              insecure: false
              insecureSkipTLSVerify: false 11
            dockerfileConfigMap: 12
              name: <my_kmod_dockerfile>
          sign:
            certSecret:
              name: <cert_secret> 13
            keySecret:
              name: <key_secret> 14
            filesToSign:
              - /opt/lib/modules/${KERNEL_FULL_VERSION}/<my_kmod>.ko
          registryTLS: 15
            insecure: false 16
            insecureSkipTLSVerify: false
    serviceAccountName: <sa_module_loader> 17
  devicePlugin: 18
    container:
      image: some.registry/org/device-plugin:latest 19
      env:
        - name: MY_DEVICE_PLUGIN_ENV_VAR
          value: SOME_VALUE
      volumeMounts: 20
        - mountPath: /some/mountPath
          name: <device_plugin_volume>
    volumes: 21
      - name: <device_plugin_volume>
        configMap:
```

```
      name: <some_configmap>
  serviceAccountName: <sa_device_plugin> (22)
imageRepoSecret: (23)
  name: <secret_name>
selector:
  node-role.kubernetes.io/worker: ""
```

(1) (1) (1) Required.

(2) Optional.

(3) Optional: Copies **/firmware/*** into **/var/lib/firmware/** on the node.

(4) Optional.

(5) At least one kernel item is required.

(6) For each node running a kernel matching the regular expression, KMM creates a **DaemonSet** resource running the image specified in **containerImage** with **${KERNEL_FULL_VERSION}** replaced with the kernel version.

(7) For any other kernel, build the image using the Dockerfile in the **my-kmod** ConfigMap.

(8) Optional.

(9) Optional: A value for **some-kubernetes-secret** can be obtained from the build environment at **/run/secrets/some-kubernetes-secret**.

(10) Optional: Avoid using this parameter. If set to **true**, the build is allowed to pull the image in the Dockerfile **FROM** instruction using plain HTTP.

(11) Optional: Avoid using this parameter. If set to **true**, the build will skip any TLS server certificate validation when pulling the image in the Dockerfile **FROM** instruction using plain HTTP.

(12) Required.

(13) Required: A secret holding the public secureboot key with the key 'cert'.

(14) Required: A secret holding the private secureboot key with the key 'key'.

(15) Optional: Avoid using this parameter. If set to **true**, KMM will be allowed to check if the container image already exists using plain HTTP.

(16) Optional: Avoid using this parameter. If set to **true**, KMM will skip any TLS server certificate validation when checking if the container image already exists.

(17) Optional.

(18) Optional.

(19) Required: If the device plugin section is present.

(20) Optional.

(21) Optional.

22 Optional.

23 Optional: Used to pull module loader and device plugin images.

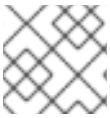
4.4. USING A MODULELOADER IMAGE

Kernel Module Management (KMM) works with purpose-built module loader images. These are standard OCI images that must satisfy the following requirements:

- **.ko** files must be located in **/opt/lib/modules/${KERNEL_VERSION}**.
- **modprobe** and **sleep** binaries must be defined in the **$PATH** variable.

4.4.1. Running depmod

If your module loader image contains several kernel modules and if one of the modules depends on another module, it is best practice to run **depmod** at the end of the build process to generate dependencies and map files.



NOTE

You must have a Red Hat subscription to download the **kernel-devel** package.

Procedure

1. To generate **modules.dep** and **.map** files for a specific kernel version, run **depmod -b /opt ${KERNEL_VERSION}**.

4.4.1.1. Example Dockerfile

If you are building your image on OpenShift Container Platform, consider using the Driver Tool Kit (DTK).

For further information, see using an entitled build .

```
apiVersion: v1
kind: ConfigMap
metadata:
  name: kmm-ci-dockerfile
data:
  dockerfile: |
    ARG DTK_AUTO
    FROM ${DTK_AUTO} as builder
    ARG KERNEL_VERSION
    WORKDIR /usr/src
    RUN ["git", "clone", "https://github.com/rh-ecosystem-edge/kernel-module-management.git"]
    WORKDIR /usr/src/kernel-module-management/ci/kmm-kmod
    RUN KERNEL_SRC_DIR=/lib/modules/${KERNEL_VERSION}/build make all
    FROM registry.redhat.io/ubi8/ubi-minimal
    ARG KERNEL_VERSION
    RUN microdnf install kmod
    COPY --from=builder /usr/src/kernel-module-management/ci/kmm-kmod/kmm_ci_a.ko
/opt/lib/modules/${KERNEL_VERSION}/
```

```
    COPY --from=builder /usr/src/kernel-module-management/ci/kmm-kmod/kmm_ci_b.ko
/opt/lib/modules/${KERNEL_VERSION}/
    RUN depmod -b /opt ${KERNEL_VERSION}
```

Additional resources

- Driver Toolkit.

4.4.2. Building in the cluster

KMM can build module loader images in the cluster. Follow these guidelines:

- Provide build instructions using the **build** section of a kernel mapping.
- Copy the Dockerfile for your container image into a **ConfigMap** resource, under the **dockerfile** key.
- Ensure that the **ConfigMap** is located in the same namespace as the **Module**.

KMM checks if the image name specified in the **containerImage** field exists. If it does, the build is skipped.

Otherwise, KMM creates a **Build** resource to build your image. After the image is built, KMM proceeds with the **Module** reconciliation. See the following example.

```
# ...
- regexp: '^.+$'
  containerImage: "some.registry/org/<my_kmod>:${KERNEL_FULL_VERSION}"
  build:
    buildArgs: (1)
      - name: ARG_NAME
        value: <some_value>
    secrets: (2)
      - name: <some_kubernetes_secret> (3)
    baseImageRegistryTLS:
      insecure: false (4)
      insecureSkipTLSVerify: false (5)
    dockerfileConfigMap: (6)
      name: <my_kmod_dockerfile>
  registryTLS:
    insecure: false (7)
    insecureSkipTLSVerify: false (8)
```

(1) Optional.

(2) Optional.

(3) Will be mounted in the build pod as **/run/secrets/some-kubernetes-secret**.

(4) Optional: Avoid using this parameter. If set to **true**, the build will be allowed to pull the image in the Dockerfile **FROM** instruction using plain HTTP.

(5) Optional: Avoid using this parameter. If set to **true**, the build will skip any TLS server certificate validation when pulling the image in the Dockerfile **FROM** instruction using plain HTTP.

6 Required.

7 Optional: Avoid using this parameter. If set to **true**, KMM will be allowed to check if the container image already exists using plain HTTP.

8 Optional: Avoid using this parameter. If set to **true**, KMM will skip any TLS server certificate validation when checking if the container image already exists.

Additional resources

- Build configuration resources.

4.4.3. Using the Driver Toolkit

The Driver Toolkit (DTK) is a convenient base image for building build module loader images. It contains tools and libraries for the OpenShift version currently running in the cluster.

Procedure

Use DTK as the first stage of a multi-stage Dockerfile.

1. Build the kernel modules.
2. Copy the **.ko** files into a smaller end-user image such as **ubi-minimal**.
3. To leverage DTK in your in-cluster build, use the **DTK_AUTO** build argument. The value is automatically set by KMM when creating the **Build** resource. See the following example.

```
ARG DTK_AUTO
FROM ${DTK_AUTO} as builder
ARG KERNEL_VERSION
WORKDIR /usr/src
RUN ["git", "clone", "https://github.com/rh-ecosystem-edge/kernel-module-management.git"]
WORKDIR /usr/src/kernel-module-management/ci/kmm-kmod
RUN KERNEL_SRC_DIR=/lib/modules/${KERNEL_VERSION}/build make all
FROM registry.redhat.io/ubi8/ubi-minimal
ARG KERNEL_VERSION
RUN microdnf install kmod
COPY --from=builder /usr/src/kernel-module-management/ci/kmm-kmod/kmm_ci_a.ko
/opt/lib/modules/${KERNEL_VERSION}/
COPY --from=builder /usr/src/kernel-module-management/ci/kmm-kmod/kmm_ci_b.ko
/opt/lib/modules/${KERNEL_VERSION}/
RUN depmod -b /opt ${KERNEL_VERSION}
```

Additional resources

- Driver Toolkit.

4.5. USING SIGNING WITH KERNEL MODULE MANAGEMENT (KMM)

On a Secure Boot enabled system, all kernel modules (kmods) must be signed with a public/private key-pair enrolled into the Machine Owner's Key (MOK) database. Drivers distributed as part of a distribution should already be signed by the distribution's private key, but for kernel modules build out-of-tree, KMM supports signing kernel modules using the **sign** section of the kernel mapping.

For more details on using Secure Boot, see Generating a public and private key pair

Prerequisites

- A public private key pair in the correct (DER) format.
- At least one secure-boot enabled node with the public key enrolled in its MOK database.
- Either a pre-built driver container image, or the source code and Dockerfile needed to build one in-cluster.

4.6. ADDING THE KEYS FOR SECUREBOOT

To use KMM Kernel Module Management (KMM) to sign kernel modules, a certificate and private key are required. For details on how to create these, see Generating a public and private key pair .

For details on how to extract the public and private key pair, see Signing kernel modules with the private key. Use steps 1 through 4 to extract the keys into files.

Procedure

1. Create the **sb_cert.cer** file that contains the certificate and the **sb_cert.priv** file that contains the private key:

```
$ openssl req -x509 -new -nodes -utf8 -sha256 -days 36500 -batch -config
configuration_file.config -outform DER -out my_signing_key_pub.der -keyout
my_signing_key.priv
```

2. Add the files by using one of the following methods:
   - Add the files as secrets directly:

```
$ oc create secret generic my-signing-key --from-file=key=<my_signing_key.priv>
```

```
$ oc create secret generic my-signing-key-pub --from-file=cert=
<my_signing_key_pub.der>
```

   - Add the files by base64 encoding them:

```
$ cat sb_cert.priv | base64 -w 0 > my_signing_key2.base64
```

```
$ cat sb_cert.cer | base64 -w 0 > my_signing_key_pub.base64
```

3. Add the encoded text to a YAML file:

```
apiVersion: v1
kind: Secret
metadata:
  name: my-signing-key-pub
  namespace: default (1)
type: Opaque
data:
  cert: <base64_encoded_secureboot_public_key>
```

```
---
apiVersion: v1
kind: Secret
metadata:
  name: my-signing-key
  namespace: default 2
type: Opaque
data:
  key: <base64_encoded_secureboot_private_key>
```

1 2 **namespace** - Replace **default** with a valid namespace.

4. Apply the YAML file:

```
$ oc apply -f <yaml_filename>
```

4.6.1. Checking the keys

After you have added the keys, you must check them to ensure they are set correctly.

Procedure

1. Check to ensure the public key secret is set correctly:

```
$ oc get secret -o yaml <certificate secret name> | awk '/cert/{print $2; exit}' | base64 -d  |
openssl x509 -inform der -text
```

This should display a certificate with a Serial Number, Issuer, Subject, and more.

2. Check to ensure the private key secret is set correctly:

```
$ oc get secret -o yaml <private key secret name> | awk '/key/{print $2; exit}' | base64 -d
```

This should display the key enclosed in the **-----BEGIN PRIVATE KEY-----** and **-----END PRIVATE KEY-----** lines.

4.7. SIGNING A PRE-BUILT DRIVER CONTAINER

Use this procedure if you have a pre-built image, such as an image either distributed by a hardware vendor or built elsewhere.

The following YAML file adds the public/private key-pair as secrets with the required key names - **key** for the private key, **cert** for the public key. The cluster then pulls down the **unsignedImage** image, opens it, signs the kernel modules listed in **filesToSign**, adds them back, and pushes the resulting image as **containerImage**.

Kernel Module Management (KMM) should then deploy the DaemonSet that loads the signed kmods onto all the nodes that match the selector. The driver containers should run successfully on any nodes that have the public key in their MOK database, and any nodes that are not secure-boot enabled, which ignore the signature. They should fail to load on any that have secure-boot enabled but do not have that key in their MOK database.

Prerequisites

- The **keySecret** and **certSecret** secrets have been created.

Procedure

1. Apply the YAML file:

```
---
apiVersion: kmm.sigs.x-k8s.io/v1beta1
kind: Module
metadata:
  name: example-module
spec:
  moduleLoader:
    serviceAccountName: default
    container:
      modprobe: 1
        moduleName: '<your module name>'
      kernelMappings:
        # the kmods will be deployed on all nodes in the cluster with a kernel that matches the
regexp
        - regexp: '^.*\.x86_64$'
          # the container to produce containing the signed kmods
          containerImage: <image name e.g. quay.io/myuser/my-driver:<kernelversion>-signed>
          sign:
            # the image containing the unsigned kmods (we need this because we are not
building the kmods within the cluster)
            unsignedImage: <image name e.g. quay.io/myuser/my-driver:<kernelversion> >
            keySecret: # a secret holding the private secureboot key with the key 'key'
              name: <private key secret name>
            certSecret: # a secret holding the public secureboot key with the key 'cert'
              name: <certificate secret name>
            filesToSign: # full path within the unsignedImage container to the kmod(s) to sign
              - /opt/lib/modules/4.18.0-348.2.1.el8_5.x86_64/kmm_ci_a.ko
  imageRepoSecret:
    # the name of a secret containing credentials to pull unsignedImage and push
containerImage to the registry
    name: repo-pull-secret
  selector:
    kubernetes.io/arch: amd64
```

1 **modprobe** - The name of the kmod to load.

4.8. BUILDING AND SIGNING A MODULELOADER CONTAINER IMAGE

Use this procedure if you have source code and must build your image first.

The following YAML file builds a new container image using the source code from the repository. The image produced is saved back in the registry with a temporary name, and this temporary image is then signed using the parameters in the **sign** section.

The temporary image name is based on the final image name and is set to be **<containerImage>:<tag>-<namespace>_<module name>_kmm_unsigned**.

For example, using the following YAML file, Kernel Module Management (KMM) builds an image named **example.org/repository/minimal-driver:final-default_example-module_kmm_unsigned** containing the build with unsigned kmods and push it to the registry. Then it creates a second image named **example.org/repository/minimal-driver:final** that contains the signed kmods. It is this second image that is loaded by the **DaemonSet** object and deploys the kmods to the cluster nodes.

After it is signed, the temporary image can be safely deleted from the registry. It will be rebuilt, if needed.

Prerequisites

- The **keySecret** and **certSecret** secrets have been created.

Procedure

1. Apply the YAML file:

```
---
apiVersion: v1
kind: ConfigMap
metadata:
  name: example-module-dockerfile
  namespace: default (1)
data:
  dockerfile: |
    ARG DTK_AUTO
    ARG KERNEL_VERSION
    FROM ${DTK_AUTO} as builder
    WORKDIR /build/
    RUN git clone -b main --single-branch https://github.com/rh-ecosystem-edge/kernel-module-management.git
    WORKDIR kernel-module-management/ci/kmm-kmod/
    RUN make
    FROM registry.access.redhat.com/ubi8/ubi:latest
    ARG KERNEL_VERSION
    RUN yum -y install kmod && yum clean all
    RUN mkdir -p /opt/lib/modules/${KERNEL_VERSION}
    COPY --from=builder /build/kernel-module-management/ci/kmm-kmod/*.ko /opt/lib/modules/${KERNEL_VERSION}/
    RUN /usr/sbin/depmod -b /opt
---
apiVersion: kmm.sigs.x-k8s.io/v1beta1
kind: Module
metadata:
  name: example-module
  namespace: default (2)
spec:
  moduleLoader:
    serviceAccountName: default (3)
    container:
      modprobe:
        moduleName: simple_kmod
      kernelMappings:
        - regexp: '^.*\.x86_64$'
          containerImage: < the name of the final driver container to produce>
          build:
```

```
        dockerfileConfigMap:
          name: example-module-dockerfile
      sign:
        keySecret:
          name: <private key secret name>
        certSecret:
          name: <certificate secret name>
        filesToSign:
          - /opt/lib/modules/4.18.0-348.2.1.el8_5.x86_64/kmm_ci_a.ko
  imageRepoSecret: 4
    name: repo-pull-secret
  selector: # top-level selector
    kubernetes.io/arch: amd64
```

1 2 **namespace** - Replace **default** with a valid namespace.

3 **serviceAccountName** - The default **serviceAccountName** does not have the required permissions to run a module that is privileged. For information on creating a service account, see "Creating service accounts" in the "Additional resources" of this section.

4 **imageRepoSecret** - Used as **imagePullSecrets** in the **DaemonSet** object and to pull and push for the build and sign features.

Additional resources

For information on creating a service account, see Creating service accounts .

4.9. DEBUGGING AND TROUBLESHOOTING

If the kmods in your driver container are not signed or are signed with the wrong key, then the container can enter a **PostStartHookError** or **CrashLoopBackOff** status. You can verify by running the **oc describe** command on your container, which displays the following message in this scenario:

```
modprobe: ERROR: could not insert '<your_kmod_name>': Required key not available
```

4.10. KMM FIRMWARE SUPPORT

Kernel modules sometimes need to load firmware files from the file system. KMM supports copying firmware files from the ModuleLoader image to the node's file system.

The contents of **.spec.moduleLoader.container.modprobe.firmwarePath** are copied into the **/var/lib/firmware** path on the node before running the **modprobe** command to insert the kernel module.

All files and empty directories are removed from that location before running the **modprobe -r** command to unload the kernel module, when the pod is terminated.

Additional resources

- Creating a ModuleLoader image .

4.10.1. Configuring the lookup path on nodes

On OpenShift Container Platform nodes, the set of default lookup paths for firmwares does not include the **/var/lib/firmware** path.

Procedure

1. Use the Machine Config Operator to create a **MachineConfig** custom resource (CR) that contains the **/var/lib/firmware** path:

```
apiVersion: machineconfiguration.openshift.io/v1
kind: MachineConfig
metadata:
  labels:
    machineconfiguration.openshift.io/role: worker (1)
  name: 99-worker-kernel-args-firmware-path
spec:
  kernelArguments:
    - 'firmware_class.path=/var/lib/firmware'
```

(1) You can configure the label based on your needs. In the case of single-node OpenShift, use either **control-pane** or **master** objects.

2. By applying the **MachineConfig** CR, the nodes are automatically rebooted.

Additional resources

- Machine Config Operator.

4.10.2. Building a ModuleLoader image

Procedure

- In addition to building the kernel module itself, include the binary firmware in the builder image:

```
FROM registry.redhat.io/ubi8/ubi-minimal as builder

# Build the kmod

RUN ["mkdir", "/firmware"]
RUN ["curl", "-o", "/firmware/firmware.bin", "https://artifacts.example.com/firmware.bin"]

FROM registry.redhat.io/ubi8/ubi-minimal

# Copy the kmod, install modprobe, run depmod

COPY --from=builder /firmware /firmware
```

4.10.3. Tuning the Module resource

Procedure

- Set **.spec.moduleLoader.container.modprobe.firmwarePath** in the **Module** custom resource (CR):

```
apiVersion: kmm.sigs.x-k8s.io/v1beta1
kind: Module
metadata:
  name: my-kmod
spec:
  moduleLoader:
    container:
      modprobe:
        moduleName: my-kmod  # Required

        firmwarePath: /firmware (1)
```

(1) Optional: Copies **/firmware/*** into **/var/lib/firmware/** on the node.

4.11. TROUBLESHOOTING KMM

When troubleshooting KMM installation issues, you can monitor logs to determine at which stage issues occur. Then, retrieve diagnostic data relevant to that stage.

4.11.1. Using the must-gather tool

The **oc adm must-gather** command is the preferred way to collect a support bundle and provide debugging information to Red Hat Support. Collect specific information by running the command with the appropriate arguments as described in the following sections.

Additional resources

- About the must-gather tool

4.11.1.1. Gathering data for KMM

Procedure

1. Gather the data for the KMM Operator controller manager:

   a. Set the **MUST_GATHER_IMAGE** variable:

   ```
   $ export MUST_GATHER_IMAGE=$(oc get deployment -n openshift-kmm kmm-operator-controller-manager -ojsonpath='{.spec.template.spec.containers[?(@.name=="manager")].env[?(@.name=="RELATED_IMAGES_MUST_GATHER")].value}')
   ```

   NOTE

   Use the **-n <namespace>** switch to specify a namespace if you installed KMM in a custom namespace.

   b. Run the **must-gather** tool:

   ```
   $ oc adm must-gather --image="${MUST_GATHER_IMAGE}" -- /usr/bin/gather
   ```

2. View the Operator logs:

```
$ oc logs -fn openshift-kmm deployments/kmm-operator-controller-manager
```

Example 4.1. Example output

```
I0228 09:36:37.352405       1 request.go:682] Waited for 1.001998746s due to client-side
throttling, not priority and fairness, request:
GET:https://172.30.0.1:443/apis/machine.openshift.io/v1beta1?timeout=32s
I0228 09:36:40.767060       1 listener.go:44] kmm/controller-runtime/metrics
"msg"="Metrics server is starting to listen" "addr"="127.0.0.1:8080"
I0228 09:36:40.769483       1 main.go:234] kmm/setup "msg"="starting manager"
I0228 09:36:40.769907       1 internal.go:366] kmm "msg"="Starting server" "addr"=
{"IP":"127.0.0.1","Port":8080,"Zone":""} "kind"="metrics" "path"="/metrics"
I0228 09:36:40.770025       1 internal.go:366] kmm "msg"="Starting server" "addr"=
{"IP":"::","Port":8081,"Zone":""} "kind"="health probe"
I0228 09:36:40.770128       1 leaderelection.go:248] attempting to acquire leader lease
openshift-kmm/kmm.sigs.x-k8s.io...
I0228 09:36:40.784396       1 leaderelection.go:258] successfully acquired lease
openshift-kmm/kmm.sigs.x-k8s.io
I0228 09:36:40.784876       1 controller.go:185] kmm "msg"="Starting EventSource"
"controller"="Module" "controllerGroup"="kmm.sigs.x-k8s.io" "controllerKind"="Module"
"source"="kind source: *v1beta1.Module"
I0228 09:36:40.784925       1 controller.go:185] kmm "msg"="Starting EventSource"
"controller"="Module" "controllerGroup"="kmm.sigs.x-k8s.io" "controllerKind"="Module"
"source"="kind source: *v1.DaemonSet"
I0228 09:36:40.784968       1 controller.go:185] kmm "msg"="Starting EventSource"
"controller"="Module" "controllerGroup"="kmm.sigs.x-k8s.io" "controllerKind"="Module"
"source"="kind source: *v1.Build"
I0228 09:36:40.785001       1 controller.go:185] kmm "msg"="Starting EventSource"
"controller"="Module" "controllerGroup"="kmm.sigs.x-k8s.io" "controllerKind"="Module"
"source"="kind source: *v1.Job"
I0228 09:36:40.785025       1 controller.go:185] kmm "msg"="Starting EventSource"
"controller"="Module" "controllerGroup"="kmm.sigs.x-k8s.io" "controllerKind"="Module"
"source"="kind source: *v1.Node"
I0228 09:36:40.785039       1 controller.go:193] kmm "msg"="Starting Controller"
"controller"="Module" "controllerGroup"="kmm.sigs.x-k8s.io" "controllerKind"="Module"
I0228 09:36:40.785458       1 controller.go:185] kmm "msg"="Starting EventSource"
"controller"="PodNodeModule" "controllerGroup"="" "controllerKind"="Pod" "source"="kind
source: *v1.Pod"
I0228 09:36:40.786947       1 controller.go:185] kmm "msg"="Starting EventSource"
"controller"="PreflightValidation" "controllerGroup"="kmm.sigs.x-k8s.io"
"controllerKind"="PreflightValidation" "source"="kind source: *v1beta1.PreflightValidation"
I0228 09:36:40.787406       1 controller.go:185] kmm "msg"="Starting EventSource"
"controller"="PreflightValidation" "controllerGroup"="kmm.sigs.x-k8s.io"
"controllerKind"="PreflightValidation" "source"="kind source: *v1.Build"
I0228 09:36:40.787474       1 controller.go:185] kmm "msg"="Starting EventSource"
"controller"="PreflightValidation" "controllerGroup"="kmm.sigs.x-k8s.io"
"controllerKind"="PreflightValidation" "source"="kind source: *v1.Job"
I0228 09:36:40.787488       1 controller.go:185] kmm "msg"="Starting EventSource"
"controller"="PreflightValidation" "controllerGroup"="kmm.sigs.x-k8s.io"
"controllerKind"="PreflightValidation" "source"="kind source: *v1beta1.Module"
I0228 09:36:40.787603       1 controller.go:185] kmm "msg"="Starting EventSource"
"controller"="NodeKernel" "controllerGroup"="" "controllerKind"="Node" "source"="kind
source: *v1.Node"
```

```
I0228 09:36:40.787634       1 controller.go:193] kmm "msg"="Starting Controller"
"controller"="NodeKernel" "controllerGroup"="" "controllerKind"="Node"
I0228 09:36:40.787680       1 controller.go:193] kmm "msg"="Starting Controller"
"controller"="PreflightValidation" "controllerGroup"="kmm.sigs.x-k8s.io"
"controllerKind"="PreflightValidation"
I0228 09:36:40.785607       1 controller.go:185] kmm "msg"="Starting EventSource"
"controller"="imagestream" "controllerGroup"="image.openshift.io"
"controllerKind"="ImageStream" "source"="kind source: *v1.ImageStream"
I0228 09:36:40.787822       1 controller.go:185] kmm "msg"="Starting EventSource"
"controller"="preflightvalidationocp" "controllerGroup"="kmm.sigs.x-k8s.io"
"controllerKind"="PreflightValidationOCP" "source"="kind source:
*v1beta1.PreflightValidationOCP"
I0228 09:36:40.787853       1 controller.go:193] kmm "msg"="Starting Controller"
"controller"="imagestream" "controllerGroup"="image.openshift.io"
"controllerKind"="ImageStream"
I0228 09:36:40.787879       1 controller.go:185] kmm "msg"="Starting EventSource"
"controller"="preflightvalidationocp" "controllerGroup"="kmm.sigs.x-k8s.io"
"controllerKind"="PreflightValidationOCP" "source"="kind source:
*v1beta1.PreflightValidation"
I0228 09:36:40.787905       1 controller.go:193] kmm "msg"="Starting Controller"
"controller"="preflightvalidationocp" "controllerGroup"="kmm.sigs.x-k8s.io"
"controllerKind"="PreflightValidationOCP"
I0228 09:36:40.786489       1 controller.go:193] kmm "msg"="Starting Controller"
"controller"="PodNodeModule" "controllerGroup"="" "controllerKind"="Pod"
```

4.11.1.2. Gathering data for KMM-Hub

Procedure

1. Gather the data for the KMM Operator hub controller manager:

   a. Set the **MUST_GATHER_IMAGE** variable:

   ```
   $ export MUST_GATHER_IMAGE=$(oc get deployment -n openshift-kmm-hub kmm-
   operator-hub-controller-manager -ojsonpath='{.spec.template.spec.containers[?
   (@.name=="manager")].env[?
   (@.name=="RELATED_IMAGES_MUST_GATHER")].value}')
   ```

   NOTE

   Use the **-n <namespace>** switch to specify a namespace if you installed KMM in a custom namespace.

   b. Run the **must-gather** tool:

   ```
   $ oc adm must-gather --image="${MUST_GATHER_IMAGE}" -- /usr/bin/gather -u
   ```

2. View the Operator logs:

   ```
   $ oc logs -fn openshift-kmm-hub deployments/kmm-operator-hub-controller-manager
   ```

   Example 4.2. Example output

```
I0417 11:34:08.807472       1 request.go:682] Waited for 1.023403273s due to client-side
throttling, not priority and fairness, request:
GET:https://172.30.0.1:443/apis/tuned.openshift.io/v1?timeout=32s
I0417 11:34:12.373413       1 listener.go:44] kmm-hub/controller-runtime/metrics
"msg"="Metrics server is starting to listen" "addr"="127.0.0.1:8080"
I0417 11:34:12.376253       1 main.go:150] kmm-hub/setup "msg"="Adding controller"
"name"="ManagedClusterModule"
I0417 11:34:12.376621       1 main.go:186] kmm-hub/setup "msg"="starting manager"
I0417 11:34:12.377690       1 leaderelection.go:248] attempting to acquire leader lease
openshift-kmm-hub/kmm-hub.sigs.x-k8s.io...
I0417 11:34:12.378078       1 internal.go:366] kmm-hub "msg"="Starting server" "addr"=
{"IP":"127.0.0.1","Port":8080,"Zone":""} "kind"="metrics" "path"="/metrics"
I0417 11:34:12.378222       1 internal.go:366] kmm-hub "msg"="Starting server" "addr"=
{"IP":"::","Port":8081,"Zone":""} "kind"="health probe"
I0417 11:34:12.395703       1 leaderelection.go:258] successfully acquired lease
openshift-kmm-hub/kmm-hub.sigs.x-k8s.io
I0417 11:34:12.396334       1 controller.go:185] kmm-hub "msg"="Starting EventSource"
"controller"="ManagedClusterModule" "controllerGroup"="hub.kmm.sigs.x-k8s.io"
"controllerKind"="ManagedClusterModule" "source"="kind source:
*v1beta1.ManagedClusterModule"
I0417 11:34:12.396403       1 controller.go:185] kmm-hub "msg"="Starting EventSource"
"controller"="ManagedClusterModule" "controllerGroup"="hub.kmm.sigs.x-k8s.io"
"controllerKind"="ManagedClusterModule" "source"="kind source: *v1.ManifestWork"
I0417 11:34:12.396430       1 controller.go:185] kmm-hub "msg"="Starting EventSource"
"controller"="ManagedClusterModule" "controllerGroup"="hub.kmm.sigs.x-k8s.io"
"controllerKind"="ManagedClusterModule" "source"="kind source: *v1.Build"
I0417 11:34:12.396469       1 controller.go:185] kmm-hub "msg"="Starting EventSource"
"controller"="ManagedClusterModule" "controllerGroup"="hub.kmm.sigs.x-k8s.io"
"controllerKind"="ManagedClusterModule" "source"="kind source: *v1.Job"
I0417 11:34:12.396522       1 controller.go:185] kmm-hub "msg"="Starting EventSource"
"controller"="ManagedClusterModule" "controllerGroup"="hub.kmm.sigs.x-k8s.io"
"controllerKind"="ManagedClusterModule" "source"="kind source: *v1.ManagedCluster"
I0417 11:34:12.396543       1 controller.go:193] kmm-hub "msg"="Starting Controller"
"controller"="ManagedClusterModule" "controllerGroup"="hub.kmm.sigs.x-k8s.io"
"controllerKind"="ManagedClusterModule"
I0417 11:34:12.397175       1 controller.go:185] kmm-hub "msg"="Starting EventSource"
"controller"="imagestream" "controllerGroup"="image.openshift.io"
"controllerKind"="ImageStream" "source"="kind source: *v1.ImageStream"
I0417 11:34:12.397221       1 controller.go:193] kmm-hub "msg"="Starting Controller"
"controller"="imagestream" "controllerGroup"="image.openshift.io"
"controllerKind"="ImageStream"
I0417 11:34:12.498335       1 filter.go:196] kmm-hub "msg"="Listing all
ManagedClusterModules" "managedcluster"="local-cluster"
I0417 11:34:12.498570       1 filter.go:205] kmm-hub "msg"="Listed
ManagedClusterModules" "count"=0 "managedcluster"="local-cluster"
I0417 11:34:12.498629       1 filter.go:238] kmm-hub "msg"="Adding reconciliation
requests" "count"=0 "managedcluster"="local-cluster"
I0417 11:34:12.498687       1 filter.go:196] kmm-hub "msg"="Listing all
ManagedClusterModules" "managedcluster"="sno1-0"
I0417 11:34:12.498750       1 filter.go:205] kmm-hub "msg"="Listed
ManagedClusterModules" "count"=0 "managedcluster"="sno1-0"
I0417 11:34:12.498801       1 filter.go:238] kmm-hub "msg"="Adding reconciliation
requests" "count"=0 "managedcluster"="sno1-0"
I0417 11:34:12.501947       1 controller.go:227] kmm-hub "msg"="Starting workers"
"controller"="imagestream" "controllerGroup"="image.openshift.io"
"controllerKind"="ImageStream" "worker count"=1
```

```
I0417 11:34:12.501948       1 controller.go:227] kmm-hub "msg"="Starting workers"
"controller"="ManagedClusterModule" "controllerGroup"="hub.kmm.sigs.x-k8s.io"
"controllerKind"="ManagedClusterModule" "worker count"=1
I0417 11:34:12.502285       1 imagestream_reconciler.go:50] kmm-hub "msg"="registered
imagestream info mapping" "ImageStream"={"name":"driver-
toolkit","namespace":"openshift"} "controller"="imagestream"
"controllerGroup"="image.openshift.io" "controllerKind"="ImageStream"
"dtkImage"="quay.io/openshift-release-dev/ocp-v4.0-art-
dev@sha256:df42b4785a7a662b30da53bdb0d206120cf4d24b45674227b16051ba4b7c393
4" "name"="driver-toolkit" "namespace"="openshift"
"osImageVersion"="412.86.202302211547-0" "reconcileID"="e709ff0a-5664-4007-8270-
49b5dff8bae9"
```

4.12. KMM HUB AND SPOKE

In hub and spoke scenarios, many spoke clusters are connected to a central, powerful hub cluster. Kernel Module Management (KMM) depends on Red Hat Advanced Cluster Management (RHACM) to operate in hub and spoke environments.

KMM is compatible with hub and spoke environments through decoupling KMM features. A **ManagedClusterModule** Custom Resource Definition (CRD) is provided to wrap the existing **Module** CRD and extend it to select Spoke clusters. Also provided is KMM-Hub, a new standalone controller that builds images and signs modules on the hub cluster.

In hub and spoke setups, spokes are focused, resource-constrained clusters that are centrally managed by a hub cluster. Spokes run the single-cluster edition of KMM, with those resource-intensive features disabled. To adapt KMM to this environment, you should reduce the workload running on the spokes to the minimum, while the hub takes care of the expensive tasks.

Building kernel module images and signing the **.ko** files, should run on the hub. The scheduling of the Module Loader and Device Plugin **DaemonSets** can only happen on the spokes.

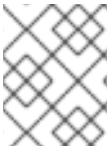
Additional resources

- Red Hat Advanced Cluster Management (RHACM)

4.12.1. KMM-Hub

The KMM project provides KMM-Hub, an edition of KMM dedicated to hub clusters. KMM-Hub monitors all kernel versions running on the spokes and determines the nodes on the cluster that should receive a kernel module.

KMM-Hub runs all compute-intensive tasks such as image builds and kmod signing, and prepares the trimmed-down **Module** to be transferred to the spokes through RHACM.



NOTE

KMM-Hub cannot be used to load kernel modules on the hub cluster. Install the regular edition of KMM to load kernel modules.

Additional resources

- Installing KMM

4.12.2. Installing KMM-Hub

You can use one of the following methods to install KMM-Hub:

- Using the Operator Lifecycle Manager (OLM)
- Creating KMM resources

Additional resources

- KMM Operator bundle

4.12.2.1. Installing KMM-Hub using the Operator Lifecycle Manager

Use the **Operators** section of the OpenShift console to install KMM-Hub.

4.12.2.2. Installing KMM-Hub by creating KMM resources

Procedure

- If you want to install KMM-Hub programmatically, you can use the following resources to create the **Namespace**, **OperatorGroup** and **Subscription** resources:

```
---
apiVersion: v1
kind: Namespace
metadata:
  name: openshift-kmm-hub
---
apiVersion: operators.coreos.com/v1
kind: OperatorGroup
metadata:
  name: kernel-module-management-hub
  namespace: openshift-kmm-hub
---
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: kernel-module-management-hub
  namespace: openshift-kmm-hub
spec:
  channel: stable
  installPlanApproval: Automatic
  name: kernel-module-management-hub
  source: redhat-operators
  sourceNamespace: openshift-marketplace
```

4.12.3. Using the ManagedClusterModule CRD

Use the **ManagedClusterModule** Custom Resource Definition (CRD) to configure the deployment of kernel modules on spoke clusters. This CRD is cluster-scoped, wraps a **Module** spec and adds the following additional fields:

```
apiVersion: hub.kmm.sigs.x-k8s.io/v1beta1
```

```
kind: ManagedClusterModule
metadata:
  name: <my-mcm>
  # No namespace, because this resource is cluster-scoped.
spec:
  moduleSpec: (1)
    selector: (2)
      node-wants-my-mcm: 'true'

  spokeNamespace: <some-namespace> (3)

  selector: (4)
    wants-my-mcm: 'true'
```

1. **moduleSpec**: Contains **moduleLoader** and **devicePlugin** sections, similar to a **Module** resource.
2. Selects nodes within the **ManagedCluster**.
3. Specifies in which namespace the **Module** should be created.
4. Selects **ManagedCluster** objects.

If build or signing instructions are present in **.spec.moduleSpec**, those pods are run on the hub cluster in the operator's namespace.

When the **.spec.selector matches** one or more **ManagedCluster** resources, then KMM-Hub creates a **ManifestWork** resource in the corresponding namespace(s). **ManifestWork** contains a trimmed-down **Module** resource, with kernel mappings preserved but all **build** and **sign** subsections are removed. **containerImage** fields that contain image names ending with a tag are replaced with their digest equivalent.

4.12.4. Running KMM on the spoke

After installing KMM on the spoke, no further action is required. Create a **ManagedClusterModule** object from the hub to deploy kernel modules on spoke clusters.

Procedure

You can install KMM on the spokes cluster through a RHACM **Policy** object. In addition to installing KMM from the Operator hub and running it in a lightweight spoke mode, the **Policy** configures additional RBAC required for the RHACM agent to be able to manage **Module** resources.

- Use the following RHACM policy to install KMM on spoke clusters:

```
---
apiVersion: policy.open-cluster-management.io/v1
kind: Policy
metadata:
  name: install-kmm
spec:
  remediationAction: enforce
  disabled: false
  policy-templates:
    - objectDefinition:
```

```
apiVersion: policy.open-cluster-management.io/v1
kind: ConfigurationPolicy
metadata:
  name: install-kmm
spec:
  severity: high
  object-templates:
  - complianceType: mustonlyhave
    objectDefinition:
      apiVersion: v1
      kind: Namespace
      metadata:
        name: openshift-kmm
  - complianceType: mustonlyhave
    objectDefinition:
      apiVersion: operators.coreos.com/v1
      kind: OperatorGroup
      metadata:
        name: kmm
        namespace: openshift-kmm
      spec:
        upgradeStrategy: Default
  - complianceType: mustonlyhave
    objectDefinition:
      apiVersion: operators.coreos.com/v1alpha1
      kind: Subscription
      metadata:
        name: kernel-module-management
        namespace: openshift-kmm
      spec:
        channel: stable
        config:
          env:
            - name: KMM_MANAGED
              value: "1"
        installPlanApproval: Automatic
        name: kernel-module-management
        source: redhat-operators
        sourceNamespace: openshift-marketplace
  - complianceType: mustonlyhave
    objectDefinition:
      apiVersion: rbac.authorization.k8s.io/v1
      kind: ClusterRole
      metadata:
        name: kmm-module-manager
      rules:
        - apiGroups: [kmm.sigs.x-k8s.io]
          resources: [modules]
          verbs: [create, delete, get, list, patch, update, watch]
  - complianceType: mustonlyhave
    objectDefinition:
      apiVersion: rbac.authorization.k8s.io/v1
      kind: ClusterRoleBinding
      metadata:
        name: klusterlet-kmm
      subjects:
```

```
            - kind: ServiceAccount
              name: klusterlet-work-sa
              namespace: open-cluster-management-agent
            roleRef:
              kind: ClusterRole
              name: kmm-module-manager
              apiGroup: rbac.authorization.k8s.io
---
apiVersion: apps.open-cluster-management.io/v1
kind: PlacementRule
metadata:
  name: all-managed-clusters
spec:
  clusterSelector: 1
    matchExpressions: []
---
apiVersion: policy.open-cluster-management.io/v1
kind: PlacementBinding
metadata:
  name: install-kmm
placementRef:
  apiGroup: apps.open-cluster-management.io
  kind: PlacementRule
  name: all-managed-clusters
subjects:
  - apiGroup: policy.open-cluster-management.io
    kind: Policy
    name: install-kmm
```

1 The **spec.clusterSelector** field can be customized to target select clusters only.