Using a KMS provider for data encryption

This page shows how to configure a Key Management Service (KMS) provider and plugin to enable secret data encryption. In Kubernetes 1.34 there are two versions of KMS at-rest encryption. You should use KMS v2 if feasible because KMS v1 is deprecated (since Kubernetes v1.28) and disabled by default (since Kubernetes v1.29). KMS v2 offers significantly better performance characteristics than KMS v1.

Caution:

This documentation is for the generally available implementation of KMS v2 (and for the deprecated version 1 implementation). If you are using any control plane components older than Kubernetes v1.29, please check the equivalent page in the documentation for the version of Kubernetes that your cluster is running. Earlier releases of Kubernetes had different behavior that may be relevant for information security.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

The version of Kubernetes that you need depends on which KMS API version you have selected. Kubernetes recommends using KMS v2.

- If you selected KMS API v1 to support clusters prior to version v1.27 or if you have a legacy KMS plugin that only supports KMS v1, any supported Kubernetes version will work. This API is deprecated as of Kubernetes v1.28. Kubernetes does not recommend the use of this API.

To check the version, enter `kubectl version`.

KMS v1

FEATURE STATE: `Kubernetes v1.28 [deprecated]`

- Kubernetes version 1.10.0 or later is required
- For version 1.29 and later, the v1 implementation of KMS is disabled by default. To enable the feature, set `--feature-gates=KMSv1=true` to configure a KMS v1 provider.
- Your cluster must use etcd v3 or later

KMS v2

FEATURE STATE: `Kubernetes v1.29 [stable]`

- Your cluster must use etcd v3 or later

KMS encryption and per-object encryption keys

The KMS encryption provider uses an envelope encryption scheme to encrypt data in etcd. The data is encrypted using a data encryption key (DEK). The DEKs are encrypted with a key encryption key (KEK) that is stored and managed in a remote KMS.

If you use the (deprecated) v1 implementation of KMS, a new DEK is generated for each encryption.

With KMS v2, a new DEK is generated **per encryption**: the API server uses a *key derivation function* to generate single use data encryption keys from a secret seed combined with some random data. The seed is rotated whenever the KEK is rotated (see the *Understanding key_id and Key Rotation* section below for more details).

The KMS provider uses gRPC to communicate with a specific KMS plugin over a UNIX domain socket. The KMS plugin, which is implemented as a gRPC server and deployed on the same host(s) as the Kubernetes control plane, is responsible for all communication with the remote KMS.

Configuring the KMS provider

To configure a KMS provider on the API server, include a provider of type `kms` in the `providers` array in the encryption configuration file and set the following properties:

KMS v1

- `apiVersion`: API Version for KMS provider. Leave this value empty or set it to `v1`.
- `name`: Display name of the KMS plugin. Cannot be changed once set.
- `endpoint`: Listen address of the gRPC server (KMS plugin). The endpoint is a UNIX domain socket.
- `cachesize`: Number of data encryption keys (DEKs) to be cached in the clear. When cached, DEKs can be used without another call to the KMS; whereas DEKs that are not cached require a call to the KMS to unwrap.
- `timeout`: How long should `kube-apiserver` wait for kms-plugin to respond before returning an error (default is 3 seconds).

KMS v2

- `apiVersion`: API Version for KMS provider. Set this to `v2`.
- `name`: Display name of the KMS plugin. Cannot be changed once set.
- `endpoint`: Listen address of the gRPC server (KMS plugin). The endpoint is a UNIX domain socket.
- `timeout`: How long should `kube-apiserver` wait for kms-plugin to respond before returning an error (default is 3 seconds).

KMS v2 does not support the `cachesize` property. All data encryption keys (DEKs) will be cached in the clear once the server has unwrapped them via a call to the KMS. Once cached, DEKs can be used to perform decryption indefinitely without making a call to the KMS.

See Understanding the encryption at rest configuration.

Implementing a KMS plugin

To implement a KMS plugin, you can develop a new plugin gRPC server or enable a KMS plugin already provided by your cloud provider. You then integrate the plugin with the remote KMS and deploy it on the Kubernetes control plane.

Enabling the KMS supported by your cloud provider

Refer to your cloud provider for instructions on enabling the cloud provider-specific KMS plugin.

Developing a KMS plugin gRPC server

You can develop a KMS plugin gRPC server using a stub file available for Go. For other languages, you use a proto file to create a stub file that you can use to develop the gRPC server code.

KMS v1

- Using Go: Use the functions and data structures in the stub file: api.pb.go to develop the gRPC server code
- Using languages other than Go: Use the protoc compiler with the proto file: api.proto to generate a stub file for the specific language

KMS v2

- Using Go: A high level library is provided to make the process easier. Low level implementations can use the functions and data structures in the stub file: api.pb.go to develop the gRPC server code
- Using languages other than Go: Use the protoc compiler with the proto file: api.proto to generate a stub file for the specific language

Then use the functions and data structures in the stub file to develop the server code.

Notes

KMS v1

- kms plugin version: `v1beta1`

  In response to procedure call Version, a compatible KMS plugin should return `v1beta1` as `VersionResponse.version`.

- message version: `v1beta1`

  All messages from KMS provider have the version field set to `v1beta1`.

- protocol: UNIX domain socket (`unix`)

  The plugin is implemented as a gRPC server that listens at UNIX domain socket. The plugin deployment should create a file on the file system to run the gRPC unix domain socket connection. The API server (gRPC client) is configured with the KMS provider (gRPC server) unix domain socket endpoint in order to communicate with it. An abstract Linux socket may be used by starting the endpoint with `/@`, i.e. `unix:///@foo`. Care must be taken when using this type of socket as they do not have concept of ACL (unlike traditional file based sockets). However, they are subject to Linux networking namespace, so will only be accessible to containers within the same pod unless host networking is used.

KMS v2

- KMS plugin version: `v2`

  In response to the `Status` remote procedure call, a compatible KMS plugin should return its KMS compatibility version as `StatusResponse.version`. That status response should also include "ok" as `StatusResponse.healthz` and a `key_id` (remote KMS KEK ID) as `StatusResponse.key_id`. The Kubernetes project recommends you make your plugin compatible with the stable `v2` KMS API. Kubernetes 1.34 also supports the `v2beta1` API for KMS; future Kubernetes releases are likely to continue supporting that beta version.

  The API server polls the `Status` procedure call approximately every minute when everything is healthy, and every 10 seconds when the plugin is not healthy. Plugins must take care to optimize this call as it will be under constant load.

- Encryption

  The `EncryptRequest` procedure call provides the plaintext and a UID for logging purposes. The response must include the ciphertext, the `key_id` for the KEK used, and, optionally, any metadata that the KMS plugin needs to aid in future `DecryptRequest` calls (via the `annotations` field). The plugin must guarantee that any distinct plaintext results in a distinct response `(ciphertext, key_id, annotations)`.

If the plugin returns a non-empty `annotations` map, all map keys must be fully qualified domain names such as `example.com`. An example use case of `annotation` is `{"kms.example.io/remote-kms-auditid":"<audit ID used by the remote KMS>"}`

The API server does not perform the `EncryptRequest` procedure call at a high rate. Plugin implementations should still aim to keep each request's latency at under 100 milliseconds.

- Decryption

  The `DecryptRequest` procedure call provides the `(ciphertext, key_id, annotations)` from `EncryptRequest` and a UID for logging purposes. As expected, it is the inverse of the `EncryptRequest` call. Plugins must verify that the `key_id` is one that they understand - they must not attempt to decrypt data unless they are sure that it was encrypted by them at an earlier time.

  The API server may perform thousands of `DecryptRequest` procedure calls on startup to fill its watch cache. Thus plugin implementations must perform these calls as quickly as possible, and should aim to keep each request's latency at under 10 milliseconds.

- Understanding `key_id` and Key Rotation

  The `key_id` is the public, non-secret name of the remote KMS KEK that is currently in use. It may be logged during regular operation of the API server, and thus must not contain any private data. Plugin implementations are encouraged to use a hash to avoid leaking any data. The KMS v2 metrics take care to hash this value before exposing it via the `/metrics` endpoint.

  The API server considers the `key_id` returned from the `Status` procedure call to be authoritative. Thus, a change to this value signals to the API server that the remote KEK has changed, and data encrypted with the old KEK should be marked stale when a no-op write is performed (as described below). If an `EncryptRequest` procedure call returns a `key_id` that is different from `Status`, the response is thrown away and the plugin is considered unhealthy. Thus implementations must guarantee that the `key_id` returned from `Status` will be the same as the one returned by `EncryptRequest`. Furthermore, plugins must ensure that the `key_id` is stable and does not flip-flop between values (i.e. during a remote KEK rotation).

  Plugins must not re-use `key_id`s, even in situations where a previously used remote KEK has been reinstated. For example, if a plugin was using `key_id=A`, switched to `key_id=B`, and then went back to `key_id=A` - instead of reporting `key_id=A` the plugin should report some derivative value such as `key_id=A_001` or use a new value such as `key_id=C`.

  Since the API server polls `Status` about every minute, `key_id` rotation is not immediate. Furthermore, the API server will coast on the last valid state for about three minutes. Thus if a user wants to take a passive approach to storage migration (i.e. by waiting), they must schedule a migration to occur at `3 + N + M` minutes after the remote KEK has been rotated (`N` is how long it takes the plugin to observe the `key_id` change and `M` is the desired buffer to allow config changes to be processed - a minimum `M` of five minutes is recommend). Note that no API server restart is required to perform KEK rotation.

  Caution:

  Because you don't control the number of writes performed with the DEK, the Kubernetes project recommends rotating the KEK at least every 90 days.

- protocol: UNIX domain socket (`unix`)

  The plugin is implemented as a gRPC server that listens at UNIX domain socket. The plugin deployment should create a file on the file system to run the gRPC unix domain socket connection. The API server (gRPC client) is configured with the KMS provider (gRPC server) unix domain socket endpoint in order to communicate with it. An abstract Linux socket may be used by starting the endpoint with `/@`, i.e. `unix:///@foo`. Care must be taken when using this type of socket as they do not have concept of ACL (unlike traditional file based sockets). However, they are subject to Linux networking namespace, so will only be accessible to containers within the same pod unless host networking is used.

Integrating a KMS plugin with the remote KMS

The KMS plugin can communicate with the remote KMS using any protocol supported by the KMS. All configuration data, including authentication credentials the KMS plugin uses to communicate with the remote KMS, are stored and managed by the KMS plugin independently. The KMS plugin can encode the ciphertext with additional metadata that may be required before sending it to the KMS for decryption (KMS v2 makes this process easier by providing a dedicated `annotations` field).

Deploying the KMS plugin

Ensure that the KMS plugin runs on the same host(s) as the Kubernetes API server(s).

Encrypting your data with the KMS provider

To encrypt the data:

1. Create a new `EncryptionConfiguration` file using the appropriate properties for the `kms` provider to encrypt resources like Secrets and ConfigMaps. If you want to encrypt an extension API that is defined in a CustomResourceDefinition, your cluster must be running Kubernetes v1.26 or newer.

2. Set the `--encryption-provider-config` flag on the kube-apiserver to point to the location of the configuration file.

3. `--encryption-provider-config-automatic-reload` boolean argument determines if the file set by `--encryption-provider-config` should be automatically reloaded if the disk contents change.

4. Restart your API server.

KMS v1

```
apiVersion: apiserver.config.k8s.io/v1
kind: EncryptionConfigurationresources:  - resources:      - secrets      - configmaps      - pandas.awesome.bears.example    prov
```

KMS v2

```
apiVersion: apiserver.config.k8s.io/v1
kind: EncryptionConfigurationresources:  - resources:      - secrets      - configmaps      - pandas.awesome.bears.example    prov
```

Setting `--encryption-provider-config-automatic-reload` to `true` collapses all health checks to a single health check endpoint. Individual health checks are only available when KMS v1 providers are in use and the encryption config is not auto-reloaded.

The following table summarizes the health check endpoints for each KMS version:

KMS configurations	Without Automatic Reload	With Automatic Reload
KMS v1 only	Individual Healthchecks	Single Healthcheck
KMS v2 only	Single Healthcheck	Single Healthcheck
Both KMS v1 and v2	Individual Healthchecks	Single Healthcheck
No KMS	None	Single Healthcheck

`Single Healthcheck` means that the only health check endpoint is `/healthz/kms-providers`.

`Individual Healthchecks` means that each KMS plugin has an associated health check endpoint based on its location in the encryption config: `/healthz/kms-provider-0`, `/healthz/kms-provider-1` etc.

These healthcheck endpoint paths are hard coded and generated/controlled by the server. The indices for individual healthchecks corresponds to the order in which the KMS encryption config is processed.

Until the steps defined in Ensuring all secrets are encrypted are performed, the `providers` list should end with the `identity: {}` provider to allow unencrypted data to be read. Once all resources are encrypted, the `identity` provider should be removed to prevent the API server from honoring unencrypted data.

For details about the `EncryptionConfiguration` format, please check the API server encryption API reference.

Verifying that the data is encrypted

When encryption at rest is correctly configured, resources are encrypted on write. After restarting your `kube-apiserver`, any newly created or updated Secret or other resource types configured in `EncryptionConfiguration` should be encrypted when stored. To verify, you can use the `etcdctl` command line program to retrieve the contents of your secret data.

1. Create a new secret called `secret1` in the `default` namespace:

   ```
   kubectl create secret generic secret1 -n default --from-literal=mykey=mydata
   ```

2. Using the `etcdctl` command line, read that secret out of etcd:

   ```
   ETCDCTL_API=3 etcdctl get /kubernetes.io/secrets/default/secret1 [...] | hexdump -C
   ```

   where `[...]` contains the additional arguments for connecting to the etcd server.

3. Verify the stored secret is prefixed with `k8s:enc:kms:v1:` for KMS v1 or prefixed with `k8s:enc:kms:v2:` for KMS v2, which indicates that the `kms` provider has encrypted the resulting data.

4. Verify that the secret is correctly decrypted when retrieved via the API:

   ```
   kubectl describe secret secret1 -n default
   ```

   The Secret should contain `mykey: mydata`

Ensuring all secrets are encrypted

When encryption at rest is correctly configured, resources are encrypted on write. Thus we can perform an in-place no-op update to ensure that data is encrypted.

The following command reads all secrets and then updates them to apply server side encryption. If an error occurs due to a conflicting write, retry the command. For larger clusters, you may wish to subdivide the secrets by namespace or script an update.

```
kubectl get secrets --all-namespaces -o json | kubectl replace -f -
```

Switching from a local encryption provider to the KMS provider

To switch from a local encryption provider to the `kms` provider and re-encrypt all of the secrets:

1. Add the `kms` provider as the first entry in the configuration file as shown in the following example.

   ```
   apiVersion: apiserver.config.k8s.io/v1
   kind: EncryptionConfigurationresources:  - resources:      - secrets    providers:      - kms:          apiVersion: v2
   ```

2. Restart all `kube-apiserver` processes.

3. Run the following command to force all secrets to be re-encrypted using the `kms` provider.

   ```
   kubectl get secrets --all-namespaces -o json | kubectl replace -f -
   ```

What's next

If you no longer want to use encryption for data persisted in the Kubernetes API, read decrypt data that are already stored at rest.

Change the Reclaim Policy of a PersistentVolume

This page shows how to change the reclaim policy of a Kubernetes PersistentVolume.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

To check the version, enter `kubectl version`.

Why change reclaim policy of a PersistentVolume

PersistentVolumes can have various reclaim policies, including "Retain", "Recycle", and "Delete". For dynamically provisioned PersistentVolumes, the default reclaim policy is "Delete". This means that a dynamically provisioned volume is automatically deleted when a user deletes the corresponding PersistentVolumeClaim. This automatic behavior might be inappropriate if the volume contains precious data. In that case, it is more appropriate to use the "Retain" policy. With the "Retain" policy, if a user deletes a PersistentVolumeClaim, the corresponding PersistentVolume will not be deleted. Instead, it is moved to the Released phase, where all of its data can be manually recovered.

Changing the reclaim policy of a PersistentVolume

1. List the PersistentVolumes in your cluster:

   ```
   kubectl get pv
   ```

   The output is similar to this:

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

   This list also includes the name of the claims that are bound to each volume for easier identification of dynamically provisioned volumes.

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

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

   where `<your-pv-name>` is the name of your chosen PersistentVolume.

   Note:

   On Windows, you must *double* quote any JSONPath template that contains spaces (not single quote as shown above for bash). This in turn means that you must use a single quote or escaped double quote around any literals in the template. For example:

   ```
   kubectl patch pv <your-pv-name> -p "{\"spec\":{\"persistentVolumeReclaimPolicy\":\"Retain\"}}"
   ```

3. Verify that your chosen PersistentVolume has the right policy:

   ```
   kubectl get pv
   ```

   The output is similar to this:

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

   In the preceding output, you can see that the volume bound to claim `default/claim3` has reclaim policy `Retain`. It will not be automatically deleted when a user deletes claim `default/claim3`.

What's next

- Learn more about PersistentVolumes.
- Learn more about PersistentVolumeClaims.

References

- PersistentVolume
  - Pay attention to the `.spec.persistentVolumeReclaimPolicy` field of PersistentVolume.
- PersistentVolumeClaim

Configure Minimum and Maximum CPU Constraints for a Namespace

Define a range of valid CPU resource limits for a namespace, so that every new Pod in that namespace falls within the range you configure.

This page shows how to set minimum and maximum values for the CPU resources used by containers and Pods in a namespace. You specify minimum and maximum CPU values in a LimitRange object. If a Pod does not meet the constraints imposed by the LimitRange, it cannot be created in the namespace.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

You must have access to create namespaces in your cluster.

Each node in your cluster must have at least 1.0 CPU available for Pods. See meaning of CPU to learn what Kubernetes means by “1 CPU”.

Create a namespace

Create a namespace so that the resources you create in this exercise are isolated from the rest of your cluster.

```
kubectl create namespace constraints-cpu-example
```

Create a LimitRange and a Pod

Here's a manifest for an example LimitRange:

admin/resource/cpu-constraints.yaml Copy admin/resource/cpu-constraints.yaml to clipboard

```
apiVersion: v1
kind: LimitRangemetadata:  name: cpu-min-max-demo-lrspec:  limits:  - max:      cpu: "800m"    min:      cpu: "200m"    type: Conta
```

Create the LimitRange:

```
kubectl apply -f https://k8s.io/examples/admin/resource/cpu-constraints.yaml --namespace=constraints-cpu-example
```

View detailed information about the LimitRange:

```
kubectl get limitrange cpu-min-max-demo-lr --output=yaml --namespace=constraints-cpu-example
```

The output shows the minimum and maximum CPU constraints as expected. But notice that even though you didn't specify default values in the configuration file for the LimitRange, they were created automatically.

```
limits:
- default:    cpu: 800m  defaultRequest:    cpu: 800m  max:    cpu: 800m  min:    cpu: 200m  type: Container
```

Now whenever you create a Pod in the constraints-cpu-example namespace (or some other client of the Kubernetes API creates an equivalent Pod), Kubernetes performs these steps:

- If any container in that Pod does not specify its own CPU request and limit, the control plane assigns the default CPU request and limit to that container.
- Verify that every container in that Pod specifies a CPU request that is greater than or equal to 200 millicpu.
- Verify that every container in that Pod specifies a CPU limit that is less than or equal to 800 millicpu.

Note:

When creating a `LimitRange` object, you can specify limits on huge-pages or GPUs as well. However, when both `default` and `defaultRequest` are specified on these resources, the two values must be the same.

Here's a manifest for a Pod that has one container. The container manifest specifies a CPU request of 500 millicpu and a CPU limit of 800 millicpu. These satisfy the minimum and maximum CPU constraints imposed by the LimitRange for this namespace.

admin/resource/cpu-constraints-pod.yaml Copy admin/resource/cpu-constraints-pod.yaml to clipboard

```
apiVersion: v1
kind: Podmetadata:  name: constraints-cpu-demospec:  containers:  - name: constraints-cpu-demo-ctr    image: nginx    resources:
```

Create the Pod:

```
kubectl apply -f https://k8s.io/examples/admin/resource/cpu-constraints-pod.yaml --namespace=constraints-cpu-example
```

Verify that the Pod is running and that its container is healthy:

```
kubectl get pod constraints-cpu-demo --namespace=constraints-cpu-example
```

View detailed information about the Pod:

```
kubectl get pod constraints-cpu-demo --output=yaml --namespace=constraints-cpu-example
```

The output shows that the Pod's only container has a CPU request of 500 millicpu and CPU limit of 800 millicpu. These satisfy the constraints imposed by the LimitRange.

```
resources:
  limits:
    cpu: 800m
  requests:
    cpu: 500m
```

Delete the Pod

```
kubectl delete pod constraints-cpu-demo --namespace=constraints-cpu-example
```

Attempt to create a Pod that exceeds the maximum CPU constraint

Here's a manifest for a Pod that has one container. The container specifies a CPU request of 500 millicpu and a cpu limit of 1.5 cpu.

admin/resource/cpu-constraints-pod-2.yaml 

```
apiVersion: v1
kind: Podmetadata:  name: constraints-cpu-demo-2spec:  containers:  - name: constraints-cpu-demo-2-ctr    image: nginx    resource
```

Attempt to create the Pod:

```
kubectl apply -f https://k8s.io/examples/admin/resource/cpu-constraints-pod-2.yaml --namespace=constraints-cpu-example
```

The output shows that the Pod does not get created, because it defines an unacceptable container. That container is not acceptable because it specifies a CPU limit that is too large:

```
Error from server (Forbidden): error when creating "examples/admin/resource/cpu-constraints-pod-2.yaml":
pods "constraints-cpu-demo-2" is forbidden: maximum cpu usage per Container is 800m, but limit is 1500m.
```

Attempt to create a Pod that does not meet the minimum CPU request

Here's a manifest for a Pod that has one container. The container specifies a CPU request of 100 millicpu and a CPU limit of 800 millicpu.

admin/resource/cpu-constraints-pod-3.yaml 

```
apiVersion: v1
kind: Podmetadata:  name: constraints-cpu-demo-3spec:  containers:  - name: constraints-cpu-demo-3-ctr    image: nginx    resource
```

Attempt to create the Pod:

```
kubectl apply -f https://k8s.io/examples/admin/resource/cpu-constraints-pod-3.yaml --namespace=constraints-cpu-example
```

The output shows that the Pod does not get created, because it defines an unacceptable container. That container is not acceptable because it specifies a CPU request that is lower than the enforced minimum:

```
Error from server (Forbidden): error when creating "examples/admin/resource/cpu-constraints-pod-3.yaml":
pods "constraints-cpu-demo-3" is forbidden: minimum cpu usage per Container is 200m, but request is 100m.
```

Create a Pod that does not specify any CPU request or limit

Here's a manifest for a Pod that has one container. The container does not specify a CPU request, nor does it specify a CPU limit.

admin/resource/cpu-constraints-pod-4.yaml

```
apiVersion: v1
kind: Podmetadata:  name: constraints-cpu-demo-4spec:  containers:  - name: constraints-cpu-demo-4-ctr    image: vish/stress
```

Create the Pod:

```
kubectl apply -f https://k8s.io/examples/admin/resource/cpu-constraints-pod-4.yaml --namespace=constraints-cpu-example
```

View detailed information about the Pod:

```
kubectl get pod constraints-cpu-demo-4 --namespace=constraints-cpu-example --output=yaml
```

The output shows that the Pod's single container has a CPU request of 800 millicpu and a CPU limit of 800 millicpu. How did that container get those values?

```
resources:
  limits:
    cpu: 800m
  requests:
    cpu: 800m
```

Because that container did not specify its own CPU request and limit, the control plane applied the default CPU request and limit from the LimitRange for this namespace.

At this point, your Pod may or may not be running. Recall that a prerequisite for this task is that your Nodes must have at least 1 CPU available for use. If each of your Nodes has only 1 CPU, then there might not be enough allocatable CPU on any Node to accommodate a request of 800 millicpu. If you happen to be using Nodes with 2 CPU, then you probably have enough CPU to accommodate the 800 millicpu request.

Delete your Pod:

```
kubectl delete pod constraints-cpu-demo-4 --namespace=constraints-cpu-example
```

Enforcement of minimum and maximum CPU constraints

The maximum and minimum CPU constraints imposed on a namespace by a LimitRange are enforced only when a Pod is created or updated. If you change the LimitRange, it does not affect Pods that were created previously.

Motivation for minimum and maximum CPU constraints

As a cluster administrator, you might want to impose restrictions on the CPU resources that Pods can use. For example:

- Each Node in a cluster has 2 CPU. You do not want to accept any Pod that requests more than 2 CPU, because no Node in the cluster can support the request.
- A cluster is shared by your production and development departments. You want to allow production workloads to consume up to 3 CPU, but you want development workloads to be limited to 1 CPU. You create separate namespaces for production and development, and you apply CPU constraints to each namespace.

Clean up

Delete your namespace:

```
kubectl delete namespace constraints-cpu-example
```

What's next

For cluster administrators

- Configure Default Memory Requests and Limits for a Namespace
- Configure Default CPU Requests and Limits for a Namespace
- Configure Minimum and Maximum Memory Constraints for a Namespace
- Configure Memory and CPU Quotas for a Namespace
- Configure a Pod Quota for a Namespace
- Configure Quotas for API Objects

For app developers

- Assign Memory Resources to Containers and Pods
- Assign CPU Resources to Containers and Pods
- Assign Pod-level CPU and memory resources
- Configure Quality of Service for Pods

Configure Access to Multiple Clusters

This page shows how to configure access to multiple clusters by using configuration files. After your clusters, users, and contexts are defined in one or more configuration files, you can quickly switch between clusters by using the `kubectl config use-context` command.

Note:

A file that is used to configure access to a cluster is sometimes called a *kubeconfig file*. This is a generic way of referring to configuration files. It does not mean that there is a file named `kubeconfig`.

Warning:

Only use kubeconfig files from trusted sources. Using a specially-crafted kubeconfig file could result in malicious code execution or file exposure. If you must use an untrusted kubeconfig file, inspect it carefully first, much as you would a shell script.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using

minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

To check that kubectl is installed, run `kubectl version --client`. The kubectl version should be within one minor version of your cluster's API server.

Define clusters, users, and contexts

Suppose you have two clusters, one for development work and one for test work. In the `development` cluster, your frontend developers work in a namespace called `frontend`, and your storage developers work in a namespace called `storage`. In your `test` cluster, developers work in the default namespace, or they create auxiliary namespaces as they see fit. Access to the development cluster requires authentication by certificate. Access to the test cluster requires authentication by username and password.

Create a directory named `config-exercise`. In your `config-exercise` directory, create a file named `config-demo` with this content:

```
apiVersion: v1
kind: Configpreferences: {}clusters:- cluster:  name: development- cluster:  name: testusers:- name: developer- name: experimenter
```

A configuration file describes clusters, users, and contexts. Your `config-demo` file has the framework to describe two clusters, two users, and three contexts.

Go to your `config-exercise` directory. Enter these commands to add cluster details to your configuration file:

```
kubectl config --kubeconfig=config-demo set-cluster development --server=https://1.2.3.4 --certificate-authority=fake-ca-file
kubectl config --kubeconfig=config-demo set-cluster test --server=https://5.6.7.8 --insecure-skip-tls-verify
```

Add user details to your configuration file:

Caution:

Storing passwords in Kubernetes client config is risky. A better alternative would be to use a credential plugin and store them separately. See: client-go credential plugins

```
kubectl config --kubeconfig=config-demo set-credentials developer --client-certificate=fake-cert-file --client-key=fake-key-seefil
kubectl config --kubeconfig=config-demo set-credentials experimenter --username=exp --password=some-password
```

Note:

- To delete a user you can run `kubectl --kubeconfig=config-demo config unset users.<name>`
- To remove a cluster, you can run `kubectl --kubeconfig=config-demo config unset clusters.<name>`
- To remove a context, you can run `kubectl --kubeconfig=config-demo config unset contexts.<name>`

Add context details to your configuration file:

```
kubectl config --kubeconfig=config-demo set-context dev-frontend --cluster=development --namespace=frontend --user=developer
kubectl config --kubeconfig=config-demo set-context dev-storage --cluster=development --namespace=storage --user=developer
kubectl config --kubeconfig=config-demo set-context exp-test --cluster=test --namespace=default --user=experimenter
```

Open your `config-demo` file to see the added details. As an alternative to opening the `config-demo` file, you can use the `config view` command.

```
kubectl config --kubeconfig=config-demo view
```

The output shows the two clusters, two users, and three contexts:

```
apiVersion: v1
clusters:- cluster:    certificate-authority: fake-ca-file    server: https://1.2.3.4  name: development- cluster:    insecure-skip
```

The `fake-ca-file`, `fake-cert-file` and `fake-key-file` above are the placeholders for the pathnames of the certificate files. You need to change these to the actual pathnames of certificate files in your environment.

Sometimes you may want to use Base64-encoded data embedded here instead of separate certificate files; in that case you need to add the suffix `-data` to the keys, for example, `certificate-authority-data`, `client-certificate-data`, `client-key-data`.

Each context is a triple (cluster, user, namespace). For example, the `dev-frontend` context says, "Use the credentials of the `developer` user to access the `frontend` namespace of the `development` cluster".

Set the current context:

```
kubectl config --kubeconfig=config-demo use-context dev-frontend
```

Now whenever you enter a `kubectl` command, the action will apply to the cluster, and namespace listed in the `dev-frontend` context. And the command will use the credentials of the user listed in the `dev-frontend` context.

To see only the configuration information associated with the current context, use the `--minify` flag.

```
kubectl config --kubeconfig=config-demo view --minify
```

The output shows configuration information associated with the `dev-frontend` context:

```
apiVersion: v1
clusters:- cluster:    certificate-authority: fake-ca-file    server: https://1.2.3.4  name: developmentcontexts:- context:    clu
```

Now suppose you want to work for a while in the test cluster.

Change the current context to `exp-test`:

```
kubectl config --kubeconfig=config-demo use-context exp-test
```

Now any `kubectl` command you give will apply to the default namespace of the `test` cluster. And the command will use the credentials of the user listed in the `exp-test` context.

View configuration associated with the new current context, `exp-test`.

```
kubectl config --kubeconfig=config-demo view --minify
```

Finally, suppose you want to work for a while in the `storage` namespace of the `development` cluster.

Change the current context to `dev-storage`:

```
kubectl config --kubeconfig=config-demo use-context dev-storage
```

View configuration associated with the new current context, `dev-storage`.

```
kubectl config --kubeconfig=config-demo view --minify
```

Create a second configuration file

In your `config-exercise` directory, create a file named `config-demo-2` with this content:

```
apiVersion: v1
kind: Configpreferences: {}contexts:- context:    cluster: development    namespace: ramp    user: developer  name: dev-ramp-up
```

The preceding configuration file defines a new context named `dev-ramp-up`.

Set the KUBECONFIG environment variable

See whether you have an environment variable named `KUBECONFIG`. If so, save the current value of your `KUBECONFIG` environment variable, so you can restore it later. For example:

Linux

```
export KUBECONFIG_SAVED="$KUBECONFIG"
```

Windows PowerShell

```
$Env:KUBECONFIG_SAVED=$ENV:KUBECONFIG
```

The `KUBECONFIG` environment variable is a list of paths to configuration files. The list is colon-delimited for Linux and Mac, and semicolon-delimited for Windows. If you have a `KUBECONFIG` environment variable, familiarize yourself with the configuration files in the list.

Temporarily append two paths to your `KUBECONFIG` environment variable. For example:

Linux

```
export KUBECONFIG="${KUBECONFIG}:config-demo:config-demo-2"
```

Windows PowerShell

```
$Env:KUBECONFIG=("config-demo;config-demo-2")
```

In your `config-exercise` directory, enter this command:

```
kubectl config view
```

The output shows merged information from all the files listed in your `KUBECONFIG` environment variable. In particular, notice that the merged information has the `dev-ramp-up` context from the `config-demo-2` file and the three contexts from the `config-demo` file:

```
contexts:
- context:    cluster: development    namespace: frontend    user: developer  name: dev-frontend- context:    cluster: development
```

For more information about how kubeconfig files are merged, see Organizing Cluster Access Using kubeconfig Files

Explore the $HOME/.kube directory

If you already have a cluster, and you can use `kubectl` to interact with the cluster, then you probably have a file named `config` in the `$HOME/.kube` directory.

Go to `$HOME/.kube`, and see what files are there. Typically, there is a file named `config`. There might also be other configuration files in this directory. Briefly familiarize yourself with the contents of these files.

Append $HOME/.kube/config to your KUBECONFIG environment variable

If you have a `$HOME/.kube/config` file, and it's not already listed in your `KUBECONFIG` environment variable, append it to your `KUBECONFIG` environment variable now. For example:

Linux

```
export KUBECONFIG="${KUBECONFIG}:${HOME}/.kube/config"
```

Windows Powershell

```
$Env:KUBECONFIG="$Env:KUBECONFIG;$HOME\.kube\config"
```

View configuration information merged from all the files that are now listed in your `KUBECONFIG` environment variable. In your config-exercise directory, enter:

```
kubectl config view
```

Clean up

Return your `KUBECONFIG` environment variable to its original value. For example:

Linux

```
export KUBECONFIG="$KUBECONFIG_SAVED"
```

Windows PowerShell

```
$Env:KUBECONFIG=$ENV:KUBECONFIG_SAVED
```

Check the subject represented by the kubeconfig

It is not always obvious what attributes (username, groups) you will get after authenticating to the cluster. It can be even more challenging if you are managing more than one cluster at the same time.

There is a `kubectl` subcommand to check subject attributes, such as username, for your selected Kubernetes client context: `kubectl auth whoami`.

Read API access to authentication information for a client to learn about this in more detail.

What's next

- Organizing Cluster Access Using kubeconfig Files
- kubectl config

Set Kubelet Parameters Via A Configuration File

Before you begin

Some steps in this page use the `jq` tool. If you don't have `jq`, you can install it via your operating system's software sources, or fetch it from https://jqlang.github.io/jq/.

Some steps also involve installing `curl`, which can be installed via your operating system's software sources.

A subset of the kubelet's configuration parameters may be set via an on-disk config file, as a substitute for command-line flags.

Providing parameters via a config file is the recommended approach because it simplifies node deployment and configuration management.

Create the config file

The subset of the kubelet's configuration that can be configured via a file is defined by the `KubeletConfiguration` struct.

The configuration file must be a JSON or YAML representation of the parameters in this struct. Make sure the kubelet has read permissions on the file.

Here is an example of what this file might look like:

```
apiVersion: kubelet.config.k8s.io/v1beta1
kind: KubeletConfigurationaddress: "192.168.0.8"port: 20250serializeImagePulls: falseevictionHard:    memory.available:  "100Mi"
```

In this example, the kubelet is configured with the following settings:

1. `address`: The kubelet will serve on IP address `192.168.0.8`.
2. `port`: The kubelet will serve on port `20250`.
3. `serializeImagePulls`: Image pulls will be done in parallel.
4. `evictionHard`: The kubelet will evict Pods under one of the following conditions:
    - When the node's available memory drops below 100MiB.
    - When the node's main filesystem's available space is less than 10%.
    - When the image filesystem's available space is less than 15%.
    - When more than 95% of the node's main filesystem's inodes are in use.

Note:

In the example, by changing the default value of only one parameter for evictionHard, the default values of other parameters will not be inherited and will be set to zero. In order to provide custom values, you should provide all the threshold values respectively. Alternatively, you can set the MergeDefaultEvictionSettings to true in the kubelet configuration file, if any parameter is changed then the other parameters will inherit their default values instead of 0.

The `imagefs` is an optional filesystem that container runtimes use to store container images and container writable layers.

Start a kubelet process configured via the config file

Note:

If you use kubeadm to initialize your cluster, use the kubelet-config while creating your cluster with `kubeadm init`. See configuring kubelet using kubeadm for details.

Start the kubelet with the `--config` flag set to the path of the kubelet's config file. The kubelet will then load its config from this file.

Note that command line flags which target the same value as a config file will override that value. This helps ensure backwards compatibility with the command-line API.

Note that relative file paths in the kubelet config file are resolved relative to the location of the kubelet config file, whereas relative paths in command line flags are resolved relative to the kubelet's current working directory.

Note that some default values differ between command-line flags and the kubelet config file. If `--config` is provided and the values are not specified via the command line, the defaults for the `KubeletConfiguration` version apply. In the above example, this version is `kubelet.config.k8s.io/v1beta1`.

Drop-in directory for kubelet configuration files

FEATURE STATE: `Kubernetes v1.30 [beta]`

You can specify a drop-in configuration directory for the kubelet. By default, the kubelet does not look for drop-in configuration files anywhere - you must specify a path. For example: `--config-dir=/etc/kubernetes/kubelet.conf.d`

For Kubernetes v1.28 to v1.29, you can only specify `--config-dir` if you also set the environment variable `KUBELET_CONFIG_DROPIN_DIR_ALPHA` for the kubelet process (the value of that variable does not matter).

Note:

The suffix of a valid kubelet drop-in configuration file **must** be `.conf`. For instance: `99-kubelet-address.conf`

The kubelet processes files in its config drop-in directory by sorting the **entire file name** alphanumerically. For instance, `00-kubelet.conf` is processed first, and then overridden with a file named `01-kubelet.conf`.

These files may contain partial configurations but should not be invalid and must include type metadata, specifically `apiVersion` and `kind`. Validation is only performed on the final resulting configuration structure stored internally in the kubelet. This offers flexibility in managing and merging kubelet configurations from different sources while preventing undesirable configurations. However, it is important to note that behavior varies based on the data type of the configuration fields.

Different data types in the kubelet configuration structure merge differently. See the reference document for more information.

Kubelet configuration merging order

On startup, the kubelet merges configuration from:

- Feature gates specified over the command line (lowest precedence).
- The kubelet configuration.
- Drop-in configuration files, according to sort order.
- Command line arguments excluding feature gates (highest precedence).

Note:

The config drop-in dir mechanism for the kubelet is similar but different from how the `kubeadm` tool allows you to patch configuration. The `kubeadm` tool uses a specific patching strategy for its configuration, whereas the only patch strategy for kubelet configuration drop-in files is `replace`. The kubelet determines the order of merges based on sorting the **suffixes** alphanumerically, and replaces every field present in a higher priority file.

Viewing the kubelet configuration

Since the configuration could now be spread over multiple files with this feature, if someone wants to inspect the final actuated configuration, they can follow these steps to inspect the kubelet configuration:

1. Start a proxy server using `kubectl proxy` in your terminal.

   ```
   kubectl proxy
   ```

   Which gives output like:

   ```
   Starting to serve on 127.0.0.1:8001
   ```

2. Open another terminal window and use `curl` to fetch the kubelet configuration. Replace `<node-name>` with the actual name of your node:

```
curl -X GET http://127.0.0.1:8001/api/v1/nodes/<node-name>/proxy/configz | jq .
```


```
{
  "kubeletconfig": {
    "enableServer": true,
    "staticPodPath": "/var/run/kubernetes/static-pods",
    "syncFrequency": "1m0s",
    "fileCheckFrequency": "20s",
    "httpCheckFrequency": "20s",
    "address": "192.168.1.16",
    "port": 10250,
    "readOnlyPort": 10255,
    "tlsCertFile": "/var/lib/kubelet/pki/kubelet.crt",
    "tlsPrivateKeyFile": "/var/lib/kubelet/pki/kubelet.key",
    "rotateCertificates": true,
    "authentication": {
      "x509": {
        "clientCAFile": "/var/run/kubernetes/client-ca.crt"
      },
      "webhook": {
        "enabled": true,
        "cacheTTL": "2m0s"
      },
      "anonymous": {
        "enabled": true
      }
    },
    "authorization": {
      "mode": "AlwaysAllow",
      "webhook": {
        "cacheAuthorizedTTL": "5m0s",
        "cacheUnauthorizedTTL": "30s"
      }
    },
    "registryPullQPS": 5,
    "registryBurst": 10,
    "eventRecordQPS": 50,
    "eventBurst": 100,
    "enableDebuggingHandlers": true,
    "healthzPort": 10248,
    "healthzBindAddress": "127.0.0.1",
    "oomScoreAdj": -999,
    "clusterDomain": "cluster.local",
    "clusterDNS": [
      "10.0.0.10"
    ],
    "streamingConnectionIdleTimeout": "4h0m0s",
    "nodeStatusUpdateFrequency": "10s",
    "nodeStatusReportFrequency": "5m0s",
    "nodeLeaseDurationSeconds": 40,
    "imageMinimumGCAge": "2m0s",
    "imageMaximumGCAge": "0s",
    "imageGCHighThresholdPercent": 85,
    "imageGCLowThresholdPercent": 80,
    "volumeStatsAggPeriod": "1m0s",
    "cgroupsPerQOS": true,
    "cgroupDriver": "systemd",
    "cpuManagerPolicy": "none",
    "cpuManagerReconcilePeriod": "10s",
    "memoryManagerPolicy": "None",
    "topologyManagerPolicy": "none",
    "topologyManagerScope": "container",
    "runtimeRequestTimeout": "2m0s",
    "hairpinMode": "promiscuous-bridge",
    "maxPods": 110,
    "podPidsLimit": -1,
    "resolvConf": "/run/systemd/resolve/resolv.conf",
    "cpuCFSQuota": true,
    "cpuCFSQuotaPeriod": "100ms",
    "nodeStatusMaxImages": 50,
    "maxOpenFiles": 1000000,
    "contentType": "application/vnd.kubernetes.protobuf",
    "kubeAPIQPS": 50,
    "kubeAPIBurst": 100,
    "serializeImagePulls": true,
    "evictionHard": {
      "imagefs.available": "15%",
      "memory.available": "100Mi",
      "nodefs.available": "10%",
      "nodefs.inodesFree": "5%",
      "imagefs.inodesFree": "5%"
    },
    "evictionPressureTransitionPeriod": "1m0s",
    "mergeDefaultEvictionSettings": false,
    "enableControllerAttachDetach": true,
    "makeIPTablesUtilChains": true,
    "iptablesMasqueradeBit": 14,
    "iptablesDropBit": 15,
    "featureGates": {
      "AllAlpha": false
    },
    "failSwapOn": false,
    "memorySwap": {},
    "containerLogMaxSize": "10Mi",
    "containerLogMaxFiles": 5,
```

```
      "configMapAndSecretChangeDetectionStrategy": "Watch",
      "enforceNodeAllocatable": [
        "pods"
      ],
      "volumePluginDir": "/usr/libexec/kubernetes/kubelet-plugins/volume/exec/",
      "logging": {
        "format": "text",
        "flushFrequency": "5s",
        "verbosity": 3,
        "options": {
          "json": {
            "infoBufferSize": "0"
          }
        }
      },
      "enableSystemLogHandler": true,
      "enableSystemLogQuery": false,
      "shutdownGracePeriod": "0s",
      "shutdownGracePeriodCriticalPods": "0s",
      "enableProfilingHandler": true,
      "enableDebugFlagsHandler": true,
      "seccompDefault": false,
      "memoryThrottlingFactor": 0.9,
      "registerNode": true,
      "localStorageCapacityIsolation": true,
      "containerRuntimeEndpoint": "unix:///var/run/crio/crio.sock"
    }
}
```


What's next

- Learn more about kubelet configuration by checking the `KubeletConfiguration` reference.
- Learn more about kubelet configuration merging in the reference document.

Change the Access Mode of a PersistentVolume to ReadWriteOncePod

This page shows how to change the access mode on an existing PersistentVolume to use `ReadWriteOncePod`.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

Your Kubernetes server must be at or later than version v1.22.

To check the version, enter `kubectl version`.

Note:

The `ReadWriteOncePod` access mode graduated to stable in the Kubernetes v1.29 release. If you are running a version of Kubernetes older than v1.29, you might need to enable a feature gate. Check the documentation for your version of Kubernetes.

Note:

The `ReadWriteOncePod` access mode is only supported for CSI volumes. To use this volume access mode you will need to update the following CSI sidecars to these versions or greater:

- csi-provisioner:v3.0.0+
- csi-attacher:v3.3.0+
- csi-resizer:v1.3.0+

Why should I use `ReadWriteOncePod`?

Prior to Kubernetes v1.22, the `ReadWriteOnce` access mode was commonly used to restrict PersistentVolume access for workloads that required single-writer access to storage. However, this access mode had a limitation: it restricted volume access to a single *node*, allowing multiple pods on the same node to read from and write to the same volume simultaneously. This could pose a risk for applications that demand strict single-writer access for data safety.

If ensuring single-writer access is critical for your workloads, consider migrating your volumes to `ReadWriteOncePod`.

Migrating existing PersistentVolumes

If you have existing PersistentVolumes, they can be migrated to use `ReadWriteOncePod`. Only migrations from `ReadWriteOnce` to `ReadWriteOncePod` are supported.

In this example, there is already a `ReadWriteOnce` "cat-pictures-pvc" PersistentVolumeClaim that is bound to a "cat-pictures-pv" PersistentVolume, and a "cat-pictures-writer" Deployment that uses this PersistentVolumeClaim.

Note:

If your storage plugin supports Dynamic provisioning, the "cat-picutres-pv" will be created for you, but its name may differ. To get your PersistentVolume's name run:

```
kubectl get pvc cat-pictures-pvc -o jsonpath='{.spec.volumeName}'
```

And you can view the PVC before you make changes. Either view the manifest locally, or run `kubectl get pvc <name-of-pvc> -o yaml`. The output is similar to:

```
# cat-pictures-pvc.yaml
kind: PersistentVolumeClaimapiVersion: v1metadata:  name: cat-pictures-pvcspec:  accessModes:  - ReadWriteOnce  resources:    requ
```

Here's an example Deployment that relies on that PersistentVolumeClaim:

```
# cat-pictures-writer-deployment.yaml
apiVersion: apps/v1kind: Deploymentmetadata:  name: cat-pictures-writerspec:  replicas: 3  selector:    matchLabels:      app: cat
```

As a first step, you need to edit your PersistentVolume's `spec.persistentVolumeReclaimPolicy` and set it to `Retain`. This ensures your PersistentVolume will not be deleted when you delete the corresponding PersistentVolumeClaim:

```
kubectl patch pv cat-pictures-pv -p '{"spec":{"persistentVolumeReclaimPolicy":"Retain"}}'
```

Next you need to stop any workloads that are using the PersistentVolumeClaim bound to the PersistentVolume you want to migrate, and then delete the PersistentVolumeClaim. Avoid making any other changes to the PersistentVolumeClaim, such as volume resizes, until after the migration is complete.

Once that is done, you need to clear your PersistentVolume's `spec.claimRef.uid` to ensure PersistentVolumeClaims can bind to it upon recreation:

```
kubectl scale --replicas=0 deployment cat-pictures-writer
kubectl delete pvc cat-pictures-pvc
kubectl patch pv cat-pictures-pv -p '{"spec":{"claimRef":{"uid":""}}}'
```

After that, replace the PersistentVolume's list of valid access modes to be (only) `ReadWriteOncePod`:

```
kubectl patch pv cat-pictures-pv -p '{"spec":{"accessModes":["ReadWriteOncePod"]}}'
```

Note:

The `ReadWriteOncePod` access mode cannot be combined with other access modes. Make sure `ReadWriteOncePod` is the only access mode on the PersistentVolume when updating, otherwise the request will fail.

Next you need to modify your PersistentVolumeClaim to set `ReadWriteOncePod` as the only access mode. You should also set the PersistentVolumeClaim's `spec.volumeName` to the name of your PersistentVolume to ensure it binds to this specific PersistentVolume.

Once this is done, you can recreate your PersistentVolumeClaim and start up your workloads:

```
# IMPORTANT: Make sure to edit your PVC in cat-pictures-pvc.yaml before applying. You need to:
# - Set ReadWriteOncePod as the only access mode
# - Set spec.volumeName to "cat-pictures-pv"

kubectl apply -f cat-pictures-pvc.yaml
kubectl apply -f cat-pictures-writer-deployment.yaml
```

Lastly you may edit your PersistentVolume's `spec.persistentVolumeReclaimPolicy` and set to it back to `Delete` if you previously changed it.

```
kubectl patch pv cat-pictures-pv -p '{"spec":{"persistentVolumeReclaimPolicy":"Delete"}}'
```

What's next

- Learn more about PersistentVolumes.
- Learn more about PersistentVolumeClaims.
- Learn more about Configuring a Pod to Use a PersistentVolume for Storage

---

Configure Minimum and Maximum Memory Constraints for a Namespace

Define a range of valid memory resource limits for a namespace, so that every new Pod in that namespace falls within the range you configure.

This page shows how to set minimum and maximum values for memory used by containers running in a namespace. You specify minimum and maximum memory values in a LimitRange object. If a Pod does not meet the constraints imposed by the LimitRange, it cannot be created in the namespace.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

You must have access to create namespaces in your cluster.

Each node in your cluster must have at least 1 GiB of memory available for Pods.

Create a namespace

Create a namespace so that the resources you create in this exercise are isolated from the rest of your cluster.

```
kubectl create namespace constraints-mem-example
```

Create a LimitRange and a Pod

Here's an example manifest for a LimitRange:

admin/resource/memory-constraints.yaml  Copy admin/resource/memory-constraints.yaml to clipboard

```
apiVersion: v1
kind: LimitRangemetadata:  name: mem-min-max-demo-lrspec:  limits:  - max:      memory: 1Gi    min:      memory: 500Mi    type: Co
```

Create the LimitRange:

```
kubectl apply -f https://k8s.io/examples/admin/resource/memory-constraints.yaml --namespace=constraints-mem-example
```

View detailed information about the LimitRange:

```
kubectl get limitrange mem-min-max-demo-lr --namespace=constraints-mem-example --output=yaml
```

The output shows the minimum and maximum memory constraints as expected. But notice that even though you didn't specify default values in the configuration file for the LimitRange, they were created automatically.

```
  limits:
  - default:
      memory: 1Gi
    defaultRequest:
      memory: 1Gi
    max:
      memory: 1Gi
    min:
      memory: 500Mi
    type: Container
```

Now whenever you define a Pod within the constraints-mem-example namespace, Kubernetes performs these steps:

- If any container in that Pod does not specify its own memory request and limit, the control plane assigns the default memory request and limit to that container.
- Verify that every container in that Pod requests at least 500 MiB of memory.
- Verify that every container in that Pod requests no more than 1024 MiB (1 GiB) of memory.

Here's a manifest for a Pod that has one container. Within the Pod spec, the sole container specifies a memory request of 600 MiB and a memory limit of 800 MiB. These satisfy the minimum and maximum memory constraints imposed by the LimitRange.

admin/resource/memory-constraints-pod.yaml  Copy admin/resource/memory-constraints-pod.yaml to clipboard

```
apiVersion: v1
kind: Podmetadata:  name: constraints-mem-demospec:  containers:  - name: constraints-mem-demo-ctr    image: nginx    resources:
```

Create the Pod:

```
kubectl apply -f https://k8s.io/examples/admin/resource/memory-constraints-pod.yaml --namespace=constraints-mem-example
```

Verify that the Pod is running and that its container is healthy:

```
kubectl get pod constraints-mem-demo --namespace=constraints-mem-example
```

View detailed information about the Pod:

```
kubectl get pod constraints-mem-demo --output=yaml --namespace=constraints-mem-example
```

The output shows that the container within that Pod has a memory request of 600 MiB and a memory limit of 800 MiB. These satisfy the constraints imposed by the LimitRange for this namespace:

```
resources:
  limits:
    memory: 800Mi
  requests:
    memory: 600Mi
```

Delete your Pod:

```
kubectl delete pod constraints-mem-demo --namespace=constraints-mem-example
```

Attempt to create a Pod that exceeds the maximum memory constraint

Here's a manifest for a Pod that has one container. The container specifies a memory request of 800 MiB and a memory limit of 1.5 GiB.

admin/resource/memory-constraints-pod-2.yaml Copy admin/resource/memory-constraints-pod-2.yaml to clipboard

```
apiVersion: v1
kind: Podmetadata:  name: constraints-mem-demo-2spec:  containers:  - name: constraints-mem-demo-2-ctr    image: nginx    resource
```

Attempt to create the Pod:

```
kubectl apply -f https://k8s.io/examples/admin/resource/memory-constraints-pod-2.yaml --namespace=constraints-mem-example
```

The output shows that the Pod does not get created, because it defines a container that requests more memory than is allowed:

```
Error from server (Forbidden): error when creating "examples/admin/resource/memory-constraints-pod-2.yaml":
pods "constraints-mem-demo-2" is forbidden: maximum memory usage per Container is 1Gi, but limit is 1536Mi.
```

Attempt to create a Pod that does not meet the minimum memory request

Here's a manifest for a Pod that has one container. That container specifies a memory request of 100 MiB and a memory limit of 800 MiB.

admin/resource/memory-constraints-pod-3.yaml Copy admin/resource/memory-constraints-pod-3.yaml to clipboard

```
apiVersion: v1
kind: Podmetadata:  name: constraints-mem-demo-3spec:  containers:  - name: constraints-mem-demo-3-ctr    image: nginx    resource
```

Attempt to create the Pod:

```
kubectl apply -f https://k8s.io/examples/admin/resource/memory-constraints-pod-3.yaml --namespace=constraints-mem-example
```

The output shows that the Pod does not get created, because it defines a container that requests less memory than the enforced minimum:

```
Error from server (Forbidden): error when creating "examples/admin/resource/memory-constraints-pod-3.yaml":
pods "constraints-mem-demo-3" is forbidden: minimum memory usage per Container is 500Mi, but request is 100Mi.
```

Create a Pod that does not specify any memory request or limit

Here's a manifest for a Pod that has one container. The container does not specify a memory request, and it does not specify a memory limit.

admin/resource/memory-constraints-pod-4.yaml Copy admin/resource/memory-constraints-pod-4.yaml to clipboard

```
apiVersion: v1
kind: Podmetadata:  name: constraints-mem-demo-4spec:  containers:  - name: constraints-mem-demo-4-ctr    image: nginx
```

Create the Pod:

```
kubectl apply -f https://k8s.io/examples/admin/resource/memory-constraints-pod-4.yaml --namespace=constraints-mem-example
```

View detailed information about the Pod:

```
kubectl get pod constraints-mem-demo-4 --namespace=constraints-mem-example --output=yaml
```

The output shows that the Pod's only container has a memory request of 1 GiB and a memory limit of 1 GiB. How did that container get those values?

```
resources:
  limits:
    memory: 1Gi
  requests:
    memory: 1Gi
```

Because your Pod did not define any memory request and limit for that container, the cluster applied a default memory request and limit from the LimitRange.

This means that the definition of that Pod shows those values. You can check it using `kubectl describe`:

```
# Look for the "Requests:" section of the output
kubectl describe pod constraints-mem-demo-4 --namespace=constraints-mem-example
```

At this point, your Pod might be running or it might not be running. Recall that a prerequisite for this task is that your Nodes have at least 1 GiB of memory. If each of your Nodes has only 1 GiB of memory, then there is not enough allocatable memory on any Node to accommodate a memory request of 1 GiB. If you happen to be using Nodes with 2 GiB of memory, then you probably have enough space to accommodate the 1 GiB request.

Delete your Pod:

```
kubectl delete pod constraints-mem-demo-4 --namespace=constraints-mem-example
```

Enforcement of minimum and maximum memory constraints

The maximum and minimum memory constraints imposed on a namespace by a LimitRange are enforced only when a Pod is created or updated. If you change the LimitRange, it does not affect Pods that were created previously.

Motivation for minimum and maximum memory constraints

As a cluster administrator, you might want to impose restrictions on the amount of memory that Pods can use. For example:

- Each Node in a cluster has 2 GiB of memory. You do not want to accept any Pod that requests more than 2 GiB of memory, because no Node in the cluster can support the request.
- A cluster is shared by your production and development departments. You want to allow production workloads to consume up to 8 GiB of memory, but you want development workloads to be limited to 512 MiB. You create separate namespaces for production and development, and you apply memory constraints to each namespace.

Clean up

Delete your namespace:

```
kubectl delete namespace constraints-mem-example
```

What's next

For cluster administrators

- Configure Default Memory Requests and Limits for a Namespace
- Configure Default CPU Requests and Limits for a Namespace
- Configure Minimum and Maximum CPU Constraints for a Namespace
- Configure Memory and CPU Quotas for a Namespace
- Configure a Pod Quota for a Namespace
- Configure Quotas for API Objects

For app developers

- Assign Memory Resources to Containers and Pods
- Assign CPU Resources to Containers and Pods
- Assign Pod-level CPU and memory resources
- Configure Quality of Service for Pods

Advertise Extended Resources for a Node

This page shows how to specify extended resources for a Node. Extended resources allow cluster administrators to advertise node-level resources that would otherwise be unknown to Kubernetes.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

To check the version, enter `kubectl version`.

Get the names of your Nodes

```
kubectl get nodes
```

Choose one of your Nodes to use for this exercise.

Advertise a new extended resource on one of your Nodes

To advertise a new extended resource on a Node, send an HTTP PATCH request to the Kubernetes API server. For example, suppose one of your Nodes has four dongles attached. Here's an example of a PATCH request that advertises four dongle resources for your Node.

```
PATCH /api/v1/nodes/<your-node-name>/status HTTP/1.1
Accept: application/json
Content-Type: application/json-patch+json
Host: k8s-master:8080

[
  {
    "op": "add",
```

```
    "path": "/status/capacity/example.com~1dongle",
    "value": "4"
  }
]
```

Note that Kubernetes does not need to know what a dongle is or what a dongle is for. The preceding PATCH request tells Kubernetes that your Node has four things that you call dongles.

Start a proxy, so that you can easily send requests to the Kubernetes API server:

```
kubectl proxy
```

In another command window, send the HTTP PATCH request. Replace `<your-node-name>` with the name of your Node:

```
curl --header "Content-Type: application/json-patch+json" \
  --request PATCH \  --data '[{"op": "add", "path": "/status/capacity/example.com~1dongle", "value": "4"}]' \  http://localhost:80(
```

Note:

In the preceding request, `~1` is the encoding for the character / in the patch path. The operation path value in JSON-Patch is interpreted as a JSON-Pointer. For more details, see IETF RFC 6901, section 3.

The output shows that the Node has a capacity of 4 dongles:

```
"capacity": {
  "cpu": "2",
  "memory": "2049008Ki",
  "example.com/dongle": "4",
```

Describe your Node:

```
kubectl describe node <your-node-name>
```

Once again, the output shows the dongle resource:

```
Capacity:
  cpu: 2
  memory: 2049008Ki
  example.com/dongle: 4
```

Now, application developers can create Pods that request a certain number of dongles. See Assign Extended Resources to a Container.

Discussion

Extended resources are similar to memory and CPU resources. For example, just as a Node has a certain amount of memory and CPU to be shared by all components running on the Node, it can have a certain number of dongles to be shared by all components running on the Node. And just as application developers can create Pods that request a certain amount of memory and CPU, they can create Pods that request a certain number of dongles.

Extended resources are opaque to Kubernetes; Kubernetes does not know anything about what they are. Kubernetes knows only that a Node has a certain number of them. Extended resources must be advertised in integer amounts. For example, a Node can advertise four dongles, but not 4.5 dongles.

Storage example

Suppose a Node has 800 GiB of a special kind of disk storage. You could create a name for the special storage, say example.com/special-storage. Then you could advertise it in chunks of a certain size, say 100 GiB. In that case, your Node would advertise that it has eight resources of type example.com/special-storage.

```
Capacity:
 ...
 example.com/special-storage: 8
```

If you want to allow arbitrary requests for special storage, you could advertise special storage in chunks of size 1 byte. In that case, you would advertise 800Gi resources of type example.com/special-storage.

```
Capacity:
 ...
 example.com/special-storage:  800Gi
```

Then a Container could request any number of bytes of special storage, up to 800Gi.

Clean up

Here is a PATCH request that removes the dongle advertisement from a Node.

```
PATCH /api/v1/nodes/<your-node-name>/status HTTP/1.1
Accept: application/json
Content-Type: application/json-patch+json
Host: k8s-master:8080

[
  {
    "op": "remove",
    "path": "/status/capacity/example.com~1dongle",
  }
]
```

Start a proxy, so that you can easily send requests to the Kubernetes API server:

```
kubectl proxy
```

In another command window, send the HTTP PATCH request. Replace `<your-node-name>` with the name of your Node:

```
curl --header "Content-Type: application/json-patch+json" \
  --request PATCH \  --data '[{"op": "remove", "path": "/status/capacity/example.com-1dongle"}]' \  http://localhost:8001/api/v1/n
```

Verify that the dongle advertisement has been removed:

```
kubectl describe node <your-node-name> | grep dongle
```

(you should not see any output)

What's next

For application developers

- Assign Extended Resources to a Container
- Extended Resource allocation by DRA

For cluster administrators

- Configure Minimum and Maximum Memory Constraints for a Namespace
- Configure Minimum and Maximum CPU Constraints for a Namespace
- Extended Resource allocation by DRA

Change the default StorageClass

This page shows how to change the default Storage Class that is used to provision volumes for PersistentVolumeClaims that have no special requirements.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

To check the version, enter `kubectl version`.

Why change the default storage class?

Depending on the installation method, your Kubernetes cluster may be deployed with an existing StorageClass that is marked as default. This default StorageClass is then used to dynamically provision storage for PersistentVolumeClaims that do not require any specific storage class. See PersistentVolumeClaim documentation for details.

The pre-installed default StorageClass may not fit well with your expected workload; for example, it might provision storage that is too expensive. If this is the case, you can either change the default StorageClass or disable it completely to avoid dynamic provisioning of storage.

Deleting the default StorageClass may not work, as it may be re-created automatically by the addon manager running in your cluster. Please consult the docs for your installation for details about addon manager and how to disable individual addons.

Changing the default StorageClass

1. List the StorageClasses in your cluster:

   ```
   kubectl get storageclass
   ```

   The output is similar to this:

   ```
   NAME                 PROVISIONER               AGE
   standard (default)   kubernetes.io/gce-pd      1d
   gold                 kubernetes.io/gce-pd      1d
   ```

   The default StorageClass is marked by `(default)`.

2. Mark the default StorageClass as non-default:

   The default StorageClass has an annotation `storageclass.kubernetes.io/is-default-class` set to `true`. Any other value or absence of the annotation is interpreted as `false`.

   To mark a StorageClass as non-default, you need to change its value to `false`:

   ```
   kubectl patch storageclass standard -p '{"metadata": {"annotations":{"storageclass.kubernetes.io/is-default-class":"false"}}}
   ```

where `standard` is the name of your chosen StorageClass.

3. Mark a StorageClass as default:

   Similar to the previous step, you need to add/set the annotation `storageclass.kubernetes.io/is-default-class=true`.

   ```
   kubectl patch storageclass gold -p '{"metadata": {"annotations":{"storageclass.kubernetes.io/is-default-class":"true"}}}'
   ```

   Please note you can have multiple `StorageClass` marked as default. If more than one `StorageClass` is marked as default, a `PersistentVolumeClaim` without an explicitly defined `storageClassName` will be created using the most recently created default `StorageClass`. When a `PersistentVolumeClaim` is created with a specified `volumeName`, it remains in a pending state if the static volume's `storageClassName` does not match the `StorageClass` on the `PersistentVolumeClaim`.

4. Verify that your chosen StorageClass is default:

   ```
   kubectl get storageclass
   ```

   The output is similar to this:

   ```
   NAME            PROVISIONER               AGE
   standard        kubernetes.io/gce-pd      1d
   gold (default)  kubernetes.io/gce-pd      1d
   ```

What's next

- Learn more about PersistentVolumes.

Troubleshooting CNI plugin-related errors

To avoid CNI plugin-related errors, verify that you are using or upgrading to a container runtime that has been tested to work correctly with your version of Kubernetes.

About the "Incompatible CNI versions" and "Failed to destroy network for sandbox" errors

Service issues exist for pod CNI network setup and tear down in containerd v1.6.0-v1.6.3 when the CNI plugins have not been upgraded and/or the CNI config version is not declared in the CNI config files. The containerd team reports, "these issues are resolved in containerd v1.6.4."

With containerd v1.6.0-v1.6.3, if you do not upgrade the CNI plugins and/or declare the CNI config version, you might encounter the following "Incompatible CNI versions" or "Failed to destroy network for sandbox" error conditions.

Incompatible CNI versions error

If the version of your CNI plugin does not correctly match the plugin version in the config because the config version is later than the plugin version, the containerd log will likely show an error message on startup of a pod similar to:

```
incompatible CNI versions; config is \"1.0.0\", plugin supports [\"0.1.0\" \"0.2.0\" \"0.3.0\" \"0.3.1\" \"0.4.0\"]"
```

To fix this issue, update your CNI plugins and CNI config files.

Failed to destroy network for sandbox error

If the version of the plugin is missing in the CNI plugin config, the pod may run. However, stopping the pod generates an error similar to:

```
ERROR[2022-04-26T00:43:24.518165483Z] StopPodSandbox for "b" failed
error="failed to destroy network for sandbox \"bbc85f891eaf060c5a879e27bba9b6b06450210161dfdecfbb2732959fb6500a\": invalid version
```

This error leaves the pod in the not-ready state with a network namespace still attached. To recover from this problem, edit the CNI config file to add the missing version information. The next attempt to stop the pod should be successful.

Updating your CNI plugins and CNI config files

If you're using containerd v1.6.0-v1.6.3 and encountered "Incompatible CNI versions" or "Failed to destroy network for sandbox" errors, consider updating your CNI plugins and editing the CNI config files.

Here's an overview of the typical steps for each node:

1. Safely drain and cordon the node.
2. After stopping your container runtime and kubelet services, perform the following upgrade operations:
   - If you're running CNI plugins, upgrade them to the latest version.
   - If you're using non-CNI plugins, replace them with CNI plugins. Use the latest version of the plugins.
   - Update the plugin configuration file to specify or match a version of the CNI specification that the plugin supports, as shown in the following "An example containerd configuration file" section.
   - For `containerd`, ensure that you have installed the latest version (v1.0.0 or later) of the CNI loopback plugin.
   - Upgrade node components (for example, the kubelet) to Kubernetes v1.24
   - Upgrade to or install the most current version of the container runtime.
3. Bring the node back into your cluster by restarting your container runtime and kubelet. Uncordon the node (`kubectl uncordon <nodename>`).

An example containerd configuration file

The following example shows a configuration for `containerd` runtime v1.6.x, which supports a recent version of the CNI specification (v1.0.0).

Please see the documentation from your plugin and networking provider for further instructions on configuring your system.

On Kubernetes, containerd runtime adds a loopback interface, `lo`, to pods as a default behavior. The containerd runtime configures the loopback interface via a CNI plugin, `loopback`. The `loopback` plugin is distributed as part of the `containerd` release packages that have the `cni` designation. `containerd` v1.6.0 and later includes a CNI v1.0.0-compatible loopback plugin as well as other default CNI plugins. The configuration for the loopback plugin is done internally by containerd, and is set to use CNI v1.0.0. This also means that the version of the `loopback` plugin must be v1.0.0 or later when this newer version `containerd` is started.

The following bash command generates an example CNI config. Here, the 1.0.0 value for the config version is assigned to the `cniVersion` field for use when `containerd` invokes the CNI bridge plugin.

```
cat << EOF | tee /etc/cni/net.d/10-containerd-net.conflist
{
 "cniVersion": "1.0.0",
 "name": "containerd-net",
 "plugins": [
   {
     "type": "bridge",
     "bridge": "cni0",
     "isGateway": true,
     "ipMasq": true,
     "promiscMode": true,
     "ipam": {
       "type": "host-local",
       "ranges": [
         [{
           "subnet": "10.88.0.0/16"
         }],
         [{
           "subnet": "2001:db8:4860::/64"
         }]
       ],
       "routes": [
         { "dst": "0.0.0.0/0" },
         { "dst": "::/0" }
       ]
     }
   },
   {
     "type": "portmap",
     "capabilities": {"portMappings": true},
     "externalSetMarkChain": "KUBE-MARK-MASQ"
   }
 ]
}
EOF
```

Update the IP address ranges in the preceding example with ones that are based on your use case and network addressing plan.

Configure a Pod Quota for a Namespace

Restrict how many Pods you can create within a namespace.

This page shows how to set a quota for the total number of Pods that can run in a Namespace. You specify quotas in a ResourceQuota object.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

You must have access to create namespaces in your cluster.

Create a namespace

Create a namespace so that the resources you create in this exercise are isolated from the rest of your cluster.

```
kubectl create namespace quota-pod-example
```

Create a ResourceQuota

Here is an example manifest for a ResourceQuota:

admin/resource/quota-pod.yaml  Copy admin/resource/quota-pod.yaml to clipboard

```
apiVersion: v1
kind: ResourceQuotametadata:  name: pod-demospec:  hard:    pods: "2"
```

Create the ResourceQuota:

```
kubectl apply -f https://k8s.io/examples/admin/resource/quota-pod.yaml --namespace=quota-pod-example
```

View detailed information about the ResourceQuota:

```
kubectl get resourcequota pod-demo --namespace=quota-pod-example --output=yaml
```

The output shows that the namespace has a quota of two Pods, and that currently there are no Pods; that is, none of the quota is used.

```
spec:
  hard:
    pods: "2"
status:  hard:    pods: "2"  used:    pods: "0"
```

Here is an example manifest for a Deployment:

admin/resource/quota-pod-deployment.yaml Copy admin/resource/quota-pod-deployment.yaml to clipboard

```
apiVersion: apps/v1
kind: Deploymentmetadata:  name: pod-quota-demospec:  selector:    matchLabels:      purpose: quota-demo  replicas: 3  template:
```

In that manifest, `replicas: 3` tells Kubernetes to attempt to create three new Pods, all running the same application.

Create the Deployment:

```
kubectl apply -f https://k8s.io/examples/admin/resource/quota-pod-deployment.yaml --namespace=quota-pod-example
```

View detailed information about the Deployment:

```
kubectl get deployment pod-quota-demo --namespace=quota-pod-example --output=yaml
```

The output shows that even though the Deployment specifies three replicas, only two Pods were created because of the quota you defined earlier:

```
spec:
  ...
  replicas: 3
...status:  availableReplicas: 2...lastUpdateTime: 2021-04-02T20:57:05Z    message: 'unable to create pods: pods "pod-quota-demo-1
```

Choice of resource

In this task you have defined a ResourceQuota that limited the total number of Pods, but you could also limit the total number of other kinds of object. For example, you might decide to limit how many CronJobs that can live in a single namespace.

Clean up

Delete your namespace:

```
kubectl delete namespace quota-pod-example
```

What's next

For cluster administrators

- Configure Default Memory Requests and Limits for a Namespace
- Configure Default CPU Requests and Limits for a Namespace
- Configure Minimum and Maximum Memory Constraints for a Namespace
- Configure Minimum and Maximum CPU Constraints for a Namespace
- Configure Memory and CPU Quotas for a Namespace
- Configure Quotas for API Objects

For app developers

- Assign Memory Resources to Containers and Pods
- Assign CPU Resources to Containers and Pods
- Assign Pod-level CPU and memory resources
- Configure Quality of Service for Pods

Migrate Replicated Control Plane To Use Cloud Controller Manager

The cloud-controller-manager is a Kubernetes control plane component that embeds cloud-specific control logic. The cloud controller manager lets you link your cluster into your cloud provider's API, and separates out the components that interact with that cloud platform from components that only interact with your cluster.

By decoupling the interoperability logic between Kubernetes and the underlying cloud infrastructure, the cloud-controller-manager component enables cloud providers to release features at a different pace compared to the main Kubernetes project.

Background

As part of the cloud provider extraction effort, all cloud specific controllers must be moved out of the `kube-controller-manager`. All existing clusters that run cloud controllers in the `kube-controller-manager` must migrate to instead run the controllers in a cloud provider specific `cloud-controller-manager`.

Leader Migration provides a mechanism in which HA clusters can safely migrate "cloud specific" controllers between the `kube-controller-manager` and the `cloud-controller-manager` via a shared resource lock between the two components while upgrading the replicated control plane. For a single-node control plane, or if unavailability of controller managers can be tolerated during the upgrade, Leader Migration is not needed and this guide can be ignored.

Leader Migration can be enabled by setting `--enable-leader-migration` on `kube-controller-manager` or `cloud-controller-manager`. Leader Migration only applies during the upgrade and can be safely disabled or left enabled after the upgrade is complete.

This guide walks you through the manual process of upgrading the control plane from `kube-controller-manager` with built-in cloud provider to running both `kube-controller-manager` and `cloud-controller-manager`. If you use a tool to deploy and manage the cluster, please refer to the documentation of the tool and the cloud provider for specific instructions of the migration.

Before you begin

It is assumed that the control plane is running Kubernetes version N and to be upgraded to version N + 1. Although it is possible to migrate within the same version, ideally the migration should be performed as part of an upgrade so that changes of configuration can be aligned to each release. The exact versions of N and N + 1 depend on each cloud provider. For example, if a cloud provider builds a `cloud-controller-manager` to work with Kubernetes 1.24, then N can be 1.23 and N + 1 can be 1.24.

The control plane nodes should run `kube-controller-manager` with Leader Election enabled, which is the default. As of version N, an in-tree cloud provider must be set with `--cloud-provider` flag and `cloud-controller-manager` should not yet be deployed.

The out-of-tree cloud provider must have built a `cloud-controller-manager` with Leader Migration implementation. If the cloud provider imports `k8s.io/cloud-provider` and `k8s.io/controller-manager` of version v0.21.0 or later, Leader Migration will be available. However, for version before v0.22.0, Leader Migration is alpha and requires feature gate `ControllerManagerLeaderMigration` to be enabled in `cloud-controller-manager`.

This guide assumes that kubelet of each control plane node starts `kube-controller-manager` and `cloud-controller-manager` as static pods defined by their manifests. If the components run in a different setting, please adjust the steps accordingly.

For authorization, this guide assumes that the cluster uses RBAC. If another authorization mode grants permissions to `kube-controller-manager` and `cloud-controller-manager` components, please grant the needed access in a way that matches the mode.

Grant access to Migration Lease

The default permissions of the controller manager allow only accesses to their main Lease. In order for the migration to work, accesses to another Lease are required.

You can grant `kube-controller-manager` full access to the leases API by modifying the `system::leader-locking-kube-controller-manager` role. This task guide assumes that the name of the migration lease is `cloud-provider-extraction-migration`.

```
kubectl patch -n kube-system role 'system::leader-locking-kube-controller-manager' -p '{"rules": [ {"apiGroups":[ "coordination.k8
```

Do the same to the `system::leader-locking-cloud-controller-manager` role.

```
kubectl patch -n kube-system role 'system::leader-locking-cloud-controller-manager' -p '{"rules": [ {"apiGroups":[ "coordination.k
```

Initial Leader Migration configuration

Leader Migration optionally takes a configuration file representing the state of controller-to-manager assignment. At this moment, with in-tree cloud provider, `kube-controller-manager` runs `route`, `service`, and `cloud-node-lifecycle`. The following example configuration shows the assignment.

Leader Migration can be enabled without a configuration. Please see Default Configuration for details.

```
kind: LeaderMigrationConfiguration
apiVersion: controllermanager.config.k8s.io/v1leaderName: cloud-provider-extraction-migrationresourceLock: leasescontrollerLeaders
```

Alternatively, because the controllers can run under either controller managers, setting `component` to `*` for both sides makes the configuration file consistent between both parties of the migration.

```
# wildcard version
kind: LeaderMigrationConfigurationapiVersion: controllermanager.config.k8s.io/v1leaderName: cloud-provider-extraction-migrationres
```

On each control plane node, save the content to `/etc/leadermigration.conf`, and update the manifest of `kube-controller-manager` so that the file is mounted inside the container at the same location. Also, update the same manifest to add the following arguments:

- `--enable-leader-migration` to enable Leader Migration on the controller manager
- `--leader-migration-config=/etc/leadermigration.conf` to set configuration file

Restart `kube-controller-manager` on each node. At this moment, `kube-controller-manager` has leader migration enabled and is ready for the migration.

Deploy Cloud Controller Manager

In version N + 1, the desired state of controller-to-manager assignment can be represented by a new configuration file, shown as follows. Please note `component` field of each `controllerLeaders` changing from `kube-controller-manager` to `cloud-controller-manager`. Alternatively, use the wildcard version mentioned above, which has the same effect.

```
kind: LeaderMigrationConfiguration
apiVersion: controllermanager.config.k8s.io/v1leaderName: cloud-provider-extraction-migrationresourceLock: leasescontrollerLeaders
```

When creating control plane nodes of version N + 1, the content should be deployed to `/etc/leadermigration.conf`. The manifest of `cloud-controller-manager` should be updated to mount the configuration file in the same manner as `kube-controller-manager` of version N. Similarly, add `--enable-leader-migration` and `--leader-migration-config=/etc/leadermigration.conf` to the arguments of `cloud-controller-manager`.

Create a new control plane node of version N + 1 with the updated `cloud-controller-manager` manifest, and with the `--cloud-provider` flag set to `external` for `kube-controller-manager`. `kube-controller-manager` of version N + 1 MUST NOT have Leader Migration enabled because, with an external cloud provider, it does not run the migrated controllers anymore, and thus it is not involved in the migration.

Please refer to Cloud Controller Manager Administration for more detail on how to deploy `cloud-controller-manager`.

Upgrade Control Plane

The control plane now contains nodes of both version N and N + 1. The nodes of version N run `kube-controller-manager` only, and these of version N + 1 run both `kube-controller-manager` and `cloud-controller-manager`. The migrated controllers, as specified in the configuration, are running under either `kube-controller-manager` of version N or `cloud-controller-manager` of version N + 1 depending on which controller manager holds the migration lease. No controller will ever be running under both controller managers at any time.

In a rolling manner, create a new control plane node of version N + 1 and bring down one of version N until the control plane contains only nodes of version N + 1. If a rollback from version N + 1 to N is required, add nodes of version N with Leader Migration enabled for `kube-controller-manager` back to the control plane, replacing one of version N + 1 each time until there are only nodes of version N.

(Optional) Disable Leader Migration

Now that the control plane has been upgraded to run both `kube-controller-manager` and `cloud-controller-manager` of version N + 1, Leader Migration has finished its job and can be safely disabled to save one Lease resource. It is safe to re-enable Leader Migration for the rollback in the future.

In a rolling manager, update manifest of `cloud-controller-manager` to unset both `--enable-leader-migration` and `--leader-migration-config=` flag, also remove the mount of `/etc/leadermigration.conf`, and finally remove `/etc/leadermigration.conf`. To re-enable Leader Migration, recreate the configuration file and add its mount and the flags that enable Leader Migration back to `cloud-controller-manager`.

Default Configuration

Starting Kubernetes 1.22, Leader Migration provides a default configuration suitable for the default controller-to-manager assignment. The default configuration can be enabled by setting `--enable-leader-migration` but without `--leader-migration-config=`.

For `kube-controller-manager` and `cloud-controller-manager`, if there are no flags that enable any in-tree cloud provider or change ownership of controllers, the default configuration can be used to avoid manual creation of the configuration file.

Special case: migrating the Node IPAM controller

If your cloud provider provides an implementation of Node IPAM controller, you should switch to the implementation in `cloud-controller-manager`. Disable Node IPAM controller in `kube-controller-manager` of version N + 1 by adding `--controllers=*,-nodeipam` to its flags. Then add `nodeipam` to the list of migrated controllers.

```
# wildcard version, with nodeipam
kind: LeaderMigrationConfigurationapiVersion: controllermanager.config.k8s.io/v1leaderName: cloud-provider-extraction-migrationres
```

What's next

- Read the Controller Manager Leader Migration enhancement proposal.

Use Calico for NetworkPolicy

This page shows a couple of quick ways to create a Calico cluster on Kubernetes.

Before you begin

Decide whether you want to deploy a cloud or local cluster.

Creating a Calico cluster with Google Kubernetes Engine (GKE)

Prerequisite: gcloud.

1. To launch a GKE cluster with Calico, include the `--enable-network-policy` flag.

   Syntax

   ```
   gcloud container clusters create [CLUSTER_NAME] --enable-network-policy
   ```

Example

```
gcloud container clusters create my-calico-cluster --enable-network-policy
```

2. To verify the deployment, use the following command.

   ```
   kubectl get pods --namespace=kube-system
   ```

   The Calico pods begin with `calico`. Check to make sure each one has a status of `Running`.

Creating a local Calico cluster with kubeadm

To get a local single-host Calico cluster in fifteen minutes using kubeadm, refer to the Calico Quickstart.

What's next

Once your cluster is running, you can follow the Declare Network Policy to try out Kubernetes NetworkPolicy.

Configure Default Memory Requests and Limits for a Namespace

Define a default memory resource limit for a namespace, so that every new Pod in that namespace has a memory resource limit configured.

This page shows how to configure default memory requests and limits for a namespace.

A Kubernetes cluster can be divided into namespaces. Once you have a namespace that has a default memory limit, and you then try to create a Pod with a container that does not specify its own memory limit, then the control plane assigns the default memory limit to that container.

Kubernetes assigns a default memory request under certain conditions that are explained later in this topic.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

You must have access to create namespaces in your cluster.

Each node in your cluster must have at least 2 GiB of memory.

Create a namespace

Create a namespace so that the resources you create in this exercise are isolated from the rest of your cluster.

```
kubectl create namespace default-mem-example
```

Create a LimitRange and a Pod

Here's a manifest for an example LimitRange. The manifest specifies a default memory request and a default memory limit.

admin/resource/memory-defaults.yaml Copy admin/resource/memory-defaults.yaml to clipboard

```
apiVersion: v1
kind: LimitRangemetadata:  name: mem-limit-rangespec:  limits:  - default:      memory: 512Mi    defaultRequest:      memory: 256M
```

Create the LimitRange in the default-mem-example namespace:

```
kubectl apply -f https://k8s.io/examples/admin/resource/memory-defaults.yaml --namespace=default-mem-example
```

Now if you create a Pod in the default-mem-example namespace, and any container within that Pod does not specify its own values for memory request and memory limit, then the control plane applies default values: a memory request of 256MiB and a memory limit of 512MiB.

Here's an example manifest for a Pod that has one container. The container does not specify a memory request and limit.

admin/resource/memory-defaults-pod.yaml Copy admin/resource/memory-defaults-pod.yaml to clipboard

```
apiVersion: v1
kind: Podmetadata:  name: default-mem-demospec:  containers:  - name: default-mem-demo-ctr    image: nginx
```

Create the Pod.

```
kubectl apply -f https://k8s.io/examples/admin/resource/memory-defaults-pod.yaml --namespace=default-mem-example
```

View detailed information about the Pod:

```
kubectl get pod default-mem-demo --output=yaml --namespace=default-mem-example
```

The output shows that the Pod's container has a memory request of 256 MiB and a memory limit of 512 MiB. These are the default values specified by the LimitRange.

```
containers:
- image: nginx
  imagePullPolicy: Always
  name: default-mem-demo-ctr
  resources:
    limits:
      memory: 512Mi
    requests:
      memory: 256Mi
```

Delete your Pod:

```
kubectl delete pod default-mem-demo --namespace=default-mem-example
```

What if you specify a container's limit, but not its request?

Here's a manifest for a Pod that has one container. The container specifies a memory limit, but not a request:

admin/resource/memory-defaults-pod-2.yaml 


```
apiVersion: v1
kind: Podmetadata:  name: default-mem-demo-2spec:  containers:  - name: default-mem-demo-2-ctr    image: nginx    resources:
```

Create the Pod:

```
kubectl apply -f https://k8s.io/examples/admin/resource/memory-defaults-pod-2.yaml --namespace=default-mem-example
```

View detailed information about the Pod:

```
kubectl get pod default-mem-demo-2 --output=yaml --namespace=default-mem-example
```

The output shows that the container's memory request is set to match its memory limit. Notice that the container was not assigned the default memory request value of 256Mi.

```
resources:
  limits:
    memory: 1Gi
  requests:
    memory: 1Gi
```

What if you specify a container's request, but not its limit?

Here's a manifest for a Pod that has one container. The container specifies a memory request, but not a limit:

admin/resource/memory-defaults-pod-3.yaml 


```
apiVersion: v1
kind: Podmetadata:  name: default-mem-demo-3spec:  containers:  - name: default-mem-demo-3-ctr    image: nginx    resources:
```

Create the Pod:

```
kubectl apply -f https://k8s.io/examples/admin/resource/memory-defaults-pod-3.yaml --namespace=default-mem-example
```

View the Pod's specification:

```
kubectl get pod default-mem-demo-3 --output=yaml --namespace=default-mem-example
```

The output shows that the container's memory request is set to the value specified in the container's manifest. The container is limited to use no more than 512MiB of memory, which matches the default memory limit for the namespace.

```
resources:
  limits:
    memory: 512Mi
  requests:
    memory: 128Mi
```

Note:

A `LimitRange` does **not** check the consistency of the default values it applies. This means that a default value for the *limit* that is set by `LimitRange` may be less than the *request* value specified for the container in the spec that a client submits to the API server. If that happens, the final Pod will not be scheduleable. See Constraints on resource limits and requests for more details.

Motivation for default memory limits and requests

If your namespace has a memory resource quota configured, it is helpful to have a default value in place for memory limit. Here are three of the restrictions that a resource quota imposes on a namespace:

- For every Pod that runs in the namespace, the Pod and each of its containers must have a memory limit. (If you specify a memory limit for every container in a Pod, Kubernetes can infer the Pod-level memory limit by adding up the limits for its containers).
- Memory limits apply a resource reservation on the node where the Pod in question is scheduled. The total amount of memory reserved for all Pods in the namespace must not exceed a specified limit.

- The total amount of memory actually used by all Pods in the namespace must also not exceed a specified limit.

When you add a LimitRange:

If any Pod in that namespace that includes a container does not specify its own memory limit, the control plane applies the default memory limit to that container, and the Pod can be allowed to run in a namespace that is restricted by a memory ResourceQuota.

Clean up

Delete your namespace:

```
kubectl delete namespace default-mem-example
```

What's next

For cluster administrators

- Configure Default CPU Requests and Limits for a Namespace
- Configure Minimum and Maximum Memory Constraints for a Namespace
- Configure Minimum and Maximum CPU Constraints for a Namespace
- Configure Memory and CPU Quotas for a Namespace
- Configure a Pod Quota for a Namespace
- Configure Quotas for API Objects

For app developers

- Assign Memory Resources to Containers and Pods
- Assign CPU Resources to Containers and Pods
- Assign Pod-level CPU and memory resources
- Configure Quality of Service for Pods

Certificate Management with kubeadm

FEATURE STATE: `Kubernetes v1.15 [stable]`

Client certificates generated by kubeadm expire after 1 year. This page explains how to manage certificate renewals with kubeadm. It also covers other tasks related to kubeadm certificate management.

The Kubernetes project recommends upgrading to the latest patch releases promptly, and to ensure that you are running a supported minor release of Kubernetes. Following this recommendation helps you to stay secure.

Before you begin

You should be familiar with PKI certificates and requirements in Kubernetes.

You should be familiar with how to pass a configuration file to the kubeadm commands.

This guide covers the usage of the `openssl` command (used for manual certificate signing, if you choose that approach), but you can use your preferred tools.

Some of the steps here use `sudo` for administrator access. You can use any equivalent tool.

Using custom certificates

By default, kubeadm generates all the certificates needed for a cluster to run. You can override this behavior by providing your own certificates.

To do so, you must place them in whatever directory is specified by the `--cert-dir` flag or the `certificatesDir` field of kubeadm's `ClusterConfiguration`. By default this is `/etc/kubernetes/pki`.

If a given certificate and private key pair exists before running `kubeadm init`, kubeadm does not overwrite them. This means you can, for example, copy an existing CA into `/etc/kubernetes/pki/ca.crt` and `/etc/kubernetes/pki/ca.key`, and kubeadm will use this CA for signing the rest of the certificates.

Choosing an encryption algorithm

kubeadm allows you to choose an encryption algorithm that is used for creating public and private keys. That can be done by using the `encryptionAlgorithm` field of the kubeadm configuration:

```
apiVersion: kubeadm.k8s.io/v1beta4
kind: ClusterConfigurationencryptionAlgorithm: <ALGORITHM>
```

<ALGORITHM> can be one of RSA-2048 (default), RSA-3072, RSA-4096 or ECDSA-P256.

Choosing certificate validity period

kubeadm allows you to choose the validity period of CA and leaf certificates. That can be done by using the certificateValidityPeriod and caCertificateValidityPeriod fields of the kubeadm configuration:

```
apiVersion: kubeadm.k8s.io/v1beta4
kind: ClusterConfigurationcertificateValidityPeriod: 8760h # Default: 365 days × 24 hours = 1 yearcaCertificateValidityPeriod: 876(
```

The values of the fields follow the accepted format for Go's time.Duration values, with the longest supported unit being h (hours).

External CA mode

It is also possible to provide only the ca.crt file and not the ca.key file (this is only available for the root CA file, not other cert pairs). If all other certificates and kubeconfig files are in place, kubeadm recognizes this condition and activates the "External CA" mode. kubeadm will proceed without the CA key on disk.

Instead, run the controller-manager standalone with --controllers=csrsigner and point to the CA certificate and key.

There are various ways to prepare the component credentials when using external CA mode.

Manual preparation of component credentials

PKI certificates and requirements includes information on how to prepare all the required by kubeadm component credentials manually.

This guide covers the usage of the openssl command (used for manual certificate signing, if you choose that approach), but you can use your preferred tools.

Preparation of credentials by signing CSRs generated by kubeadm

kubeadm can generate CSR files that you can sign manually with tools like openssl and your external CA. These CSR files will include all the specification for credentials that components deployed by kubeadm require.

Automated preparation of component credentials by using kubeadm phases

Alternatively, it is possible to use kubeadm phase commands to automate this process.

- Go to a host that you want to prepare as a kubeadm control plane node with external CA.
- Copy the external CA files ca.crt and ca.key that you have into /etc/kubernetes/pki on the node.
- Prepare a temporary kubeadm configuration file called config.yaml that can be used with kubeadm init. Make sure that this file includes any relevant cluster wide or host-specific information that could be included in certificates, such as, ClusterConfiguration.controlPlaneEndpoint, ClusterConfiguration.certSANs and InitConfiguration.APIEndpoint.
- On the same host execute the commands kubeadm init phase kubeconfig all --config config.yaml and kubeadm init phase certs all --config config.yaml. This will generate all required kubeconfig files and certificates under /etc/kubernetes/ and its pki sub directory.
- Inspect the generated files. Delete /etc/kubernetes/pki/ca.key, delete or move to a safe location the file /etc/kubernetes/super-admin.conf.
- On nodes where kubeadm join will be called also delete /etc/kubernetes/kubelet.conf. This file is only required on the first node where kubeadm init will be called.
- Note that some files such pki/sa.*, pki/front-proxy-ca.* and pki/etc/ca.* are shared between control plane nodes, You can generate them once and distribute them manually to nodes where kubeadm join will be called, or you can use the --upload-certs functionality of kubeadm init and --certificate-key of kubeadm join to automate this distribution.

Once the credentials are prepared on all nodes, call kubeadm init and kubeadm join for these nodes to join the cluster. kubeadm will use the existing kubeconfig and certificate files under /etc/kubernetes/ and its pki sub directory.

Certificate expiry and management

Note:

kubeadm cannot manage certificates signed by an external CA.

You can use the check-expiration subcommand to check when certificates expire:

```
kubeadm certs check-expiration
```

The output is similar to this:

```
CERTIFICATE                EXPIRES                  RESIDUAL TIME   CERTIFICATE AUTHORITY   EXTERNALLY MANAGED
admin.conf                 Dec 30, 2020 23:36 UTC   364d                                    no
apiserver                  Dec 30, 2020 23:36 UTC   364d            ca                      no
apiserver-etcd-client      Dec 30, 2020 23:36 UTC   364d            etcd-ca                 no
apiserver-kubelet-client   Dec 30, 2020 23:36 UTC   364d            ca                      no
controller-manager.conf    Dec 30, 2020 23:36 UTC   364d                                    no
etcd-healthcheck-client    Dec 30, 2020 23:36 UTC   364d            etcd-ca                 no
etcd-peer                  Dec 30, 2020 23:36 UTC   364d            etcd-ca                 no
etcd-server                Dec 30, 2020 23:36 UTC   364d            etcd-ca                 no
front-proxy-client         Dec 30, 2020 23:36 UTC   364d            front-proxy-ca          no
scheduler.conf             Dec 30, 2020 23:36 UTC   364d                                    no
CERTIFICATE AUTHORITY   EXPIRES                  RESIDUAL TIME   EXTERNALLY MANAGEDca                    Dec 28, 2029 23:36 UTC
```

The command shows expiration/residual time for the client certificates in the `/etc/kubernetes/pki` folder and for the client certificate embedded in the kubeconfig files used by kubeadm (`admin.conf`, `controller-manager.conf` and `scheduler.conf`).

Additionally, kubeadm informs the user if the certificate is externally managed; in this case, the user should take care of managing certificate renewal manually/using other tools.

The `kubelet.conf` configuration file is not included in the list above because kubeadm configures kubelet for automatic certificate renewal with rotatable certificates under `/var/lib/kubelet/pki`. To repair an expired kubelet client certificate see Kubelet client certificate rotation fails.

Note:

On nodes created with `kubeadm init` from versions prior to kubeadm version 1.17, there is a bug where you manually have to modify the contents of `kubelet.conf`. After `kubeadm init` finishes, you should update `kubelet.conf` to point to the rotated kubelet client certificates, by replacing `client-certificate-data` and `client-key-data` with:

```
client-certificate: /var/lib/kubelet/pki/kubelet-client-current.pem
client-key: /var/lib/kubelet/pki/kubelet-client-current.pem
```

Automatic certificate renewal

kubeadm renews all the certificates during control plane upgrade.

This feature is designed for addressing the simplest use cases; if you don't have specific requirements on certificate renewal and perform Kubernetes version upgrades regularly (less than 1 year in between each upgrade), kubeadm will take care of keeping your cluster up to date and reasonably secure.

If you have more complex requirements for certificate renewal, you can opt out from the default behavior by passing `--certificate-renewal=false` to `kubeadm upgrade apply` or to `kubeadm upgrade node`.

Manual certificate renewal

You can renew your certificates manually at any time with the `kubeadm certs renew` command, with the appropriate command line options. If you are running cluster with a replicated control plane, this command needs to be executed on all the control-plane nodes.

This command performs the renewal using CA (or front-proxy-CA) certificate and key stored in `/etc/kubernetes/pki`.

`kubeadm certs renew` uses the existing certificates as the authoritative source for attributes (Common Name, Organization, subject alternative name) and does not rely on the `kubeadm-config` ConfigMap. Even so, the Kubernetes project recommends keeping the served certificate and the associated values in that ConfigMap synchronized, to avoid any risk of confusion.

After running the command you should restart the control plane Pods. This is required since dynamic certificate reload is currently not supported for all components and certificates. Static Pods are managed by the local kubelet and not by the API Server, thus kubectl cannot be used to delete and restart them. To restart a static Pod you can temporarily remove its manifest file from `/etc/kubernetes/manifests/` and wait for 20 seconds (see the `fileCheckFrequency` value in KubeletConfiguration struct). The kubelet will terminate the Pod if it's no longer in the manifest directory. You can then move the file back and after another `fileCheckFrequency` period, the kubelet will recreate the Pod and the certificate renewal for the component can complete.

`kubeadm certs renew` can renew any specific certificate or, with the subcommand `all`, it can renew all of them:

```
# If you are running cluster with a replicated control plane, this command
# needs to be executed on all the control-plane nodes.
kubeadm certs renew all
```

Copying the administrator certificate (optional)

Clusters built with kubeadm often copy the `admin.conf` certificate into `$HOME/.kube/config`, as instructed in Creating a cluster with kubeadm. On such a system, to update the contents of `$HOME/.kube/config` after renewing the `admin.conf`, you could run the following commands:

```
sudo cp -i /etc/kubernetes/admin.conf $HOME/.kube/config
sudo chown $(id -u):$(id -g) $HOME/.kube/config
```

Renew certificates with the Kubernetes certificates API

This section provides more details about how to execute manual certificate renewal using the Kubernetes certificates API.

Caution:

These are advanced topics for users who need to integrate their organization's certificate infrastructure into a kubeadm-built cluster. If the default kubeadm configuration satisfies your needs, you should let kubeadm manage certificates instead.

Set up a signer

The Kubernetes Certificate Authority does not work out of the box. You can configure an external signer such as cert-manager, or you can use the built-in signer.

The built-in signer is part of `kube-controller-manager`.

To activate the built-in signer, you must pass the `--cluster-signing-cert-file` and `--cluster-signing-key-file` flags.

If you're creating a new cluster, you can use a kubeadm configuration file:

```
apiVersion: kubeadm.k8s.io/v1beta4
```

```
kind: ClusterConfigurationcontrollerManager:  extraArgs:  - name: "cluster-signing-cert-file"    value: "/etc/kubernetes/pki/ca.cr
```

Create certificate signing requests (CSR)

See Create CertificateSigningRequest for creating CSRs with the Kubernetes API.

Renew certificates with external CA

This section provide more details about how to execute manual certificate renewal using an external CA.

To better integrate with external CAs, kubeadm can also produce certificate signing requests (CSRs). A CSR represents a request to a CA for a signed certificate for a client. In kubeadm terms, any certificate that would normally be signed by an on-disk CA can be produced as a CSR instead. A CA, however, cannot be produced as a CSR.

Renewal by using certificate signing requests (CSR)

Renewal of ceritficates is possible by generating new CSRs and signing them with the external CA. For more details about working with CSRs generated by kubeadm see the section Signing certificate signing requests (CSR) generated by kubeadm.

Certificate authority (CA) rotation

Kubeadm does not support rotation or replacement of CA certificates out of the box.

For more information about manual rotation or replacement of CA, see manual rotation of CA certificates.

Enabling signed kubelet serving certificates

By default the kubelet serving certificate deployed by kubeadm is self-signed. This means a connection from external services like the metrics-server to a kubelet cannot be secured with TLS.

To configure the kubelets in a new kubeadm cluster to obtain properly signed serving certificates you must pass the following minimal configuration to `kubeadm init`:

```
apiVersion: kubeadm.k8s.io/v1beta4
kind: ClusterConfiguration---apiVersion: kubelet.config.k8s.io/v1beta1kind: KubeletConfigurationserverTLSBootstrap: true
```

If you have already created the cluster you must adapt it by doing the following:

- Find and edit the `kubelet-config` ConfigMap in the `kube-system` namespace. In that ConfigMap, the `kubelet` key has a KubeletConfiguration document as its value. Edit the KubeletConfiguration document to set `serverTLSBootstrap: true`.
- On each node, add the `serverTLSBootstrap: true` field in `/var/lib/kubelet/config.yaml` and restart the kubelet with `systemctl restart kubelet`

The field `serverTLSBootstrap: true` will enable the bootstrap of kubelet serving certificates by requesting them from the `certificates.k8s.io` API. One known limitation is that the CSRs (Certificate Signing Requests) for these certificates cannot be automatically approved by the default signer in the kube-controller-manager - `kubernetes.io/kubelet-serving`. This will require action from the user or a third party controller.

These CSRs can be viewed using:

```
kubectl get csr

NAME        AGE     SIGNERNAME                      REQUESTOR                     CONDITION
csr-9wvgt   112s    kubernetes.io/kubelet-serving   system:node:worker-1          Pending
csr-lz97v   1m58s   kubernetes.io/kubelet-serving   system:node:control-plane-1   Pending
```

To approve them you can do the following:

```
kubectl certificate approve <CSR-name>
```

By default, these serving certificate will expire after one year. Kubeadm sets the `KubeletConfiguration` field `rotateCertificates` to `true`, which means that close to expiration a new set of CSRs for the serving certificates will be created and must be approved to complete the rotation. To understand more see Certificate Rotation.

If you are looking for a solution for automatic approval of these CSRs it is recommended that you contact your cloud provider and ask if they have a CSR signer that verifies the node identity with an out of band mechanism.

Note: This section links to third party projects that provide functionality required by Kubernetes. The Kubernetes project authors aren't responsible for these projects, which are listed alphabetically. To add a project to this list, read the content guide before submitting a change. More information.

Third party custom controllers can be used:

- kubelet-csr-approver

Such a controller is not a secure mechanism unless it not only verifies the CommonName in the CSR but also verifies the requested IPs and domain names. This would prevent a malicious actor that has access to a kubelet client certificate to create CSRs requesting serving certificates for any IP or domain name.

Generating kubeconfig files for additional users

During cluster creation, `kubeadm init` signs the certificate in the `super-admin.conf` to have `Subject: O = system:masters, CN = kubernetes-super-admin`. `system:masters` is a break-glass, super user group that bypasses the authorization layer (for example, RBAC). The file `admin.conf` is also created by kubeadm on control plane nodes and it contains a certificate with `Subject: O = kubeadm:cluster-admins, CN = kubernetes-admin`. `kubeadm:cluster-`

`admins` is a group logically belonging to kubeadm. If your cluster uses RBAC (the kubeadm default), the `kubeadm:cluster-admins` group is bound to the `cluster-admin` ClusterRole.

Warning:

Avoid sharing the `super-admin.conf` or `admin.conf` files. Instead, create least privileged access even for people who work as administrators and use that least privilege alternative for anything other than break-glass (emergency) access.

You can use the `kubeadm kubeconfig user` command to generate kubeconfig files for additional users. The command accepts a mixture of command line flags and kubeadm configuration options. The generated kubeconfig will be written to stdout and can be piped to a file using `kubeadm kubeconfig user ... > somefile.conf`.

Example configuration file that can be used with `--config`:

```
# example.yaml
apiVersion: kubeadm.k8s.io/v1beta4kind: ClusterConfiguration# Will be used as the target "cluster" in the kubeconfigclusterName: "
```

Make sure that these settings match the desired target cluster settings. To see the settings of an existing cluster use:

```
kubectl get cm kubeadm-config -n kube-system -o=jsonpath="{.data.ClusterConfiguration}"
```

The following example will generate a kubeconfig file with credentials valid for 24 hours for a new user `johndoe` that is part of the `appdevs` group:

```
kubeadm kubeconfig user --config example.yaml --org appdevs --client-name johndoe --validity-period 24h
```

The following example will generate a kubeconfig file with administrator credentials valid for 1 week:

```
kubeadm kubeconfig user --config example.yaml --client-name admin --validity-period 168h
```

Signing certificate signing requests (CSR) generated by kubeadm

You can create certificate signing requests with `kubeadm certs generate-csr`. Calling this command will generate `.csr` / `.key` file pairs for regular certificates. For certificates embedded in kubeconfig files, the command will generate a `.csr` / `.conf` pair where the key is already embedded in the `.conf` file.

A CSR file contains all relevant information for a CA to sign a certificate. kubeadm uses a well defined specification for all its certificates and CSRs.

The default certificate directory is `/etc/kubernetes/pki`, while the default directory for kubeconfig files is `/etc/kubernetes`. These defaults can be overridden with the flags `--cert-dir` and `--kubeconfig-dir`, respectively.

To pass custom options to `kubeadm certs generate-csr` use the `--config` flag, which accepts a kubeadm configuration file, similarly to commands such as `kubeadm init`. Any specification such as extra SANs and custom IP addresses must be stored in the same configuration file and used for all relevant kubeadm commands by passing it as `--config`.

Note:

This guide uses the default Kubernetes directory `/etc/kubernetes`, which requires a super user. If you are following this guide and are using directories that you can write to (typically, this means running `kubeadm` with `--cert-dir` and `--kubeconfig-dir`) then you can omit the `sudo` command.

You must then copy the files that you produced over to within the `/etc/kubernetes` directory so that `kubeadm init` or `kubeadm join` will find them.

Preparing CA and service account files

On the primary control plane node, where `kubeadm init` will be executed, call the following commands:

```
sudo kubeadm init phase certs ca
sudo kubeadm init phase certs etcd-ca
sudo kubeadm init phase certs front-proxy-ca
sudo kubeadm init phase certs sa
```

This will populate the folders `/etc/kubernetes/pki` and `/etc/kubernetes/pki/etcd` with all self-signed CA files (certificates and keys) and service account (public and private keys) that kubeadm needs for a control plane node.

Note:

If you are using an external CA, you must generate the same files out of band and manually copy them to the primary control plane node in `/etc/kubernetes`.

Once all CSRs are signed, you can delete the root CA key (`ca.key`) as noted in the External CA mode section.

For secondary control plane nodes (`kubeadm join --control-plane`) there is no need to call the above commands. Depending on how you setup the High Availability cluster, you either have to manually copy the same files from the primary control plane node, or use the automated `--upload-certs` functionality of `kubeadm init`.

Generate CSRs

The `kubeadm certs generate-csr` command generates CSRs for all known certificates managed by kubeadm. Once the command is done you must manually delete `.csr`, `.conf` or `.key` files that you don't need.

Considerations for kubelet.conf

This section applies to both control plane and worker nodes.

If you have deleted the `ca.key` file from control plane nodes (External CA mode), the active kube-controller-manager in this cluster will not be able to sign kubelet client certificates. If no external method for signing these certificates exists in your setup (such as an external signer), you could manually sign the `kubelet.conf.csr` as explained in this guide.

Note that this also means that the automatic kubelet client certificate rotation will be disabled. If so, close to certificate expiration, you must generate a new `kubelet.conf.csr`, sign the certificate, embed it in `kubelet.conf` and restart the kubelet.

If this does not apply to your setup, you can skip processing the `kubelet.conf.csr` on secondary control plane and on workers nodes (all nodes that call `kubeadm join ...`). That is because the active kube-controller-manager will be responsible for signing new kubelet client certificates.

Note:

You must process the `kubelet.conf.csr` file on the primary control plane node (the host where you originally ran `kubeadm init`). This is because `kubeadm` considers that as the node that bootstraps the cluster, and a pre-populated `kubelet.conf` is needed.

Control plane nodes

Execute the following command on primary (`kubeadm init`) and secondary (`kubeadm join --control-plane`) control plane nodes to generate all CSR files:

```
sudo kubeadm certs generate-csr
```

If external etcd is to be used, follow the External etcd with kubeadm guide to understand what CSR files are needed on the kubeadm and etcd nodes. Other `.csr` and `.key` files under `/etc/kubernetes/pki/etcd` can be removed.

Based on the explanation in Considerations for kubelet.conf keep or delete the `kubelet.conf` and `kubelet.conf.csr` files.

Worker nodes

Based on the explanation in Considerations for kubelet.conf, optionally call:

```
sudo kubeadm certs generate-csr
```

and keep only the `kubelet.conf` and `kubelet.conf.csr` files. Alternatively skip the steps for worker nodes entirely.

Signing CSRs for all certificates

Note:

If you are using external CA and already have CA serial number files (`.srl`) for `openssl`, you can copy such files to a kubeadm node where CSRs will be processed. The `.srl` files to copy are `/etc/kubernetes/pki/ca.srl`, `/etc/kubernetes/pki/front-proxy-ca.srl` and `/etc/kubernetes/pki/etcd/ca.srl`. The files can be then moved to a new node where CSR files will be processed.

If a `.srl` file is missing for a CA on a node, the script below will generate a new SRL file with a random starting serial number.

To read more about `.srl` files see the `openssl` documentation for the `-CAserial` flag.

Repeat this step for all nodes that have CSR files.

Write the following script in the `/etc/kubernetes` directory, navigate to the directory and execute the script. The script will generate certificates for all CSR files that are present in the `/etc/kubernetes` tree.

```
#!/bin/bash
# Set certificate expiration time in daysDAYS=365# Process all CSR files except those for front-proxy and etcdfind ./ -name "*.csr
```

Embedding certificates in kubeconfig files

Repeat this step for all nodes that have CSR files.

Write the following script in the `/etc/kubernetes` directory, navigate to the directory and execute the script. The script will take the `.crt` files that were signed for kubeconfig files from CSRs in the previous step and will embed them in the kubeconfig files.

```
#!/bin/bash
CLUSTER=kubernetesfind ./ -name "*.conf" | while read -r FILE;do    echo "* Processing ${FILE} ..."    KUBECONFIG="${FILE}" kubect
```

Performing cleanup

Perform this step on all nodes that have CSR files.

Write the following script in the `/etc/kubernetes` directory, navigate to the directory and execute the script.

```
#!/bin/bash
# Cleanup CSR filesrm -f ./*.csr ./pki/*.csr ./pki/etcd/*.csr # Clean all CSR files# Cleanup CRT files that were already embedded .
```

Optionally, move `.srl` files to the next node to be processed.

Optionally, if using external CA remove the `/etc/kubernetes/pki/ca.key` file, as explained in the External CA node section.

kubeadm node initialization

Once CSR files have been signed and required certificates are in place on the hosts you want to use as nodes, you can use the commands `kubeadm init` and `kubeadm join` to create a Kubernetes cluster from these nodes. During `init` and `join`, kubeadm uses existing certificates, encryption keys and kubeconfig files that it finds in the `/etc/kubernetes` tree on the host's local filesystem.

Limit Storage Consumption

This example demonstrates how to limit the amount of storage consumed in a namespace.

The following resources are used in the demonstration: ResourceQuota, LimitRange, and PersistentVolumeClaim.

Before you begin

- You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:
  - iximiuz Labs
  - Killercoda
  - KodeKloud
  - Play with Kubernetes

  To check the version, enter `kubectl version`.

Scenario: Limiting Storage Consumption

The cluster-admin is operating a cluster on behalf of a user population and the admin wants to control how much storage a single namespace can consume in order to control cost.

The admin would like to limit:

1. The number of persistent volume claims in a namespace
2. The amount of storage each claim can request
3. The amount of cumulative storage the namespace can have

LimitRange to limit requests for storage

Adding a `LimitRange` to a namespace enforces storage request sizes to a minimum and maximum. Storage is requested via `PersistentVolumeClaim`. The admission controller that enforces limit ranges will reject any PVC that is above or below the values set by the admin.

In this example, a PVC requesting 10Gi of storage would be rejected because it exceeds the 2Gi max.

```
apiVersion: v1
kind: LimitRangemetadata:  name: storagelimitsspec:  limits:  - type: PersistentVolumeClaim    max:      storage: 2Gi    min:
```

Minimum storage requests are used when the underlying storage provider requires certain minimums. For example, AWS EBS volumes have a 1Gi minimum requirement.

ResourceQuota to limit PVC count and cumulative storage capacity

Admins can limit the number of PVCs in a namespace as well as the cumulative capacity of those PVCs. New PVCs that exceed either maximum value will be rejected.

In this example, a 6th PVC in the namespace would be rejected because it exceeds the maximum count of 5. Alternatively, a 5Gi maximum quota when combined with the 2Gi max limit above, cannot have 3 PVCs where each has 2Gi. That would be 6Gi requested for a namespace capped at 5Gi.

```
apiVersion: v1
kind: ResourceQuotametadata:  name: storagequotaspec:  hard:    persistentvolumeclaims: "5"    requests.storage: "5Gi"
```

Summary

A limit range can put a ceiling on how much storage is requested while a resource quota can effectively cap the storage consumed by a namespace through claim counts and cumulative storage capacity. The allows a cluster-admin to plan their cluster's storage budget without risk of any one project going over their allotment.

Reserve Compute Resources for System Daemons

Kubernetes nodes can be scheduled to `Capacity`. Pods can consume all the available capacity on a node by default. This is an issue because nodes typically run quite a few system daemons that power the OS and Kubernetes itself. Unless resources are set aside for these system daemons, pods and system daemons compete for resources and lead to resource starvation issues on the node.

The `kubelet` exposes a feature named 'Node Allocatable' that helps to reserve compute resources for system daemons. Kubernetes recommends cluster administrators to configure 'Node Allocatable' based on their workload density on each node.

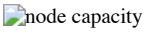
Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

You can configure below kubelet configuration settings using the kubelet configuration file.

Node Allocatable



'Allocatable' on a Kubernetes node is defined as the amount of compute resources that are available for pods. The scheduler does not over-subscribe 'Allocatable'. 'CPU', 'memory' and 'ephemeral-storage' are supported as of now.

Node Allocatable is exposed as part of `v1.Node` object in the API and as part of `kubectl describe node` in the CLI.

Resources can be reserved for two categories of system daemons in the `kubelet`.

Enabling QoS and Pod level cgroups

To properly enforce node allocatable constraints on the node, you must enable the new cgroup hierarchy via the `cgroupsPerQOS` setting. This setting is enabled by default. When enabled, the `kubelet` will parent all end-user pods under a cgroup hierarchy managed by the `kubelet`.

Configuring a cgroup driver

The `kubelet` supports manipulation of the cgroup hierarchy on the host using a cgroup driver. The driver is configured via the `cgroupDriver` setting.

The supported values are the following:

- `cgroupfs` is the default driver that performs direct manipulation of the cgroup filesystem on the host in order to manage cgroup sandboxes.
- `systemd` is an alternative driver that manages cgroup sandboxes using transient slices for resources that are supported by that init system.

Depending on the configuration of the associated container runtime, operators may have to choose a particular cgroup driver to ensure proper system behavior. For example, if operators use the `systemd` cgroup driver provided by the `containerd` runtime, the `kubelet` must be configured to use the `systemd` cgroup driver.

Kube Reserved

- **KubeletConfiguration Setting**: `kubeReserved: {}`. Example value `{cpu: 100m, memory: 100Mi, ephemeral-storage: 1Gi, pid=1000}`
- **KubeletConfiguration Setting**: `kubeReservedCgroup: ""`

`kubeReserved` is meant to capture resource reservation for kubernetes system daemons like the `kubelet`, `container runtime`, etc. It is not meant to reserve resources for system daemons that are run as pods. `kubeReserved` is typically a function of `pod density` on the nodes.

In addition to `cpu`, `memory`, and `ephemeral-storage`, `pid` may be specified to reserve the specified number of process IDs for kubernetes system daemons.

To optionally enforce `kubeReserved` on kubernetes system daemons, specify the parent control group for kube daemons as the value for `kubeReservedCgroup` setting, and add `kube-reserved` to `enforceNodeAllocatable`.

It is recommended that the kubernetes system daemons are placed under a top level control group (`runtime.slice` on systemd machines for example). Each system daemon should ideally run within its own child control group. Refer to the design proposal for more details on recommended control group hierarchy.

Note that Kubelet **does not** create `kubeReservedCgroup` if it doesn't exist. The kubelet will fail to start if an invalid cgroup is specified. With `systemd` cgroup driver, you should follow a specific pattern for the name of the cgroup you define: the name should be the value you set for `kubeReservedCgroup`, with `.slice` appended.

System Reserved

- **KubeletConfiguration Setting**: `systemReserved: {}`. Example value `{cpu: 100m, memory: 100Mi, ephemeral-storage: 1Gi, pid=1000}`
- **KubeletConfiguration Setting**: `systemReservedCgroup: ""`

`systemReserved` is meant to capture resource reservation for OS system daemons like `sshd`, `udev`, etc. `systemReserved` should reserve `memory` for the `kernel` too since `kernel` memory is not accounted to pods in Kubernetes at this time. Reserving resources for user login sessions is also recommended (`user.slice` in systemd world).

In addition to `cpu`, `memory`, and `ephemeral-storage`, `pid` may be specified to reserve the specified number of process IDs for OS system daemons.

To optionally enforce `systemReserved` on system daemons, specify the parent control group for OS system daemons as the value for `systemReservedCgroup` setting, and add `system-reserved` to `enforceNodeAllocatable`.

It is recommended that the OS system daemons are placed under a top level control group (`system.slice` on systemd machines for example).

Note that `kubelet` **does not** create `systemReservedCgroup` if it doesn't exist. `kubelet` will fail if an invalid cgroup is specified. With `systemd` cgroup driver, you should follow a specific pattern for the name of the cgroup you define: the name should be the value you set for `systemReservedCgroup`, with `.slice` appended.

Explicitly Reserved CPU List

FEATURE STATE: `Kubernetes v1.17 [stable]`

KubeletConfiguration Setting: `reservedSystemCPUs:`. Example value `0-3`

`reservedSystemCPUs` is meant to define an explicit CPU set for OS system daemons and kubernetes system daemons. `reservedSystemCPUs` is for systems that do not intend to define separate top level cgroups for OS system daemons and kubernetes system daemons with regard to cpuset resource. If the Kubelet **does not** have `kubeReservedCgroup` and `systemReservedCgroup`, the explicit cpuset provided by `reservedSystemCPUs` will take precedence over the CPUs defined by `kubeReservedCgroup` and `systemReservedCgroup` options.

This option is specifically designed for Telco/NFV use cases where uncontrolled interrupts/timers may impact the workload performance. you can use this option to define the explicit cpuset for the system/kubernetes daemons as well as the interrupts/timers, so the rest CPUs on the system can be used exclusively for workloads, with less impact from uncontrolled interrupts/timers. To move the system daemon, kubernetes daemons and interrupts/timers to the explicit cpuset defined by this option, other mechanism outside Kubernetes should be used. For example: in Centos, you can do this using the tuned toolset.

Eviction Thresholds

KubeletConfiguration Setting: `evictionHard: {memory.available: "100Mi", nodefs.available: "10%", nodefs.inodesFree: "5%", imagefs.available: "15%"}`. Example value: `{memory.available: "<500Mi"}`

Memory pressure at the node level leads to System OOMs which affects the entire node and all pods running on it. Nodes can go offline temporarily until memory has been reclaimed. To avoid (or reduce the probability of) system OOMs kubelet provides out of resource management. Evictions are supported for `memory` and `ephemeral-storage` only. By reserving some memory via `evictionHard` setting, the `kubelet` attempts to evict pods whenever memory availability on the node drops below the reserved value. Hypothetically, if system daemons did not exist on a node, pods cannot use more than `capacity - eviction-hard`. For this reason, resources reserved for evictions are not available for pods.

Enforcing Node Allocatable

KubeletConfiguration setting: `enforceNodeAllocatable: [pods]`. Example value: `[pods,system-reserved,kube-reserved]`

The scheduler treats 'Allocatable' as the available `capacity` for pods.

`kubelet` enforce 'Allocatable' across pods by default. Enforcement is performed by evicting pods whenever the overall usage across all pods exceeds 'Allocatable'. More details on eviction policy can be found on the node pressure eviction page. This enforcement is controlled by specifying `pods` value to the KubeletConfiguration setting `enforceNodeAllocatable`.

Optionally, `kubelet` can be made to enforce `kubeReserved` and `systemReserved` by specifying `kube-reserved` & `system-reserved` values in the same setting. Note that to enforce `kubeReserved` or `systemReserved`, `kubeReservedCgroup` or `systemReservedCgroup` needs to be specified respectively.

General Guidelines

System daemons are expected to be treated similar to Guaranteed pods. System daemons can burst within their bounding control groups and this behavior needs to be managed as part of kubernetes deployments. For example, `kubelet` should have its own control group and share `kubeReserved` resources with the container runtime. However, Kubelet cannot burst and use up all available Node resources if `kubeReserved` is enforced.

Be extra careful while enforcing `systemReserved` reservation since it can lead to critical system services being CPU starved, OOM killed, or unable to fork on the node. The recommendation is to enforce `systemReserved` only if a user has profiled their nodes exhaustively to come up with precise estimates and is confident in their ability to recover if any process in that group is oom-killed.

- To begin with enforce 'Allocatable' on `pods`.
- Once adequate monitoring and alerting is in place to track kube system daemons, attempt to enforce `kubeReserved` based on usage heuristics.
- If absolutely necessary, enforce `systemReserved` over time.

The resource requirements of kube system daemons may grow over time as more and more features are added. Over time, kubernetes project will attempt to bring down utilization of node system daemons, but that is not a priority as of now. So expect a drop in `Allocatable` capacity in future releases.

Example Scenario

Here is an example to illustrate Node Allocatable computation:

- Node has `32Gi` of `memory`, `16 CPUs` and `100Gi` of `Storage`
- `kubeReserved` is set to `{cpu: 1000m, memory: 2Gi, ephemeral-storage: 1Gi}`
- `systemReserved` is set to `{cpu: 500m, memory: 1Gi, ephemeral-storage: 1Gi}`
- `evictionHard` is set to `{memory.available: "<500Mi", nodefs.available: "<10%"}`

Under this scenario, 'Allocatable' will be 14.5 CPUs, 28.5Gi of memory and `88Gi` of local storage. Scheduler ensures that the total memory `requests` across all pods on this node does not exceed 28.5Gi and storage doesn't exceed 88Gi. Kubelet evicts pods whenever the overall memory usage across pods exceeds 28.5Gi, or if overall disk usage exceeds 88Gi. If all processes on the node consume as much CPU as they can, pods together cannot consume more than 14.5 CPUs.

If `kubeReserved` and/or `systemReserved` is not enforced and system daemons exceed their reservation, `kubelet` evicts pods whenever the overall node memory usage is higher than 31.5Gi or `storage` is greater than 90Gi.

Accessing Clusters

This topic discusses multiple ways to interact with clusters.

Accessing for the first time with kubectl

When accessing the Kubernetes API for the first time, we suggest using the Kubernetes CLI, `kubectl`.

To access a cluster, you need to know the location of the cluster and have credentials to access it. Typically, this is automatically set-up when you work through a Getting started guide, or someone else set up the cluster and provided you with credentials and a location.

Check the location and credentials that kubectl knows about with this command:

```
kubectl config view
```

Many of the examples provide an introduction to using `kubectl`, and complete documentation is found in the kubectl reference.

Directly accessing the REST API

Kubectl handles locating and authenticating to the apiserver. If you want to directly access the REST API with an http client like curl or wget, or a browser, there are several ways to locate and authenticate:

- Run kubectl in proxy mode.
  - Recommended approach.
  - Uses stored apiserver location.
  - Verifies identity of apiserver using self-signed cert. No MITM possible.
  - Authenticates to apiserver.
  - In future, may do intelligent client-side load-balancing and failover.
- Provide the location and credentials directly to the http client.
  - Alternate approach.
  - Works with some types of client code that are confused by using a proxy.
  - Need to import a root cert into your browser to protect against MITM.

Using kubectl proxy

The following command runs kubectl in a mode where it acts as a reverse proxy. It handles locating the apiserver and authenticating. Run it like this:

```
kubectl proxy --port=8080
```

See kubectl proxy for more details.

Then you can explore the API with curl, wget, or a browser, replacing localhost with [::1] for IPv6, like so:

```
curl http://localhost:8080/api/
```

The output is similar to this:

```
{
  "kind": "APIVersions",
  "versions": [
    "v1"
  ],
  "serverAddressByClientCIDRs": [
    {
      "clientCIDR": "0.0.0.0/0",
      "serverAddress": "10.0.1.149:443"
    }
  ]
}
```

Without kubectl proxy

Use `kubectl apply` and `kubectl describe secret...` to create a token for the default service account with grep/cut:

First, create the Secret, requesting a token for the default ServiceAccount:

```
kubectl apply -f - <<EOF
apiVersion: v1
kind: Secret
metadata:
  name: default-token
  annotations:
    kubernetes.io/service-account.name: default
type: kubernetes.io/service-account-token
EOF
```

Next, wait for the token controller to populate the Secret with a token:

```
while ! kubectl describe secret default-token | grep -E '^token' >/dev/null; do
  echo "waiting for token..." >&2
  sleep 1
done
```

Capture and use the generated token:

```
APISERVER=$(kubectl config view --minify | grep server | cut -f 2- -d ":" | tr -d " ")
TOKEN=$(kubectl describe secret default-token | grep -E '^token' | cut -f2 -d':' | tr -d " ")

curl $APISERVER/api --header "Authorization: Bearer $TOKEN" --insecure
```

The output is similar to this:

```
{
  "kind": "APIVersions",
  "versions": [
    "v1"
  ],
  "serverAddressByClientCIDRs": [
    {
      "clientCIDR": "0.0.0.0/0",
      "serverAddress": "10.0.1.149:443"
    }
  ]
}
```

Using `jsonpath`:

```
APISERVER=$(kubectl config view --minify -o jsonpath='{.clusters[0].cluster.server}')
TOKEN=$(kubectl get secret default-token -o jsonpath='{.data.token}' | base64 --decode)

curl $APISERVER/api --header "Authorization: Bearer $TOKEN" --insecure
```

The output is similar to this:

```
{
  "kind": "APIVersions",
  "versions": [
    "v1"
  ],
  "serverAddressByClientCIDRs": [
    {
      "clientCIDR": "0.0.0.0/0",
      "serverAddress": "10.0.1.149:443"
    }
  ]
}
```

The above examples use the `--insecure` flag. This leaves it subject to MITM attacks. When kubectl accesses the cluster it uses a stored root certificate and client certificates to access the server. (These are installed in the `~/.kube` directory). Since cluster certificates are typically self-signed, it may take special configuration to get your http client to use root certificate.

On some clusters, the apiserver does not require authentication; it may serve on localhost, or be protected by a firewall. There is not a standard for this. Controlling Access to the API describes how a cluster admin can configure this.

Programmatic access to the API

Kubernetes officially supports Go and Python client libraries.

Go client

- To get the library, run the following command: `go get k8s.io/client-go@kubernetes-<kubernetes-version-number>`, see INSTALL.md for detailed installation instructions. See https://github.com/kubernetes/client-go to see which versions are supported.
- Write an application atop of the client-go clients. Note that client-go defines its own API objects, so if needed, please import API definitions from client-go rather than from the main repository, e.g., `import "k8s.io/client-go/kubernetes"` is correct.

The Go client can use the same kubeconfig file as the kubectl CLI does to locate and authenticate to the apiserver. See this example.

If the application is deployed as a Pod in the cluster, please refer to the next section.

Python client

To use Python client, run the following command: `pip install kubernetes`. See Python Client Library page for more installation options.

The Python client can use the same kubeconfig file as the kubectl CLI does to locate and authenticate to the apiserver. See this example.

Other languages

There are client libraries for accessing the API from other languages. See documentation for other libraries for how they authenticate.

Accessing the API from a Pod

When accessing the API from a pod, locating and authenticating to the API server are somewhat different.

Please check Accessing the API from within a Pod for more details.

Accessing services running on the cluster

The previous section describes how to connect to the Kubernetes API server. For information about connecting to other services running on a Kubernetes cluster, see Access Cluster Services.

Requesting redirects

The redirect capabilities have been deprecated and removed. Please use a proxy (see below) instead.

So many proxies

There are several different proxies you may encounter when using Kubernetes:

1. The kubectl proxy:
    - runs on a user's desktop or in a pod
    - proxies from a localhost address to the Kubernetes apiserver
    - client to proxy uses HTTP
    - proxy to apiserver uses HTTPS
    - locates apiserver
    - adds authentication headers
2. The apiserver proxy:
    - is a bastion built into the apiserver
    - connects a user outside of the cluster to cluster IPs which otherwise might not be reachable
    - runs in the apiserver processes
    - client to proxy uses HTTPS (or http if apiserver so configured)
    - proxy to target may use HTTP or HTTPS as chosen by proxy using available information
    - can be used to reach a Node, Pod, or Service
    - does load balancing when used to reach a Service
3. The kube proxy:
    - runs on each node
    - proxies UDP and TCP
    - does not understand HTTP
    - provides load balancing
    - is only used to reach services
4. A Proxy/Load-balancer in front of apiserver(s):
    - existence and implementation varies from cluster to cluster (e.g. nginx)
    - sits between all clients and one or more apiservers
    - acts as load balancer if there are several apiservers.
5. Cloud Load Balancers on external services:
    - are provided by some cloud providers (e.g. AWS ELB, Google Cloud Load Balancer)
    - are created automatically when the Kubernetes service has type `LoadBalancer`
    - use UDP/TCP only
    - implementation varies by cloud provider.

Kubernetes users will typically not need to worry about anything other than the first two types. The cluster admin will typically ensure that the latter types are set up correctly.

Check whether dockershim removal affects you

The `dockershim` component of Kubernetes allows the use of Docker as a Kubernetes's container runtime. Kubernetes' built-in `dockershim` component was removed in release v1.24.

This page explains how your cluster could be using Docker as a container runtime, provides details on the role that `dockershim` plays when in use, and shows steps you can take to check whether any workloads could be affected by `dockershim` removal.

Finding if your app has a dependencies on Docker

If you are using Docker for building your application containers, you can still run these containers on any container runtime. This use of Docker does not count as a dependency on Docker as a container runtime.

When alternative container runtime is used, executing Docker commands may either not work or yield unexpected output. This is how you can find whether you have a dependency on Docker:

1. Make sure no privileged Pods execute Docker commands (like `docker ps`), restart the Docker service (commands such as `systemctl restart docker.service`), or modify Docker-specific files such as `/etc/docker/daemon.json`.
2. Check for any private registries or image mirror settings in the Docker configuration file (like `/etc/docker/daemon.json`). Those typically need to be reconfigured for another container runtime.
3. Check that scripts and apps running on nodes outside of your Kubernetes infrastructure do not execute Docker commands. It might be:
    - SSH to nodes to troubleshoot;
    - Node startup scripts;
    - Monitoring and security agents installed on nodes directly.
4. Third-party tools that perform above mentioned privileged operations. See Migrating telemetry and security agents from dockershim for more information.
5. Make sure there are no indirect dependencies on dockershim behavior. This is an edge case and unlikely to affect your application. Some tooling may be configured to react to Docker-specific behaviors, for example, raise alert on specific metrics or search for a specific log message as part of troubleshooting instructions. If you have such tooling configured, test the behavior on a test cluster before migration.

Dependency on Docker explained

A container runtime is software that can execute the containers that make up a Kubernetes pod. Kubernetes is responsible for orchestration and scheduling of Pods; on each node, the kubelet uses the container runtime interface as an abstraction so that you can use any compatible container runtime.

In its earliest releases, Kubernetes offered compatibility with one container runtime: Docker. Later in the Kubernetes project's history, cluster operators wanted to adopt additional container runtimes. The CRI was designed to allow this kind of flexibility - and the kubelet began supporting CRI. However, because Docker existed before the CRI specification was invented, the Kubernetes project created an adapter component, `dockershim`. The dockershim adapter allows the kubelet to interact with Docker as if Docker were a CRI compatible runtime.

You can read about it in Kubernetes Containerd integration goes GA blog post.

Switching to Containerd as a container runtime eliminates the middleman. All the same containers can be run by container runtimes like Containerd as before. But now, since containers schedule directly with the container runtime, they are not visible to Docker. So any Docker tooling or fancy UI you might have used before to check on these containers is no longer available.

You cannot get container information using `docker ps` or `docker inspect` commands. As you cannot list containers, you cannot get logs, stop containers, or execute something inside a container using `docker exec`.

Note:

If you're running workloads via Kubernetes, the best way to stop a container is through the Kubernetes API rather than directly through the container runtime (this advice applies for all container runtimes, not only Docker).

You can still pull images or build them using `docker build` command. But images built or pulled by Docker would not be visible to container runtime and Kubernetes. They needed to be pushed to some registry to allow them to be used by Kubernetes.

Known issues

Some filesystem metrics are missing and the metrics format is different

The Kubelet `/metrics/cadvisor` endpoint provides Prometheus metrics, as documented in Metrics for Kubernetes system components. If you install a metrics collector that depends on that endpoint, you might see the following issues:

- The metrics format on the Docker node is `k8s_<container-name>_<pod-name>_<namespace>_<pod-uid>_<restart-count>` but the format on other runtime is different. For example, on containerd node it is `<container-id>`.
- Some filesystem metrics are missing, as follows:

```
container_fs_inodes_free
container_fs_inodes_total
container_fs_io_current
container_fs_io_time_seconds_total
container_fs_io_time_weighted_seconds_total
container_fs_limit_bytes
container_fs_read_seconds_total
container_fs_reads_merged_total
container_fs_sector_reads_total
container_fs_sector_writes_total
container_fs_usage_bytes
container_fs_write_seconds_total
container_fs_writes_merged_total
```

Workaround

You can mitigate this issue by using cAdvisor as a standalone daemonset.

1. Find the latest cAdvisor release with the name pattern `vX.Y.Z-containerd-cri` (for example, `v0.42.0-containerd-cri`).
2. Follow the steps in cAdvisor Kubernetes Daemonset to create the daemonset.
3. Point the installed metrics collector to use the cAdvisor `/metrics` endpoint which provides the full set of Prometheus container metrics.

Alternatives:

- Use alternative third party metrics collection solution.
- Collect metrics from the Kubelet summary API that is served at `/stats/summary`.

What's next

- Read Migrating from dockershim to understand your next steps
- Read the dockershim deprecation FAQ article for more information.

Verify Signed Kubernetes Artifacts

FEATURE STATE: `Kubernetes v1.26 [beta]`

Before you begin

You will need to have the following tools installed:

- `cosign` (install guide)

- `curl` (often provided by your operating system)
- `jq` (download jq)

Verifying binary signatures

The Kubernetes release process signs all binary artifacts (tarballs, SPDX files, standalone binaries) by using cosign's keyless signing. To verify a particular binary, retrieve it together with its signature and certificate:

```
URL=https://dl.k8s.io/release/v1.34.0/bin/linux/amd64
BINARY=kubectl

FILES=(
    "$BINARY"
    "$BINARY.sig"
    "$BINARY.cert"
)

for FILE in "${FILES[@]}"; do
    curl -sSfL --retry 3 --retry-delay 3 "$URL/$FILE" -o "$FILE"
done
```

Then verify the blob by using `cosign verify-blob`:

```
cosign verify-blob "$BINARY" \
  --signature "$BINARY".sig \  --certificate "$BINARY".cert \  --certificate-identity krel-staging@k8s-releng-prod.iam.gserviceacc
```

Note:

Cosign 2.0 requires the `--certificate-identity` and `--certificate-oidc-issuer` options.

To learn more about keyless signing, please refer to Keyless Signatures.

Previous versions of Cosign required that you set `COSIGN_EXPERIMENTAL=1`.

For additional information, please refer to the sigstore Blog

Verifying image signatures

For a complete list of images that are signed please refer to Releases.

Pick one image from this list and verify its signature using the `cosign verify` command:

```
cosign verify registry.k8s.io/kube-apiserver-amd64:v1.34.0 \
  --certificate-identity krel-trust@k8s-releng-prod.iam.gserviceaccount.com \  --certificate-oidc-issuer https://accounts.google.c
```

Verifying images for all control plane components

To verify all signed control plane images for the latest stable version (v1.34.0), please run the following commands:

```
curl -Ls "https://sbom.k8s.io/$(curl -Ls https://dl.k8s.io/release/stable.txt)/release" \
  | grep "SPDXID: SPDXRef-Package-registry.k8s.io" \  | grep -v sha256 | cut -d- -f3- | sed 's/-/\//' | sed 's/-v1/:v1/' \  | sort
```

Once you have verified an image, you can specify the image by its digest in your Pod manifests as per this example:

```
registry-url/image-name@sha256:45b23dee08af5e43a7fea6c4cf9c25ccf269ee113168c19722f87876677c5cb2
```

For more information, please refer to the Image Pull Policy section.

Verifying Image Signatures with Admission Controller

For non-control plane images (for example conformance image), signatures can also be verified at deploy time using sigstore policy-controller admission controller.

Here are some helpful resources to get started with `policy-controller`:

- Installation
- Configuration Options

Verify the Software Bill Of Materials

You can verify the Kubernetes Software Bill of Materials (SBOM) by using the sigstore certificate and signature, or the corresponding SHA files:

```
# Retrieve the latest available Kubernetes release version
VERSION=$(curl -Ls https://dl.k8s.io/release/stable.txt)

# Verify the SHA512 sum
curl -Ls "https://sbom.k8s.io/$VERSION/release" -o "$VERSION.spdx"
echo "$(curl -Ls "https://sbom.k8s.io/$VERSION/release.sha512") $VERSION.spdx" | sha512sum --check

# Verify the SHA256 sum
echo "$(curl -Ls "https://sbom.k8s.io/$VERSION/release.sha256") $VERSION.spdx" | sha256sum --check

# Retrieve sigstore signature and certificate
curl -Ls "https://sbom.k8s.io/$VERSION/release.sig" -o "$VERSION.spdx.sig"
```

```
curl -Ls "https://sbom.k8s.io/$VERSION/release.cert" -o "$VERSION.spdx.cert"

# Verify the sigstore signature
cosign verify-blob \
    --certificate "$VERSION.spdx.cert" \    --signature "$VERSION.spdx.sig" \    --certificate-identity krel-staging@k8s-releng-pr
```

Using NodeLocal DNSCache in Kubernetes Clusters

FEATURE STATE: `Kubernetes v1.18 [stable]`

This page provides an overview of NodeLocal DNSCache feature in Kubernetes.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

To check the version, enter `kubectl version`.

Introduction

NodeLocal DNSCache improves Cluster DNS performance by running a DNS caching agent on cluster nodes as a DaemonSet. In today's architecture, Pods in 'ClusterFirst' DNS mode reach out to a kube-dns `serviceIP` for DNS queries. This is translated to a kube-dns/CoreDNS endpoint via iptables rules added by kube-proxy. With this new architecture, Pods will reach out to the DNS caching agent running on the same node, thereby avoiding iptables DNAT rules and connection tracking. The local caching agent will query kube-dns service for cache misses of cluster hostnames ("`cluster.local`" suffix by default).

Motivation

- With the current DNS architecture, it is possible that Pods with the highest DNS QPS have to reach out to a different node, if there is no local kube-dns/CoreDNS instance. Having a local cache will help improve the latency in such scenarios.
- Skipping iptables DNAT and connection tracking will help reduce conntrack races and avoid UDP DNS entries filling up conntrack table.
- Connections from the local caching agent to kube-dns service can be upgraded to TCP. TCP conntrack entries will be removed on connection close in contrast with UDP entries that have to timeout (default `nf_conntrack_udp_timeout` is 30 seconds)
- Upgrading DNS queries from UDP to TCP would reduce tail latency attributed to dropped UDP packets and DNS timeouts usually up to 30s (3 retries + 10s timeout). Since the nodelocal cache listens for UDP DNS queries, applications don't need to be changed.
- Metrics & visibility into DNS requests at a node level.
- Negative caching can be re-enabled, thereby reducing the number of queries for the kube-dns service.

Architecture Diagram

This is the path followed by DNS Queries after NodeLocal DNSCache is enabled:


NodeLocal DNSCache flow

Nodelocal DNSCache flow

This image shows how NodeLocal DNSCache handles DNS queries.

Configuration

Note:

The local listen IP address for NodeLocal DNSCache can be any address that can be guaranteed to not collide with any existing IP in your cluster. It's recommended to use an address with a local scope, for example, from the 'link-local' range '169.254.0.0/16' for IPv4 or from the 'Unique Local Address' range in IPv6 'fd00::/8'.

This feature can be enabled using the following steps:

- Prepare a manifest similar to the sample `nodelocaldns.yaml` and save it as `nodelocaldns.yaml`.
- If using IPv6, the CoreDNS configuration file needs to enclose all the IPv6 addresses into square brackets if used in 'IP:Port' format. If you are using the sample manifest from the previous point, this will require you to modify the configuration line L70 like this: "`health [__PILLAR__LOCAL__DNS__]:8080`"
- Substitute the variables in the manifest with the right values:

```
kubedns=`kubectl get svc kube-dns -n kube-system -o jsonpath={.spec.clusterIP}`
domain=<cluster-domain>
localdns=<node-local-address>
```

`<cluster-domain>` is "`cluster.local`" by default. `<node-local-address>` is the local listen IP address chosen for NodeLocal DNSCache.

- If kube-proxy is running in IPTABLES mode:

  ```
  sed -i "s/__PILLAR__LOCAL__DNS__/$localdns/g; s/__PILLAR__DNS__DOMAIN__/$domain/g; s/__PILLAR__DNS__SERVER__/$kubedns/g"
  ```

  `__PILLAR__CLUSTER__DNS__` and `__PILLAR__UPSTREAM__SERVERS__` will be populated by the `node-local-dns` pods. In this mode, the `node-local-dns` pods listen on both the kube-dns service IP as well as `<node-local-address>`, so pods can look up DNS records using either IP address.

- If kube-proxy is running in IPVS mode:

  ```
  sed -i "s/__PILLAR__LOCAL__DNS__/$localdns/g; s/__PILLAR__DNS__DOMAIN__/$domain/g; s/,__PILLAR__DNS__SERVER__//g; s/__PI
  ```

  In this mode, the `node-local-dns` pods listen only on `<node-local-address>`. The `node-local-dns` interface cannot bind the kube-dns cluster IP since the interface used for IPVS loadbalancing already uses this address. `__PILLAR__UPSTREAM__SERVERS__` will be populated by the node-local-dns pods.

- Run `kubectl create -f nodelocaldns.yaml`
- If using kube-proxy in IPVS mode, `--cluster-dns` flag to kubelet needs to be modified to use `<node-local-address>` that NodeLocal DNSCache is listening on. Otherwise, there is no need to modify the value of the `--cluster-dns` flag, since NodeLocal DNSCache listens on both the kube-dns service IP as well as `<node-local-address>`.

Once enabled, the `node-local-dns` Pods will run in the `kube-system` namespace on each of the cluster nodes. This Pod runs CoreDNS in cache mode, so all CoreDNS metrics exposed by the different plugins will be available on a per-node basis.

You can disable this feature by removing the DaemonSet, using `kubectl delete -f <manifest>`. You should also revert any changes you made to the kubelet configuration.

StubDomains and Upstream server Configuration

StubDomains and upstream servers specified in the `kube-dns` ConfigMap in the `kube-system` namespace are automatically picked up by `node-local-dns` pods. The ConfigMap contents need to follow the format shown in the example. The `node-local-dns` ConfigMap can also be modified directly with the stubDomain configuration in the Corefile format. Some cloud providers might not allow modifying `node-local-dns` ConfigMap directly. In those cases, the `kube-dns` ConfigMap can be updated.

Setting memory limits

The `node-local-dns` Pods use memory for storing cache entries and processing queries. Since they do not watch Kubernetes objects, the cluster size or the number of Services / EndpointSlices do not directly affect memory usage. Memory usage is influenced by the DNS query pattern. From CoreDNS docs,

> The default cache size is 10000 entries, which uses about 30 MB when completely filled.

This would be the memory usage for each server block (if the cache gets completely filled). Memory usage can be reduced by specifying smaller cache sizes.

The number of concurrent queries is linked to the memory demand, because each extra goroutine used for handling a query requires an amount of memory. You can set an upper limit using the `max_concurrent` option in the forward plugin.

If a `node-local-dns` Pod attempts to use more memory than is available (because of total system resources, or because of a configured resource limit), the operating system may shut down that pod's container. If this happens, the container that is terminated ("OOMKilled") does not clean up the custom packet filtering rules that it previously added during startup. The `node-local-dns` container should get restarted (since managed as part of a DaemonSet), but this will lead to a brief DNS downtime each time that the container fails: the packet filtering rules direct DNS queries to a local Pod that is unhealthy.

You can determine a suitable memory limit by running node-local-dns pods without a limit and measuring the peak usage. You can also set up and use a VerticalPodAutoscaler in *recommender mode*, and then check its recommendations.

Use Cascading Deletion in a Cluster

This page shows you how to specify the type of cascading deletion to use in your cluster during garbage collection.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

You also need to create a sample Deployment to experiment with the different types of cascading deletion. You will need to recreate the Deployment for each type.

Check owner references on your pods

Check that the `ownerReferences` field is present on your pods:

```
kubectl get pods -l app=nginx --output=yaml
```

The output has an `ownerReferences` field similar to this:

```
apiVersion: v1
    ...
    ownerReferences:
    - apiVersion: apps/v1
      blockOwnerDeletion: true
      controller: true
      kind: ReplicaSet
      name: nginx-deployment-6b474476c4
      uid: 4fdcd81c-bd5d-41f7-97af-3a3b759af9a7
    ...
```

Use foreground cascading deletion

By default, Kubernetes uses background cascading deletion to delete dependents of an object. You can switch to foreground cascading deletion using either `kubectl` or the Kubernetes API, depending on the Kubernetes version your cluster runs.

To check the version, enter `kubectl version`.

You can delete objects using foreground cascading deletion using `kubectl` or the Kubernetes API.

Using kubectl

Run the following command:

```
kubectl delete deployment nginx-deployment --cascade=foreground
```

Using the Kubernetes API

1. Start a local proxy session:

   ```
   kubectl proxy --port=8080
   ```

2. Use `curl` to trigger deletion:

   ```
   curl -X DELETE localhost:8080/apis/apps/v1/namespaces/default/deployments/nginx-deployment \
       -d '{"kind":"DeleteOptions","apiVersion":"v1","propagationPolicy":"Foreground"}' \    -H "Content-Type: application/json"
   ```

   The output contains a `foregroundDeletion` finalizer like this:

   ```
   "kind": "Deployment",
   "apiVersion": "apps/v1",
   "metadata": {
       "name": "nginx-deployment",
       "namespace": "default",
       "uid": "d1ce1b02-cae8-4288-8a53-30e84d8fa505",
       "resourceVersion": "1363097",
       "creationTimestamp": "2021-07-08T20:24:37Z",
       "deletionTimestamp": "2021-07-08T20:27:39Z",
       "finalizers": [
         "foregroundDeletion"
       ]
       ...
   ```

Use background cascading deletion

1. Create a sample Deployment.
2. Use either `kubectl` or the Kubernetes API to delete the Deployment, depending on the Kubernetes version your cluster runs.

   To check the version, enter `kubectl version`.

You can delete objects using background cascading deletion using `kubectl` or the Kubernetes API.

Kubernetes uses background cascading deletion by default, and does so even if you run the following commands without the `--cascade` flag or the `propagationPolicy` argument.

Using kubectl

Run the following command:

```
kubectl delete deployment nginx-deployment --cascade=background
```

Using the Kubernetes API

1. Start a local proxy session:

   ```
   kubectl proxy --port=8080
   ```

2. Use `curl` to trigger deletion:

```
curl -X DELETE localhost:8080/apis/apps/v1/namespaces/default/deployments/nginx-deployment \
    -d '{"kind":"DeleteOptions","apiVersion":"v1","propagationPolicy":"Background"}' \    -H "Content-Type: application/json"
```

The output is similar to this:

```
"kind": "Status",
"apiVersion": "v1",
...
"status": "Success",
"details": {
    "name": "nginx-deployment",
    "group": "apps",
    "kind": "deployments",
    "uid": "cc9eefb9-2d49-4445-b1c1-d261c9396456"
}
```

Delete owner objects and orphan dependents

By default, when you tell Kubernetes to delete an object, the controller also deletes dependent objects. You can make Kubernetes *orphan* these dependents using `kubectl` or the Kubernetes API, depending on the Kubernetes version your cluster runs.

To check the version, enter `kubectl version`.

Using kubectl

Run the following command:

```
kubectl delete deployment nginx-deployment --cascade=orphan
```

Using the Kubernetes API

1. Start a local proxy session:

   ```
   kubectl proxy --port=8080
   ```

2. Use `curl` to trigger deletion:

   ```
   curl -X DELETE localhost:8080/apis/apps/v1/namespaces/default/deployments/nginx-deployment \
       -d '{"kind":"DeleteOptions","apiVersion":"v1","propagationPolicy":"Orphan"}' \    -H "Content-Type: application/json"
   ```

   The output contains `orphan` in the `finalizers` field, similar to this:

   ```
   "kind": "Deployment",
   "apiVersion": "apps/v1",
   "namespace": "default",
   "uid": "6f577034-42a0-479d-be21-78018c466f1f",
   "creationTimestamp": "2021-07-09T16:46:37Z",
   "deletionTimestamp": "2021-07-09T16:47:08Z",
   "deletionGracePeriodSeconds": 0,
   "finalizers": [
     "orphan"
   ],
   ...
   ```

You can check that the Pods managed by the Deployment are still running:

```
kubectl get pods -l app=nginx
```

What's next

- Learn about owners and dependents in Kubernetes.
- Learn about Kubernetes finalizers.
- Learn about garbage collection.

Connect a Frontend to a Backend Using Services

This task shows how to create a *frontend* and a *backend* microservice. The backend microservice is a hello greeter. The frontend exposes the backend using nginx and a Kubernetes Service object.

Objectives

- Create and run a sample `hello` backend microservice using a Deployment object.
- Use a Service object to send traffic to the backend microservice's multiple replicas.
- Create and run a `nginx` frontend microservice, also using a Deployment object.
- Configure the frontend microservice to send traffic to the backend microservice.
- Use a Service object of `type=LoadBalancer` to expose the frontend microservice outside the cluster.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

To check the version, enter `kubectl version`.

This task uses Services with external load balancers, which require a supported environment. If your environment does not support this, you can use a Service of type NodePort instead.

Creating the backend using a Deployment

The backend is a simple hello greeter microservice. Here is the configuration file for the backend Deployment:

service/access/backend-deployment.yaml Copy service/access/backend-deployment.yaml to clipboard

```
---
apiVersion: apps/v1kind: Deploymentmetadata:  name: backendspec:  selector:    matchLabels:      app: hello      tier: backend
```

Create the backend Deployment:

```
kubectl apply -f https://k8s.io/examples/service/access/backend-deployment.yaml
```

View information about the backend Deployment:

```
kubectl describe deployment backend
```

The output is similar to this:

```
Name:                           backend
Namespace:                      default
CreationTimestamp:              Mon, 24 Oct 2016 14:21:02 -0700
Labels:                         app=hello
                                tier=backend
                                track=stable
Annotations:                    deployment.kubernetes.io/revision=1
Selector:                       app=hello,tier=backend,track=stable
Replicas:                       3 desired | 3 updated | 3 total | 3 available | 0 unavailable
StrategyType:                   RollingUpdate
MinReadySeconds:                0
RollingUpdateStrategy:          1 max unavailable, 1 max surge
Pod Template:
  Labels:       app=hello
                tier=backend
                track=stable
  Containers:
   hello:
    Image:              "gcr.io/google-samples/hello-go-gke:1.0"
    Port:               80/TCP
    Environment:        <none>
    Mounts:             <none>
  Volumes:              <none>
Conditions:
  Type          Status  Reason
  ----          ------  ------
  Available     True    MinimumReplicasAvailable
  Progressing   True    NewReplicaSetAvailable
OldReplicaSets:                 <none>
NewReplicaSet:                  hello-3621623197 (3/3 replicas created)
Events:
...
```

Creating the `hello` Service object

The key to sending requests from a frontend to a backend is the backend Service. A Service creates a persistent IP address and DNS name entry so that the backend microservice can always be reached. A Service uses selectors to find the Pods that it routes traffic to.

First, explore the Service configuration file:

service/access/backend-service.yaml Copy service/access/backend-service.yaml to clipboard

```
---
apiVersion: v1kind: Servicemetadata:  name: hellospec:  selector:    app: hello    tier: backend  ports:  - protocol: TCP    port:
```

In the configuration file, you can see that the Service, named `hello` routes traffic to Pods that have the labels `app: hello` and `tier: backend`.

Create the backend Service:

```
kubectl apply -f https://k8s.io/examples/service/access/backend-service.yaml
```

At this point, you have a `backend` Deployment running three replicas of your `hello` application, and you have a Service that can route traffic to them. However, this service is neither available nor resolvable outside the cluster.

Creating the frontend

Now that you have your backend running, you can create a frontend that is accessible outside the cluster, and connects to the backend by proxying requests to it.

The frontend sends requests to the backend worker Pods by using the DNS name given to the backend Service. The DNS name is `hello`, which is the value of the `name` field in the `examples/service/access/backend-service.yaml` configuration file.

The Pods in the frontend Deployment run a nginx image that is configured to proxy requests to the `hello` backend Service. Here is the nginx configuration file:

service/access/frontend-nginx.conf  Copy service/access/frontend-nginx.conf to clipboard

```
# The identifier Backend is internal to nginx, and used to name this specific upstream
upstream Backend {
    # hello is the internal DNS name used by the backend Service inside Kubernetes
    server hello;
}

server {
listen 80;



location / {
    # The following statement will proxy traffic to the upstream named Backend
    proxy_pass http://Backend;
}

}
```

Similar to the backend, the frontend has a Deployment and a Service. An important difference to notice between the backend and frontend services, is that the configuration for the frontend Service has `type: LoadBalancer`, which means that the Service uses a load balancer provisioned by your cloud provider and will be accessible from outside the cluster.

service/access/frontend-service.yaml  Copy service/access/frontend-service.yaml to clipboard

```
---
apiVersion: v1kind: Servicemetadata:  name: frontendspec:  selector:    app: hello    tier: frontend  ports:  - protocol: "TCP"
```

service/access/frontend-deployment.yaml Copy service/access/frontend-deployment.yaml to clipboard

```
---
apiVersion: apps/v1kind: Deploymentmetadata:  name: frontendspec:  selector:    matchLabels:      app: hello      tier: frontend
```

Create the frontend Deployment and Service:

```
kubectl apply -f https://k8s.io/examples/service/access/frontend-deployment.yaml
kubectl apply -f https://k8s.io/examples/service/access/frontend-service.yaml
```

The output verifies that both resources were created:

```
deployment.apps/frontend created
service/frontend created
```

Note:

The nginx configuration is baked into the container image. A better way to do this would be to use a ConfigMap, so that you can change the configuration more easily.

Interact with the frontend Service

Once you've created a Service of type LoadBalancer, you can use this command to find the external IP:

```
kubectl get service frontend --watch
```

This displays the configuration for the `frontend` Service and watches for changes. Initially, the external IP is listed as `<pending>`:

```
NAME       TYPE           CLUSTER-IP      EXTERNAL-IP   PORT(S)  AGE
frontend   LoadBalancer   10.51.252.116   <pending>     80/TCP   10s
```

As soon as an external IP is provisioned, however, the configuration updates to include the new IP under the `EXTERNAL-IP` heading:

```
NAME       TYPE           CLUSTER-IP      EXTERNAL-IP        PORT(S)  AGE
frontend   LoadBalancer   10.51.252.116   XXX.XXX.XXX.XXX    80/TCP   1m
```

That IP can now be used to interact with the `frontend` service from outside the cluster.

Send traffic through the frontend

The frontend and backend are now connected. You can hit the endpoint by using the curl command on the external IP of your frontend Service.

```
curl http://${EXTERNAL_IP} # replace this with the EXTERNAL-IP you saw earlier
```

The output shows the message generated by the backend:

```
{"message":"Hello"}
```

Cleaning up

To delete the Services, enter this command:

```
kubectl delete services frontend backend
```

To delete the Deployments, the ReplicaSets and the Pods that are running the backend and frontend applications, enter this command:

```
kubectl delete deployment frontend backend
```

What's next

- Learn more about Services
- Learn more about ConfigMaps
- Learn more about DNS for Service and Pods

Configure Memory and CPU Quotas for a Namespace

Define overall memory and CPU resource limits for a namespace.

This page shows how to set quotas for the total amount memory and CPU that can be used by all Pods running in a namespace. You specify quotas in a ResourceQuota object.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

You must have access to create namespaces in your cluster.

Each node in your cluster must have at least 1 GiB of memory.

Create a namespace

Create a namespace so that the resources you create in this exercise are isolated from the rest of your cluster.

```
kubectl create namespace quota-mem-cpu-example
```

Create a ResourceQuota

Here is a manifest for an example ResourceQuota:

admin/resource/quota-mem-cpu.yaml Copy admin/resource/quota-mem-cpu.yaml to clipboard

```
apiVersion: v1
kind: ResourceQuotametadata:  name: mem-cpu-demospec:  hard:    requests.cpu: "1"    requests.memory: 1Gi    limits.cpu: "2"    li
```

Create the ResourceQuota:

```
kubectl apply -f https://k8s.io/examples/admin/resource/quota-mem-cpu.yaml --namespace=quota-mem-cpu-example
```

View detailed information about the ResourceQuota:

```
kubectl get resourcequota mem-cpu-demo --namespace=quota-mem-cpu-example --output=yaml
```

The ResourceQuota places these requirements on the quota-mem-cpu-example namespace:

- For every Pod in the namespace, each container must have a memory request, memory limit, cpu request, and cpu limit.
- The memory request total for all Pods in that namespace must not exceed 1 GiB.
- The memory limit total for all Pods in that namespace must not exceed 2 GiB.
- The CPU request total for all Pods in that namespace must not exceed 1 cpu.
- The CPU limit total for all Pods in that namespace must not exceed 2 cpu.

See meaning of CPU to learn what Kubernetes means by “1 CPU”.

Create a Pod

Here is a manifest for an example Pod:

admin/resource/quota-mem-cpu-pod.yaml Copy admin/resource/quota-mem-cpu-pod.yaml to clipboard

```
apiVersion: v1
kind: Podmetadata:  name: quota-mem-cpu-demospec:  containers:  - name: quota-mem-cpu-demo-ctr    image: nginx    resources:
```

Create the Pod:

```
kubectl apply -f https://k8s.io/examples/admin/resource/quota-mem-cpu-pod.yaml --namespace=quota-mem-cpu-example
```

Verify that the Pod is running and that its (only) container is healthy:

```
kubectl get pod quota-mem-cpu-demo --namespace=quota-mem-cpu-example
```

Once again, view detailed information about the ResourceQuota:

```
kubectl get resourcequota mem-cpu-demo --namespace=quota-mem-cpu-example --output=yaml
```

The output shows the quota along with how much of the quota has been used. You can see that the memory and CPU requests and limits for your Pod do not exceed the quota.

```
status:
  hard:
    limits.cpu: "2"
    limits.memory: 2Gi
    requests.cpu: "1"
    requests.memory: 1Gi
  used:
    limits.cpu: 800m
    limits.memory: 800Mi
    requests.cpu: 400m
    requests.memory: 600Mi
```

If you have the `jq` tool, you can also query (using JSONPath) for just the `used` values, **and** pretty-print that that of the output. For example:

```
kubectl get resourcequota mem-cpu-demo --namespace=quota-mem-cpu-example -o jsonpath='{ .status.used }' | jq .
```

Attempt to create a second Pod

Here is a manifest for a second Pod:

admin/resource/quota-mem-cpu-pod-2.yaml Copy admin/resource/quota-mem-cpu-pod-2.yaml to clipboard

```
apiVersion: v1
kind: Podmetadata:  name: quota-mem-cpu-demo-2spec:  containers:  - name: quota-mem-cpu-demo-2-ctr    image: redis    resources:
```

In the manifest, you can see that the Pod has a memory request of 700 MiB. Notice that the sum of the used memory request and this new memory request exceeds the memory request quota: 600 MiB + 700 MiB > 1 GiB.

Attempt to create the Pod:

```
kubectl apply -f https://k8s.io/examples/admin/resource/quota-mem-cpu-pod-2.yaml --namespace=quota-mem-cpu-example
```

The second Pod does not get created. The output shows that creating the second Pod would cause the memory request total to exceed the memory request quota.

```
Error from server (Forbidden): error when creating "examples/admin/resource/quota-mem-cpu-pod-2.yaml":
pods "quota-mem-cpu-demo-2" is forbidden: exceeded quota: mem-cpu-demo,
requested: requests.memory=700Mi,used: requests.memory=600Mi, limited: requests.memory=1Gi
```

Discussion

As you have seen in this exercise, you can use a ResourceQuota to restrict the memory request total for all Pods running in a namespace. You can also restrict the totals for memory limit, cpu request, and cpu limit.

Instead of managing total resource use within a namespace, you might want to restrict individual Pods, or the containers in those Pods. To achieve that kind of limiting, use a LimitRange.

Clean up

Delete your namespace:

```
kubectl delete namespace quota-mem-cpu-example
```

What's next

For cluster administrators

- Configure Default Memory Requests and Limits for a Namespace
- Configure Default CPU Requests and Limits for a Namespace
- Configure Minimum and Maximum Memory Constraints for a Namespace
- Configure Minimum and Maximum CPU Constraints for a Namespace
- Configure a Pod Quota for a Namespace
- Configure Quotas for API Objects

For app developers

- Assign Memory Resources to Containers and Pods

- Assign CPU Resources to Containers and Pods
- Assign Pod-level CPU and memory resources
- Configure Quality of Service for Pods

Using sysctls in a Kubernetes Cluster

FEATURE STATE: `Kubernetes v1.21 [stable]`

This document describes how to configure and use kernel parameters within a Kubernetes cluster using the sysctl interface.

Note:

Starting from Kubernetes version 1.23, the kubelet supports the use of either `/` or `.` as separators for sysctl names. Starting from Kubernetes version 1.25, setting Sysctls for a Pod supports setting sysctls with slashes. For example, you can represent the same sysctl name as `kernel.shm_rmid_forced` using a period as the separator, or as `kernel/shm_rmid_forced` using a slash as a separator. For more sysctl parameter conversion method details, please refer to the page sysctl.d(5) from the Linux man-pages project.

Before you begin

Note:

`sysctl` is a Linux-specific command-line tool used to configure various kernel parameters and it is not available on non-Linux operating systems.

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

For some steps, you also need to be able to reconfigure the command line options for the kubelets running on your cluster.

Listing all Sysctl Parameters

In Linux, the sysctl interface allows an administrator to modify kernel parameters at runtime. Parameters are available via the `/proc/sys/` virtual process file system. The parameters cover various subsystems such as:

- kernel (common prefix: `kernel.`)
- networking (common prefix: `net.`)
- virtual memory (common prefix: `vm.`)
- MDADM (common prefix: `dev.`)
- More subsystems are described in Kernel docs.

To get a list of all parameters, you can run

```
sudo sysctl -a
```

Safe and Unsafe Sysctls

Kubernetes classes sysctls as either *safe* or *unsafe*. In addition to proper namespacing, a *safe* sysctl must be properly *isolated* between pods on the same node. This means that setting a *safe* sysctl for one pod

- must not have any influence on any other pod on the node
- must not allow to harm the node's health
- must not allow to gain CPU or memory resources outside of the resource limits of a pod.

By far, most of the *namespaced* sysctls are not necessarily considered *safe*. The following sysctls are supported in the *safe* set:

- `kernel.shm_rmid_forced`;
- `net.ipv4.ip_local_port_range`;
- `net.ipv4.tcp_syncookies`;
- `net.ipv4.ping_group_range` (since Kubernetes 1.18);
- `net.ipv4.ip_unprivileged_port_start` (since Kubernetes 1.22);
- `net.ipv4.ip_local_reserved_ports` (since Kubernetes 1.27, needs kernel 3.16+);
- `net.ipv4.tcp_keepalive_time` (since Kubernetes 1.29, needs kernel 4.5+);
- `net.ipv4.tcp_fin_timeout` (since Kubernetes 1.29, needs kernel 4.6+);
- `net.ipv4.tcp_keepalive_intvl` (since Kubernetes 1.29, needs kernel 4.5+);
- `net.ipv4.tcp_keepalive_probes` (since Kubernetes 1.29, needs kernel 4.5+).
- `net.ipv4.tcp_rmem` (since Kubernetes 1.32, needs kernel 4.15+).
- `net.ipv4.tcp_wmem` (since Kubernetes 1.32, needs kernel 4.15+).

Note:

There are some exceptions to the set of safe sysctls:

- The `net.*` sysctls are not allowed with host networking enabled.
- The `net.ipv4.tcp_syncookies` sysctl is not namespaced on Linux kernel version 4.5 or lower.

This list will be extended in future Kubernetes versions when the kubelet supports better isolation mechanisms.

Enabling Unsafe Sysctls

All *safe* sysctls are enabled by default.

All *unsafe* sysctls are disabled by default and must be allowed manually by the cluster admin on a per-node basis. Pods with disabled unsafe sysctls will be scheduled, but will fail to launch.

With the warning above in mind, the cluster admin can allow certain *unsafe* sysctls for very special situations such as high-performance or real-time application tuning. *Unsafe* sysctls are enabled on a node-by-node basis with a flag of the kubelet; for example:

```
kubelet --allowed-unsafe-sysctls \
  'kernel.msg*,net.core.somaxconn' ...
```

For Minikube, this can be done via the `extra-config` flag:

```
minikube start --extra-config="kubelet.allowed-unsafe-sysctls=kernel.msg*,net.core.somaxconn"...
```

Only *namespaced* sysctls can be enabled this way.

Setting Sysctls for a Pod

A number of sysctls are *namespaced* in today's Linux kernels. This means that they can be set independently for each pod on a node. Only namespaced sysctls are configurable via the pod securityContext within Kubernetes.

The following sysctls are known to be namespaced. This list could change in future versions of the Linux kernel.

- `kernel.shm*`,
- `kernel.msg*`,
- `kernel.sem`,
- `fs.mqueue.*`,
- Those `net.*` that can be set in container networking namespace. However, there are exceptions (e.g., `net.netfilter.nf_conntrack_max` and `net.netfilter.nf_conntrack_expect_max` can be set in container networking namespace but are unnamespaced before Linux 5.12.2).

Sysctls with no namespace are called *node-level* sysctls. If you need to set them, you must manually configure them on each node's operating system, or by using a DaemonSet with privileged containers.

Use the pod securityContext to configure namespaced sysctls. The securityContext applies to all containers in the same pod.

This example uses the pod securityContext to set a safe sysctl `kernel.shm_rmid_forced` and two unsafe sysctls `net.core.somaxconn` and `kernel.msgmax`. There is no distinction between *safe* and *unsafe* sysctls in the specification.

Warning:

Only modify sysctl parameters after you understand their effects, to avoid destabilizing your operating system.

```
apiVersion: v1
kind: Podmetadata:  name: sysctl-examplespec:  securityContext:    sysctls:    - name: kernel.shm_rmid_forced      value: "0"    -
```

Warning:

Due to their nature of being *unsafe*, the use of *unsafe* sysctls is at-your-own-risk and can lead to severe problems like wrong behavior of containers, resource shortage or complete breakage of a node.

It is good practice to consider nodes with special sysctl settings as *tainted* within a cluster, and only schedule pods onto them which need those sysctl settings. It is suggested to use the Kubernetes *taints and toleration* feature to implement this.

A pod with the *unsafe* sysctls will fail to launch on any node which has not enabled those two *unsafe* sysctls explicitly. As with *node-level* sysctls it is recommended to use *taints and toleration* feature or taints on nodes to schedule those pods onto the right nodes.

Operating etcd clusters for Kubernetes

etcd is a consistent and highly-available key value store used as Kubernetes' backing store for all cluster data.

If your Kubernetes cluster uses etcd as its backing store, make sure you have a back up plan for the data.

You can find in-depth information about etcd in the official documentation.

Before you begin

Before you follow steps in this page to deploy, manage, back up or restore etcd, you need to understand the typical expectations for operating an etcd cluster. Refer to the etcd documentation for more context.

Key details include:

- The minimum recommended etcd versions to run in production are `3.4.22+` and `3.5.6+`.
- etcd is a leader-based distributed system. Ensure that the leader periodically send heartbeats on time to all followers to keep the cluster stable.
- You should run etcd as a cluster with an odd number of members.
- Aim to ensure that no resource starvation occurs.

  Performance and stability of the cluster is sensitive to network and disk I/O. Any resource starvation can lead to heartbeat timeout, causing instability of the cluster. An unstable etcd indicates that no leader is elected. Under such circumstances, a cluster cannot make any changes to its current state, which implies no new pods can be scheduled.

Resource requirements for etcd

Operating etcd with limited resources is suitable only for testing purposes. For deploying in production, advanced hardware configuration is required. Before deploying etcd in production, see resource requirement reference.

Keeping etcd clusters stable is critical to the stability of Kubernetes clusters. Therefore, run etcd clusters on dedicated machines or isolated environments for guaranteed resource requirements.

Tools

Depending on which specific outcome you're working on, you will need the `etcdctl` tool or the `etcdutl` tool (you may need both).

Understanding etcdctl and etcdutl

`etcdctl` and `etcdutl` are command-line tools used to interact with etcd clusters, but they serve different purposes:

- `etcdctl`: This is the primary command-line client for interacting with etcd over a network. It is used for day-to-day operations such as managing keys and values, administering the cluster, checking health, and more.
- `etcdutl`: This is an administration utility designed to operate directly on etcd data files, including migrating data between etcd versions, defragmenting the database, restoring snapshots, and validating data consistency. For network operations, `etcdctl` should be used.

For more information on `etcdutl`, you can refer to the etcd recovery documentation.

Starting etcd clusters

This section covers starting a single-node and multi-node etcd cluster.

This guide assumes that `etcd` is already installed.

Single-node etcd cluster

Use a single-node etcd cluster only for testing purposes.

1. Run the following:

   ```
   etcd --listen-client-urls=http://$PRIVATE_IP:2379 \
      --advertise-client-urls=http://$PRIVATE_IP:2379
   ```

2. Start the Kubernetes API server with the flag `--etcd-servers=$PRIVATE_IP:2379`.

   Make sure `PRIVATE_IP` is set to your etcd client IP.

Multi-node etcd cluster

For durability and high availability, run etcd as a multi-node cluster in production and back it up periodically. A five-member cluster is recommended in production. For more information, see FAQ documentation.

As you're using Kubernetes, you have the option to run etcd as a container inside one or more Pods. The `kubeadm` tool sets up etcd static pods by default, or you can deploy a separate cluster and instruct kubeadm to use that etcd cluster as the control plane's backing store.

You configure an etcd cluster either by static member information or by dynamic discovery. For more information on clustering, see etcd clustering documentation.

For an example, consider a five-member etcd cluster running with the following client URLs: `http://$IP1:2379`, `http://$IP2:2379`, `http://$IP3:2379`, `http://$IP4:2379`, and `http://$IP5:2379`. To start a Kubernetes API server:

1. Run the following:

   ```
   etcd --listen-client-urls=http://$IP1:2379,http://$IP2:2379,http://$IP3:2379,http://$IP4:2379,http://$IP5:2379 --advertise-cl
   ```

2. Start the Kubernetes API servers with the flag `--etcd-servers=$IP1:2379,$IP2:2379,$IP3:2379,$IP4:2379,$IP5:2379`.

   Make sure the `IP<n>` variables are set to your client IP addresses.

Multi-node etcd cluster with load balancer

To run a load balancing etcd cluster:

1. Set up an etcd cluster.
2. Configure a load balancer in front of the etcd cluster. For example, let the address of the load balancer be `$LB`.
3. Start Kubernetes API Servers with the flag `--etcd-servers=$LB:2379`.

Securing etcd clusters

Access to etcd is equivalent to root permission in the cluster so ideally only the API server should have access to it. Considering the sensitivity of the data, it is recommended to grant permission to only those nodes that require access to etcd clusters.

To secure etcd, either set up firewall rules or use the security features provided by etcd. etcd security features depend on x509 Public Key Infrastructure (PKI). To begin, establish secure communication channels by generating a key and certificate pair. For example, use key pairs `peer.key` and `peer.cert` for securing communication between etcd members, and `client.key` and `client.cert` for securing communication between etcd and its clients. See the example scripts provided by the etcd project to generate key pairs and CA files for client authentication.

Securing communication

To configure etcd with secure peer communication, specify flags `--peer-key-file=peer.key` and `--peer-cert-file=peer.cert`, and use HTTPS as the URL schema.

Similarly, to configure etcd with secure client communication, specify flags `--key=k8sclient.key` and `--cert=k8sclient.cert`, and use HTTPS as the URL schema. Here is an example on a client command that uses secure communication:

```
ETCDCTL_API=3 etcdctl --endpoints 10.2.0.9:2379 \
  --cert=/etc/kubernetes/pki/etcd/server.crt \
  --key=/etc/kubernetes/pki/etcd/server.key \
  --cacert=/etc/kubernetes/pki/etcd/ca.crt \
  member list
```

Limiting access of etcd clusters

After configuring secure communication, restrict the access of the etcd cluster to only the Kubernetes API servers using TLS authentication.

For example, consider key pairs `k8sclient.key` and `k8sclient.cert` that are trusted by the CA `etcd.ca`. When etcd is configured with `--client-cert-auth` along with TLS, it verifies the certificates from clients by using system CAs or the CA passed in by `--trusted-ca-file` flag. Specifying flags `--client-cert-auth=true` and `--trusted-ca-file=etcd.ca` will restrict the access to clients with the certificate `k8sclient.cert`.

Once etcd is configured correctly, only clients with valid certificates can access it. To give Kubernetes API servers the access, configure them with the flags `--etcd-certfile=k8sclient.cert`, `--etcd-keyfile=k8sclient.key` and `--etcd-cafile=ca.cert`.

Note:

etcd authentication is not planned for Kubernetes.

Replacing a failed etcd member

etcd cluster achieves high availability by tolerating minor member failures. However, to improve the overall health of the cluster, replace failed members immediately. When multiple members fail, replace them one by one. Replacing a failed member involves two steps: removing the failed member and adding a new member.

Though etcd keeps unique member IDs internally, it is recommended to use a unique name for each member to avoid human errors. For example, consider a three-member etcd cluster. Let the URLs be, `member1=http://10.0.0.1`, `member2=http://10.0.0.2`, and `member3=http://10.0.0.3`. When `member1` fails, replace it with `member4=http://10.0.0.4`.

1. Get the member ID of the failed `member1`:

   ```
   etcdctl --endpoints=http://10.0.0.2,http://10.0.0.3 member list
   ```

   The following message is displayed:

   ```
   8211f1d0f64f3269, started, member1, http://10.0.0.1:2380, http://10.0.0.1:2379
   91bc3c398fb3c146, started, member2, http://10.0.0.2:2380, http://10.0.0.2:2379
   fd422379fda50e48, started, member3, http://10.0.0.3:2380, http://10.0.0.3:2379
   ```

2. Do either of the following:

   1. If each Kubernetes API server is configured to communicate with all etcd members, remove the failed member from the `--etcd-servers` flag, then restart each Kubernetes API server.
   2. If each Kubernetes API server communicates with a single etcd member, then stop the Kubernetes API server that communicates with the failed etcd.

3. Stop the etcd server on the broken node. It is possible that other clients besides the Kubernetes API server are causing traffic to etcd and it is desirable to stop all traffic to prevent writes to the data directory.

4. Remove the failed member:

   ```
   etcdctl member remove 8211f1d0f64f3269
   ```

   The following message is displayed:

   ```
   Removed member 8211f1d0f64f3269 from cluster
   ```

5. Add the new member:

   ```
   etcdctl member add member4 --peer-urls=http://10.0.0.4:2380
   ```

   The following message is displayed:

   ```
   Member 2be1eb8f84b7f63e added to cluster ef37ad9dc622a7c4
   ```

6. Start the newly added member on a machine with the IP `10.0.0.4`:

   ```
   export ETCD_NAME="member4"
   export ETCD_INITIAL_CLUSTER="member2=http://10.0.0.2:2380,member3=http://10.0.0.3:2380,member4=http://10.0.0.4:2380"
   export ETCD_INITIAL_CLUSTER_STATE=existing
   etcd [flags]
   ```

7. Do either of the following:

   1. If each Kubernetes API server is configured to communicate with all etcd members, add the newly added member to the `--etcd-servers` flag, then restart each Kubernetes API server.
   2. If each Kubernetes API server communicates with a single etcd member, start the Kubernetes API server that was stopped in step 2. Then configure Kubernetes API server clients to again route requests to the Kubernetes API server that was stopped. This can often be done by configuring a load balancer.

For more information on cluster reconfiguration, see etcd reconfiguration documentation.

Backing up an etcd cluster

All Kubernetes objects are stored in etcd. Periodically backing up the etcd cluster data is important to recover Kubernetes clusters under disaster scenarios, such as losing all control plane nodes. The snapshot file contains all the Kubernetes state and critical information. In order to keep the sensitive Kubernetes data safe, encrypt the snapshot files.

Backing up an etcd cluster can be accomplished in two ways: etcd built-in snapshot and volume snapshot.

Built-in snapshot

etcd supports built-in snapshot. A snapshot may either be created from a live member with the `etcdctl snapshot save` command or by copying the `member/snap/db` file from an etcd data directory that is not currently used by an etcd process. Creating the snapshot will not affect the performance of the member.

Below is an example for creating a snapshot of the keyspace served by `$ENDPOINT` to the file `snapshot.db`:

```
ETCDCTL_API=3 etcdctl --endpoints $ENDPOINT snapshot save snapshot.db
```

Verify the snapshot:

- Use etcdutl
- Use etcdctl (Deprecated)

The below example depicts the usage of the `etcdutl` tool for verifying a snapshot:

```
etcdutl --write-out=table snapshot status snapshot.db
```

This should generate an output resembling the example provided below:

```
+----------+----------+------------+------------+
|   HASH   | REVISION | TOTAL KEYS | TOTAL SIZE |
+----------+----------+------------+------------+
| fe01cf57 |       10 |          7 | 2.1 MB     |
+----------+----------+------------+------------+
```

Note:

The usage of `etcdctl snapshot status` has been **deprecated** since etcd v3.5.x and is slated for removal from etcd v3.6. It is recommended to utilize `etcdutl` instead.

The below example depicts the usage of the `etcdctl` tool for verifying a snapshot:

```
export ETCDCTL_API=3
etcdctl --write-out=table snapshot status snapshot.db
```

This should generate an output resembling the example provided below:

```
Deprecated: Use `etcdutl snapshot status` instead.
+----------+----------+------------+------------+|   HASH   | REVISION | TOTAL KEYS | TOTAL SIZE |+----------+----------+----------
```

Volume snapshot

If etcd is running on a storage volume that supports backup, such as Amazon Elastic Block Store, back up etcd data by creating a snapshot of the storage volume.

Snapshot using etcdctl options

We can also create the snapshot using various options given by etcdctl. For example:

```
ETCDCTL_API=3 etcdctl -h
```

will list various options available from etcdctl. For example, you can create a snapshot by specifying the endpoint, certificates and key as shown below:

```
ETCDCTL_API=3 etcdctl --endpoints=https://127.0.0.1:2379 \
  --cacert=<trusted-ca-file> --cert=<cert-file> --key=<key-file> \  snapshot save <backup-file-location>
```

where `trusted-ca-file`, `cert-file` and `key-file` can be obtained from the description of the etcd Pod.

Scaling out etcd clusters

Scaling out etcd clusters increases availability by trading off performance. Scaling does not increase cluster performance nor capability. A general rule is not to scale out or in etcd clusters. Do not configure any auto scaling groups for etcd clusters. It is strongly recommended to always run a static five-member etcd cluster for production Kubernetes clusters at any officially supported scale.

A reasonable scaling is to upgrade a three-member cluster to a five-member one, when more reliability is desired. See etcd reconfiguration documentation for information on how to add members into an existing cluster.

Restoring an etcd cluster

Caution:

If any API servers are running in your cluster, you should not attempt to restore instances of etcd. Instead, follow these steps to restore etcd:

- stop *all* API server instances
- restore state in all etcd instances
- restart all API server instances

The Kubernetes project also recommends restarting Kubernetes components (`kube-scheduler`, `kube-controller-manager`, `kubelet`) to ensure that they don't rely on some stale data. In practice the restore takes a bit of time. During the restoration, critical components will lose leader lock and restart themselves.

etcd supports restoring from snapshots that are taken from an etcd process of the major.minor version. Restoring a version from a different patch version of etcd is also supported. A restore operation is employed to recover the data of a failed cluster.

Before starting the restore operation, a snapshot file must be present. It can either be a snapshot file from a previous backup operation, or from a remaining data directory.

- Use etcdutl
- Use etcdctl (Deprecated)

When restoring the cluster using `etcdutl`, use the `--data-dir` option to specify to which folder the cluster should be restored:

```
etcdutl --data-dir <data-dir-location> snapshot restore snapshot.db
```

where `<data-dir-location>` is a directory that will be created during the restore process.

Note:

The usage of `etcdctl` for restoring has been **deprecated** since etcd v3.5.x and is slated for removal from etcd v3.6. It is recommended to utilize `etcdutl` instead.

The below example depicts the usage of the `etcdctl` tool for the restore operation:

```
export ETCDCTL_API=3
etcdctl --data-dir <data-dir-location> snapshot restore snapshot.db
```

If `<data-dir-location>` is the same folder as before, delete it and stop the etcd process before restoring the cluster. Otherwise, change etcd configuration and restart the etcd process after restoration to have it use the new data directory: first change `/etc/kubernetes/manifests/etcd.yaml`'s `volumes.hostPath.path` for `name: etcd-data` to `<data-dir-location>`, then execute `kubectl -n kube-system delete pod <name-of-etcd-pod>` or `systemctl restart kubelet.service` (or both).

For more information and examples on restoring a cluster from a snapshot file, see etcd disaster recovery documentation.

If the access URLs of the restored cluster are changed from the previous cluster, the Kubernetes API server must be reconfigured accordingly. In this case, restart Kubernetes API servers with the flag `--etcd-servers=$NEW_ETCD_CLUSTER` instead of the flag `--etcd-servers=$OLD_ETCD_CLUSTER`. Replace `$NEW_ETCD_CLUSTER` and `$OLD_ETCD_CLUSTER` with the respective IP addresses. If a load balancer is used in front of an etcd cluster, you might need to update the load balancer instead.

If the majority of etcd members have permanently failed, the etcd cluster is considered failed. In this scenario, Kubernetes cannot make any changes to its current state. Although the scheduled pods might continue to run, no new pods can be scheduled. In such cases, recover the etcd cluster and potentially reconfigure Kubernetes API servers to fix the issue.

Upgrading etcd clusters

Caution:

Before you start an upgrade, back up your etcd cluster first.

For details on etcd upgrade, refer to the etcd upgrades documentation.

Maintaining etcd clusters

For more details on etcd maintenance, please refer to the etcd maintenance documentation.

Cluster defragmentation

☐ This item links to a third party project or product that is not part of Kubernetes itself. More information

Defragmentation is an expensive operation, so it should be executed as infrequently as possible. On the other hand, it's also necessary to make sure any etcd member will not exceed the storage quota. The Kubernetes project recommends that when you perform defragmentation, you use a tool such as etcd-defrag.

You can also run the defragmentation tool as a Kubernetes CronJob, to make sure that defragmentation happens regularly. See `etcd-defrag-cronjob.yaml` for details.

Upgrade A Cluster

This page provides an overview of the steps you should follow to upgrade a Kubernetes cluster.

The Kubernetes project recommends upgrading to the latest patch releases promptly, and to ensure that you are running a supported minor release of Kubernetes. Following this recommendation helps you to stay secure.

The way that you upgrade a cluster depends on how you initially deployed it and on any subsequent changes.

At a high level, the steps you perform are:

- Upgrade the control plane
- Upgrade the nodes in your cluster
- Upgrade clients such as kubectl
- Adjust manifests and other resources based on the API changes that accompany the new Kubernetes version

Before you begin

You must have an existing cluster. This page is about upgrading from Kubernetes 1.33 to Kubernetes 1.34. If your cluster is not currently running Kubernetes 1.33 then please check the documentation for the version of Kubernetes that you plan to upgrade to.

Upgrade approaches

kubeadm

If your cluster was deployed using the `kubeadm` tool, refer to Upgrading kubeadm clusters for detailed information on how to upgrade the cluster.

Once you have upgraded the cluster, remember to install the latest version of `kubectl`.

Manual deployments

Caution:

These steps do not account for third-party extensions such as network and storage plugins.

You should manually update the control plane following this sequence:

- etcd (all instances)
- kube-apiserver (all control plane hosts)
- kube-controller-manager
- kube-scheduler
- cloud controller manager, if you use one

At this point you should install the latest version of `kubectl`.

For each node in your cluster, drain that node and then either replace it with a new node that uses the 1.34 kubelet, or upgrade the kubelet on that node and bring the node back into service.

Caution:

Draining nodes before upgrading kubelet ensures that pods are re-admitted and containers are re-created, which may be necessary to resolve some security issues or other important bugs.

Other deployments

Refer to the documentation for your cluster deployment tool to learn the recommended set up steps for maintenance.

Post-upgrade tasks

Switch your cluster's storage API version

The objects that are serialized into etcd for a cluster's internal representation of the Kubernetes resources active in the cluster are written using a particular version of the API.

When the supported API changes, these objects may need to be rewritten in the newer API. Failure to do this will eventually result in resources that are no longer decodable or usable by the Kubernetes API server.

For each affected object, fetch it using the latest supported API and then write it back also using the latest supported API.

Update manifests

Upgrading to a new Kubernetes version can provide new APIs.

You can use `kubectl convert` command to convert manifests between different API versions. For example:

```
kubectl convert -f pod.yaml --output-version v1
```

The `kubectl` tool replaces the contents of `pod.yaml` with a manifest that sets `kind` to Pod (unchanged), but with a revised `apiVersion`.

Device Plugins

If your cluster is running device plugins and the node needs to be upgraded to a Kubernetes release with a newer device plugin API version, device plugins must be upgraded to support both version before the node is upgraded in order to guarantee that device allocations continue to complete successfully during the upgrade.

Refer to API compatibility and Kubelet Device Manager API Versions for more details.

Communicate Between Containers in the Same Pod Using a Shared Volume

This page shows how to use a Volume to communicate between two Containers running in the same Pod. See also how to allow processes to communicate by sharing process namespace between containers.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

To check the version, enter `kubectl version`.

Creating a Pod that runs two Containers

In this exercise, you create a Pod that runs two Containers. The two containers share a Volume that they can use to communicate. Here is the configuration file for the Pod:

pods/two-container-pod.yaml Copy pods/two-container-pod.yaml to clipboard

```
apiVersion: v1
kind: Podmetadata:  name: two-containersspec:  restartPolicy: Never  volumes:  - name: shared-data    emptyDir: {}  containers:  -
```

In the configuration file, you can see that the Pod has a Volume named `shared-data`.

The first container listed in the configuration file runs an nginx server. The mount path for the shared Volume is `/usr/share/nginx/html`. The second container is based on the debian image, and has a mount path of `/pod-data`. The second container runs the following command and then terminates.

```
echo Hello from the debian container > /pod-data/index.html
```

Notice that the second container writes the `index.html` file in the root directory of the nginx server.

Create the Pod and the two Containers:

```
kubectl apply -f https://k8s.io/examples/pods/two-container-pod.yaml
```

View information about the Pod and the Containers:

```
kubectl get pod two-containers --output=yaml
```

Here is a portion of the output:

```
apiVersion: v1
kind: Pod
metadata:
  ...
  name: two-containers
  namespace: default
```

```
  ...
spec:
  ...
  containerStatuses:

  - containerID: docker://c1d8abd1 ...
    image: debian
    ...
    lastState:
      terminated:
        ...
    name: debian-container
    ...

  - containerID: docker://96c1ff2c5bb ...
    image: nginx
    ...
    name: nginx-container
    ...
    state:
      running:
    ...
```

You can see that the debian Container has terminated, and the nginx Container is still running.

Get a shell to nginx Container:

```
kubectl exec -it two-containers -c nginx-container -- /bin/bash
```

In your shell, verify that nginx is running:

```
root@two-containers:/# apt-get update
root@two-containers:/# apt-get install curl procps
root@two-containers:/# ps aux
```

The output is similar to this:

```
USER       PID  ...  STAT START   TIME COMMAND
root         1  ...  Ss   21:12   0:00 nginx: master process nginx -g daemon off;
```

Recall that the debian Container created the `index.html` file in the nginx root directory. Use `curl` to send a GET request to the nginx server:

```
root@two-containers:/# curl localhost
```

The output shows that nginx serves a web page written by the debian container:

```
Hello from the debian container
```

Discussion

The primary reason that Pods can have multiple containers is to support helper applications that assist a primary application. Typical examples of helper applications are data pullers, data pushers, and proxies. Helper and primary applications often need to communicate with each other. Typically this is done through a shared filesystem, as shown in this exercise, or through the loopback network interface, localhost. An example of this pattern is a web server along with a helper program that polls a Git repository for new updates.

The Volume in this exercise provides a way for Containers to communicate during the life of the Pod. If the Pod is deleted and recreated, any data stored in the shared Volume is lost.

What's next

- Learn more about patterns for composite containers.
- Learn about composite containers for modular architecture.
- See Configuring a Pod to Use a Volume for Storage.
- See Configure a Pod to share process namespace between containers in a Pod
- See Volume.
- See Pod.

Safely Drain a Node

This page shows how to safely drain a node, optionally respecting the PodDisruptionBudget you have defined.

Before you begin

This task assumes that you have met the following prerequisites:

1. You do not require your applications to be highly available during the node drain, or
2. You have read about the PodDisruptionBudget concept, and have configured PodDisruptionBudgets for applications that need them.

(Optional) Configure a disruption budget

To ensure that your workloads remain available during maintenance, you can configure a PodDisruptionBudget.

If availability is important for any applications that run or could run on the node(s) that you are draining, configure a PodDisruptionBudgets first and then continue following this guide.

It is recommended to set `AlwaysAllow` Unhealthy Pod Eviction Policy to your PodDisruptionBudgets to support eviction of misbehaving applications during a node drain. The default behavior is to wait for the application pods to become healthy before the drain can proceed.

Use `kubectl drain` to remove a node from service

You can use `kubectl drain` to safely evict all of your pods from a node before you perform maintenance on the node (e.g. kernel upgrade, hardware maintenance, etc.). Safe evictions allow the pod's containers to gracefully terminate and will respect the PodDisruptionBudgets you have specified.

Note:

By default `kubectl drain` ignores certain system pods on the node that cannot be killed; see the kubectl drain documentation for more details.

When `kubectl drain` returns successfully, that indicates that all of the pods (except the ones excluded as described in the previous paragraph) have been safely evicted (respecting the desired graceful termination period, and respecting the PodDisruptionBudget you have defined). It is then safe to bring down the node by powering down its physical machine or, if running on a cloud platform, deleting its virtual machine.

Note:

If any new Pods tolerate the `node.kubernetes.io/unschedulable` taint, then those Pods might be scheduled to the node you have drained. Avoid tolerating that taint other than for DaemonSets.

If you or another API user directly set the `nodeName` field for a Pod (bypassing the scheduler), then the Pod is bound to the specified node and will run there, even though you have drained that node and marked it unschedulable.

First, identify the name of the node you wish to drain. You can list all of the nodes in your cluster with

```
kubectl get nodes
```

Next, tell Kubernetes to drain the node:

```
kubectl drain --ignore-daemonsets <node name>
```

If there are pods managed by a DaemonSet, you will need to specify `--ignore-daemonsets` with `kubectl` to successfully drain the node. The `kubectl drain` subcommand on its own does not actually drain a node of its DaemonSet pods: the DaemonSet controller (part of the control plane) immediately replaces missing Pods with new equivalent Pods. The DaemonSet controller also creates Pods that ignore unschedulable taints, which allows the new Pods to launch onto a node that you are draining.

Once it returns (without giving an error), you can power down the node (or equivalently, if on a cloud platform, delete the virtual machine backing the node). If you leave the node in the cluster during the maintenance operation, you need to run

```
kubectl uncordon <node name>
```

afterwards to tell Kubernetes that it can resume scheduling new pods onto the node.

Draining multiple nodes in parallel

The `kubectl drain` command should only be issued to a single node at a time. However, you can run multiple `kubectl drain` commands for different nodes in parallel, in different terminals or in the background. Multiple drain commands running concurrently will still respect the PodDisruptionBudget you specify.

For example, if you have a StatefulSet with three replicas and have set a PodDisruptionBudget for that set specifying `minAvailable: 2`, `kubectl drain` only evicts a pod from the StatefulSet if all three replicas pods are healthy; if then you issue multiple drain commands in parallel, Kubernetes respects the PodDisruptionBudget and ensures that only 1 (calculated as `replicas - minAvailable`) Pod is unavailable at any given time. Any drains that would cause the number of healthy replicas to fall below the specified budget are blocked.

The Eviction API

If you prefer not to use kubectl drain (such as to avoid calling to an external command, or to get finer control over the pod eviction process), you can also programmatically cause evictions using the eviction API.

For more information, see API-initiated eviction.

What's next

- Follow steps to protect your application by configuring a Pod Disruption Budget.

Share a Cluster with Namespaces

This page shows how to view, work in, and delete namespaces. The page also shows how to use Kubernetes namespaces to subdivide your cluster.

Before you begin

- Have an existing Kubernetes cluster.
- You have a basic understanding of Kubernetes Pods, Services, and Deployments.

Viewing namespaces

List the current namespaces in a cluster using:

```
kubectl get namespaces
```

```
NAME              STATUS   AGE
default           Active   11d
kube-node-lease   Active   11d
kube-public       Active   11d
kube-system       Active   11d
```

Kubernetes starts with four initial namespaces:

- `default` The default namespace for objects with no other namespace
- `kube-node-lease` This namespace holds Lease objects associated with each node. Node leases allow the kubelet to send heartbeats so that the control plane can detect node failure.
- `kube-public` This namespace is created automatically and is readable by all users (including those not authenticated). This namespace is mostly reserved for cluster usage, in case that some resources should be visible and readable publicly throughout the whole cluster. The public aspect of this namespace is only a convention, not a requirement.
- `kube-system` The namespace for objects created by the Kubernetes system

You can also get the summary of a specific namespace using:

```
kubectl get namespaces <name>
```

Or you can get detailed information with:

```
kubectl describe namespaces <name>
```

```
Name:           default
Labels:         <none>
Annotations:    <none>
Status:         Active
No resource quota.Resource Limits Type       Resource    Min Max Default ----                --------    --- --- --- Container
```

Note that these details show both resource quota (if present) as well as resource limit ranges.

Resource quota tracks aggregate usage of resources in the Namespace and allows cluster operators to define *Hard* resource usage limits that a Namespace may consume.

A limit range defines min/max constraints on the amount of resources a single entity can consume in a Namespace.

See Admission control: Limit Range

A namespace can be in one of two phases:

- `Active` the namespace is in use
- `Terminating` the namespace is being deleted, and can not be used for new objects

For more details, see Namespace in the API reference.

Creating a new namespace

Note:

Avoid creating namespace with prefix `kube-`, since it is reserved for Kubernetes system namespaces.

Create a new YAML file called `my-namespace.yaml` with the contents:

```
apiVersion: v1
kind: Namespacemetadata:  name: <insert-namespace-name-here>
```

Then run:

```
kubectl create -f ./my-namespace.yaml
```

Alternatively, you can create namespace using below command:

```
kubectl create namespace <insert-namespace-name-here>
```

The name of your namespace must be a valid DNS label.

There's an optional field `finalizers`, which allows observables to purge resources whenever the namespace is deleted. Keep in mind that if you specify a nonexistent finalizer, the namespace will be created but will get stuck in the `Terminating` state if the user tries to delete it.

More information on `finalizers` can be found in the namespace design doc.

Deleting a namespace

Delete a namespace with

```
kubectl delete namespaces <insert-some-namespace-name>
```

Warning:

This deletes *everything* under the namespace!

This delete is asynchronous, so for a time you will see the namespace in the `Terminating` state.

Subdividing your cluster using Kubernetes namespaces

By default, a Kubernetes cluster will instantiate a default namespace when provisioning the cluster to hold the default set of Pods, Services, and Deployments used by the cluster.

Assuming you have a fresh cluster, you can introspect the available namespaces by doing the following:

```
kubectl get namespaces
```

```
NAME      STATUS    AGE
default   Active    13m
```

Create new namespaces

For this exercise, we will create two additional Kubernetes namespaces to hold our content.

In a scenario where an organization is using a shared Kubernetes cluster for development and production use cases:

- The development team would like to maintain a space in the cluster where they can get a view on the list of Pods, Services, and Deployments they use to build and run their application. In this space, Kubernetes resources come and go, and the restrictions on who can or cannot modify resources are relaxed to enable agile development.
- The operations team would like to maintain a space in the cluster where they can enforce strict procedures on who can or cannot manipulate the set of Pods, Services, and Deployments that run the production site.

One pattern this organization could follow is to partition the Kubernetes cluster into two namespaces: `development` and `production`. Let's create two new namespaces to hold our work.

Create the `development` namespace using kubectl:

```
kubectl create -f https://k8s.io/examples/admin/namespace-dev.json
```

And then let's create the `production` namespace using kubectl:

```
kubectl create -f https://k8s.io/examples/admin/namespace-prod.json
```

To be sure things are right, list all of the namespaces in our cluster.

```
kubectl get namespaces --show-labels
```

```
NAME          STATUS    AGE       LABELS
default       Active    32m       <none>
development   Active    29s       name=development
production    Active    23s       name=production
```

Create pods in each namespace

A Kubernetes namespace provides the scope for Pods, Services, and Deployments in the cluster. Users interacting with one namespace do not see the content in another namespace. To demonstrate this, let's spin up a simple Deployment and Pods in the `development` namespace.

```
kubectl create deployment snowflake \
  --image=registry.k8s.io/serve_hostname \  -n=development --replicas=2
```

We have created a deployment whose replica size is 2 that is running the pod called `snowflake` with a basic container that serves the hostname.

```
kubectl get deployment -n=development
```

```
NAME         READY   UP-TO-DATE   AVAILABLE   AGE
snowflake    2/2     2            2           2m
```

```
kubectl get pods -l app=snowflake -n=development
```

```
NAME                         READY     STATUS    RESTARTS   AGE
snowflake-3968820950-9dgr8   1/1       Running   0          2m
snowflake-3968820950-vgc4n   1/1       Running   0          2m
```

And this is great, developers are able to do what they want, and they do not have to worry about affecting content in the `production` namespace.

Let's switch to the `production` namespace and show how resources in one namespace are hidden from the other. The `production` namespace should be empty, and the following commands should return nothing.

```
kubectl get deployment -n=production
kubectl get pods -n=production
```

Production likes to run cattle, so let's create some cattle pods.

```
kubectl create deployment cattle --image=registry.k8s.io/serve_hostname -n=production
```

```
kubectl scale deployment cattle --replicas=5 -n=production

kubectl get deployment -n=production

NAME          READY   UP-TO-DATE   AVAILABLE   AGE
cattle        5/5     5            5           10s

kubectl get pods -l app=cattle -n=production

NAME                      READY     STATUS    RESTARTS   AGE
cattle-2263376956-41xy6   1/1       Running   0          34s
cattle-2263376956-kw466   1/1       Running   0          34s
cattle-2263376956-n4v97   1/1       Running   0          34s
cattle-2263376956-p5p3i   1/1       Running   0          34s
cattle-2263376956-sxpth   1/1       Running   0          34s
```

At this point, it should be clear that the resources users create in one namespace are hidden from the other namespace.

As the policy support in Kubernetes evolves, we will extend this scenario to show how you can provide different authorization rules for each namespace.

Understanding the motivation for using namespaces

A single cluster should be able to satisfy the needs of multiple users or groups of users (henceforth in this document a *user community*).

Kubernetes *namespaces* help different projects, teams, or customers to share a Kubernetes cluster.

It does this by providing the following:

1. A scope for names.
2. A mechanism to attach authorization and policy to a subsection of the cluster.

Use of multiple namespaces is optional.

Each user community wants to be able to work in isolation from other communities. Each user community has its own:

1. resources (pods, services, replication controllers, etc.)
2. policies (who can or cannot perform actions in their community)
3. constraints (this community is allowed this much quota, etc.)

A cluster operator may create a Namespace for each unique user community.

The Namespace provides a unique scope for:

1. named resources (to avoid basic naming collisions)
2. delegated management authority to trusted users
3. ability to limit community resource consumption

Use cases include:

1. As a cluster operator, I want to support multiple user communities on a single cluster.
2. As a cluster operator, I want to delegate authority to partitions of the cluster to trusted users in those communities.
3. As a cluster operator, I want to limit the amount of resources each community can consume in order to limit the impact to other communities using the cluster.
4. As a cluster user, I want to interact with resources that are pertinent to my user community in isolation of what other user communities are doing on the cluster.

Understanding namespaces and DNS

When you create a Service, it creates a corresponding DNS entry. This entry is of the form `<service-name>.<namespace-name>.svc.cluster.local`, which means that if a container uses `<service-name>` it will resolve to the service which is local to a namespace. This is useful for using the same configuration across multiple namespaces such as Development, Staging and Production. If you want to reach across namespaces, you need to use the fully qualified domain name (FQDN).

What's next

- Learn more about setting the namespace preference.
- Learn more about setting the namespace for a request
- See namespaces design.

Generate Certificates Manually

When using client certificate authentication, you can generate certificates manually through `easyrsa`, `openssl` or `cfssl`.

easyrsa

easyrsa can manually generate certificates for your cluster.

1. Download, unpack, and initialize the patched version of `easyrsa3`.

   ```
   curl -LO https://dl.k8s.io/easy-rsa/easy-rsa.tar.gz
   tar xzf easy-rsa.tar.gz
   ```

```
cd easy-rsa-master/easyrsa3
./easyrsa init-pki
```

2. Generate a new certificate authority (CA). `--batch` sets automatic mode; `--req-cn` specifies the Common Name (CN) for the CA's new root certificate.

```
./easyrsa --batch "--req-cn=${MASTER_IP}@`date +%s`" build-ca nopass
```

3. Generate server certificate and key.

   The argument `--subject-alt-name` sets the possible IPs and DNS names the API server will be accessed with. The `MASTER_CLUSTER_IP` is usually the first IP from the service CIDR that is specified as the `--service-cluster-ip-range` argument for both the API server and the controller manager component. The argument `--days` is used to set the number of days after which the certificate expires. The sample below also assumes that you are using `cluster.local` as the default DNS domain name.

```
./easyrsa --subject-alt-name="IP:${MASTER_IP},"\
"IP:${MASTER_CLUSTER_IP},"\"DNS:kubernetes,"\"DNS:kubernetes.default,"\"DNS:kubernetes.default.svc,"\"DNS:kubernetes.default.
```

4. Copy `pki/ca.crt`, `pki/issued/server.crt`, and `pki/private/server.key` to your directory.

5. Fill in and add the following parameters into the API server start parameters:

```
--client-ca-file=/yourdirectory/ca.crt
--tls-cert-file=/yourdirectory/server.crt
--tls-private-key-file=/yourdirectory/server.key
```

openssl

openssl can manually generate certificates for your cluster.

1. Generate a ca.key with 2048bit:

```
openssl genrsa -out ca.key 2048
```

2. According to the ca.key generate a ca.crt (use `-days` to set the certificate effective time):

```
openssl req -x509 -new -nodes -key ca.key -subj "/CN=${MASTER_IP}" -days 10000 -out ca.crt
```

3. Generate a server.key with 2048bit:

```
openssl genrsa -out server.key 2048
```

4. Create a config file for generating a Certificate Signing Request (CSR).

   Be sure to substitute the values marked with angle brackets (e.g. `<MASTER_IP>`) with real values before saving this to a file (e.g. `csr.conf`). Note that the value for `MASTER_CLUSTER_IP` is the service cluster IP for the API server as described in previous subsection. The sample below also assumes that you are using `cluster.local` as the default DNS domain name.

```
[ req ]
default_bits = 2048
prompt = no
default_md = sha256
req_extensions = req_ext
distinguished_name = dn

[ dn ]
C = <country>
ST = <state>
L = <city>
O = <organization>
OU = <organization unit>
CN = <MASTER_IP>

[ req_ext ]
subjectAltName = @alt_names

[ alt_names ]
DNS.1 = kubernetes
DNS.2 = kubernetes.default
DNS.3 = kubernetes.default.svc
DNS.4 = kubernetes.default.svc.cluster
DNS.5 = kubernetes.default.svc.cluster.local
IP.1 = <MASTER_IP>
IP.2 = <MASTER_CLUSTER_IP>

[ v3_ext ]
authorityKeyIdentifier=keyid,issuer:always
basicConstraints=CA:FALSE
keyUsage=keyEncipherment,dataEncipherment
extendedKeyUsage=serverAuth,clientAuth
subjectAltName=@alt_names
```

5. Generate the certificate signing request based on the config file:

```
openssl req -new -key server.key -out server.csr -config csr.conf
```

6. Generate the server certificate using the ca.key, ca.crt and server.csr:

```
openssl x509 -req -in server.csr -CA ca.crt -CAkey ca.key \
    -CAcreateserial -out server.crt -days 10000 \    -extensions v3_ext -extfile csr.conf -sha256
```

7. View the certificate signing request:

   ```
   openssl req  -noout -text -in ./server.csr
   ```

8. View the certificate:

   ```
   openssl x509  -noout -text -in ./server.crt
   ```

Finally, add the same parameters into the API server start parameters.

cfssl

cfssl is another tool for certificate generation.

1. Download, unpack and prepare the command line tools as shown below.

   Note that you may need to adapt the sample commands based on the hardware architecture and cfssl version you are using.

   ```
   curl -L https://github.com/cloudflare/cfssl/releases/download/v1.5.0/cfssl_1.5.0_linux_amd64 -o cfssl
   chmod +x cfssl
   curl -L https://github.com/cloudflare/cfssl/releases/download/v1.5.0/cfssljson_1.5.0_linux_amd64 -o cfssljson
   chmod +x cfssljson
   curl -L https://github.com/cloudflare/cfssl/releases/download/v1.5.0/cfssl-certinfo_1.5.0_linux_amd64 -o cfssl-certinfo
   chmod +x cfssl-certinfo
   ```

2. Create a directory to hold the artifacts and initialize cfssl:

   ```
   mkdir cert
   cd cert
   ../cfssl print-defaults config > config.json
   ../cfssl print-defaults csr > csr.json
   ```

3. Create a JSON config file for generating the CA file, for example, `ca-config.json`:

   ```
   {
     "signing": {
       "default": {
         "expiry": "8760h"
       },
       "profiles": {
         "kubernetes": {
           "usages": [
             "signing",
             "key encipherment",
             "server auth",
             "client auth"
           ],
           "expiry": "8760h"
         }
       }
     }
   }
   ```

4. Create a JSON config file for CA certificate signing request (CSR), for example, `ca-csr.json`. Be sure to replace the values marked with angle brackets with real values you want to use.

   ```
   {
     "CN": "kubernetes",
     "key": {
       "algo": "rsa",
       "size": 2048
     },
     "names":[{
       "C": "<country>",
       "ST": "<state>",
       "L": "<city>",
       "O": "<organization>",
       "OU": "<organization unit>"
     }]
   }
   ```

5. Generate CA key (`ca-key.pem`) and certificate (`ca.pem`):

   ```
   ../cfssl gencert -initca ca-csr.json | ../cfssljson -bare ca
   ```

6. Create a JSON config file for generating keys and certificates for the API server, for example, `server-csr.json`. Be sure to replace the values in angle brackets with real values you want to use. The `<MASTER_CLUSTER_IP>` is the service cluster IP for the API server as described in previous subsection. The sample below also assumes that you are using `cluster.local` as the default DNS domain name.

   ```
   {
     "CN": "kubernetes",
     "hosts": [
       "127.0.0.1",
       "<MASTER_IP>",
       "<MASTER_CLUSTER_IP>",
       "kubernetes",
       "kubernetes.default",
       "kubernetes.default.svc",
       "kubernetes.default.svc.cluster",
       "kubernetes.default.svc.cluster.local"
     ],
     "key": {
   ```

```
      "algo": "rsa",
      "size": 2048
    },
    "names": [{
      "C": "<country>",
      "ST": "<state>",
      "L": "<city>",
      "O": "<organization>",
      "OU": "<organization unit>"
    }]
}
```

7. Generate the key and certificate for the API server, which are by default saved into file `server-key.pem` and `server.pem` respectively:

```
../cfssl gencert -ca=ca.pem -ca-key=ca-key.pem \
     --config=ca-config.json -profile=kubernetes \     server-csr.json | ../cfssljson -bare server
```

Distributing Self-Signed CA Certificate

A client node may refuse to recognize a self-signed CA certificate as valid. For a non-production deployment, or for a deployment that runs behind a company firewall, you can distribute a self-signed CA certificate to all clients and refresh the local list for valid certificates.

On each client, perform the following operations:

```
sudo cp ca.crt /usr/local/share/ca-certificates/kubernetes.crt
sudo update-ca-certificates
```

```
Updating certificates in /etc/ssl/certs...
1 added, 0 removed; done.
Running hooks in /etc/ca-certificates/update.d....
done.
```

Certificates API

You can use the `certificates.k8s.io` API to provision x509 certificates to use for authentication as documented in the Managing TLS in a cluster task page.

Upgrading Windows nodes

FEATURE STATE: `Kubernetes v1.18 [beta]`

This page explains how to upgrade a Windows node created with kubeadm.

Before you begin

You need to have shell access to all the nodes, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts.

Your Kubernetes server must be at or later than version 1.17.

To check the version, enter `kubectl version`.

- Familiarize yourself with the process for upgrading the rest of your kubeadm cluster. You will want to upgrade the control plane nodes before upgrading your Windows nodes.

Upgrading worker nodes

Upgrade kubeadm

1. From the Windows node, upgrade kubeadm:

```
# replace 1.34.0 with your desired version
curl.exe -Lo <path-to-kubeadm.exe>  "https://dl.k8s.io/v1.34.0/bin/windows/amd64/kubeadm.exe"
```

Drain the node

1. From a machine with access to the Kubernetes API, prepare the node for maintenance by marking it unschedulable and evicting the workloads:

```
# replace <node-to-drain> with the name of your node you are draining
kubectl drain <node-to-drain> --ignore-daemonsets
```

You should see output similar to this:

```
node/ip-172-31-85-18 cordoned
node/ip-172-31-85-18 drained
```

Upgrade the kubelet configuration

1. From the Windows node, call the following command to sync new kubelet configuration:

```
kubeadm upgrade node
```

Upgrade kubelet and kube-proxy

1. From the Windows node, upgrade and restart the kubelet:

   ```
   stop-service kubelet
   curl.exe -Lo <path-to-kubelet.exe> "https://dl.k8s.io/v1.34.0/bin/windows/amd64/kubelet.exe"
   restart-service kubelet
   ```

2. From the Windows node, upgrade and restart the kube-proxy.

   ```
   stop-service kube-proxy
   curl.exe -Lo <path-to-kube-proxy.exe> "https://dl.k8s.io/v1.34.0/bin/windows/amd64/kube-proxy.exe"
   restart-service kube-proxy
   ```

Note:

If you are running kube-proxy in a HostProcess container within a Pod, and not as a Windows Service, you can upgrade kube-proxy by applying a newer version of your kube-proxy manifests.

Uncordon the node

1. From a machine with access to the Kubernetes API, bring the node back online by marking it schedulable:

   ```
   # replace <node-to-drain> with the name of your node
   kubectl uncordon <node-to-drain>
   ```

What's next

- See how to Upgrade Linux nodes.

Deploy and Access the Kubernetes Dashboard

Deploy the web UI (Kubernetes Dashboard) and access it.

Dashboard is a web-based Kubernetes user interface. You can use Dashboard to deploy containerized applications to a Kubernetes cluster, troubleshoot your containerized application, and manage the cluster resources. You can use Dashboard to get an overview of applications running on your cluster, as well as for creating or modifying individual Kubernetes resources (such as Deployments, Jobs, DaemonSets, etc). For example, you can scale a Deployment, initiate a rolling update, restart a pod or deploy new applications using a deploy wizard.

Dashboard also provides information on the state of Kubernetes resources in your cluster and on any errors that may have occurred.


Kubernetes Dashboard UI

Deploying the Dashboard UI

Note:

Kubernetes Dashboard supports only Helm-based installation currently as it is faster and gives us better control over all dependencies required by Dashboard to run.

The Dashboard UI is not deployed by default. To deploy it, run the following command:

```
# Add kubernetes-dashboard repository
helm repo add kubernetes-dashboard https://kubernetes.github.io/dashboard/
# Deploy a Helm Release named "kubernetes-dashboard" using the kubernetes-dashboard chart
helm upgrade --install kubernetes-dashboard kubernetes-dashboard/kubernetes-dashboard --create-namespace --namespace kubernetes-da
```

Accessing the Dashboard UI

To protect your cluster data, Dashboard deploys with a minimal RBAC configuration by default. Currently, Dashboard only supports logging in with a Bearer Token. To create a token for this demo, you can follow our guide on creating a sample user.

Warning:

The sample user created in the tutorial will have administrative privileges and is for educational purposes only.

Command line proxy

You can enable access to the Dashboard using the `kubectl` command-line tool, by running the following command:

```
kubectl -n kubernetes-dashboard port-forward svc/kubernetes-dashboard-kong-proxy 8443:443
```

Kubectl will make Dashboard available at https://localhost:8443.

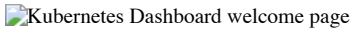
The UI can *only* be accessed from the machine where the command is executed. See `kubectl port-forward --help` for more options.

Note:

The kubeconfig authentication method does **not** support external identity providers or X.509 certificate-based authentication.

Welcome view

When you access Dashboard on an empty cluster, you'll see the welcome page. This page contains a link to this document as well as a button to deploy your first application. In addition, you can view which system applications are running by default in the `kube-system` namespace of your cluster, for example the Dashboard itself.


Kubernetes Dashboard welcome page

Deploying containerized applications

Dashboard lets you create and deploy a containerized application as a Deployment and optional Service with a simple wizard. You can either manually specify application details, or upload a YAML or JSON *manifest* file containing application configuration.

Click the **CREATE** button in the upper right corner of any page to begin.

Specifying application details

The deploy wizard expects that you provide the following information:

- **App name** (mandatory): Name for your application. A label with the name will be added to the Deployment and Service, if any, that will be deployed.

  The application name must be unique within the selected Kubernetes namespace. It must start with a lowercase character, and end with a lowercase character or a number, and contain only lowercase letters, numbers and dashes (-). It is limited to 24 characters. Leading and trailing spaces are ignored.

- **Container image** (mandatory): The URL of a public Docker container image on any registry, or a private image (commonly hosted on the Google Container Registry or Docker Hub). The container image specification must end with a colon.

- **Number of pods** (mandatory): The target number of Pods you want your application to be deployed in. The value must be a positive integer.

  A Deployment will be created to maintain the desired number of Pods across your cluster.

- **Service** (optional): For some parts of your application (e.g. frontends) you may want to expose a Service onto an external, maybe public IP address outside of your cluster (external Service).

  Note:

  For external Services, you may need to open up one or more ports to do so.

  Other Services that are only visible from inside the cluster are called internal Services.

  Irrespective of the Service type, if you choose to create a Service and your container listens on a port (incoming), you need to specify two ports. The Service will be created mapping the port (incoming) to the target port seen by the container. This Service will route to your deployed Pods. Supported protocols are TCP and UDP. The internal DNS name for this Service will be the value you specified as application name above.

If needed, you can expand the **Advanced options** section where you can specify more settings:

- **Description**: The text you enter here will be added as an annotation to the Deployment and displayed in the application's details.

- **Labels**: Default labels to be used for your application are application name and version. You can specify additional labels to be applied to the Deployment, Service (if any), and Pods, such as release, environment, tier, partition, and release track.

  Example:

  ```
  release=1.0
  tier=frontend
  environment=pod
  track=stable
  ```

- **Namespace**: Kubernetes supports multiple virtual clusters backed by the same physical cluster. These virtual clusters are called namespaces. They let you partition resources into logically named groups.

  Dashboard offers all available namespaces in a dropdown list, and allows you to create a new namespace. The namespace name may contain a maximum of 63 alphanumeric characters and dashes (-) but can not contain capital letters. Namespace names should not consist of only numbers. If the name is set as a number, such as 10, the pod will be put in the default namespace.

  In case the creation of the namespace is successful, it is selected by default. If the creation fails, the first namespace is selected.

- **Image Pull Secret**: In case the specified Docker container image is private, it may require pull secret credentials.

  Dashboard offers all available secrets in a dropdown list, and allows you to create a new secret. The secret name must follow the DNS domain name syntax, for example `new.image-pull.secret`. The content of a secret must be base64-encoded and specified in a `.dockercfg` file. The secret name may consist of a maximum of 253 characters.

  In case the creation of the image pull secret is successful, it is selected by default. If the creation fails, no secret is applied.

- **CPU requirement (cores)** and **Memory requirement (MiB)**: You can specify the minimum resource limits for the container. By default, Pods run with unbounded CPU and memory limits.

- **Run command** and **Run command arguments**: By default, your containers run the specified Docker image's default entrypoint command. You can use the command options and arguments to override the default.
- **Run as privileged**: This setting determines whether processes in privileged containers are equivalent to processes running as root on the host. Privileged containers can make use of capabilities like manipulating the network stack and accessing devices.
- **Environment variables**: Kubernetes exposes Services through environment variables. You can compose environment variable or pass arguments to your commands using the values of environment variables. They can be used in applications to find a Service. Values can reference other variables using the `$(VAR_NAME)` syntax.

Uploading a YAML or JSON file

Kubernetes supports declarative configuration. In this style, all configuration is stored in manifests (YAML or JSON configuration files). The manifests use Kubernetes API resource schemas.

As an alternative to specifying application details in the deploy wizard, you can define your application in one or more manifests, and upload the files using Dashboard.

Using Dashboard

Following sections describe views of the Kubernetes Dashboard UI; what they provide and how can they be used.

Navigation

When there are Kubernetes objects defined in the cluster, Dashboard shows them in the initial view. By default only objects from the *default* namespace are shown and this can be changed using the namespace selector located in the navigation menu.

Dashboard shows most Kubernetes object kinds and groups them in a few menu categories.

Admin overview

For cluster and namespace administrators, Dashboard lists Nodes, Namespaces and PersistentVolumes and has detail views for them. Node list view contains CPU and memory usage metrics aggregated across all Nodes. The details view shows the metrics for a Node, its specification, status, allocated resources, events and pods running on the node.

Workloads

Shows all applications running in the selected namespace. The view lists applications by workload kind (for example: Deployments, ReplicaSets, StatefulSets). Each workload kind can be viewed separately. The lists summarize actionable information about the workloads, such as the number of ready pods for a ReplicaSet or current memory usage for a Pod.

Detail views for workloads show status and specification information and surface relationships between objects. For example, Pods that ReplicaSet is controlling or new ReplicaSets and HorizontalPodAutoscalers for Deployments.

Services

Shows Kubernetes resources that allow for exposing services to external world and discovering them within a cluster. For that reason, Service and Ingress views show Pods targeted by them, internal endpoints for cluster connections and external endpoints for external users.

Storage

Storage view shows PersistentVolumeClaim resources which are used by applications for storing data.

ConfigMaps and Secrets

Shows all Kubernetes resources that are used for live configuration of applications running in clusters. The view allows for editing and managing config objects and displays secrets hidden by default.

Logs viewer

Pod lists and detail pages link to a logs viewer that is built into Dashboard. The viewer allows for drilling down logs from containers belonging to a single Pod.

 Logs viewer

What's next

For more information, see the Kubernetes Dashboard project page.

Find Out What Container Runtime is Used on a Node

This page outlines steps to find out what container runtime the nodes in your cluster use.

Depending on the way you run your cluster, the container runtime for the nodes may have been pre-configured or you need to configure it. If you're using a managed Kubernetes service, there might be vendor-specific ways to check what container runtime is configured for the nodes. The method described on this

page should work whenever the execution of `kubectl` is allowed.

Before you begin

Install and configure `kubectl`. See Install Tools section for details.

Find out the container runtime used on a Node

Use `kubectl` to fetch and show node information:

```
kubectl get nodes -o wide
```

The output is similar to the following. The column `CONTAINER-RUNTIME` outputs the runtime and its version.

For Docker Engine, the output is similar to this:

```
NAME          STATUS   VERSION    CONTAINER-RUNTIME
node-1        Ready    v1.16.15   docker://19.3.1
node-2        Ready    v1.16.15   docker://19.3.1
node-3        Ready    v1.16.15   docker://19.3.1
```

If your runtime shows as Docker Engine, you still might not be affected by the removal of dockershim in Kubernetes v1.24. Check the runtime endpoint to see if you use dockershim. If you don't use dockershim, you aren't affected.

For containerd, the output is similar to this:

```
NAME          STATUS   VERSION   CONTAINER-RUNTIME
node-1        Ready    v1.19.6   containerd://1.4.1
node-2        Ready    v1.19.6   containerd://1.4.1
node-3        Ready    v1.19.6   containerd://1.4.1
```

Find out more information about container runtimes on Container Runtimes page.

Find out what container runtime endpoint you use

The container runtime talks to the kubelet over a Unix socket using the CRI protocol, which is based on the gRPC framework. The kubelet acts as a client, and the runtime acts as the server. In some cases, you might find it useful to know which socket your nodes use. For example, with the removal of dockershim in Kubernetes v1.24 and later, you might want to know whether you use Docker Engine with dockershim.

Note:

If you currently use Docker Engine in your nodes with `cri-dockerd`, you aren't affected by the dockershim removal.

You can check which socket you use by checking the kubelet configuration on your nodes.

1. Read the starting commands for the kubelet process:

   ```
   tr \\0 ' ' < /proc/"$(pgrep kubelet)"/cmdline
   ```

   If you don't have `tr` or `pgrep`, check the command line for the kubelet process manually.

2. In the output, look for the `--container-runtime` flag and the `--container-runtime-endpoint` flag.

   - If your nodes use Kubernetes v1.23 and earlier and these flags aren't present or if the `--container-runtime` flag is not `remote`, you use the dockershim socket with Docker Engine. The `--container-runtime` command line argument is not available in Kubernetes v1.27 and later.
   - If the `--container-runtime-endpoint` flag is present, check the socket name to find out which runtime you use. For example, `unix:///run/containerd/containerd.sock` is the containerd endpoint.

If you want to change the Container Runtime on a Node from Docker Engine to containerd, you can find out more information on migrating from Docker Engine to containerd, or, if you want to continue using Docker Engine in Kubernetes v1.24 and later, migrate to a CRI-compatible adapter like `cri-dockerd`.

Adding Linux worker nodes

This page explains how to add Linux worker nodes to a kubeadm cluster.

Before you begin

- Each joining worker node has installed the required components from Installing kubeadm, such as, kubeadm, the kubelet and a container runtime.
- A running kubeadm cluster created by `kubeadm init` and following the steps in the document Creating a cluster with kubeadm.
- You need superuser access to the node.

Adding Linux worker nodes

To add new Linux worker nodes to your cluster do the following for each machine:

1. Connect to the machine by using SSH or another method.
2. Run the command that was output by `kubeadm init`. For example:

```
sudo kubeadm join --token <token> <control-plane-host>:<control-plane-port> --discovery-token-ca-cert-hash sha256:<hash>
```

Additional information for kubeadm join

Note:

To specify an IPv6 tuple for `<control-plane-host>:<control-plane-port>`, IPv6 address must be enclosed in square brackets, for example: `[2001:db8::101]:2073`.

If you do not have the token, you can get it by running the following command on the control plane node:

```
# Run this on a control plane node
sudo kubeadm token list
```

The output is similar to this:

```
TOKEN                     TTL  EXPIRES              USAGES           DESCRIPTION            EXTRA GROUPS
8ewj1p.9r9hcjoqgajrj4gi   23h  2018-06-12T02:51:28Z authentication,  The default bootstrap  system:
                                                    signing          token generated by     bootstrappers:
                                                                     'kubeadm init'.        kubeadm:
                                                                                            default-node-token
```

By default, node join tokens expire after 24 hours. If you are joining a node to the cluster after the current token has expired, you can create a new token by running the following command on the control plane node:

```
# Run this on a control plane node
sudo kubeadm token create
```

The output is similar to this:

```
5didvk.d09sbcov8ph2amjw
```

To print a kubeadm join command while also generating a new token you can use:

```
sudo kubeadm token create --print-join-command
```

If you don't have the value of `--discovery-token-ca-cert-hash`, you can get it by running the following commands on the control plane node:

```
# Run this on a control plane node
sudo cat /etc/kubernetes/pki/ca.crt | openssl x509 -pubkey  | openssl rsa -pubin -outform der 2>/dev/null | \
   openssl dgst -sha256 -hex | sed 's/^.* //'
```

The output is similar to:

```
8cb2de97839780a412b93877f8507ad6c94f73add17d5d7058e91741c9d5ec78
```

The output of the `kubeadm join` command should look something like:

```
[preflight] Running pre-flight checks

... (log output of join workflow) ...

Node join complete:
* Certificate signing request sent to control-plane and response
  received.
* Kubelet informed of new secure connection details.

Run 'kubectl get nodes' on control-plane to see this machine join.
```

A few seconds later, you should notice this node in the output from `kubectl get nodes`. (for example, run `kubectl` on a control plane node).

Note:

As the cluster nodes are usually initialized sequentially, the CoreDNS Pods are likely to all run on the first control plane node. To provide higher availability, please rebalance the CoreDNS Pods with `kubectl -n kube-system rollout restart deployment coredns` after at least one new node is joined.

What's next

- See how to add Windows worker nodes.

Romana for NetworkPolicy

This page shows how to use Romana for NetworkPolicy.

Before you begin

Complete steps 1, 2, and 3 of the kubeadm getting started guide.

Installing Romana with kubeadm

Follow the containerized installation guide for kubeadm.

Applying network policies

To apply network policies use one of the following:

- Romana network policies.
  - Example of Romana network policy.
- The NetworkPolicy API.

What's next

Once you have installed Romana, you can follow the Declare Network Policy to try out Kubernetes NetworkPolicy.

Changing the Container Runtime on a Node from Docker Engine to containerd

This task outlines the steps needed to update your container runtime to containerd from Docker. It is applicable for cluster operators running Kubernetes 1.23 or earlier. This also covers an example scenario for migrating from dockershim to containerd. Alternative container runtimes can be picked from this page.

Before you begin

Note: This section links to third party projects that provide functionality required by Kubernetes. The Kubernetes project authors aren't responsible for these projects, which are listed alphabetically. To add a project to this list, read the content guide before submitting a change. More information.

Install containerd. For more information see containerd's installation documentation and for specific prerequisite follow the containerd guide.

Drain the node

```
kubectl drain <node-to-drain> --ignore-daemonsets
```

Replace `<node-to-drain>` with the name of your node you are draining.

Stop the Docker daemon

```
systemctl stop kubelet
systemctl disable docker.service --now
```

Install Containerd

Follow the guide for detailed steps to install containerd.

- Linux
- Windows (PowerShell)

1. Install the `containerd.io` package from the official Docker repositories. Instructions for setting up the Docker repository for your respective Linux distribution and installing the `containerd.io` package can be found at Getting started with containerd.

2. Configure containerd:

   ```
   sudo mkdir -p /etc/containerd
   containerd config default | sudo tee /etc/containerd/config.toml
   ```

3. Restart containerd:

   ```
   sudo systemctl restart containerd
   ```

Start a Powershell session, set `$Version` to the desired version (ex: `$Version="1.4.3"`), and then run the following commands:

1. Download containerd:

   ```
   curl.exe -L https://github.com/containerd/containerd/releases/download/v$Version/containerd-$Version-windows-amd64.tar.gz -o
   tar.exe xvf .\containerd-windows-amd64.tar.gz
   ```

2. Extract and configure:

   ```
   Copy-Item -Path ".\bin\" -Destination "$Env:ProgramFiles\containerd" -Recurse -Force
   cd $Env:ProgramFiles\containerd\
   .\containerd.exe config default | Out-File config.toml -Encoding ascii

   # Review the configuration. Depending on setup you may want to adjust:
   # - the sandbox_image (Kubernetes pause image)
   # - cni bin_dir and conf_dir locations
   Get-Content config.toml

   # (Optional - but highly recommended) Exclude containerd from Windows Defender Scans
   Add-MpPreference -ExclusionProcess "$Env:ProgramFiles\containerd\containerd.exe"
   ```

3. Start containerd:

```
.\containerd.exe --register-service
Start-Service containerd
```

Configure the kubelet to use containerd as its container runtime

Edit the file `/var/lib/kubelet/kubeadm-flags.env` and add the containerd runtime to the flags; `--container-runtime-endpoint=unix:///run/containerd/containerd.sock`.

Users using kubeadm should be aware that the kubeadm tool stores the host's CRI socket in the

`/var/lib/kubelet/instance-config.yaml` file on each node. You can create this `/var/lib/kubelet/instance-config.yaml` file on the node.

The `/var/lib/kubelet/instance-config.yaml` file allows setting the `containerRuntimeEndpoint` parameter.

You can set this parameter's value to the path of your chosen CRI socket (for example `unix:///run/containerd/containerd.sock`).

Restart the kubelet

```
systemctl start kubelet
```

Verify that the node is healthy

Run `kubectl get nodes -o wide` and containerd appears as the runtime for the node we just changed.

Remove Docker Engine

Note: This section links to third party projects that provide functionality required by Kubernetes. The Kubernetes project authors aren't responsible for these projects, which are listed alphabetically. To add a project to this list, read the content guide before submitting a change. More information.

If the node appears healthy, remove Docker.

- CentOS
- Debian
- Fedora
- Ubuntu

```
sudo yum remove docker-ce docker-ce-cli
```

```
sudo apt-get purge docker-ce docker-ce-cli
```

```
sudo dnf remove docker-ce docker-ce-cli
```

```
sudo apt-get purge docker-ce docker-ce-cli
```

The preceding commands don't remove images, containers, volumes, or customized configuration files on your host. To delete them, follow Docker's instructions to Uninstall Docker Engine.

Caution:

Docker's instructions for uninstalling Docker Engine create a risk of deleting containerd. Be careful when executing commands.

Uncordon the node

```
kubectl uncordon <node-to-uncordon>
```

Replace `<node-to-uncordon>` with the name of your node you previously drained.

IP Masquerade Agent User Guide

This page shows how to configure and enable the `ip-masq-agent`.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

To check the version, enter `kubectl version`.

IP Masquerade Agent User Guide

The `ip-masq-agent` configures iptables rules to hide a pod's IP address behind the cluster node's IP address. This is typically done when sending traffic to destinations outside the cluster's pod CIDR range.

Key Terms

- **NAT (Network Address Translation)**: Is a method of remapping one IP address to another by modifying either the source and/or destination address information in the IP header. Typically performed by a device doing IP routing.
- **Masquerading**: A form of NAT that is typically used to perform a many to one address translation, where multiple source IP addresses are masked behind a single address, which is typically the device doing the IP routing. In Kubernetes this is the Node's IP address.
- **CIDR (Classless Inter-Domain Routing)**: Based on the variable-length subnet masking, allows specifying arbitrary-length prefixes. CIDR introduced a new method of representation for IP addresses, now commonly known as **CIDR notation**, in which an address or routing prefix is written with a suffix indicating the number of bits of the prefix, such as 192.168.2.0/24.
- **Link Local**: A link-local address is a network address that is valid only for communications within the network segment or the broadcast domain that the host is connected to. Link-local addresses for IPv4 are defined in the address block 169.254.0.0/16 in CIDR notation.

The ip-masq-agent configures iptables rules to handle masquerading node/pod IP addresses when sending traffic to destinations outside the cluster node's IP and the Cluster IP range. This essentially hides pod IP addresses behind the cluster node's IP address. In some environments, traffic to "external" addresses must come from a known machine address. For example, in Google Cloud, any traffic to the internet must come from a VM's IP. When containers are used, as in Google Kubernetes Engine, the Pod IP will be rejected for egress. To avoid this, we must hide the Pod IP behind the VM's own IP address - generally known as "masquerade". By default, the agent is configured to treat the three private IP ranges specified by RFC 1918 as non-masquerade CIDR. These ranges are `10.0.0.0/8`, `172.16.0.0/12`, and `192.168.0.0/16`. The agent will also treat link-local (169.254.0.0/16) as a non-masquerade CIDR by default. The agent is configured to reload its configuration from the location */etc/config/ip-masq-agent* every 60 seconds, which is also configurable.


masq/non-masq example

The agent configuration file must be written in YAML or JSON syntax, and may contain three optional keys:

- `nonMasqueradeCIDRs`: A list of strings in CIDR notation that specify the non-masquerade ranges.
- `masqLinkLocal`: A Boolean (true/false) which indicates whether to masquerade traffic to the link local prefix `169.254.0.0/16`. False by default.
- `resyncInterval`: A time interval at which the agent attempts to reload config from disk. For example: '30s', where 's' means seconds, 'ms' means milliseconds.

Traffic to 10.0.0.0/8, 172.16.0.0/12 and 192.168.0.0/16 ranges will NOT be masqueraded. Any other traffic (assumed to be internet) will be masqueraded. An example of a local destination from a pod could be its Node's IP address as well as another node's address or one of the IP addresses in Cluster's IP range. Any other traffic will be masqueraded by default. The below entries show the default set of rules that are applied by the ip-masq-agent:

```
iptables -t nat -L IP-MASQ-AGENT

target     prot opt source               destination
RETURN     all  --  anywhere             169.254.0.0/16       /* ip-masq-agent: cluster-local traffic should not be subject to MAS(
RETURN     all  --  anywhere             10.0.0.0/8           /* ip-masq-agent: cluster-local traffic should not be subject to MAS(
RETURN     all  --  anywhere             172.16.0.0/12        /* ip-masq-agent: cluster-local traffic should not be subject to MAS(
RETURN     all  --  anywhere             192.168.0.0/16       /* ip-masq-agent: cluster-local traffic should not be subject to MAS(
MASQUERADE  all  --  anywhere             anywhere             /* ip-masq-agent: outbound traffic should be subject to MASQUERADE
```

By default, in GCE/Google Kubernetes Engine, if network policy is enabled or you are using a cluster CIDR not in the 10.0.0.0/8 range, the `ip-masq-agent` will run in your cluster. If you are running in another environment, you can add the `ip-masq-agent` DaemonSet to your cluster.

Create an ip-masq-agent

To create an ip-masq-agent, run the following kubectl command:

```
kubectl apply -f https://raw.githubusercontent.com/kubernetes-sigs/ip-masq-agent/master/ip-masq-agent.yaml
```

You must also apply the appropriate node label to any nodes in your cluster that you want the agent to run on.

```
kubectl label nodes my-node node.kubernetes.io/masq-agent-ds-ready=true
```

More information can be found in the ip-masq-agent documentation here.

In most cases, the default set of rules should be sufficient; however, if this is not the case for your cluster, you can create and apply a ConfigMap to customize the IP ranges that are affected. For example, to allow only 10.0.0.0/8 to be considered by the ip-masq-agent, you can create the following ConfigMap in a file called "config".

Note:

It is important that the file is called config since, by default, that will be used as the key for lookup by the `ip-masq-agent`:

```
nonMasqueradeCIDRs:
  - 10.0.0.0/8
resyncInterval: 60s
```

Run the following command to add the configmap to your cluster:

```
kubectl create configmap ip-masq-agent --from-file=config --namespace=kube-system
```

This will update a file located at `/etc/config/ip-masq-agent` which is periodically checked every `resyncInterval` and applied to the cluster node. After the resync interval has expired, you should see the iptables rules reflect your changes:

```
iptables -t nat -L IP-MASQ-AGENT

Chain IP-MASQ-AGENT (1 references)
target     prot opt source               destination
RETURN     all  --  anywhere             169.254.0.0/16       /* ip-masq-agent: cluster-local traffic should not be subject to MAS(
```

```
RETURN     all  --  anywhere             10.0.0.0/8           /* ip-masq-agent: cluster-local
MASQUERADE  all  --  anywhere             anywhere             /* ip-masq-agent: outbound traffic should be subject to MASQUERADE
```

By default, the link local range (169.254.0.0/16) is also handled by the ip-masq agent, which sets up the appropriate iptables rules. To have the ip-masq-agent ignore link local, you can set `masqLinkLocal` to true in the ConfigMap.

```
nonMasqueradeCIDRs:
  - 10.0.0.0/8
resyncInterval: 60smasqLinkLocal: true
```

Configure Quotas for API Objects

This page shows how to configure quotas for API objects, including PersistentVolumeClaims and Services. A quota restricts the number of objects, of a particular type, that can be created in a namespace. You specify quotas in a ResourceQuota object.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

To check the version, enter `kubectl version`.

Create a namespace

Create a namespace so that the resources you create in this exercise are isolated from the rest of your cluster.

```
kubectl create namespace quota-object-example
```

Create a ResourceQuota

Here is the configuration file for a ResourceQuota object:

admin/resource/quota-objects.yaml Copy admin/resource/quota-objects.yaml to clipboard

```
apiVersion: v1
kind: ResourceQuotametadata:  name: object-quota-demospec:  hard:    persistentvolumeclaims: "1"    services.loadbalancers: "2"
```

Create the ResourceQuota:

```
kubectl apply -f https://k8s.io/examples/admin/resource/quota-objects.yaml --namespace=quota-object-example
```

View detailed information about the ResourceQuota:

```
kubectl get resourcequota object-quota-demo --namespace=quota-object-example --output=yaml
```

The output shows that in the quota-object-example namespace, there can be at most one PersistentVolumeClaim, at most two Services of type LoadBalancer, and no Services of type NodePort.

```
status:
  hard:
    persistentvolumeclaims: "1"
    services.loadbalancers: "2"
    services.nodeports: "0"
  used:
    persistentvolumeclaims: "0"
    services.loadbalancers: "0"
    services.nodeports: "0"
```

Create a PersistentVolumeClaim

Here is the configuration file for a PersistentVolumeClaim object:

admin/resource/quota-objects-pvc.yaml  Copy admin/resource/quota-objects-pvc.yaml to clipboard

```
apiVersion: v1
kind: PersistentVolumeClaimmetadata:  name: pvc-quota-demospec:  storageClassName: manual  accessModes:    - ReadWriteOnce  resour
```

Create the PersistentVolumeClaim:

```
kubectl apply -f https://k8s.io/examples/admin/resource/quota-objects-pvc.yaml --namespace=quota-object-example
```

Verify that the PersistentVolumeClaim was created:

```
kubectl get persistentvolumeclaims --namespace=quota-object-example
```

The output shows that the PersistentVolumeClaim exists and has status Pending:

```
NAME             STATUS
pvc-quota-demo   Pending
```

Attempt to create a second PersistentVolumeClaim

Here is the configuration file for a second PersistentVolumeClaim:

admin/resource/quota-objects-pvc-2.yaml Copy admin/resource/quota-objects-pvc-2.yaml to clipboard

```
apiVersion: v1
kind: PersistentVolumeClaimmetadata:  name: pvc-quota-demo-2spec:  storageClassName: manual  accessModes:    - ReadWriteOnce  reso
```

Attempt to create the second PersistentVolumeClaim:

```
kubectl apply -f https://k8s.io/examples/admin/resource/quota-objects-pvc-2.yaml --namespace=quota-object-example
```

The output shows that the second PersistentVolumeClaim was not created, because it would have exceeded the quota for the namespace.

```
persistentvolumeclaims "pvc-quota-demo-2" is forbidden:
exceeded quota: object-quota-demo, requested: persistentvolumeclaims=1,
used: persistentvolumeclaims=1, limited: persistentvolumeclaims=1
```

Notes

These are the strings used to identify API resources that can be constrained by quotas:

String	API Object
"pods"	Pod
"services"	Service
"replicationcontrollers"	ReplicationController
"resourcequotas"	ResourceQuota
"secrets"	Secret
"configmaps"	ConfigMap
"persistentvolumeclaims"	PersistentVolumeClaim
"services.nodeports"	Service of type NodePort
"services.loadbalancers"	Service of type LoadBalancer

Clean up

Delete your namespace:

```
kubectl delete namespace quota-object-example
```

What's next

For cluster administrators

- Configure Default Memory Requests and Limits for a Namespace
- Configure Default CPU Requests and Limits for a Namespace
- Configure Minimum and Maximum Memory Constraints for a Namespace
- Configure Minimum and Maximum CPU Constraints for a Namespace
- Configure Memory and CPU Quotas for a Namespace
- Configure a Pod Quota for a Namespace

For app developers

- Assign Memory Resources to Containers and Pods
- Assign CPU Resources to Containers and Pods
- Assign Pod-level CPU and memory resources
- Configure Quality of Service for Pods

Manage Memory, CPU, and API Resources

Configure Default Memory Requests and Limits for a Namespace

Define a default memory resource limit for a namespace, so that every new Pod in that namespace has a memory resource limit configured.

Configure Default CPU Requests and Limits for a Namespace

Define a default CPU resource limits for a namespace, so that every new Pod in that namespace has a CPU resource limit configured.

Configure Minimum and Maximum Memory Constraints for a Namespace

Define a range of valid memory resource limits for a namespace, so that every new Pod in that namespace falls within the range you configure.

Configure Minimum and Maximum CPU Constraints for a Namespace

Define a range of valid CPU resource limits for a namespace, so that every new Pod in that namespace falls within the range you configure.

Configure Memory and CPU Quotas for a Namespace

Define overall memory and CPU resource limits for a namespace.

Configure a Pod Quota for a Namespace

Restrict how many Pods you can create within a namespace.

Securing a Cluster

This document covers topics related to protecting a cluster from accidental or malicious access and provides recommendations on overall security.

Before you begin

- You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:
  - iximiuz Labs
  - Killercoda
  - KodeKloud
  - Play with Kubernetes

  To check the version, enter `kubectl version`.

Controlling access to the Kubernetes API

As Kubernetes is entirely API-driven, controlling and limiting who can access the cluster and what actions they are allowed to perform is the first line of defense.

Use Transport Layer Security (TLS) for all API traffic

Kubernetes expects that all API communication in the cluster is encrypted by default with TLS, and the majority of installation methods will allow the necessary certificates to be created and distributed to the cluster components. Note that some components and installation methods may enable local ports over HTTP and administrators should familiarize themselves with the settings of each component to identify potentially unsecured traffic.

API Authentication

Choose an authentication mechanism for the API servers to use that matches the common access patterns when you install a cluster. For instance, small, single-user clusters may wish to use a simple certificate or static Bearer token approach. Larger clusters may wish to integrate an existing OIDC or LDAP server that allow users to be subdivided into groups.

All API clients must be authenticated, even those that are part of the infrastructure like nodes, proxies, the scheduler, and volume plugins. These clients are typically service accounts or use x509 client certificates, and they are created automatically at cluster startup or are setup as part of the cluster installation.

Consult the authentication reference document for more information.

API Authorization

Once authenticated, every API call is also expected to pass an authorization check. Kubernetes ships an integrated Role-Based Access Control (RBAC) component that matches an incoming user or group to a set of permissions bundled into roles. These permissions combine verbs (get, create, delete) with resources (pods, services, nodes) and can be namespace-scoped or cluster-scoped. A set of out-of-the-box roles are provided that offer reasonable default separation of responsibility depending on what actions a client might want to perform. It is recommended that you use the Node and RBAC authorizers together, in combination with the NodeRestriction admission plugin.

As with authentication, simple and broad roles may be appropriate for smaller clusters, but as more users interact with the cluster, it may become necessary to separate teams into separate namespaces with more limited roles.

With authorization, it is important to understand how updates on one object may cause actions in other places. For instance, a user may not be able to create pods directly, but allowing them to create a deployment, which creates pods on their behalf, will let them create those pods indirectly. Likewise, deleting a node from the API will result in the pods scheduled to that node being terminated and recreated on other nodes. The out-of-the box roles represent a balance between flexibility and common use cases, but more limited roles should be carefully reviewed to prevent accidental escalation. You can make roles specific to your use case if the out-of-box ones don't meet your needs.

Consult the authorization reference section for more information.

Controlling access to the Kubelet

Kubelets expose HTTPS endpoints which grant powerful control over the node and containers. By default Kubelets allow unauthenticated access to this API.

Production clusters should enable Kubelet authentication and authorization.

Consult the Kubelet authentication/authorization reference for more information.

Controlling the capabilities of a workload or user at runtime

Authorization in Kubernetes is intentionally high level, focused on coarse actions on resources. More powerful controls exist as **policies** to limit by use case how those objects act on the cluster, themselves, and other resources.

Limiting resource usage on a cluster

Resource quota limits the number or capacity of resources granted to a namespace. This is most often used to limit the amount of CPU, memory, or persistent disk a namespace can allocate, but can also control how many pods, services, or volumes exist in each namespace.

Limit ranges restrict the maximum or minimum size of some of the resources above, to prevent users from requesting unreasonably high or low values for commonly reserved resources like memory, or to provide default limits when none are specified.

Controlling what privileges containers run with

A pod definition contains a security context that allows it to request access to run as a specific Linux user on a node (like root), access to run privileged or access the host network, and other controls that would otherwise allow it to run unfettered on a hosting node.

You can configure Pod security admission to enforce use of a particular Pod Security Standard in a namespace, or to detect breaches.

Generally, most application workloads need limited access to host resources so they can successfully run as a root process (uid 0) without access to host information. However, considering the privileges associated with the root user, you should write application containers to run as a non-root user. Similarly, administrators who wish to prevent client applications from escaping their containers should apply the **Baseline** or **Restricted** Pod Security Standard.

Preventing containers from loading unwanted kernel modules

The Linux kernel automatically loads kernel modules from disk if needed in certain circumstances, such as when a piece of hardware is attached or a filesystem is mounted. Of particular relevance to Kubernetes, even unprivileged processes can cause certain network-protocol-related kernel modules to be loaded, just by creating a socket of the appropriate type. This may allow an attacker to exploit a security hole in a kernel module that the administrator assumed was not in use.

To prevent specific modules from being automatically loaded, you can uninstall them from the node, or add rules to block them. On most Linux distributions, you can do that by creating a file such as `/etc/modprobe.d/kubernetes-blacklist.conf` with contents like:

```
# DCCP is unlikely to be needed, has had multiple serious
# vulnerabilities, and is not well-maintained.
blacklist dccp

# SCTP is not used in most Kubernetes clusters, and has also had
# vulnerabilities in the past.
blacklist sctp
```

To block module loading more generically, you can use a Linux Security Module (such as SELinux) to completely deny the `module_request` permission to containers, preventing the kernel from loading modules for containers under any circumstances. (Pods would still be able to use modules that had been loaded manually, or modules that were loaded by the kernel on behalf of some more-privileged process.)

Restricting network access

The network policies for a namespace allows application authors to restrict which pods in other namespaces may access pods and ports within their namespaces. Many of the supported Kubernetes networking providers now respect network policy.

Quota and limit ranges can also be used to control whether users may request node ports or load-balanced services, which on many clusters can control whether those users applications are visible outside of the cluster.

Additional protections may be available that control network rules on a per-plugin or per- environment basis, such as per-node firewalls, physically separating cluster nodes to prevent cross talk, or advanced networking policy.

Restricting cloud metadata API access

Cloud platforms (AWS, Azure, GCE, etc.) often expose metadata services locally to instances. By default these APIs are accessible by pods running on an instance and can contain cloud credentials for that node, or provisioning data such as kubelet credentials. These credentials can be used to escalate within the cluster or to other cloud services under the same account.

When running Kubernetes on a cloud platform, limit permissions given to instance credentials, use network policies to restrict pod access to the metadata API, and avoid using provisioning data to deliver secrets.

Controlling which nodes pods may access

By default, there are no restrictions on which nodes may run a pod. Kubernetes offers a rich set of policies for controlling placement of pods onto nodes and the taint-based pod placement and eviction that are available to end users. For many clusters use of these policies to separate workloads can be a convention

that authors adopt or enforce via tooling.

As an administrator, a beta admission plugin `PodNodeSelector` can be used to force pods within a namespace to default or require a specific node selector, and if end users cannot alter namespaces, this can strongly limit the placement of all of the pods in a specific workload.

Protecting cluster components from compromise

This section describes some common patterns for protecting clusters from compromise.

Restrict access to etcd

Write access to the etcd backend for the API is equivalent to gaining root on the entire cluster, and read access can be used to escalate fairly quickly. Administrators should always use strong credentials from the API servers to their etcd server, such as mutual auth via TLS client certificates, and it is often recommended to isolate the etcd servers behind a firewall that only the API servers may access.

Caution:

Allowing other components within the cluster to access the master etcd instance with read or write access to the full keyspace is equivalent to granting cluster-admin access. Using separate etcd instances for non-master components or using etcd ACLs to restrict read and write access to a subset of the keyspace is strongly recommended.

Enable audit logging

The audit logger is a beta feature that records actions taken by the API for later analysis in the event of a compromise. It is recommended to enable audit logging and archive the audit file on a secure server.

Restrict access to alpha or beta features

Alpha and beta Kubernetes features are in active development and may have limitations or bugs that result in security vulnerabilities. Always assess the value an alpha or beta feature may provide against the possible risk to your security posture. When in doubt, disable features you do not use.

Rotate infrastructure credentials frequently

The shorter the lifetime of a secret or credential the harder it is for an attacker to make use of that credential. Set short lifetimes on certificates and automate their rotation. Use an authentication provider that can control how long issued tokens are available and use short lifetimes where possible. If you use service-account tokens in external integrations, plan to rotate those tokens frequently. For example, once the bootstrap phase is complete, a bootstrap token used for setting up nodes should be revoked or its authorization removed.

Review third party integrations before enabling them

Many third party integrations to Kubernetes may alter the security profile of your cluster. When enabling an integration, always review the permissions that an extension requests before granting it access. For example, many security integrations may request access to view all secrets on your cluster which is effectively making that component a cluster admin. When in doubt, restrict the integration to functioning in a single namespace if possible.

Components that create pods may also be unexpectedly powerful if they can do so inside namespaces like the `kube-system` namespace, because those pods can gain access to service account secrets or run with elevated permissions if those service accounts are granted access to permissive PodSecurityPolicies.

If you use Pod Security admission and allow any component to create Pods within a namespace that permits privileged Pods, those Pods may be able to escape their containers and use this widened access to elevate their privileges.

You should not allow untrusted components to create Pods in any system namespace (those with names that start with `kube-`) nor in any namespace where that access grant allows the possibility of privilege escalation.

Encrypt secrets at rest

In general, the etcd database will contain any information accessible via the Kubernetes API and may grant an attacker significant visibility into the state of your cluster. Always encrypt your backups using a well reviewed backup and encryption solution, and consider using full disk encryption where possible.

Kubernetes supports optional encryption at rest for information in the Kubernetes API. This lets you ensure that when Kubernetes stores data for objects (for example, `Secret` or `ConfigMap` objects), the API server writes an encrypted representation of the object. That encryption means that even someone who has access to etcd backup data is unable to view the content of those objects. In Kubernetes 1.34 you can also encrypt custom resources; encryption-at-rest for extension APIs defined in CustomResourceDefinitions was added to Kubernetes as part of the v1.26 release.

Receiving alerts for security updates and reporting vulnerabilities

Join the kubernetes-announce group for emails about security announcements. See the security reporting page for more on how to report vulnerabilities.

What's next

- Security Checklist for additional information on Kubernetes security guidance.
- Seccomp Node Reference

Create an External Load Balancer

This page shows how to create an external load balancer.

When creating a Service, you have the option of automatically creating a cloud load balancer. This provides an externally-accessible IP address that sends traffic to the correct port on your cluster nodes, *provided your cluster runs in a supported environment and is configured with the correct cloud load balancer provider package*.

You can also use an Ingress in place of Service. For more information, check the Ingress documentation.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

Your cluster must be running in a cloud or other environment that already has support for configuring external load balancers.

Create a Service

Create a Service from a manifest

To create an external load balancer, add the following line to your Service manifest:

```
    type: LoadBalancer
```

Your manifest might then look like:

```
apiVersion: v1
kind: Servicemetadata:  name: example-servicespec:  selector:    app: example  ports:    - port: 8765      targetPort: 9376  type:
```

Create a Service using kubectl

You can alternatively create the service with the `kubectl expose` command and its `--type=LoadBalancer` flag:

```
kubectl expose deployment example --port=8765 --target-port=9376 \
        --name=example-service --type=LoadBalancer
```

This command creates a new Service using the same selectors as the referenced resource (in the case of the example above, a Deployment named `example`).

For more information, including optional flags, refer to the `kubectl expose` reference.

Finding your IP address

You can find the IP address created for your service by getting the service information through `kubectl`:

```
kubectl describe services example-service
```

which should produce output similar to:

```
Name:                     example-service
Namespace:                default
Labels:                   app=example
Annotations:              <none>
Selector:                 app=example
Type:                     LoadBalancer
IP Families:              <none>
IP:                       10.3.22.96
IPs:                      10.3.22.96
LoadBalancer Ingress:     192.0.2.89
Port:                     <unset>  8765/TCP
TargetPort:               9376/TCP
NodePort:                 <unset>  30593/TCP
Endpoints:                172.17.0.3:9376
Session Affinity:         None
External Traffic Policy:  Cluster
Events:                   <none>
```

The load balancer's IP address is listed next to `LoadBalancer Ingress`.

Note:

If you are running your service on Minikube, you can find the assigned IP address and port with:

```
minikube service example-service --url
```

Preserving the client source IP

By default, the source IP seen in the target container is *not the original source IP* of the client. To enable preservation of the client IP, the following fields can be configured in the `.spec` of the Service:

- `.spec.externalTrafficPolicy` - denotes if this Service desires to route external traffic to node-local or cluster-wide endpoints. There are two available options: `Cluster` (default) and `Local`. `Cluster` obscures the client source IP and may cause a second hop to another node, but should have good overall load-spreading. `Local` preserves the client source IP and avoids a second hop for LoadBalancer and NodePort type Services, but risks potentially imbalanced traffic spreading.
- `.spec.healthCheckNodePort` - specifies the health check node port (numeric port number) for the service. If you don't specify `healthCheckNodePort`, the service controller allocates a port from your cluster's NodePort range.
  You can configure that range by setting an API server command line option, `--service-node-port-range`. The Service will use the user-specified `healthCheckNodePort` value if you specify it, provided that the Service `type` is set to LoadBalancer and `externalTrafficPolicy` is set to `Local`.

Setting `externalTrafficPolicy` to Local in the Service manifest activates this feature. For example:

```
apiVersion: v1
kind: Servicemetadata:  name: example-servicespec:  selector:    app: example  ports:    - port: 8765      targetPort: 9376  exter
```

Caveats and limitations when preserving source IPs

Load balancing services from some cloud providers do not let you configure different weights for each target.

With each target weighted equally in terms of sending traffic to Nodes, external traffic is not equally load balanced across different Pods. The external load balancer is unaware of the number of Pods on each node that are used as a target.

Where `NumServicePods << NumNodes` or `NumServicePods >> NumNodes`, a fairly close-to-equal distribution will be seen, even without weights.

Internal pod to pod traffic should behave similar to ClusterIP services, with equal probability across all pods.

Garbage collecting load balancers

FEATURE STATE: `Kubernetes v1.17 [stable]`

In usual case, the correlating load balancer resources in cloud provider should be cleaned up soon after a LoadBalancer type Service is deleted. But it is known that there are various corner cases where cloud resources are orphaned after the associated Service is deleted. Finalizer Protection for Service LoadBalancers was introduced to prevent this from happening. By using finalizers, a Service resource will never be deleted until the correlating load balancer resources are also deleted.

Specifically, if a Service has `type` LoadBalancer, the service controller will attach a finalizer named `service.kubernetes.io/load-balancer-cleanup`. The finalizer will only be removed after the load balancer resource is cleaned up. This prevents dangling load balancer resources even in corner cases such as the service controller crashing.

External load balancer providers

It is important to note that the datapath for this functionality is provided by a load balancer external to the Kubernetes cluster.

When the Service `type` is set to LoadBalancer, Kubernetes provides functionality equivalent to `type` equals ClusterIP to pods within the cluster and extends it by programming the (external to Kubernetes) load balancer with entries for the nodes hosting the relevant Kubernetes pods. The Kubernetes control plane automates the creation of the external load balancer, health checks (if needed), and packet filtering rules (if needed). Once the cloud provider allocates an IP address for the load balancer, the control plane looks up that external IP address and populates it into the Service object.

What's next

- Follow the Connecting Applications with Services tutorial
- Read about Service
- Read about Ingress

Control Topology Management Policies on a node

FEATURE STATE: `Kubernetes v1.27 [stable]`

An increasing number of systems leverage a combination of CPUs and hardware accelerators to support latency-critical execution and high-throughput parallel computation. These include workloads in fields such as telecommunications, scientific computing, machine learning, financial services and data analytics. Such hybrid systems comprise a high performance environment.

In order to extract the best performance, optimizations related to CPU isolation, memory and device locality are required. However, in Kubernetes, these optimizations are handled by a disjoint set of components.

Topology Manager is a kubelet component that aims to coordinate the set of components that are responsible for these optimizations.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

Your Kubernetes server must be at or later than version v1.18.

To check the version, enter `kubectl version`.

How topology manager works

Prior to the introduction of Topology Manager, the CPU and Device Manager in Kubernetes make resource allocation decisions independently of each other. This can result in undesirable allocations on multiple-socketed systems, and performance/latency sensitive applications will suffer due to these undesirable allocations. Undesirable in this case meaning, for example, CPUs and devices being allocated from different NUMA Nodes, thus incurring additional latency.

The Topology Manager is a kubelet component, which acts as a source of truth so that other kubelet components can make topology aligned resource allocation choices.

The Topology Manager provides an interface for components, called *Hint Providers*, to send and receive topology information. The Topology Manager has a set of node level policies which are explained below.

The Topology Manager receives topology information from the *Hint Providers* as a bitmask denoting NUMA Nodes available and a preferred allocation indication. The Topology Manager policies perform a set of operations on the hints provided and converge on the hint determined by the policy to give the optimal result. If an undesirable hint is stored, the preferred field for the hint will be set to false. In the current policies preferred is the narrowest preferred mask. The selected hint is stored as part of the Topology Manager. Depending on the policy configured, the pod can be accepted or rejected from the node based on the selected hint. The hint is then stored in the Topology Manager for use by the *Hint Providers* when making the resource allocation decisions.

The flow can be seen in the following diagram.

 topology_manager_flow

Windows Support

FEATURE STATE: `Kubernetes v1.32 [alpha]` (enabled by default: false)

The Topology Manager support can be enabled on Windows by using the `WindowsCPUAndMemoryAffinity` feature gate and it requires support in the container runtime.

Topology manager scopes and policies

The Topology Manager currently:

- aligns Pods of all QoS classes.
- aligns the requested resources that Hint Provider provides topology hints for.

If these conditions are met, the Topology Manager will align the requested resources.

In order to customize how this alignment is carried out, the Topology Manager provides two distinct options: `scope` and `policy`.

The `scope` defines the granularity at which you would like resource alignment to be performed, for example, at the `pod` or `container` level. And the `policy` defines the actual policy used to carry out the alignment, for example, `best-effort`, `restricted`, and `single-numa-node`. Details on the various `scopes` and `policies` available today can be found below.

Note:

To align CPU resources with other requested resources in a Pod spec, the CPU Manager should be enabled and proper CPU Manager policy should be configured on a Node. See Control CPU Management Policies on the Node.

Note:

To align memory (and hugepages) resources with other requested resources in a Pod spec, the Memory Manager should be enabled and proper Memory Manager policy should be configured on a Node. Refer to Memory Manager documentation.

Topology manager scopes

The Topology Manager can deal with the alignment of resources in a couple of distinct scopes:

- `container` (default)
- `pod`

Either option can be selected at a time of the kubelet startup, by setting the `topologyManagerScope` in the kubelet configuration file.

`container` scope

The `container` scope is used by default. You can also explicitly set the `topologyManagerScope` to `container` in the kubelet configuration file.

Within this scope, the Topology Manager performs a number of sequential resource alignments, i.e., for each container (in a pod) a separate alignment is computed. In other words, there is no notion of grouping the containers to a specific set of NUMA nodes, for this particular scope. In effect, the Topology Manager performs an arbitrary alignment of individual containers to NUMA nodes.

The notion of grouping the containers was endorsed and implemented on purpose in the following scope, for example the `pod` scope.

`pod` scope

To select the `pod` scope, set `topologyManagerScope` in the kubelet configuration file to `pod`.

This scope allows for grouping all containers in a pod to a common set of NUMA nodes. That is, the Topology Manager treats a pod as a whole and attempts to allocate the entire pod (all containers) to either a single NUMA node or a common set of NUMA nodes. The following examples illustrate the alignments produced by the Topology Manager on different occasions:

- all containers can be and are allocated to a single NUMA node;
- all containers can be and are allocated to a shared set of NUMA nodes.

The total amount of particular resource demanded for the entire pod is calculated according to effective requests/limits formula, and thus, this total value is equal to the maximum of:

- the sum of all app container requests,
- the maximum of init container requests,

for a resource.

Using the `pod` scope in tandem with `single-numa-node` Topology Manager policy is specifically valuable for workloads that are latency sensitive or for high-throughput applications that perform IPC. By combining both options, you are able to place all containers in a pod onto a single NUMA node; hence, the inter-NUMA communication overhead can be eliminated for that pod.

In the case of `single-numa-node` policy, a pod is accepted only if a suitable set of NUMA nodes is present among possible allocations. Reconsider the example above:

- a set containing only a single NUMA node - it leads to pod being admitted,
- whereas a set containing more NUMA nodes - it results in pod rejection (because instead of one NUMA node, two or more NUMA nodes are required to satisfy the allocation).

To recap, the Topology Manager first computes a set of NUMA nodes and then tests it against the Topology Manager policy, which either leads to the rejection or admission of the pod.

Topology manager policies

The Topology Manager supports four allocation policies. You can set a policy via a kubelet flag, `--topology-manager-policy`. There are four supported policies:

- `none` (default)
- `best-effort`
- `restricted`
- `single-numa-node`

Note:

If the Topology Manager is configured with the **pod** scope, the container, which is considered by the policy, is reflecting requirements of the entire pod, and thus each container from the pod will result with **the same** topology alignment decision.

`none` policy

This is the default policy and does not perform any topology alignment.

`best-effort` policy

For each container in a Pod, the kubelet, with `best-effort` topology management policy, calls each Hint Provider to discover their resource availability. Using this information, the Topology Manager stores the preferred NUMA Node affinity for that container. If the affinity is not preferred, the Topology Manager will store this and admit the pod to the node anyway.

The *Hint Providers* can then use this information when making the resource allocation decision.

`restricted` policy

For each container in a Pod, the kubelet, with `restricted` topology management policy, calls each Hint Provider to discover their resource availability. Using this information, the Topology Manager stores the preferred NUMA Node affinity for that container. If the affinity is not preferred, the Topology Manager will reject this pod from the node. This will result in a pod entering a `Terminated` state with a pod admission failure.

Once the pod is in a `Terminated` state, the Kubernetes scheduler will **not** attempt to reschedule the pod. It is recommended to use a ReplicaSet or Deployment to trigger a redeployment of the pod. An external control loop could be also implemented to trigger a redeployment of pods that have the `Topology Affinity` error.

If the pod is admitted, the *Hint Providers* can then use this information when making the resource allocation decision.

`single-numa-node` policy

For each container in a Pod, the kubelet, with `single-numa-node` topology management policy, calls each Hint Provider to discover their resource availability. Using this information, the Topology Manager determines if a single NUMA Node affinity is possible. If it is, Topology Manager will store this and the *Hint Providers* can then use this information when making the resource allocation decision. If, however, this is not possible then the Topology Manager will reject the pod from the node. This will result in a pod in a `Terminated` state with a pod admission failure.

Once the pod is in a `Terminated` state, the Kubernetes scheduler will **not** attempt to reschedule the pod. It is recommended to use a Deployment with replicas to trigger a redeployment of the Pod. An external control loop could be also implemented to trigger a redeployment of pods that have the `Topology Affinity` error.

Topology manager policy options

Support for the Topology Manager policy options requires `TopologyManagerPolicyOptions` feature gate to be enabled (it is enabled by default).

You can toggle groups of options on and off based upon their maturity level using the following feature gates:

- `TopologyManagerPolicyBetaOptions` default enabled. Enable to show beta-level options.
- `TopologyManagerPolicyAlphaOptions` default disabled. Enable to show alpha-level options.

You will still have to enable each option using the `TopologyManagerPolicyOptions` kubelet option.

`prefer-closest-numa-nodes`

The `prefer-closest-numa-nodes` option is GA since Kubernetes 1.32. In Kubernetes 1.34 this policy option is visible by default provided that the `TopologyManagerPolicyOptions` feature gate is enabled.

The Topology Manager is not aware by default of NUMA distances, and does not take them into account when making Pod admission decisions. This limitation surfaces in multi-socket, as well as single-socket multi NUMA systems, and can cause significant performance degradation in latency-critical execution and high-throughput applications if the Topology Manager decides to align resources on non-adjacent NUMA nodes.

If you specify the `prefer-closest-numa-nodes` policy option, the `best-effort` and `restricted` policies favor sets of NUMA nodes with shorter distance between them when making admission decisions.

You can enable this option by adding `prefer-closest-numa-nodes=true` to the Topology Manager policy options.

By default (without this option), the Topology Manager aligns resources on either a single NUMA node or, in the case where more than one NUMA node is required, using the minimum number of NUMA nodes.

`max-allowable-numa-nodes` (beta)

The `max-allowable-numa-nodes` option is beta since Kubernetes 1.31. In Kubernetes 1.34, this policy option is visible by default provided that the `TopologyManagerPolicyOptions` and `TopologyManagerPolicyBetaOptions` feature gates are enabled.

The time to admit a pod is tied to the number of NUMA nodes on the physical machine. By default, Kubernetes does not run a kubelet with the Topology Manager enabled, on any (Kubernetes) node where more than 8 NUMA nodes are detected.

Note:

If you select the `max-allowable-numa-nodes` policy option, nodes with more than 8 NUMA nodes can be allowed to run with the Topology Manager enabled. The Kubernetes project only has limited data on the impact of using the Topology Manager on (Kubernetes) nodes with more than 8 NUMA nodes. Because of that lack of data, using this policy option with Kubernetes 1.34 is **not** recommended and is at your own risk.

You can enable this option by adding `max-allowable-numa-nodes=true` to the Topology Manager policy options.

Setting a value of `max-allowable-numa-nodes` does not (in and of itself) affect the latency of pod admission, but binding a Pod to a (Kubernetes) node with many NUMA does have an impact. Future, potential improvements to Kubernetes may improve Pod admission performance and the high latency that happens as the number of NUMA nodes increases.

Pod interactions with topology manager policies

Consider the containers in the following Pod manifest:

```yaml
spec:
  containers:
  - name: nginx
    image: nginx
```

This pod runs in the `BestEffort` QoS class because no resource `requests` or `limits` are specified.

```yaml
spec:
  containers:
  - name: nginx
    image: nginx
    resources:
      limits:
        memory: "200Mi"
      requests:
        memory: "100Mi"
```

This pod runs in the `Burstable` QoS class because requests are less than limits.

If the selected policy is anything other than `none`, the Topology Manager would consider these Pod specifications. The Topology Manager would consult the Hint Providers to get topology hints. In the case of the `static`, the CPU Manager policy would return default topology hint, because these Pods do not explicitly request CPU resources.

```yaml
spec:
  containers:
  - name: nginx
    image: nginx
```

```
    resources:
      limits:
        memory: "200Mi"
        cpu: "2"
        example.com/device: "1"
      requests:
        memory: "200Mi"
        cpu: "2"
        example.com/device: "1"
```

This pod with integer CPU request runs in the `Guaranteed` QoS class because `requests` are equal to `limits`.

```
spec:
  containers:
  - name: nginx
    image: nginx
    resources:
      limits:
        memory: "200Mi"
        cpu: "300m"
        example.com/device: "1"
      requests:
        memory: "200Mi"
        cpu: "300m"
        example.com/device: "1"
```

This pod with sharing CPU request runs in the `Guaranteed` QoS class because `requests` are equal to `limits`.

```
spec:
  containers:
  - name: nginx
    image: nginx
    resources:
      limits:
        example.com/deviceA: "1"
        example.com/deviceB: "1"
      requests:
        example.com/deviceA: "1"
        example.com/deviceB: "1"
```

This pod runs in the `BestEffort` QoS class because there are no CPU and memory requests.

The Topology Manager would consider the above pods. The Topology Manager would consult the Hint Providers, which are CPU and Device Manager to get topology hints for the pods.

In the case of the `Guaranteed` pod with integer CPU request, the `static` CPU Manager policy would return topology hints relating to the exclusive CPU and the Device Manager would send back hints for the requested device.

In the case of the `Guaranteed` pod with sharing CPU request, the `static` CPU Manager policy would return default topology hint as there is no exclusive CPU request and the Device Manager would send back hints for the requested device.

In the above two cases of the `Guaranteed` pod, the `none` CPU Manager policy would return default topology hint.

In the case of the `BestEffort` pod, the `static` CPU Manager policy would send back the default topology hint as there is no CPU request and the Device Manager would send back the hints for each of the requested devices.

Using this information the Topology Manager calculates the optimal hint for the pod and stores this information, which will be used by the Hint Providers when they are making their resource assignments.

Known limitations

1. The maximum number of NUMA nodes that Topology Manager allows is 8. With more than 8 NUMA nodes, there will be a state explosion when trying to enumerate the possible NUMA affinities and generating their hints. See `max-allowable-numa-nodes` (beta) for more options.

2. The scheduler is not topology-aware, so it is possible to be scheduled on a node and then fail on the node due to the Topology Manager.

Enable Or Disable A Kubernetes API

This page shows how to enable or disable an API version from your cluster's control plane.

Specific API versions can be turned on or off by passing `--runtime-config=api/<version>` as a command line argument to the API server. The values for this argument are a comma-separated list of API versions. Later values override earlier values.

The `runtime-config` command line argument also supports 2 special keys:

- `api/all`, representing all known APIs
- `api/legacy`, representing only legacy APIs. Legacy APIs are any APIs that have been explicitly deprecated.

For example, to turn off all API versions except v1, pass `--runtime-config=api/all=false,api/v1=true` to the `kube-apiserver`.

What's next

Read the full documentation for the `kube-apiserver` component.

Declare Network Policy

This document helps you get started using the Kubernetes NetworkPolicy API to declare network policies that govern how pods communicate with each other.

Note: This section links to third party projects that provide functionality required by Kubernetes. The Kubernetes project authors aren't responsible for these projects, which are listed alphabetically. To add a project to this list, read the content guide before submitting a change. More information.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

Your Kubernetes server must be at or later than version v1.8.

To check the version, enter `kubectl version`.

Make sure you've configured a network provider with network policy support. There are a number of network providers that support NetworkPolicy, including:

- Antrea
- Calico
- Cilium
- Kube-router
- Romana
- Weave Net

Create an `nginx` deployment and expose it via a service

To see how Kubernetes network policy works, start off by creating an `nginx` Deployment.

```
kubectl create deployment nginx --image=nginx
```

```
deployment.apps/nginx created
```

Expose the Deployment through a Service called `nginx`.

```
kubectl expose deployment nginx --port=80
```

```
service/nginx exposed
```

The above commands create a Deployment with an nginx Pod and expose the Deployment through a Service named `nginx`. The `nginx` Pod and Deployment are found in the `default` namespace.

```
kubectl get svc,pod
```

```
NAME                        CLUSTER-IP    EXTERNAL-IP   PORT(S)    AGE
service/kubernetes          10.100.0.1    <none>        443/TCP    46m
service/nginx               10.100.0.16   <none>        80/TCP     33s

NAME                        READY         STATUS        RESTARTS   AGE
pod/nginx-701339712-e0qfq   1/1           Running       0          35s
```

Test the service by accessing it from another Pod

You should be able to access the new `nginx` service from other Pods. To access the `nginx` Service from another Pod in the `default` namespace, start a busybox container:

```
kubectl run busybox --rm -ti --image=busybox -- /bin/sh
```

In your shell, run the following command:

```
wget --spider --timeout=1 nginx
```

```
Connecting to nginx (10.100.0.16:80)
remote file exists
```

Limit access to the `nginx` service

To limit the access to the `nginx` service so that only Pods with the label `access: true` can query it, create a NetworkPolicy object as follows:

service/networking/nginx-policy.yaml Copy service/networking/nginx-policy.yaml to clipboard

```
apiVersion: networking.k8s.io/v1
kind: NetworkPolicymetadata:  name: access-nginxspec:  podSelector:    matchLabels:      app: nginx  ingress:  - from:    - podSel
```

The name of a NetworkPolicy object must be a valid DNS subdomain name.

Note:

NetworkPolicy includes a `podSelector` which selects the grouping of Pods to which the policy applies. You can see this policy selects Pods with the label `app=nginx`. The label was automatically added to the Pod in the `nginx` Deployment. An empty `podSelector` selects all pods in the namespace.

Assign the policy to the service

Use kubectl to create a NetworkPolicy from the above `nginx-policy.yaml` file:

```
kubectl apply -f https://k8s.io/examples/service/networking/nginx-policy.yaml
```

```
networkpolicy.networking.k8s.io/access-nginx created
```

Test access to the service when access label is not defined

When you attempt to access the `nginx` Service from a Pod without the correct labels, the request times out:

```
kubectl run busybox --rm -ti --image=busybox -- /bin/sh
```

In your shell, run the command:

```
wget --spider --timeout=1 nginx
```

```
Connecting to nginx (10.100.0.16:80)
wget: download timed out
```

Define access label and test again

You can create a Pod with the correct labels to see that the request is allowed:

```
kubectl run busybox --rm -ti --labels="access=true" --image=busybox -- /bin/sh
```

In your shell, run the command:

```
wget --spider --timeout=1 nginx
```

```
Connecting to nginx (10.100.0.16:80)
remote file exists
```

Reconfiguring a kubeadm cluster

kubeadm does not support automated ways of reconfiguring components that were deployed on managed nodes. One way of automating this would be by using a custom operator.

To modify the components configuration you must manually edit associated cluster objects and files on disk.

This guide shows the correct sequence of steps that need to be performed to achieve kubeadm cluster reconfiguration.

Before you begin

- You need a cluster that was deployed using kubeadm
- Have administrator credentials (`/etc/kubernetes/admin.conf`) and network connectivity to a running kube-apiserver in the cluster from a host that has kubectl installed
- Have a text editor installed on all hosts

Reconfiguring the cluster

kubeadm writes a set of cluster wide component configuration options in ConfigMaps and other objects. These objects must be manually edited. The command `kubectl edit` can be used for that.

The `kubectl edit` command will open a text editor where you can edit and save the object directly.

You can use the environment variables `KUBECONFIG` and `KUBE_EDITOR` to specify the location of the kubectl consumed kubeconfig file and preferred text editor.

For example:

```
KUBECONFIG=/etc/kubernetes/admin.conf KUBE_EDITOR=nano kubectl edit <parameters>
```

Note:

Upon saving any changes to these cluster objects, components running on nodes may not be automatically updated. The steps below instruct you on how to perform that manually.

Warning:

Component configuration in ConfigMaps is stored as unstructured data (YAML string). This means that validation will not be performed upon updating the contents of a ConfigMap. You have to be careful to follow the documented API format for a particular component configuration and avoid introducing typos and YAML indentation mistakes.

Applying cluster configuration changes

Updating the `ClusterConfiguration`

During cluster creation and upgrade, kubeadm writes its `ClusterConfiguration` in a ConfigMap called `kubeadm-config` in the `kube-system` namespace.

To change a particular option in the `ClusterConfiguration` you can edit the ConfigMap with this command:

```
kubectl edit cm -n kube-system kubeadm-config
```

The configuration is located under the `data.ClusterConfiguration` key.

Note:

The `ClusterConfiguration` includes a variety of options that affect the configuration of individual components such as kube-apiserver, kube-scheduler, kube-controller-manager, CoreDNS, etcd and kube-proxy. Changes to the configuration must be reflected on node components manually.

Reflecting `ClusterConfiguration` changes on control plane nodes

kubeadm manages the control plane components as static Pod manifests located in the directory `/etc/kubernetes/manifests`. Any changes to the `ClusterConfiguration` under the `apiServer`, `controllerManager`, `scheduler` or `etcd` keys must be reflected in the associated files in the manifests directory on a control plane node.

Such changes may include:

- `extraArgs` - requires updating the list of flags passed to a component container
- `extraVolumes` - requires updating the volume mounts for a component container
- `*SANs` - requires writing new certificates with updated Subject Alternative Names

Before proceeding with these changes, make sure you have backed up the directory `/etc/kubernetes/`.

To write new certificates you can use:

```
kubeadm init phase certs <component-name> --config <config-file>
```

To write new manifest files in `/etc/kubernetes/manifests` you can use:

```
# For Kubernetes control plane components
kubeadm init phase control-plane <component-name> --config <config-file>
# For local etcd
kubeadm init phase etcd local --config <config-file>
```

The `<config-file>` contents must match the updated `ClusterConfiguration`. The `<component-name>` value must be a name of a Kubernetes control plane component (`apiserver`, `controller-manager` or `scheduler`).

Note:

Updating a file in `/etc/kubernetes/manifests` will tell the kubelet to restart the static Pod for the corresponding component. Try doing these changes one node at a time to leave the cluster without downtime.

Applying kubelet configuration changes

Updating the `KubeletConfiguration`

During cluster creation and upgrade, kubeadm writes its `KubeletConfiguration` in a ConfigMap called `kubelet-config` in the `kube-system` namespace.

You can edit the ConfigMap with this command:

```
kubectl edit cm -n kube-system kubelet-config
```

The configuration is located under the `data.kubelet` key.

Reflecting the kubelet changes

To reflect the change on kubeadm nodes you must do the following:

- Log in to a kubeadm node
- Run `kubeadm upgrade node phase kubelet-config` to download the latest `kubelet-config` ConfigMap contents into the local file `/var/lib/kubelet/config.yaml`
- Edit the file `/var/lib/kubelet/kubeadm-flags.env` to apply additional configuration with flags
- Restart the kubelet service with `systemctl restart kubelet`

Note:

Do these changes one node at a time to allow workloads to be rescheduled properly.

Note:

During `kubeadm upgrade`, kubeadm downloads the `KubeletConfiguration` from the `kubelet-config` ConfigMap and overwrite the contents of `/var/lib/kubelet/config.yaml`. This means that node local configuration must be applied either by flags in `/var/lib/kubelet/kubeadm-flags.env` or by manually updating the contents of `/var/lib/kubelet/config.yaml` after `kubeadm upgrade`, and then restarting the kubelet.

Applying kube-proxy configuration changes

Updating the `KubeProxyConfiguration`

During cluster creation and upgrade, kubeadm writes its `KubeProxyConfiguration` in a ConfigMap in the `kube-system` namespace called `kube-proxy`.

This ConfigMap is used by the `kube-proxy` DaemonSet in the `kube-system` namespace.

To change a particular option in the `KubeProxyConfiguration`, you can edit the ConfigMap with this command:

```
kubectl edit cm -n kube-system kube-proxy
```

The configuration is located under the `data.config.conf` key.

Reflecting the kube-proxy changes

Once the `kube-proxy` ConfigMap is updated, you can restart all kube-proxy Pods:

Delete the Pods with:

```
kubectl delete po -n kube-system -l k8s-app=kube-proxy
```

New Pods that use the updated ConfigMap will be created.

Note:

Because kubeadm deploys kube-proxy as a DaemonSet, node specific configuration is unsupported.

Applying CoreDNS configuration changes

Updating the CoreDNS Deployment and Service

kubeadm deploys CoreDNS as a Deployment called `coredns` and with a Service `kube-dns`, both in the `kube-system` namespace.

To update any of the CoreDNS settings, you can edit the Deployment and Service objects:

```
kubectl edit deployment -n kube-system coredns
kubectl edit service -n kube-system kube-dns
```

Reflecting the CoreDNS changes

Once the CoreDNS changes are applied you can restart the CoreDNS deployment:

```
kubectl rollout restart deployment -n kube-system coredns
```

Note:

kubeadm does not allow CoreDNS configuration during cluster creation and upgrade. This means that if you execute `kubeadm upgrade apply`, your changes to the CoreDNS objects will be lost and must be reapplied.

Persisting the reconfiguration

During the execution of `kubeadm upgrade` on a managed node, kubeadm might overwrite configuration that was applied after the cluster was created (reconfiguration).

Persisting Node object reconfiguration

kubeadm writes Labels, Taints, CRI socket and other information on the Node object for a particular Kubernetes node. To change any of the contents of this Node object you can use:

```
kubectl edit no <node-name>
```

During `kubeadm upgrade` the contents of such a Node might get overwritten. If you would like to persist your modifications to the Node object after upgrade, you can prepare a kubectl patch and apply it to the Node object:

```
kubectl patch no <node-name> --patch-file <patch-file>
```

Persisting control plane component reconfiguration

The main source of control plane configuration is the `ClusterConfiguration` object stored in the cluster. To extend the static Pod manifests configuration, patches can be used.

These patch files must remain as files on the control plane nodes to ensure that they can be used by the `kubeadm upgrade ... --patches <directory>`.

If reconfiguration is done to the `ClusterConfiguration` and static Pod manifests on disk, the set of node specific patches must be updated accordingly.

Persisting kubelet reconfiguration

Any changes to the `KubeletConfiguration` stored in `/var/lib/kubelet/config.yaml` will be overwritten on `kubeadm upgrade` by downloading the contents of the cluster wide `kubelet-config` ConfigMap. To persist kubelet node specific configuration either the file `/var/lib/kubelet/config.yaml` has to be updated manually post-upgrade or the file `/var/lib/kubelet/kubeadm-flags.env` can include flags. The kubelet flags override the associated `KubeletConfiguration` options, but note that some of the flags are deprecated.

A kubelet restart will be required after changing `/var/lib/kubelet/config.yaml` or `/var/lib/kubelet/kubeadm-flags.env`.

What's next

- Upgrading kubeadm clusters
- Customizing components with the kubeadm API
- Certificate management with kubeadm
- Find more about kubeadm set-up

Guaranteed Scheduling For Critical Add-On Pods

Kubernetes core components such as the API server, scheduler, and controller-manager run on a control plane node. However, add-ons must run on a regular cluster node. Some of these add-ons are critical to a fully functional cluster, such as metrics-server, DNS, and UI. A cluster may stop working properly if a critical add-on is evicted (either manually or as a side effect of another operation like upgrade) and becomes pending (for example when the cluster is highly utilized and either there are other pending pods that schedule into the space vacated by the evicted critical add-on pod or the amount of resources available on the node changed for some other reason).

Note that marking a pod as critical is not meant to prevent evictions entirely; it only prevents the pod from becoming permanently unavailable. A static pod marked as critical can't be evicted. However, non-static pods marked as critical are always rescheduled.

Marking pod as critical

To mark a Pod as critical, set priorityClassName for that Pod to `system-cluster-critical` or `system-node-critical`. `system-node-critical` is the highest available priority, even higher than `system-cluster-critical`.

Upgrading kubeadm clusters

This page explains how to upgrade a Kubernetes cluster created with kubeadm from version 1.33.x to version 1.34.x, and from version 1.34.x to 1.34.y (where `y > x`). Skipping MINOR versions when upgrading is unsupported. For more details, please visit Version Skew Policy.

To see information about upgrading clusters created using older versions of kubeadm, please refer to following pages instead:

- Upgrading a kubeadm cluster from 1.32 to 1.33
- Upgrading a kubeadm cluster from 1.31 to 1.32
- Upgrading a kubeadm cluster from 1.30 to 1.31
- Upgrading a kubeadm cluster from 1.29 to 1.30

The Kubernetes project recommends upgrading to the latest patch releases promptly, and to ensure that you are running a supported minor release of Kubernetes. Following this recommendation helps you to stay secure.

The upgrade workflow at high level is the following:

1. Upgrade a primary control plane node.
2. Upgrade additional control plane nodes.
3. Upgrade worker nodes.

Before you begin

- Make sure you read the release notes carefully.
- The cluster should use a static control plane and etcd pods or external etcd.
- Make sure to back up any important components, such as app-level state stored in a database. `kubeadm upgrade` does not touch your workloads, only components internal to Kubernetes, but backups are always a best practice.
- Swap must be disabled.

Additional information

- The instructions below outline when to drain each node during the upgrade process. If you are performing a **minor** version upgrade for any kubelet, you **must** first drain the node (or nodes) that you are upgrading. In the case of control plane nodes, they could be running CoreDNS Pods or other critical workloads. For more information see Draining nodes.
- The Kubernetes project recommends that you match your kubelet and kubeadm versions. You can instead use a version of kubelet that is older than kubeadm, provided it is within the range of supported versions. For more details, please visit kubeadm's skew against the kubelet.
- All containers are restarted after upgrade, because the container spec hash value is changed.
- To verify that the kubelet service has successfully restarted after the kubelet has been upgraded, you can execute `systemctl status kubelet` or view the service logs with `journalctl -xeu kubelet`.
- `kubeadm upgrade` supports `--config` with a `UpgradeConfiguration` API type which can be used to configure the upgrade process.
- `kubeadm upgrade` does not support reconfiguration of an existing cluster. Follow the steps in Reconfiguring a kubeadm cluster instead.

Considerations when upgrading etcd

Because the `kube-apiserver` static pod is running at all times (even if you have drained the node), when you perform a kubeadm upgrade which includes an etcd upgrade, in-flight requests to the server will stall while the new etcd static pod is restarting. As a workaround, it is possible to actively stop the `kube-apiserver` process a few seconds before starting the `kubeadm upgrade apply` command. This permits to complete in-flight requests and close existing connections, and minimizes the consequence of the etcd downtime. This can be done as follows on control plane nodes:

```
killall -s SIGTERM kube-apiserver # trigger a graceful kube-apiserver shutdown
sleep 20 # wait a little bit to permit completing in-flight requests
kubeadm upgrade ... # execute a kubeadm upgrade command
```

Changing the package repository

If you're using the community-owned package repositories (`pkgs.k8s.io`), you need to enable the package repository for the desired Kubernetes minor release. This is explained in Changing the Kubernetes package repository document.

Note: The legacy package repositories (`apt.kubernetes.io` and `yum.kubernetes.io`) have been deprecated and frozen starting from September 13, 2023. **Using the new package repositories hosted at `pkgs.k8s.io` is strongly recommended and required in order to install Kubernetes versions released after September 13, 2023.** The deprecated legacy repositories, and their contents, might be removed at any time in the future and without a further notice period. The new package repositories provide downloads for Kubernetes versions starting with v1.24.0.

Determine which version to upgrade to

Find the latest patch release for Kubernetes 1.34 using the OS package manager:

- Ubuntu, Debian or HypriotOS
- CentOS, RHEL or Fedora

```
# Find the latest 1.34 version in the list.
# It should look like 1.34.x-*, where x is the latest patch.
sudo apt update
sudo apt-cache madison kubeadm
```

For systems with DNF:

```
# Find the latest 1.34 version in the list.
# It should look like 1.34.x-*, where x is the latest patch.
sudo yum list --showduplicates kubeadm --disableexcludes=kubernetes
```

For systems with DNF5:

```
# Find the latest 1.34 version in the list.
# It should look like 1.34.x-*, where x is the latest patch.
sudo yum list --showduplicates kubeadm --setopt=disable_excludes=kubernetes
```

If you don't see the version you expect to upgrade to, verify if the Kubernetes package repositories are used.

Upgrading control plane nodes

The upgrade procedure on control plane nodes should be executed one node at a time. Pick a control plane node that you wish to upgrade first. It must have the `/etc/kubernetes/admin.conf` file.

Call "kubeadm upgrade"

For the first control plane node

1. Upgrade kubeadm:

   - Ubuntu, Debian or HypriotOS
   - CentOS, RHEL or Fedora

   ```
   # replace x in 1.34.x-* with the latest patch version
   sudo apt-mark unhold kubeadm && \
   sudo apt-get update && sudo apt-get install -y kubeadm='1.34.x-*' && \sudo apt-mark hold kubeadm
   ```

   For systems with DNF:

   ```
   # replace x in 1.34.x-* with the latest patch version
   sudo yum install -y kubeadm-'1.34.x-*' --disableexcludes=kubernetes
   ```

   For systems with DNF5:

   ```
   # replace x in 1.34.x-* with the latest patch version
   sudo yum install -y kubeadm-'1.34.x-*' --setopt=disable_excludes=kubernetes
   ```

2. Verify that the download works and has the expected version:

   ```
   kubeadm version
   ```

3. Verify the upgrade plan:

   ```
   sudo kubeadm upgrade plan
   ```

This command checks that your cluster can be upgraded, and fetches the versions you can upgrade to. It also shows a table with the component config version states.

Note:

`kubeadm upgrade` also automatically renews the certificates that it manages on this node. To opt-out of certificate renewal the flag `--certificate-renewal=false` can be used. For more information see the certificate management guide.

4. Choose a version to upgrade to, and run the appropriate command. For example:

```
# replace x with the patch version you picked for this upgrade
sudo kubeadm upgrade apply v1.34.x
```

Once the command finishes you should see:

```
[upgrade/successful] SUCCESS! Your cluster was upgraded to "v1.34.x". Enjoy!

[upgrade/kubelet] Now that your control plane is upgraded, please proceed with upgrading your kubelets if you haven't already
```

Note:

For versions earlier than v1.28, kubeadm defaulted to a mode that upgrades the addons (including CoreDNS and kube-proxy) immediately during `kubeadm upgrade apply`, regardless of whether there are other control plane instances that have not been upgraded. This may cause compatibility problems. Since v1.28, kubeadm defaults to a mode that checks whether all the control plane instances have been upgraded before starting to upgrade the addons. You must perform control plane instances upgrade sequentially or at least ensure that the last control plane instance upgrade is not started until all the other control plane instances have been upgraded completely, and the addons upgrade will be performed after the last control plane instance is upgraded.

5. Manually upgrade your CNI provider plugin.

Your Container Network Interface (CNI) provider may have its own upgrade instructions to follow. Check the addons page to find your CNI provider and see whether additional upgrade steps are required.

This step is not required on additional control plane nodes if the CNI provider runs as a DaemonSet.

For the other control plane nodes

Same as the first control plane node but use:

```
sudo kubeadm upgrade node
```

instead of:

```
sudo kubeadm upgrade apply
```

Also calling `kubeadm upgrade plan` and upgrading the CNI provider plugin is no longer needed.

Drain the node

Prepare the node for maintenance by marking it unschedulable and evicting the workloads:

```
# replace <node-to-drain> with the name of your node you are draining
kubectl drain <node-to-drain> --ignore-daemonsets
```

Upgrade kubelet and kubectl

1. Upgrade the kubelet and kubectl:

   - Ubuntu, Debian or HypriotOS
   - CentOS, RHEL or Fedora

```
# replace x in 1.34.x-* with the latest patch version
sudo apt-mark unhold kubelet kubectl && \
sudo apt-get update && sudo apt-get install -y kubelet='1.34.x-*' kubectl='1.34.x-*' && \sudo apt-mark hold kubelet kubectl
```

For systems with DNF:

```
# replace x in 1.34.x-* with the latest patch version
sudo yum install -y kubelet-'1.34.x-*' kubectl-'1.34.x-*' --disableexcludes=kubernetes
```

For systems with DNF5:

```
# replace x in 1.34.x-* with the latest patch version
sudo yum install -y kubelet-'1.34.x-*' kubectl-'1.34.x-*' --setopt=disable_excludes=kubernetes
```

2. Restart the kubelet:

```
sudo systemctl daemon-reload
sudo systemctl restart kubelet
```

Uncordon the node

Bring the node back online by marking it schedulable:

```
# replace <node-to-uncordon> with the name of your node
```

```
kubectl uncordon <node-to-uncordon>
```

Upgrade worker nodes

The upgrade procedure on worker nodes should be executed one node at a time or few nodes at a time, without compromising the minimum required capacity for running your workloads.

The following pages show how to upgrade Linux and Windows worker nodes:

- Upgrade Linux nodes
- Upgrade Windows nodes

Verify the status of the cluster

After the kubelet is upgraded on all nodes verify that all nodes are available again by running the following command from anywhere kubectl can access the cluster:

```
kubectl get nodes
```

The `STATUS` column should show `Ready` for all your nodes, and the version number should be updated.

Recovering from a failure state

If `kubeadm upgrade` fails and does not roll back, for example because of an unexpected shutdown during execution, you can run `kubeadm upgrade` again. This command is idempotent and eventually makes sure that the actual state is the desired state you declare.

To recover from a bad state, you can also run `sudo kubeadm upgrade apply --force` without changing the version that your cluster is running.

During upgrade kubeadm writes the following backup folders under `/etc/kubernetes/tmp`:

- `kubeadm-backup-etcd-<date>-<time>`
- `kubeadm-backup-manifests-<date>-<time>`

`kubeadm-backup-etcd` contains a backup of the local etcd member data for this control plane Node. In case of an etcd upgrade failure and if the automatic rollback does not work, the contents of this folder can be manually restored in `/var/lib/etcd`. In case external etcd is used this backup folder will be empty.

`kubeadm-backup-manifests` contains a backup of the static Pod manifest files for this control plane Node. In case of a upgrade failure and if the automatic rollback does not work, the contents of this folder can be manually restored in `/etc/kubernetes/manifests`. If for some reason there is no difference between a pre-upgrade and post-upgrade manifest file for a certain component, a backup file for it will not be written.

Note:

After the cluster upgrade using kubeadm, the backup directory `/etc/kubernetes/tmp` will remain and these backup files will need to be cleared manually.

How it works

`kubeadm upgrade apply` does the following:

- Checks that your cluster is in an upgradeable state:
  - The API server is reachable
  - All nodes are in the `Ready` state
  - The control plane is healthy
- Enforces the version skew policies.
- Makes sure the control plane images are available or available to pull to the machine.
- Generates replacements and/or uses user supplied overwrites if component configs require version upgrades.
- Upgrades the control plane components or rollbacks if any of them fails to come up.
- Applies the new `CoreDNS` and `kube-proxy` manifests and makes sure that all necessary RBAC rules are created.
- Creates new certificate and key files of the API server and backs up old files if they're about to expire in 180 days.

`kubeadm upgrade node` does the following on additional control plane nodes:

- Fetches the kubeadm `ClusterConfiguration` from the cluster.
- Optionally backups the kube-apiserver certificate.
- Upgrades the static Pod manifests for the control plane components.
- Upgrades the kubelet configuration for this node.

`kubeadm upgrade node` does the following on worker nodes:

- Fetches the kubeadm `ClusterConfiguration` from the cluster.
- Upgrades the kubelet configuration for this node.

Weave Net for NetworkPolicy

This page shows how to use Weave Net for NetworkPolicy.

Before you begin

You need to have a Kubernetes cluster. Follow the kubeadm getting started guide to bootstrap one.

Install the Weave Net addon

Follow the Integrating Kubernetes via the Addon guide.

The Weave Net addon for Kubernetes comes with a Network Policy Controller that automatically monitors Kubernetes for any NetworkPolicy annotations on all namespaces and configures `iptables` rules to allow or block traffic as directed by the policies.

Test the installation

Verify that the weave works.

Enter the following command:

```
kubectl get pods -n kube-system -o wide
```

The output is similar to this:

```
NAME                              READY     STATUS    RESTARTS   AGE       IP              NODE
weave-net-1t1qg                   2/2       Running   0          9d        192.168.2.10    worknode3
weave-net-231d7                   2/2       Running   1          7d        10.2.0.17       worknodegpu
weave-net-7nmwt                   2/2       Running   3          9d        192.168.2.131   masternode
weave-net-pmw8w                   2/2       Running   0          9d        192.168.2.216   worknode2
```

Each Node has a weave Pod, and all Pods are `Running` and `2/2 READY`. (`2/2` means that each Pod has `weave` and `weave-npc`.)

What's next

Once you have installed the Weave Net addon, you can follow the Declare Network Policy to try out Kubernetes NetworkPolicy. If you have any question, contact us at #weave-community on Slack or Weave User Group.

Migrating from dockershim

This section presents information you need to know when migrating from dockershim to other container runtimes.

Since the announcement of dockershim deprecation in Kubernetes 1.20, there were questions on how this will affect various workloads and Kubernetes installations. Our Dockershim Removal FAQ is there to help you to understand the problem better.

Dockershim was removed from Kubernetes with the release of v1.24. If you use Docker Engine via dockershim as your container runtime and wish to upgrade to v1.24, it is recommended that you either migrate to another runtime or find an alternative means to obtain Docker Engine support. Check out the container runtimes section to know your options.

The version of Kubernetes with dockershim (1.23) is out of support and the v1.24 will run out of support soon. Make sure to report issues you encountered with the migration so the issues can be fixed in a timely manner and your cluster would be ready for dockershim removal. After v1.24 running out of support, you will need to contact your Kubernetes provider for support or upgrade multiple versions at a time if there are critical issues affecting your cluster.

Your cluster might have more than one kind of node, although this is not a common configuration.

These tasks will help you to migrate:

- Check whether Dockershim removal affects you
- Migrating telemetry and security agents from dockershim

What's next

- Check out container runtimes to understand your options for an alternative.
- If you find a defect or other technical concern relating to migrating away from dockershim, you can report an issue to the Kubernetes project.

Use Antrea for NetworkPolicy

This page shows how to install and use Antrea CNI plugin on Kubernetes. For background on Project Antrea, read the Introduction to Antrea.

Before you begin

You need to have a Kubernetes cluster. Follow the kubeadm getting started guide to bootstrap one.

Deploying Antrea with kubeadm

Follow Getting Started guide to deploy Antrea for kubeadm.

What's next

Once your cluster is running, you can follow the Declare Network Policy to try out Kubernetes NetworkPolicy.

Debugging DNS Resolution

This page provides hints on diagnosing DNS problems.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

Your cluster must be configured to use the CoreDNS addon or its precursor, kube-dns.

Your Kubernetes server must be at or later than version v1.6.

To check the version, enter `kubectl version`.

Create a simple Pod to use as a test environment

admin/dns/dnsutils.yaml Copy admin/dns/dnsutils.yaml to clipboard

```
apiVersion: v1
kind: Podmetadata:  name: dnsutils  namespace: defaultspec:  containers:  - name: dnsutils    image: registry.k8s.io/e2e-test-imag
```

Note:

This example creates a pod in the `default` namespace. DNS name resolution for services depends on the namespace of the pod. For more information, review DNS for Services and Pods.

Use that manifest to create a Pod:

```
kubectl apply -f https://k8s.io/examples/admin/dns/dnsutils.yaml
```

```
pod/dnsutils created
```

…and verify its status:

```
kubectl get pods dnsutils
```

```
NAME       READY     STATUS    RESTARTS   AGE
dnsutils   1/1       Running   0          <some-time>
```

Once that Pod is running, you can exec `nslookup` in that environment. If you see something like the following, DNS is working correctly.

```
kubectl exec -i -t dnsutils -- nslookup kubernetes.default
```

```
Server:    10.0.0.10
Address 1: 10.0.0.10

Name:      kubernetes.default
Address 1: 10.0.0.1
```

If the `nslookup` command fails, check the following:

Check the local DNS configuration first

Take a look inside the resolv.conf file. (See Customizing DNS Service and Known issues below for more information)

```
kubectl exec -ti dnsutils -- cat /etc/resolv.conf
```

Verify that the search path and name server are set up like the following (note that search path may vary for different cloud providers):

```
search default.svc.cluster.local svc.cluster.local cluster.local google.internal c.gce_project_id.internal
nameserver 10.0.0.10
options ndots:5
```

Errors such as the following indicate a problem with the CoreDNS (or kube-dns) add-on or with associated Services:

```
kubectl exec -i -t dnsutils -- nslookup kubernetes.default
```

```
Server:    10.0.0.10
Address 1: 10.0.0.10

nslookup: can't resolve 'kubernetes.default'
```

or

```
kubectl exec -i -t dnsutils -- nslookup kubernetes.default

Server:    10.0.0.10
Address 1: 10.0.0.10 kube-dns.kube-system.svc.cluster.local

nslookup: can't resolve 'kubernetes.default'
```

Check if the DNS pod is running

Use the `kubectl get pods` command to verify that the DNS pod is running.

```
kubectl get pods --namespace=kube-system -l k8s-app=kube-dns

NAME                        READY     STATUS    RESTARTS   AGE
...
coredns-7b96bf9f76-5hsxb    1/1       Running   0          1h
coredns-7b96bf9f76-mvmmt    1/1       Running   0          1h
...
```

Note:

The value for label `k8s-app` is `kube-dns` for both CoreDNS and kube-dns deployments.

If you see that no CoreDNS Pod is running or that the Pod has failed/completed, the DNS add-on may not be deployed by default in your current environment and you will have to deploy it manually.

Check for errors in the DNS pod

Use the `kubectl logs` command to see logs for the DNS containers.

For CoreDNS:

```
kubectl logs --namespace=kube-system -l k8s-app=kube-dns
```

Here is an example of a healthy CoreDNS log:

```
.:53
2018/08/15 14:37:17 [INFO] CoreDNS-1.2.2
2018/08/15 14:37:17 [INFO] linux/amd64, go1.10.3, 2e322f6
CoreDNS-1.2.2
linux/amd64, go1.10.3, 2e322f6
2018/08/15 14:37:17 [INFO] plugin/reload: Running configuration MD5 = 24e6c59e83ce706f07bcc82c31b1ea1c
```

See if there are any suspicious or unexpected messages in the logs.

Is DNS service up?

Verify that the DNS service is up by using the `kubectl get service` command.

```
kubectl get svc --namespace=kube-system

NAME          TYPE        CLUSTER-IP     EXTERNAL-IP   PORT(S)             AGE
...
kube-dns      ClusterIP   10.0.0.10      <none>        53/UDP,53/TCP        1h
...
```

Note:

The service name is `kube-dns` for both CoreDNS and kube-dns deployments.

If you have created the Service or in the case it should be created by default but it does not appear, see debugging Services for more information.

Are DNS endpoints exposed?

You can verify that DNS endpoints are exposed by using the `kubectl get endpointslice` command.

```
kubectl get endpointslice -l k8s.io/service-name=kube-dns --namespace=kube-system

NAME             ADDRESSTYPE   PORTS   ENDPOINTS                 AGE
kube-dns-zxoja   IPv4          53      10.180.3.17,10.180.3.17   1h
```

If you do not see the endpoints, see the endpoints section in the debugging Services documentation.

Are DNS queries being received/processed?

You can verify if queries are being received by CoreDNS by adding the `log` plugin to the CoreDNS configuration (aka Corefile). The CoreDNS Corefile is held in a ConfigMap named `coredns`. To edit it, use the command:

```
kubectl -n kube-system edit configmap coredns
```

Then add `log` in the Corefile section per the example below:

```
apiVersion: v1
kind: ConfigMapmetadata:  name: coredns  namespace: kube-systemdata:  Corefile: |    .:53 {        log        errors        health
```

After saving the changes, it may take up to minute or two for Kubernetes to propagate these changes to the CoreDNS pods.

Next, make some queries and view the logs per the sections above in this document. If CoreDNS pods are receiving the queries, you should see them in the logs.

Here is an example of a query in the log:

```
.:53
2018/08/15 14:37:15 [INFO] CoreDNS-1.2.0
2018/08/15 14:37:15 [INFO] linux/amd64, go1.10.3, 2e322f6
CoreDNS-1.2.0
linux/amd64, go1.10.3, 2e322f6
2018/09/07 15:29:04 [INFO] plugin/reload: Running configuration MD5 = 162475cdf272d8aa601e6fe67a6ad42f
2018/09/07 15:29:04 [INFO] Reloading complete
172.17.0.18:41675 - [07/Sep/2018:15:29:11 +0000] 59925 "A IN kubernetes.default.svc.cluster.local. udp 54 false 512" NOERROR qr,aa
```

Does CoreDNS have sufficient permissions?

CoreDNS must be able to list service and endpointslice related resources to properly resolve service names.

Sample error message:

```
2022-03-18T07:12:15.699431183Z [INFO] 10.96.144.227:52299 - 3686 "A IN serverproxy.contoso.net.cluster.local. udp 52 false 512" SE
```

First, get the current ClusterRole of `system:coredns`:

```
kubectl describe clusterrole system:coredns -n kube-system
```

Expected output:

```
PolicyRule:
  Resources                        Non-Resource URLs  Resource Names  Verbs
  ---------                        -----------------  --------------  -----
  endpoints                        []                 []              [list watch]
  namespaces                       []                 []              [list watch]
  pods                             []                 []              [list watch]
  services                         []                 []              [list watch]
  endpointslices.discovery.k8s.io  []                 []              [list watch]
```

If any permissions are missing, edit the ClusterRole to add them:

```
kubectl edit clusterrole system:coredns -n kube-system
```

Example insertion of EndpointSlices permissions:

```
...
- apiGroups:
  - discovery.k8s.io
  resources:
  - endpointslices
  verbs:
  - list
  - watch
...
```

Are you in the right namespace for the service?

DNS queries that don't specify a namespace are limited to the pod's namespace.

If the namespace of the pod and service differ, the DNS query must include the namespace of the service.

This query is limited to the pod's namespace:

```
kubectl exec -i -t dnsutils -- nslookup <service-name>
```

This query specifies the namespace:

```
kubectl exec -i -t dnsutils -- nslookup <service-name>.<namespace>
```

To learn more about name resolution, see DNS for Services and Pods.

Known issues

Some Linux distributions (e.g. Ubuntu) use a local DNS resolver by default (systemd-resolved). Systemd-resolved moves and replaces `/etc/resolv.conf` with a stub file that can cause a fatal forwarding loop when resolving names in upstream servers. This can be fixed manually by using kubelet's `--resolv-conf` flag to point to the correct `resolv.conf` (With `systemd-resolved`, this is `/run/systemd/resolve/resolv.conf`). kubeadm automatically detects `systemd-resolved`, and adjusts the kubelet flags accordingly.

Kubernetes installs do not configure the nodes' `resolv.conf` files to use the cluster DNS by default, because that process is inherently distribution-specific. This should probably be implemented eventually.

Linux's libc (a.k.a. glibc) has a limit for the DNS `nameserver` records to 3 by default and Kubernetes needs to consume 1 `nameserver` record. This means that if a local installation already uses 3 `nameservers`, some of those entries will be lost. To work around this limit, the node can run `dnsmasq`, which will provide more `nameserver` entries. You can also use kubelet's `--resolv-conf` flag.

If you are using Alpine version 3.17 or earlier as your base image, DNS may not work properly due to a design issue with Alpine. Until musl version 1.24 didn't include TCP fallback to the DNS stub resolver meaning any DNS call above 512 bytes would fail. Please upgrade your images to Alpine version 3.18 or above.

What's next

- See Autoscaling the DNS Service in a Cluster.
- Read DNS for Services and Pods

Customizing DNS Service

This page explains how to configure your DNS Pod(s) and customize the DNS resolution process in your cluster.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

Your cluster must be running the CoreDNS add-on.

Your Kubernetes server must be at or later than version v1.12.

To check the version, enter `kubectl version`.

Introduction

DNS is a built-in Kubernetes service launched automatically using the *addon manager* cluster add-on.

Note:

The CoreDNS Service is named `kube-dns` in the `metadata.name` field.
The intent is to ensure greater interoperability with workloads that relied on the legacy `kube-dns` Service name to resolve addresses internal to the cluster. Using a Service named `kube-dns` abstracts away the implementation detail of which DNS provider is running behind that common name.

If you are running CoreDNS as a Deployment, it will typically be exposed as a Kubernetes Service with a static IP address. The kubelet passes DNS resolver information to each container with the `--cluster-dns=<dns-service-ip>` flag.

DNS names also need domains. You configure the local domain in the kubelet with the flag `--cluster-domain=<default-local-domain>`.

The DNS server supports forward lookups (A and AAAA records), port lookups (SRV records), reverse IP address lookups (PTR records), and more. For more information, see DNS for Services and Pods.

If a Pod's `dnsPolicy` is set to `default`, it inherits the name resolution configuration from the node that the Pod runs on. The Pod's DNS resolution should behave the same as the node. But see Known issues.

If you don't want this, or if you want a different DNS config for pods, you can use the kubelet's `--resolv-conf` flag. Set this flag to "" to prevent Pods from inheriting DNS. Set it to a valid file path to specify a file other than `/etc/resolv.conf` for DNS inheritance.

CoreDNS

CoreDNS is a general-purpose authoritative DNS server that can serve as cluster DNS, complying with the DNS specifications.

CoreDNS ConfigMap options

CoreDNS is a DNS server that is modular and pluggable, with plugins adding new functionalities. The CoreDNS server can be configured by maintaining a Corefile, which is the CoreDNS configuration file. As a cluster administrator, you can modify the ConfigMap for the CoreDNS Corefile to change how DNS service discovery behaves for that cluster.

In Kubernetes, CoreDNS is installed with the following default Corefile configuration:

```
apiVersion: v1
kind: ConfigMapmetadata:  name: coredns  namespace: kube-systemdata:  Corefile: |    .:53 {        errors        health {
```

The Corefile configuration includes the following plugins of CoreDNS:

- errors: Errors are logged to stdout.
- health: Health of CoreDNS is reported to `http://localhost:8080/health`. In this extended syntax `lameduck` will make the process unhealthy then wait for 5 seconds before the process is shut down.
- ready: An HTTP endpoint on port 8181 will return 200 OK, when all plugins that are able to signal readiness have done so.
- kubernetes: CoreDNS will reply to DNS queries based on IP of the Services and Pods. You can find more details about this plugin on the CoreDNS website.
  - `ttl` allows you to set a custom TTL for responses. The default is 5 seconds. The minimum TTL allowed is 0 seconds, and the maximum is capped at 3600 seconds. Setting TTL to 0 will prevent records from being cached.
  - The `pods insecure` option is provided for backward compatibility with `kube-dns`.
  - You can use the `pods verified` option, which returns an A record only if there exists a pod in the same namespace with a matching IP.

    - The `pods disabled` option can be used if you don't use pod records.
- prometheus: Metrics of CoreDNS are available at `http://localhost:9153/metrics` in the Prometheus format (also known as OpenMetrics).
- forward: Any queries that are not within the Kubernetes cluster domain are forwarded to predefined resolvers (/etc/resolv.conf).
- cache: This enables a frontend cache.
- loop: Detects simple forwarding loops and halts the CoreDNS process if a loop is found.
- reload: Allows automatic reload of a changed Corefile. After you edit the ConfigMap configuration, allow two minutes for your changes to take effect.
- loadbalance: This is a round-robin DNS loadbalancer that randomizes the order of A, AAAA, and MX records in the answer.

You can modify the default CoreDNS behavior by modifying the ConfigMap.

Configuration of Stub-domain and upstream nameserver using CoreDNS

CoreDNS has the ability to configure stub-domains and upstream nameservers using the forward plugin.

Example

If a cluster operator has a Consul domain server located at "10.150.0.1", and all Consul names have the suffix ".consul.local". To configure it in CoreDNS, the cluster administrator creates the following stanza in the CoreDNS ConfigMap.

```
consul.local:53 {
    errors
    cache 30
    forward . 10.150.0.1
}
```

To explicitly force all non-cluster DNS lookups to go through a specific nameserver at 172.16.0.1, point the `forward` to the nameserver instead of `/etc/resolv.conf`

```
forward .  172.16.0.1
```

The final ConfigMap along with the default `Corefile` configuration looks like:

```
apiVersion: v1
kind: ConfigMapmetadata:  name: coredns  namespace: kube-systemdata:  Corefile: |    .:53 {        errors        health        kub
```

Note:

CoreDNS does not support FQDNs for stub-domains and nameservers (eg: "ns.foo.com"). During translation, all FQDN nameservers will be omitted from the CoreDNS config.

What's next

- Read Debugging DNS Resolution

Use Kube-router for NetworkPolicy

This page shows how to use Kube-router for NetworkPolicy.

Before you begin

You need to have a Kubernetes cluster running. If you do not already have a cluster, you can create one by using any of the cluster installers like Kops, Bootkube, Kubeadm etc.

Installing Kube-router addon

The Kube-router Addon comes with a Network Policy Controller that watches Kubernetes API server for any NetworkPolicy and pods updated and configures iptables rules and ipsets to allow or block traffic as directed by the policies. Please follow the trying Kube-router with cluster installers guide to install Kube-router addon.

What's next

Once you have installed the Kube-router addon, you can follow the Declare Network Policy to try out Kubernetes NetworkPolicy.

Autoscale the DNS Service in a Cluster

This page shows how to enable and configure autoscaling of the DNS service in your Kubernetes cluster.

Before you begin

- You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:
    - iximiuz Labs

- Killercoda
- KodeKloud
- Play with Kubernetes

To check the version, enter `kubectl version`.

- This guide assumes your nodes use the AMD64 or Intel 64 CPU architecture.
- Make sure Kubernetes DNS is enabled.

Determine whether DNS horizontal autoscaling is already enabled

List the Deployments in your cluster in the kube-system namespace:

```
kubectl get deployment --namespace=kube-system
```

The output is similar to this:

```
NAME                   READY   UP-TO-DATE   AVAILABLE   AGE
...
kube-dns-autoscaler    1/1     1            1           ...
...
```

If you see "kube-dns-autoscaler" in the output, DNS horizontal autoscaling is already enabled, and you can skip to Tuning autoscaling parameters.

Get the name of your DNS Deployment

List the DNS deployments in your cluster in the kube-system namespace:

```
kubectl get deployment -l k8s-app=kube-dns --namespace=kube-system
```

The output is similar to this:

```
NAME      READY   UP-TO-DATE   AVAILABLE   AGE
...
coredns   2/2     2            2           ...
...
```

If you don't see a Deployment for DNS services, you can also look for it by name:

```
kubectl get deployment --namespace=kube-system
```

and look for a deployment named `coredns` or `kube-dns`.

Your scale target is

```
Deployment/<your-deployment-name>
```

where `<your-deployment-name>` is the name of your DNS Deployment. For example, if the name of your Deployment for DNS is coredns, your scale target is Deployment/coredns.

Note:

CoreDNS is the default DNS service for Kubernetes. CoreDNS sets the label `k8s-app=kube-dns` so that it can work in clusters that originally used kube-dns.

Enable DNS horizontal autoscaling

In this section, you create a new Deployment. The Pods in the Deployment run a container based on the `cluster-proportional-autoscaler-amd64` image.

Create a file named `dns-horizontal-autoscaler.yaml` with this content:

admin/dns/dns-horizontal-autoscaler.yaml Copy admin/dns/dns-horizontal-autoscaler.yaml to clipboard

```
kind: ServiceAccount
apiVersion: v1metadata:  name: kube-dns-autoscaler  namespace: kube-system---kind: ClusterRoleapiVersion: rbac.authorization.k8s.i
```

In the file, replace `<SCALE_TARGET>` with your scale target.

Go to the directory that contains your configuration file, and enter this command to create the Deployment:

```
kubectl apply -f dns-horizontal-autoscaler.yaml
```

The output of a successful command is:

```
deployment.apps/kube-dns-autoscaler created
```

DNS horizontal autoscaling is now enabled.

Tune DNS autoscaling parameters

Verify that the kube-dns-autoscaler ConfigMap exists:

```
kubectl get configmap --namespace=kube-system
```

The output is similar to this:

```
NAME                   DATA      AGE
...
kube-dns-autoscaler    1         ...
...
```

Modify the data in the ConfigMap:

```
kubectl edit configmap kube-dns-autoscaler --namespace=kube-system
```

Look for this line:

```
linear: '{"coresPerReplica":256,"min":1,"nodesPerReplica":16}'
```

Modify the fields according to your needs. The "min" field indicates the minimal number of DNS backends. The actual number of backends is calculated using this equation:

```
replicas = max( ceil( cores × 1/coresPerReplica ) , ceil( nodes × 1/nodesPerReplica ) )
```

Note that the values of both `coresPerReplica` and `nodesPerReplica` are floats.

The idea is that when a cluster is using nodes that have many cores, `coresPerReplica` dominates. When a cluster is using nodes that have fewer cores, `nodesPerReplica` dominates.

There are other supported scaling patterns. For details, see cluster-proportional-autoscaler.

Disable DNS horizontal autoscaling

There are a few options for tuning DNS horizontal autoscaling. Which option to use depends on different conditions.

Option 1: Scale down the kube-dns-autoscaler deployment to 0 replicas

This option works for all situations. Enter this command:

```
kubectl scale deployment --replicas=0 kube-dns-autoscaler --namespace=kube-system
```

The output is:

```
deployment.apps/kube-dns-autoscaler scaled
```

Verify that the replica count is zero:

```
kubectl get rs --namespace=kube-system
```

The output displays 0 in the DESIRED and CURRENT columns:

```
NAME                                    DESIRED   CURRENT   READY   AGE
...
kube-dns-autoscaler-6b59789fc8          0         0         0       ...
...
```

Option 2: Delete the kube-dns-autoscaler deployment

This option works if kube-dns-autoscaler is under your own control, which means no one will re-create it:

```
kubectl delete deployment kube-dns-autoscaler --namespace=kube-system
```

The output is:

```
deployment.apps "kube-dns-autoscaler" deleted
```

Option 3: Delete the kube-dns-autoscaler manifest file from the master node

This option works if kube-dns-autoscaler is under control of the (deprecated) Addon Manager, and you have write access to the master node.

Sign in to the master node and delete the corresponding manifest file. The common path for this kube-dns-autoscaler is:

```
/etc/kubernetes/addons/dns-horizontal-autoscaler/dns-horizontal-autoscaler.yaml
```

After the manifest file is deleted, the Addon Manager will delete the kube-dns-autoscaler Deployment.

Understanding how DNS horizontal autoscaling works

- The cluster-proportional-autoscaler application is deployed separately from the DNS service.
- An autoscaler Pod runs a client that polls the Kubernetes API server for the number of nodes and cores in the cluster.
- A desired replica count is calculated and applied to the DNS backends based on the current schedulable nodes and cores and the given scaling parameters.
- The scaling parameters and data points are provided via a ConfigMap to the autoscaler, and it refreshes its parameters table every poll interval to be up to date with the latest desired scaling parameters.

- Changes to the scaling parameters are allowed without rebuilding or restarting the autoscaler Pod.
- The autoscaler provides a controller interface to support two control patterns: *linear* and *ladder*.

What's next

- Read about Guaranteed Scheduling For Critical Add-On Pods.
- Learn more about the implementation of cluster-proportional-autoscaler.

Switching from Polling to CRI Event-based Updates to Container Status

FEATURE STATE: `Kubernetes v1.26 [alpha]` (enabled by default: false)

This page shows how to migrate nodes to use event based updates for container status. The event-based implementation reduces node resource consumption by the kubelet, compared to the legacy approach that relies on polling. You may know this feature as *evented Pod lifecycle event generator (PLEG)*. That's the name used internally within the Kubernetes project for a key implementation detail.

The polling based approach is referred to as *generic PLEG*.

Before you begin

- You need to run a version of Kubernetes that provides this feature. Kubernetes v1.27 includes beta support for event-based container status updates. The feature is beta but is *disabled* by default because it requires support from the container runtime.
- Your Kubernetes server must be at or later than version 1.26.

  To check the version, enter `kubectl version`.

  If you are running a different version of Kubernetes, check the documentation for that release.
- The container runtime in use must support container lifecycle events. The kubelet automatically switches back to the legacy generic PLEG mechanism if the container runtime does not announce support for container lifecycle events, even if you have this feature gate enabled.

Why switch to Evented PLEG?

- The *Generic PLEG* incurs non-negligible overhead due to frequent polling of container statuses.
- This overhead is exacerbated by Kubelet's parallelized polling of container states, thus limiting its scalability and causing poor performance and reliability problems.
- The goal of *Evented PLEG* is to reduce unnecessary work during inactivity by replacing periodic polling.

Switching to Evented PLEG

1. Start the Kubelet with the feature gate `EventedPLEG` enabled. You can manage the kubelet feature gates editing the kubelet config file and restarting the kubelet service. You need to do this on each node where you are using this feature.

2. Make sure the node is drained before proceeding.

3. Start the container runtime with the container event generation enabled.

   - Containerd
   - CRI-O

   Version 1.7+

   Version 1.26+

   Check if the CRI-O is already configured to emit CRI events by verifying the configuration,

   ```
   crio config | grep enable_pod_events
   ```

   If it is enabled, the output should be similar to the following:

   ```
   enable_pod_events = true
   ```

   To enable it, start the CRI-O daemon with the flag `--enable-pod-events=true` or use a dropin config with the following lines:

   ```
   [crio.runtime]
   enable_pod_events: true
   ```

   Your Kubernetes server must be at or later than version 1.26.

   To check the version, enter `kubectl version`.

4. Verify that the kubelet is using event-based container stage change monitoring. To check, look for the term `EventedPLEG` in the kubelet logs.

   The output should be similar to this:

   ```
   I0314 11:10:13.909915 1105457 feature_gate.go:249] feature gates: &{map[EventedPLEG:true]}
   ```

   If you have set `--v` to 4 and above, you might see more entries that indicate that the kubelet is using event-based container state monitoring.

```
I0314 11:12:42.009542 1110177 evented.go:238] "Evented PLEG: Generated pod status from the received event" podUID=3b2c6172-b1
I0314 11:12:44.623326 1110177 evented.go:238] "Evented PLEG: Generated pod status from the received event" podUID=b3fba5ea-a8
I0314 11:12:44.714564 1110177 evented.go:238] "Evented PLEG: Generated pod status from the received event" podUID=b3fba5ea-a8
```

What's next

- Learn more about the design in the Kubernetes Enhancement Proposal (KEP): Kubelet Evented PLEG for Better Performance.

Upgrading Linux nodes

This page explains how to upgrade a Linux Worker Nodes created with kubeadm.

Before you begin

You need to have shell access to all the nodes, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts.

To check the version, enter `kubectl version`.

- Familiarize yourself with the process for upgrading the rest of your kubeadm cluster. You will want to upgrade the control plane nodes before upgrading your Linux Worker nodes.

Changing the package repository

If you're using the community-owned package repositories (`pkgs.k8s.io`), you need to enable the package repository for the desired Kubernetes minor release. This is explained in Changing the Kubernetes package repository document.

Note: The legacy package repositories (`apt.kubernetes.io` and `yum.kubernetes.io`) have been deprecated and frozen starting from September 13, 2023. **Using the new package repositories hosted at `pkgs.k8s.io` is strongly recommended and required in order to install Kubernetes versions released after September 13, 2023.** The deprecated legacy repositories, and their contents, might be removed at any time in the future and without a further notice period. The new package repositories provide downloads for Kubernetes versions starting with v1.24.0.

Upgrading worker nodes

Upgrade kubeadm

Upgrade kubeadm:

- Ubuntu, Debian or HypriotOS
- CentOS, RHEL or Fedora

```
# replace x in 1.34.x-* with the latest patch version
sudo apt-mark unhold kubeadm && \
sudo apt-get update && sudo apt-get install -y kubeadm='1.34.x-*' && \sudo apt-mark hold kubeadm
```

For systems with DNF:

```
# replace x in 1.34.x-* with the latest patch version
sudo yum install -y kubeadm-'1.34.x-*' --disableexcludes=kubernetes
```

For systems with DNF5:

```
# replace x in 1.34.x-* with the latest patch version
sudo yum install -y kubeadm-'1.34.x-*' --setopt=disable_excludes=kubernetes
```

Call "kubeadm upgrade"

For worker nodes this upgrades the local kubelet configuration:

```
sudo kubeadm upgrade node
```

Drain the node

Prepare the node for maintenance by marking it unschedulable and evicting the workloads:

```
# execute this command on a control plane node
# replace <node-to-drain> with the name of your node you are draining
kubectl drain <node-to-drain> --ignore-daemonsets
```

Upgrade kubelet and kubectl

1. Upgrade the kubelet and kubectl:

   - Ubuntu, Debian or HypriotOS
   - CentOS, RHEL or Fedora

   ```
   # replace x in 1.34.x-* with the latest patch version
   sudo apt-mark unhold kubelet kubectl && \
   sudo apt-get update && sudo apt-get install -y kubelet='1.34.x-*' kubectl='1.34.x-*' && \sudo apt-mark hold kubelet kubectl
   ```

For systems with DNF:

```
# replace x in 1.34.x-* with the latest patch version
sudo yum install -y kubelet-'1.34.x-*' kubectl-'1.34.x-*' --disableexcludes=kubernetes
```

For systems with DNF5:

```
# replace x in 1.34.x-* with the latest patch version
sudo yum install -y kubelet-'1.34.x-*' kubectl-'1.34.x-*' --setopt=disable_excludes=kubernetes
```

2. Restart the kubelet:

```
sudo systemctl daemon-reload
sudo systemctl restart kubelet
```

Uncordon the node

Bring the node back online by marking it schedulable:

```
# execute this command on a control plane node
# replace <node-to-uncordon> with the name of your node
kubectl uncordon <node-to-uncordon>
```

What's next

- See how to Upgrade Windows nodes.

Use a Service to Access an Application in a Cluster

This page shows how to create a Kubernetes Service object that external clients can use to access an application running in a cluster. The Service provides load balancing for an application that has two running instances.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

Objectives

- Run two instances of a Hello World application.
- Create a Service object that exposes a node port.
- Use the Service object to access the running application.

Creating a service for an application running in two pods

Here is the configuration file for the application Deployment:

service/access/hello-application.yaml Copy service/access/hello-application.yaml to clipboard

```
apiVersion: apps/v1
kind: Deploymentmetadata:  name: hello-worldspec:  selector:    matchLabels:      run: load-balancer-example  replicas: 2  templat
```

1. Run a Hello World application in your cluster: Create the application Deployment using the file above:

   ```
   kubectl apply -f https://k8s.io/examples/service/access/hello-application.yaml
   ```

   The preceding command creates a Deployment and an associated ReplicaSet. The ReplicaSet has two Pods each of which runs the Hello World application.

2. Display information about the Deployment:

   ```
   kubectl get deployments hello-world
   kubectl describe deployments hello-world
   ```

3. Display information about your ReplicaSet objects:

   ```
   kubectl get replicasets
   kubectl describe replicasets
   ```

4. Create a Service object that exposes the deployment:

   ```
   kubectl expose deployment hello-world --type=NodePort --name=example-service
   ```

5. Display information about the Service:

```
kubectl describe services example-service
```

The output is similar to this:

```
Name:                   example-service
Namespace:              default
Labels:                 run=load-balancer-example
Annotations:            <none>
Selector:               run=load-balancer-example
Type:                   NodePort
IP:                     10.32.0.16
Port:                   <unset> 8080/TCP
TargetPort:             8080/TCP
NodePort:               <unset> 31496/TCP
Endpoints:              10.200.1.4:8080,10.200.2.5:8080
Session Affinity:       None
Events:                 <none>
```

Make a note of the NodePort value for the Service. For example, in the preceding output, the NodePort value is 31496.

6. List the pods that are running the Hello World application:

```
kubectl get pods --selector="run=load-balancer-example" --output=wide
```

The output is similar to this:

```
NAME                           READY   STATUS    ...  IP           NODE
hello-world-2895499144-bsbk5   1/1     Running   ...  10.200.1.4   worker1
hello-world-2895499144-m1pwt   1/1     Running   ...  10.200.2.5   worker2
```

7. Get the public IP address of one of your nodes that is running a Hello World pod. How you get this address depends on how you set up your cluster. For example, if you are using Minikube, you can see the node address by running `kubectl cluster-info`. If you are using Google Compute Engine instances, you can use the `gcloud compute instances list` command to see the public addresses of your nodes.

8. On your chosen node, create a firewall rule that allows TCP traffic on your node port. For example, if your Service has a NodePort value of 31568, create a firewall rule that allows TCP traffic on port 31568. Different cloud providers offer different ways of configuring firewall rules.

9. Use the node address and node port to access the Hello World application:

```
curl http://<public-node-ip>:<node-port>
```

where `<public-node-ip>` is the public IP address of your node, and `<node-port>` is the NodePort value for your service. The response to a successful request is a hello message:

```
Hello, world!
Version: 2.0.0
Hostname: hello-world-cdd4458f4-m47c8
```

Using a service configuration file

As an alternative to using `kubectl expose`, you can use a service configuration file to create a Service.

Cleaning up

To delete the Service, enter this command:

```
kubectl delete services example-service
```

To delete the Deployment, the ReplicaSet, and the Pods that are running the Hello World application, enter this command:

```
kubectl delete deployment hello-world
```

What's next

Follow the Connecting Applications with Services tutorial.

Adding Windows worker nodes

FEATURE STATE: `Kubernetes v1.18 [beta]`

This page explains how to add Windows worker nodes to a kubeadm cluster.

Before you begin

- A running Windows Server 2022 (or higher) instance with administrative access.
- A running kubeadm cluster created by `kubeadm init` and following the steps in the document Creating a cluster with kubeadm.

Adding Windows worker nodes

Note:

To facilitate the addition of Windows worker nodes to a cluster, PowerShell scripts from the repository https://sigs.k8s.io/sig-windows-tools are used.

Do the following for each machine:

1. Open a PowerShell session on the machine.
2. Make sure you are Administrator or a privileged user.

Then proceed with the steps outlined below.

Install containerd

Note: This section links to third party projects that provide functionality required by Kubernetes. The Kubernetes project authors aren't responsible for these projects, which are listed alphabetically. To add a project to this list, read the content guide before submitting a change. More information.

To install containerd, first run the following command:

```
curl.exe -LO https://raw.githubusercontent.com/kubernetes-sigs/sig-windows-tools/master/hostprocess/Install-Containerd.ps1
```

Then run the following command, but first replace `CONTAINERD_VERSION` with a recent release from the containerd repository. The version must not have a `v` prefix. For example, use `1.7.22` instead of `v1.7.22`:

```
.\Install-Containerd.ps1 -ContainerDVersion CONTAINERD_VERSION
```

- Adjust any other parameters for `Install-Containerd.ps1` such as `netAdapterName` as you need them.
- Set `skipHypervisorSupportCheck` if your machine does not support Hyper-V and cannot host Hyper-V isolated containers.
- If you change the `Install-Containerd.ps1` optional parameters `CNIBinPath` and/or `CNIConfigPath` you will need to configure the installed Windows CNI plugin with matching values.

Install kubeadm and kubelet

Run the following commands to install kubeadm and the kubelet:

```
curl.exe -LO https://raw.githubusercontent.com/kubernetes-sigs/sig-windows-tools/master/hostprocess/PrepareNode.ps1
.\PrepareNode.ps1 -KubernetesVersion v1.34
```

- Adjust the parameter `KubernetesVersion` of `PrepareNode.ps1` if needed.

Run `kubeadm join`

Run the command that was output by `kubeadm init`. For example:

```
kubeadm join --token <token> <control-plane-host>:<control-plane-port> --discovery-token-ca-cert-hash sha256:<hash>
```

Additional information about kubeadm join

Note:

To specify an IPv6 tuple for `<control-plane-host>:<control-plane-port>`, IPv6 address must be enclosed in square brackets, for example: `[2001:db8::101]:2073`.

If you do not have the token, you can get it by running the following command on the control plane node:

```
# Run this on a control plane node
sudo kubeadm token list
```

The output is similar to this:

```
TOKEN                    TTL  EXPIRES              USAGES           DESCRIPTION            EXTRA GROUPS
8ewj1p.9r9hcjoqgajrj4gi  23h  2018-06-12T02:51:28Z authentication,  The default bootstrap  system:
                                                   signing          token generated by     bootstrappers:
                                                                    'kubeadm init'.        kubeadm:
                                                                                           default-node-token
```

By default, node join tokens expire after 24 hours. If you are joining a node to the cluster after the current token has expired, you can create a new token by running the following command on the control plane node:

```
# Run this on a control plane node
sudo kubeadm token create
```

The output is similar to this:

```
5didvk.d09sbcov8ph2amjw
```

If you don't have the value of `--discovery-token-ca-cert-hash`, you can get it by running the following commands on the control plane node:

```
sudo cat /etc/kubernetes/pki/ca.crt | openssl x509 -pubkey  | openssl rsa -pubin -outform der 2>/dev/null | \
   openssl dgst -sha256 -hex | sed 's/^.* //'
```

The output is similar to:

```
8cb2de97839780a412b93877f8507ad6c94f73add17d5d7058e91741c9d5ec78
```

The output of the `kubeadm join` command should look something like:

```
[preflight] Running pre-flight checks

... (log output of join workflow) ...

Node join complete:
* Certificate signing request sent to control-plane and response
  received.
* Kubelet informed of new secure connection details.

Run 'kubectl get nodes' on control-plane to see this machine join.
```

A few seconds later, you should notice this node in the output from `kubectl get nodes`. (for example, run `kubectl` on a control plane node).

Network configuration

CNI setup on clusters mixed with Linux and Windows nodes requires more steps than just running `kubectl apply` on a manifest file. Additionally, the CNI plugin running on control plane nodes must be prepared to support the CNI plugin running on Windows worker nodes.

Note: This section links to third party projects that provide functionality required by Kubernetes. The Kubernetes project authors aren't responsible for these projects, which are listed alphabetically. To add a project to this list, read the content guide before submitting a change. More information.

Only a few CNI plugins currently support Windows. Below you can find individual setup instructions for them:

- Flannel
- Calico

Install kubectl for Windows (optional)

See Install and Set Up kubectl on Windows.

What's next

- See how to add Linux worker nodes.

Access Applications in a Cluster

Configure load balancing, port forwarding, or setup firewall or DNS configurations to access applications in a cluster.

Deploy and Access the Kubernetes Dashboard

Deploy the web UI (Kubernetes Dashboard) and access it.

Accessing Clusters

Configure Access to Multiple Clusters

Use Port Forwarding to Access Applications in a Cluster

Use a Service to Access an Application in a Cluster

Connect a Frontend to a Backend Using Services

Create an External Load Balancer

List All Container Images Running in a Cluster

Communicate Between Containers in the Same Pod Using a Shared Volume

Configure DNS for a Cluster

Access Services Running on Clusters

Running Kubernetes Node Components as a Non-root User

FEATURE STATE: `Kubernetes v1.22 [alpha]`

This document describes how to run Kubernetes Node components such as kubelet, CRI, OCI, and CNI without root privileges, by using a user namespace.

This technique is also known as *rootless mode*.

Note:

This document describes how to run Kubernetes Node components (and hence pods) as a non-root user.

If you are just looking for how to run a pod as a non-root user, see SecurityContext.

Before you begin

Your Kubernetes server must be at or later than version 1.22.

To check the version, enter `kubectl version`.

- Enable Cgroup v2
- Enable systemd with user session
- Configure several sysctl values, depending on host Linux distribution
- Ensure that your unprivileged user is listed in `/etc/subuid` and `/etc/subgid`
- Enable the `KubeletInUserNamespace` feature gate

Running Kubernetes inside Rootless Docker/Podman

kind

kind supports running Kubernetes inside Rootless Docker or Rootless Podman.

See Running kind with Rootless Docker.

minikube

minikube also supports running Kubernetes inside Rootless Docker or Rootless Podman.

See the Minikube documentation:

- Rootless Docker
- Rootless Podman

Running Kubernetes inside Unprivileged Containers

Note: This section links to third party projects that provide functionality required by Kubernetes. The Kubernetes project authors aren't responsible for these projects, which are listed alphabetically. To add a project to this list, read the content guide before submitting a change. More information.

sysbox

Sysbox is an open-source container runtime (similar to "runc") that supports running system-level workloads such as Docker and Kubernetes inside unprivileged containers isolated with the Linux user namespace.

See Sysbox Quick Start Guide: Kubernetes-in-Docker for more info.

Sysbox supports running Kubernetes inside unprivileged containers without requiring Cgroup v2 and without the `KubeletInUserNamespace` feature gate. It does this by exposing specially crafted `/proc` and `/sys` filesystems inside the container plus several other advanced OS virtualization techniques.

Running Rootless Kubernetes directly on a host

Note: This section links to third party projects that provide functionality required by Kubernetes. The Kubernetes project authors aren't responsible for these projects, which are listed alphabetically. To add a project to this list, read the content guide before submitting a change. More information.

K3s

K3s experimentally supports rootless mode.

See Running K3s with Rootless mode for the usage.

Usernetes

Usernetes is a reference distribution of Kubernetes that can be installed under `$HOME` directory without the root privilege.

Usernetes supports both containerd and CRI-O as CRI runtimes. Usernetes supports multi-node clusters using Flannel (VXLAN).

See the Usernetes repo for the usage.

Manually deploy a node that runs the kubelet in a user namespace

This section provides hints for running Kubernetes in a user namespace manually.

Note:

This section is intended to be read by developers of Kubernetes distributions, not by end users.

Creating a user namespace

The first step is to create a user namespace.

If you are trying to run Kubernetes in a user-namespaced container such as Rootless Docker/Podman or LXC/LXD, you are all set, and you can go to the next subsection.

Otherwise you have to create a user namespace by yourself, by calling `unshare(2)` with `CLONE_NEWUSER`.

A user namespace can be also unshared by using command line tools such as:

- `unshare(1)`
- RootlessKit
- become-root

After unsharing the user namespace, you will also have to unshare other namespaces such as mount namespace.

You do *not* need to call `chroot()` nor `pivot_root()` after unsharing the mount namespace, however, you have to mount writable filesystems on several directories *in* the namespace.

At least, the following directories need to be writable *in* the namespace (not *outside* the namespace):

- `/etc`
- `/run`
- `/var/logs`
- `/var/lib/kubelet`
- `/var/lib/cni`
- `/var/lib/containerd` (for containerd)
- `/var/lib/containers` (for CRI-O)

Creating a delegated cgroup tree

In addition to the user namespace, you also need to have a writable cgroup tree with cgroup v2.

Note:

Kubernetes support for running Node components in user namespaces requires cgroup v2. Cgroup v1 is not supported.

If you are trying to run Kubernetes in Rootless Docker/Podman or LXC/LXD on a systemd-based host, you are all set.

Otherwise you have to create a systemd unit with `Delegate=yes` property to delegate a cgroup tree with writable permission.

On your node, systemd must already be configured to allow delegation; for more details, see cgroup v2 in the Rootless Containers documentation.

Configuring network

Note: This section links to third party projects that provide functionality required by Kubernetes. The Kubernetes project authors aren't responsible for these projects, which are listed alphabetically. To add a project to this list, read the content guide before submitting a change. More information.

The network namespace of the Node components has to have a non-loopback interface, which can be for example configured with slirp4netns, VPNKit, or lxc-user-nic(1).

The network namespaces of the Pods can be configured with regular CNI plugins. For multi-node networking, Flannel (VXLAN, 8472/UDP) is known to work.

Ports such as the kubelet port (10250/TCP) and `NodePort` service ports have to be exposed from the Node network namespace to the host with an external port forwarder, such as RootlessKit, slirp4netns, or socat(1).

You can use the port forwarder from K3s. See Running K3s in Rootless Mode for more details. The implementation can be found in the `pkg/rootlessports` package of k3s.

Configuring CRI

The kubelet relies on a container runtime. You should deploy a container runtime such as containerd or CRI-O and ensure that it is running within the user namespace before the kubelet starts.

- containerd
- CRI-O

Running CRI plugin of containerd in a user namespace is supported since containerd 1.4.

Running containerd within a user namespace requires the following configurations.

```
version = 2

[plugins."io.containerd.grpc.v1.cri"]
# Disable AppArmor
  disable_apparmor = true
# Ignore an error during setting oom_score_adj
  restrict_oom_score_adj = true
# Disable hugetlb cgroup v2 controller (because systemd does not support delegating hugetlb controller)
  disable_hugetlb_controller = true

[plugins."io.containerd.grpc.v1.cri".containerd]
# Using non-fuse overlayfs is also possible for kernel >= 5.11, but requires SELinux to be disabled
  snapshotter = "fuse-overlayfs"

[plugins."io.containerd.grpc.v1.cri".containerd.runtimes.runc.options]
```

```
# We use cgroupfs that is delegated by systemd, so we do not use SystemdCgroup driver
# (unless you run another systemd in the namespace)
  SystemdCgroup = false
```

The default path of the configuration file is `/etc/containerd/config.toml`. The path can be specified with `containerd -c /path/to/containerd/config.toml`.

Running CRI-O in a user namespace is supported since CRI-O 1.22.

CRI-O requires an environment variable `_CRIO_ROOTLESS=1` to be set.

The following configurations are also recommended:

```
[crio]
  storage_driver = "overlay"
# Using non-fuse overlayfs is also possible for kernel >= 5.11, but requires SELinux to be disabled
  storage_option = ["overlay.mount_program=/usr/local/bin/fuse-overlayfs"]

[crio.runtime]
# We use cgroupfs that is delegated by systemd, so we do not use "systemd" driver
# (unless you run another systemd in the namespace)
  cgroup_manager = "cgroupfs"
```

The default path of the configuration file is `/etc/crio/crio.conf`. The path can be specified with `crio --config /path/to/crio/crio.conf`.

Configuring kubelet

Running kubelet in a user namespace requires the following configuration:

```
apiVersion: kubelet.config.k8s.io/v1beta1
kind: KubeletConfigurationfeatureGates:  KubeletInUserNamespace: true# We use cgroupfs that is delegated by systemd, so we do not
```

When the `KubeletInUserNamespace` feature gate is enabled, the kubelet ignores errors that may happen during setting the following sysctl values on the node.

- `vm.overcommit_memory`
- `vm.panic_on_oom`
- `kernel.panic`
- `kernel.panic_on_oops`
- `kernel.keys.root_maxkeys`
- `kernel.keys.root_maxbytes`.

Within a user namespace, the kubelet also ignores any error raised from trying to open `/dev/kmsg`. This feature gate also allows kube-proxy to ignore an error during setting `RLIMIT_NOFILE`.

The `KubeletInUserNamespace` feature gate was introduced in Kubernetes v1.22 with "alpha" status.

Running kubelet in a user namespace without using this feature gate is also possible by mounting a specially crafted proc filesystem (as done by Sysbox), but not officially supported.

Configuring kube-proxy

Running kube-proxy in a user namespace requires the following configuration:

```
apiVersion: kubeproxy.config.k8s.io/v1alpha1
kind: KubeProxyConfigurationmode: "iptables" # or "userspace"conntrack:# Skip setting sysctl value "net.netfilter.nf_conntrack_max
```

Caveats

- Most of "non-local" volume drivers such as `nfs` and `iscsi` do not work. Local volumes like `local`, `hostPath`, `emptyDir`, `configMap`, `secret`, and `downwardAPI` are known to work.
- Some CNI plugins may not work. Flannel (VXLAN) is known to work.

For more on this, see the Caveats and Future work page on the rootlesscontaine.rs website.

See Also

- rootlesscontaine.rs
- Rootless Containers 2020 (KubeCon NA 2020)
- Running kind with Rootless Docker
- Usernetes
- Running K3s with rootless mode
- KEP-2033: Kubelet-in-UserNS (aka Rootless mode)

Control CPU Management Policies on the Node

FEATURE STATE: `Kubernetes v1.26 [stable]`

Kubernetes keeps many aspects of how pods execute on nodes abstracted from the user. This is by design. However, some workloads require stronger guarantees in terms of latency and/or performance in order to operate acceptably. The kubelet provides methods to enable more complex workload

placement policies while keeping the abstraction free from explicit placement directives.

For detailed information on resource management, please refer to the Resource Management for Pods and Containers documentation.

For detailed information on how the kubelet implements resource management, please refer to the Node ResourceManagers documentation.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

Your Kubernetes server must be at or later than version v1.26.

To check the version, enter `kubectl version`.

If you are running an older version of Kubernetes, please look at the documentation for the version you are actually running.

Configuring CPU management policies

By default, the kubelet uses CFS quota to enforce pod CPU limits. When the node runs many CPU-bound pods, the workload can move to different CPU cores depending on whether the pod is throttled and which CPU cores are available at scheduling time. Many workloads are not sensitive to this migration and thus work fine without any intervention.

However, in workloads where CPU cache affinity and scheduling latency significantly affect workload performance, the kubelet allows alternative CPU management policies to determine some placement preferences on the node.

Windows Support

FEATURE STATE: `Kubernetes v1.32 [alpha]` (enabled by default: false)

CPU Manager support can be enabled on Windows by using the `WindowsCPUAndMemoryAffinity` feature gate and it requires support in the container runtime. Once the feature gate is enabled, follow the steps below to configure the CPU manager policy.

Configuration

The CPU Manager policy is set with the `--cpu-manager-policy` kubelet flag or the `cpuManagerPolicy` field in KubeletConfiguration. There are two supported policies:

- `none`: the default policy.
- `static`: allows pods with certain resource characteristics to be granted increased CPU affinity and exclusivity on the node.

The CPU manager periodically writes resource updates through the CRI in order to reconcile in-memory CPU assignments with cgroupfs. The reconcile frequency is set through a new Kubelet configuration value `--cpu-manager-reconcile-period`. If not specified, it defaults to the same duration as `--node-status-update-frequency`.

The behavior of the static policy can be fine-tuned using the `--cpu-manager-policy-options` flag. The flag takes a comma-separated list of `key=value` policy options. If you disable the `CPUManagerPolicyOptions` feature gate then you cannot fine-tune CPU manager policies. In that case, the CPU manager operates only using its default settings.

In addition to the top-level `CPUManagerPolicyOptions` feature gate, the policy options are split into two groups: alpha quality (hidden by default) and beta quality (visible by default). The groups are guarded respectively by the `CPUManagerPolicyAlphaOptions` and `CPUManagerPolicyBetaOptions` feature gates. Diverging from the Kubernetes standard, these feature gates guard groups of options, because it would have been too cumbersome to add a feature gate for each individual option.

Changing the CPU Manager Policy

Since the CPU manager policy can only be applied when kubelet spawns new pods, simply changing from "none" to "static" won't apply to existing pods. So in order to properly change the CPU manager policy on a node, perform the following steps:

1. Drain the node.
2. Stop kubelet.
3. Remove the old CPU manager state file. The path to this file is `/var/lib/kubelet/cpu_manager_state` by default. This clears the state maintained by the CPUManager so that the cpu-sets set up by the new policy won't conflict with it.
4. Edit the kubelet configuration to change the CPU manager policy to the desired value.
5. Start kubelet.

Repeat this process for every node that needs its CPU manager policy changed. Skipping this process will result in kubelet crashlooping with the following error:

```
could not restore state from checkpoint: configured policy "static" differs from state checkpoint policy "none", please drain this
```

Note:

if the set of online CPUs changes on the node, the node must be drained and CPU manager manually reset by deleting the state file `cpu_manager_state` in the kubelet root directory.

`none` policy configuration

This policy has no extra configuration items.

`static` policy configuration

This policy manages a shared pool of CPUs that initially contains all CPUs in the node. The amount of exclusively allocatable CPUs is equal to the total number of CPUs in the node minus any CPU reservations by the kubelet `--kube-reserved` or `--system-reserved` options. From 1.17, the CPU reservation list can be specified explicitly by kubelet `--reserved-cpus` option. The explicit CPU list specified by `--reserved-cpus` takes precedence over the CPU reservation specified by `--kube-reserved` and `--system-reserved`. CPUs reserved by these options are taken, in integer quantity, from the initial shared pool in ascending order by physical core ID. This shared pool is the set of CPUs on which any containers in `BestEffort` and `Burstable` pods run. Containers in `Guaranteed` pods with fractional CPU `requests` also run on CPUs in the shared pool. Only containers that are both part of a `Guaranteed` pod and have integer CPU `requests` are assigned exclusive CPUs.

Note:

The kubelet requires a CPU reservation greater than zero be made using either `--kube-reserved` and/or `--system-reserved` or `--reserved-cpus` when the static policy is enabled. This is because zero CPU reservation would allow the shared pool to become empty.

Static policy options

You can toggle groups of options on and off based upon their maturity level using the following feature gates:

- `CPUManagerPolicyBetaOptions` default enabled. Disable to hide beta-level options.
- `CPUManagerPolicyAlphaOptions` default disabled. Enable to show alpha-level options. You will still have to enable each option using the `CPUManagerPolicyOptions` kubelet option.

The following policy options exist for the static `CPUManager` policy:

- `full-pcpus-only` (GA, visible by default) (1.33 or higher)
- `distribute-cpus-across-numa` (beta, visible by default) (1.33 or higher)
- `align-by-socket` (alpha, hidden by default) (1.25 or higher)
- `distribute-cpus-across-cores` (alpha, hidden by default) (1.31 or higher)
- `strict-cpu-reservation` (beta, visible by default) (1.32 or higher)
- `prefer-align-cpus-by-uncorecache` (beta, visible by default) (1.34 or higher)

The `full-pcpus-only` option can be enabled by adding `full-pcpus-only=true` to the CPUManager policy options. Likewise, the `distribute-cpus-across-numa` option can be enabled by adding `distribute-cpus-across-numa=true` to the CPUManager policy options. When both are set, they are "additive" in the sense that CPUs will be distributed across NUMA nodes in chunks of full-pcpus rather than individual cores. The `align-by-socket` policy option can be enabled by adding `align-by-socket=true` to the `CPUManager` policy options. It is also additive to the `full-pcpus-only` and `distribute-cpus-across-numa` policy options.

The `distribute-cpus-across-cores` option can be enabled by adding `distribute-cpus-across-cores=true` to the `CPUManager` policy options. It cannot be used with `full-pcpus-only` or `distribute-cpus-across-numa` policy options together at this moment.

The `strict-cpu-reservation` option can be enabled by adding `strict-cpu-reservation=true` to the CPUManager policy options followed by removing the `/var/lib/kubelet/cpu_manager_state` file and restart kubelet.

The `prefer-align-cpus-by-uncorecache` option can be enabled by adding the `prefer-align-cpus-by-uncorecache` to the `CPUManager` policy options. If incompatible options are used, the kubelet will fail to start with the error explained in the logs.

For mode detail about the behavior of the individual options you can configure, please refer to the Node ResourceManagers documentation.

Configure a kubelet image credential provider

FEATURE STATE: `Kubernetes v1.26 [stable]`

Starting from Kubernetes v1.20, the kubelet can dynamically retrieve credentials for a container image registry using exec plugins. The kubelet and the exec plugin communicate through stdio (stdin, stdout, and stderr) using Kubernetes versioned APIs. These plugins allow the kubelet to request credentials for a container registry dynamically as opposed to storing static credentials on disk. For example, the plugin may talk to a local metadata server to retrieve short-lived credentials for an image that is being pulled by the kubelet.

You may be interested in using this capability if any of the below are true:

- API calls to a cloud provider service are required to retrieve authentication information for a registry.
- Credentials have short expiration times and requesting new credentials frequently is required.
- Storing registry credentials on disk or in imagePullSecrets is not acceptable.

This guide demonstrates how to configure the kubelet's image credential provider plugin mechanism.

Service Account Token for Image Pulls

FEATURE STATE: `Kubernetes v1.34 [beta]` (enabled by default: true)

Starting from Kubernetes v1.33, the kubelet can be configured to send a service account token bound to the pod for which the image pull is being performed to the credential provider plugin.

This allows the plugin to exchange the token for credentials to access the image registry.

To enable this feature, the `KubeletServiceAccountTokenForCredentialProviders` feature gate must be enabled on the kubelet, and the `tokenAttributes` field must be set in the `CredentialProviderConfig` file for the plugin.

The `tokenAttributes` field contains information about the service account token that will be passed to the plugin, including the intended audience for the token and whether the plugin requires the pod to have a service account.

Using service account token credentials can enable the following use-cases:

- Avoid needing a kubelet/node-based identity to pull images from a registry.
- Allow workloads to pull images based on their own runtime identity without long-lived/persisted secrets.

Before you begin

- You need a Kubernetes cluster with nodes that support kubelet credential provider plugins. This support is available in Kubernetes 1.34; Kubernetes v1.24 and v1.25 included this as a beta feature, enabled by default.
- If you are configuring a credential provider plugin that requires the service account token, you need a Kubernetes cluster with nodes running Kubernetes v1.33 or later and the `KubeletServiceAccountTokenForCredentialProviders` feature gate enabled on the kubelet.
- A working implementation of a credential provider exec plugin. You can build your own plugin or use one provided by cloud providers.

Your Kubernetes server must be at or later than version v1.26.

To check the version, enter `kubectl version`.

Installing Plugins on Nodes

A credential provider plugin is an executable binary that will be run by the kubelet. Ensure that the plugin binary exists on every node in your cluster and stored in a known directory. The directory will be required later when configuring kubelet flags.

Configuring the Kubelet

In order to use this feature, the kubelet expects two flags to be set:

- `--image-credential-provider-config` - the path to the credential provider plugin config file.
- `--image-credential-provider-bin-dir` - the path to the directory where credential provider plugin binaries are located.

Configure a kubelet credential provider

The configuration file passed into `--image-credential-provider-config` is read by the kubelet to determine which exec plugins should be invoked for which container images. Here's an example configuration file you may end up using if you are using the ECR-based plugin:

```
apiVersion: kubelet.config.k8s.io/v1
kind: CredentialProviderConfig# providers is a list of credential provider helper plugins that will be enabled by the kubelet.# Mu
```

The `providers` field is a list of enabled plugins used by the kubelet. Each entry has a few required fields:

- `name`: the name of the plugin which MUST match the name of the executable binary that exists in the directory passed into `--image-credential-provider-bin-dir`.
- `matchImages`: a list of strings used to match against images in order to determine if this provider should be invoked. More on this below.
- `defaultCacheDuration`: the default duration the kubelet will cache credentials in-memory if a cache duration was not specified by the plugin.
- `apiVersion`: the API version that the kubelet and the exec plugin will use when communicating.

Each credential provider can also be given optional args and environment variables as well. Consult the plugin implementors to determine what set of arguments and environment variables are required for a given plugin.

If you are using the KubeletServiceAccountTokenForCredentialProviders feature gate and configuring the plugin to use the service account token by setting the tokenAttributes field, the following fields are required:

- `serviceAccountTokenAudience`: the intended audience for the projected service account token. This cannot be the empty string.
- `cacheType`: the type of cache key used for caching the credentials returned by the plugin when the service account token is used. The most conservative option is to set this to `Token`, which means the kubelet will cache returned credentials on a per-token basis. This should be set if the returned credential's lifetime is limited to the service account token's lifetime. If the plugin's credential retrieval logic depends only on the service account and not on pod-specific claims, then the plugin can set this to `ServiceAccount`. In this case, the kubelet will cache returned credentials on a per-service account basis. Use this when the returned credential is valid for all pods using the same service account.
- `requireServiceAccount`: whether the plugin requires the pod to have a service account.
  - If set to `true`, kubelet will only invoke the plugin if the pod has a service account.
  - If set to `false`, kubelet will invoke the plugin even if the pod does not have a service account and will not include a token in the `CredentialProviderRequest`.

This is useful for plugins that are used to pull images for pods without service accounts (e.g., static pods).

Configure image matching

The `matchImages` field for each credential provider is used by the kubelet to determine whether a plugin should be invoked for a given image that a Pod is using. Each entry in `matchImages` is an image pattern which can optionally contain a port and a path. Globs can be used in the domain, but not in the port or

the path. Globs are supported as subdomains like `*.k8s.io` or `k8s.*.io`, and top-level domains such as `k8s.*`. Matching partial subdomains like `app*.k8s.io` is also supported. Each glob can only match a single subdomain segment, so `*.io` does NOT match `*.k8s.io`.

A match exists between an image name and a `matchImage` entry when all of the below are true:

- Both contain the same number of domain parts and each part matches.
- The URL path of match image must be a prefix of the target image URL path.
- If the matchImages contains a port, then the port must match in the image as well.

Some example values of `matchImages` patterns are:

- `123456789.dkr.ecr.us-east-1.amazonaws.com`
- `*.azurecr.io`
- `gcr.io`
- `*.*.registry.io`
- `foo.registry.io:8080/path`

What's next

- Read the details about `CredentialProviderConfig` in the kubelet configuration API (v1) reference.
- Read the kubelet credential provider API reference (v1).

Developing Cloud Controller Manager

FEATURE STATE: `Kubernetes v1.11 [beta]`

The cloud-controller-manager is a Kubernetes control plane component that embeds cloud-specific control logic. The cloud controller manager lets you link your cluster into your cloud provider's API, and separates out the components that interact with that cloud platform from components that only interact with your cluster.

By decoupling the interoperability logic between Kubernetes and the underlying cloud infrastructure, the cloud-controller-manager component enables cloud providers to release features at a different pace compared to the main Kubernetes project.

Background

Since cloud providers develop and release at a different pace compared to the Kubernetes project, abstracting the provider-specific code to the `cloud-controller-manager` binary allows cloud vendors to evolve independently from the core Kubernetes code.

The Kubernetes project provides skeleton cloud-controller-manager code with Go interfaces to allow you (or your cloud provider) to plug in your own implementations. This means that a cloud provider can implement a cloud-controller-manager by importing packages from Kubernetes core; each cloudprovider will register their own code by calling `cloudprovider.RegisterCloudProvider` to update a global variable of available cloud providers.

Developing

Out of tree

To build an out-of-tree cloud-controller-manager for your cloud:

1. Create a go package with an implementation that satisfies cloudprovider.Interface.
2. Use `main.go` in cloud-controller-manager from Kubernetes core as a template for your `main.go`. As mentioned above, the only difference should be the cloud package that will be imported.
3. Import your cloud package in `main.go`, ensure your package has an `init` block to run `cloudprovider.RegisterCloudProvider`.

Many cloud providers publish their controller manager code as open source. If you are creating a new cloud-controller-manager from scratch, you could take an existing out-of-tree cloud controller manager as your starting point.

In tree

For in-tree cloud providers, you can run the in-tree cloud controller manager as a DaemonSet in your cluster. See Cloud Controller Manager Administration for more details.

Utilizing the NUMA-aware Memory Manager

FEATURE STATE: `Kubernetes v1.32 [stable]` (enabled by default: true)

The Kubernetes *Memory Manager* enables the feature of guaranteed memory (and hugepages) allocation for pods in the `Guaranteed` QoS class.

The Memory Manager employs hint generation protocol to yield the most suitable NUMA affinity for a pod. The Memory Manager feeds the central manager (*Topology Manager*) with these affinity hints. Based on both the hints and Topology Manager policy, the pod is rejected or admitted to the node.

Moreover, the Memory Manager ensures that the memory which a pod requests is allocated from a minimum number of NUMA nodes.

The Memory Manager is only pertinent to Linux based hosts.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

Your Kubernetes server must be at or later than version v1.32.

To check the version, enter `kubectl version`.

To align memory resources with other requested resources in a Pod spec:

- the CPU Manager should be enabled and proper CPU Manager policy should be configured on a Node. See control CPU Management Policies;
- the Topology Manager should be enabled and proper Topology Manager policy should be configured on a Node. See control Topology Management Policies.

Starting from v1.22, the Memory Manager is enabled by default through `MemoryManager` feature gate.

Preceding v1.22, the `kubelet` must be started with the following flag:

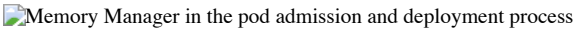
```
--feature-gates=MemoryManager=true
```

in order to enable the Memory Manager feature.

How does the Memory Manager Operate?

The Memory Manager currently offers the guaranteed memory (and hugepages) allocation for Pods in Guaranteed QoS class. To immediately put the Memory Manager into operation follow the guidelines in the section Memory Manager configuration, and subsequently, prepare and deploy a `Guaranteed` pod as illustrated in the section Placing a Pod in the Guaranteed QoS class.

The Memory Manager is a Hint Provider, and it provides topology hints for the Topology Manager which then aligns the requested resources according to these topology hints. On Linux, it also enforces `cgroups` (i.e. `cpuset.mems`) for pods. The complete flow diagram concerning pod admission and deployment process is illustrated in Memory Manager KEP: Design Overview and below:


Memory Manager in the pod admission and deployment process

During this process, the Memory Manager updates its internal counters stored in Node Map and Memory Maps to manage guaranteed memory allocation.

The Memory Manager updates the Node Map during the startup and runtime as follows.

Startup

This occurs once a node administrator employs `--reserved-memory` (section Reserved memory flag). In this case, the Node Map becomes updated to reflect this reservation as illustrated in Memory Manager KEP: Memory Maps at start-up (with examples).

The administrator must provide `--reserved-memory` flag when `Static` policy is configured.

Runtime

Reference Memory Manager KEP: Memory Maps at runtime (with examples) illustrates how a successful pod deployment affects the Node Map, and it also relates to how potential Out-of-Memory (OOM) situations are handled further by Kubernetes or operating system.

Important topic in the context of Memory Manager operation is the management of NUMA groups. Each time pod's memory request is in excess of single NUMA node capacity, the Memory Manager attempts to create a group that comprises several NUMA nodes and features extend memory capacity. The problem has been solved as elaborated in Memory Manager KEP: How to enable the guaranteed memory allocation over many NUMA nodes?. Also, reference Memory Manager KEP: Simulation - how the Memory Manager works? (by examples) illustrates how the management of groups occurs.

Windows Support

FEATURE STATE: `Kubernetes v1.32 [alpha]` (enabled by default: false)

Windows support can be enabled via the `WindowsCPUAndMemoryAffinity` feature gate and it requires support in the container runtime. Only the BestEffort Policy is supported on Windows.

Memory Manager configuration

Other Managers should be first pre-configured. Next, the Memory Manager feature should be enabled and be run with `Static` policy (section Static policy). Optionally, some amount of memory can be reserved for system or kubelet processes to increase node stability (section Reserved memory flag).

Policies

Memory Manager supports two policies. You can select a policy via a `kubelet` flag `--memory-manager-policy`:

- `None` (default)

- `Static` (Linux only)
- `BestEffort` (Windows Only)

None policy

This is the default policy and does not affect the memory allocation in any way. It acts the same as if the Memory Manager is not present at all.

The `None` policy returns default topology hint. This special hint denotes that Hint Provider (Memory Manager in this case) has no preference for NUMA affinity with any resource.

Static policy

In the case of the `Guaranteed` pod, the `Static` Memory Manager policy returns topology hints relating to the set of NUMA nodes where the memory can be guaranteed, and reserves the memory through updating the internal NodeMap object.

In the case of the `BestEffort` or `Burstable` pod, the `Static` Memory Manager policy sends back the default topology hint as there is no request for the guaranteed memory, and does not reserve the memory in the internal NodeMap object.

This policy is only supported on Linux.

BestEffort policy

FEATURE STATE: `Kubernetes v1.32 [alpha]` (enabled by default: false)

This policy is only supported on Windows.

On Windows, NUMA node assignment works differently than Linux. There is no mechanism to ensure that Memory access only comes from a specific NUMA node. Instead the Windows scheduler will select the most optimal NUMA node based on the CPU(s) assignments. It is possible that Windows might use other NUMA nodes if deemed optimal by the Windows scheduler.

The policy does track the amount of memory available and requested through the internal NodeMap. The memory manager will make a best effort at ensuring that enough memory is available on a NUMA node before making the assignment.
This means that in most cases memory assignment should function as expected.

Reserved memory flag

The Node Allocatable mechanism is commonly used by node administrators to reserve K8S node system resources for the kubelet or operating system processes in order to enhance the node stability. A dedicated set of flags can be used for this purpose to set the total amount of reserved memory for a node. This pre-configured value is subsequently utilized to calculate the real amount of node's "allocatable" memory available to pods.

The Kubernetes scheduler incorporates "allocatable" to optimise pod scheduling process. The foregoing flags include `--kube-reserved`, `--system-reserved` and `--eviction-threshold`. The sum of their values will account for the total amount of reserved memory.

A new `--reserved-memory` flag was added to Memory Manager to allow for this total reserved memory to be split (by a node administrator) and accordingly reserved across many NUMA nodes.

The flag specifies a comma-separated list of memory reservations of different memory types per NUMA node. Memory reservations across multiple NUMA nodes can be specified using semicolon as separator. This parameter is only useful in the context of the Memory Manager feature. The Memory Manager will not use this reserved memory for the allocation of container workloads.

For example, if you have a NUMA node "NUMA0" with `10Gi` of memory available, and the `--reserved-memory` was specified to reserve `1Gi` of memory at "NUMA0", the Memory Manager assumes that only `9Gi` is available for containers.

You can omit this parameter, however, you should be aware that the quantity of reserved memory from all NUMA nodes should be equal to the quantity of memory specified by the Node Allocatable feature. If at least one node allocatable parameter is non-zero, you will need to specify `--reserved-memory` for at least one NUMA node. In fact, `eviction-hard` threshold value is equal to `100Mi` by default, so if `Static` policy is used, `--reserved-memory` is obligatory.

Also, avoid the following configurations:

1. duplicates, i.e. the same NUMA node or memory type, but with a different value;
2. setting zero limit for any of memory types;
3. NUMA node IDs that do not exist in the machine hardware;
4. memory type names different than `memory` or `hugepages-<size>` (hugepages of particular `<size>` should also exist).

Syntax:

```
--reserved-memory N:memory-type1=value1,memory-type2=value2,...
```

- `N` (integer) - NUMA node index, e.g. `0`
- `memory-type` (string) - represents memory type:
  - `memory` - conventional memory
  - `hugepages-2Mi` or `hugepages-1Gi` - hugepages
- `value` (string) - the quantity of reserved memory, e.g. `1Gi`

Example usage:

```
--reserved-memory 0:memory=1Gi,hugepages-1Gi=2Gi
```

or

```
--reserved-memory 0:memory=1Gi --reserved-memory 1:memory=2Gi
```

or

```
--reserved-memory '0:memory=1Gi;1:memory=2Gi'
```

When you specify values for `--reserved-memory` flag, you must comply with the setting that you prior provided via Node Allocatable Feature flags. That is, the following rule must be obeyed for each memory type:

```
sum(reserved-memory(i)) = kube-reserved + system-reserved + eviction-threshold,
```

where `i` is an index of a NUMA node.

If you do not follow the formula above, the Memory Manager will show an error on startup.

In other words, the example above illustrates that for the conventional memory (`type=memory`), we reserve `3Gi` in total, i.e.:

```
sum(reserved-memory(i)) = reserved-memory(0) + reserved-memory(1) = 1Gi + 2Gi = 3Gi
```

An example of kubelet command-line arguments relevant to the node Allocatable configuration:

- `--kube-reserved=cpu=500m,memory=50Mi`
- `--system-reserved=cpu=123m,memory=333Mi`
- `--eviction-hard=memory.available<500Mi`

Note:

The default hard eviction threshold is 100MiB, and **not** zero. Remember to increase the quantity of memory that you reserve by setting `--reserved-memory` by that hard eviction threshold. Otherwise, the kubelet will not start Memory Manager and display an error.

Here is an example of a correct configuration:

```
--kube-reserved=cpu=4,memory=4Gi
--system-reserved=cpu=1,memory=1Gi
--memory-manager-policy=Static
--reserved-memory '0:memory=3Gi;1:memory=2148Mi'
```

Prior to Kubernetes 1.32, you also need to add

```
--feature-gates=MemoryManager=true
```

Let us validate the configuration above:

1. `kube-reserved + system-reserved + eviction-hard(default) = reserved-memory(0) + reserved-memory(1)`
2. `4GiB + 1GiB + 100MiB = 3GiB + 2148MiB`
3. `5120MiB + 100MiB = 3072MiB + 2148MiB`
4. `5220MiB = 5220MiB` (which is correct)

Placing a Pod in the Guaranteed QoS class

If the selected policy is anything other than `None`, the Memory Manager identifies pods that are in the `Guaranteed` QoS class. The Memory Manager provides specific topology hints to the Topology Manager for each `Guaranteed` pod. For pods in a QoS class other than `Guaranteed`, the Memory Manager provides default topology hints to the Topology Manager.

The following excerpts from pod manifests assign a pod to the `Guaranteed` QoS class.

Pod with integer CPU(s) runs in the `Guaranteed` QoS class, when `requests` are equal to `limits`:

```
spec:
  containers:
  - name: nginx
    image: nginx
    resources:
      limits:
        memory: "200Mi"
        cpu: "2"
        example.com/device: "1"
      requests:
        memory: "200Mi"
        cpu: "2"
        example.com/device: "1"
```

Also, a pod sharing CPU(s) runs in the `Guaranteed` QoS class, when `requests` are equal to `limits`.

```
spec:
  containers:
  - name: nginx
    image: nginx
    resources:
      limits:
        memory: "200Mi"
        cpu: "300m"
        example.com/device: "1"
      requests:
        memory: "200Mi"
        cpu: "300m"
        example.com/device: "1"
```

Notice that both CPU and memory requests must be specified for a Pod to lend it to Guaranteed QoS class.

Troubleshooting

The following means can be used to troubleshoot the reason why a pod could not be deployed or became rejected at a node:

- pod status - indicates topology affinity errors
- system logs - include valuable information for debugging, e.g., about generated hints
- state file - the dump of internal state of the Memory Manager (includes Node Map and Memory Maps)
- starting from v1.22, the device plugin resource API can be used to retrieve information about the memory reserved for containers

Pod status (TopologyAffinityError)

This error typically occurs in the following situations:

- a node has not enough resources available to satisfy the pod's request
- the pod's request is rejected due to particular Topology Manager policy constraints

The error appears in the status of a pod:

```
kubectl get pods

NAME         READY   STATUS                  RESTARTS   AGE
guaranteed   0/1     TopologyAffinityError   0          113s
```

Use `kubectl describe pod <id>` or `kubectl get events` to obtain detailed error message:

```
Warning  TopologyAffinityError  10m   kubelet, dell8  Resources cannot be allocated with Topology locality
```

System logs

Search system logs with respect to a particular pod.

The set of hints that Memory Manager generated for the pod can be found in the logs. Also, the set of hints generated by CPU Manager should be present in the logs.

Topology Manager merges these hints to calculate a single best hint. The best hint should be also present in the logs.

The best hint indicates where to allocate all the resources. Topology Manager tests this hint against its current policy, and based on the verdict, it either admits the pod to the node or rejects it.

Also, search the logs for occurrences associated with the Memory Manager, e.g. to find out information about `cgroups` and `cpuset.mems` updates.

Examine the memory manager state on a node

Let us first deploy a sample `Guaranteed` pod whose specification is as follows:

```
apiVersion: v1
kind: Podmetadata:  name: guaranteedspec:  containers:  - name: guaranteed    image: consumer    imagePullPolicy: Never    resourc
```

Next, let us log into the node where it was deployed and examine the state file in `/var/lib/kubelet/memory_manager_state`:

```
{
   "policyName":"Static",
   "machineState":{
      "0":{
         "numberOfAssignments":1,
         "memoryMap":{
            "hugepages-1Gi":{
               "total":0,
               "systemReserved":0,
               "allocatable":0,
               "reserved":0,
               "free":0
            },
            "memory":{
               "total":134987354112,
               "systemReserved":3221225472,
               "allocatable":131766128640,
               "reserved":131766128640,
               "free":0
            }
         },
         "nodes":[
            0,
            1
         ]
      },
      "1":{
         "numberOfAssignments":1,
         "memoryMap":{
            "hugepages-1Gi":{
               "total":0,
               "systemReserved":0,
               "allocatable":0,
               "reserved":0,
               "free":0
            },
            "memory":{
               "total":135286722560,
```

```
                "systemReserved":2252341248,
                "allocatable":133034381312,
                "reserved":29295144960,
                "free":103739236352
             }
          },
          "nodes":[
             0,
             1
          ]
       }
    },
    "entries":{
       "fa9bdd38-6df9-4cf9-aa67-8c4814da37a8":{
          "guaranteed":[
             {
                "numaAffinity":[
                   0,
                   1
                ],
                "type":"memory",
                "size":161061273600
             }
          ]
       }
    },
    "checksum":4142013182
}
```


It can be deduced from the state file that the pod was pinned to both NUMA nodes, i.e.:


```
"numaAffinity":[
   0,
   1
],
```


Pinned term means that pod's memory consumption is constrained (through `cgroups` configuration) to these NUMA nodes.

This automatically implies that Memory Manager instantiated a new group that comprises these two NUMA nodes, i.e. `0` and `1` indexed NUMA nodes.

Notice that the management of groups is handled in a relatively complex manner, and further elaboration is provided in Memory Manager KEP in this and this sections.

In order to analyse memory resources available in a group,the corresponding entries from NUMA nodes belonging to the group must be added up.

For example, the total amount of free "conventional" memory in the group can be computed by adding up the free memory available at every NUMA node in the group, i.e., in the `"memory"` section of NUMA node `0` (`"free":0`) and NUMA node `1` (`"free":103739236352`). So, the total amount of free "conventional" memory in this group is equal to `0 + 103739236352` bytes.

The line `"systemReserved":3221225472` indicates that the administrator of this node reserved `3221225472` bytes (i.e. `3Gi`) to serve kubelet and system processes at NUMA node `0`, by using `--reserved-memory` flag.

Device plugin resource API

The kubelet provides a `PodResourceLister` gRPC service to enable discovery of resources and associated metadata. By using its List gRPC endpoint, information about reserved memory for each container can be retrieved, which is contained in protobuf `ContainerMemory` message. This information can be retrieved solely for pods in Guaranteed QoS class.

What's next

- Memory Manager KEP: Design Overview
- Memory Manager KEP: Memory Maps at start-up (with examples)
- Memory Manager KEP: Memory Maps at runtime (with examples)
- Memory Manager KEP: Simulation - how the Memory Manager works? (by examples)
- Memory Manager KEP: The Concept of Node Map and Memory Maps
- Memory Manager KEP: How to enable the guaranteed memory allocation over many NUMA nodes?

Overprovision Node Capacity For A Cluster

This page guides you through configuring Node overprovisioning in your Kubernetes cluster. Node overprovisioning is a strategy that proactively reserves a portion of your cluster's compute resources. This reservation helps reduce the time required to schedule new pods during scaling events, enhancing your cluster's responsiveness to sudden spikes in traffic or workload demands.

By maintaining some unused capacity, you ensure that resources are immediately available when new pods are created, preventing them from entering a pending state while the cluster scales up.

Before you begin

- You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster.
- You should already have a basic understanding of Deployments, Pod priority, and PriorityClasses.
- Your cluster must be set up with an autoscaler that manages nodes based on demand.

Create a PriorityClass

Begin by defining a PriorityClass for the placeholder Pods. First, create a PriorityClass with a negative priority value, that you will shortly assign to the placeholder pods. Later, you will set up a Deployment that uses this PriorityClass

priorityclass/low-priority-class.yaml  Copy priorityclass/low-priority-class.yaml to clipboard

```
apiVersion: scheduling.k8s.io/v1
kind: PriorityClassmetadata:  name: placeholder # these Pods represent placeholder capacityvalue: -1000globalDefault: falsedescrip
```

Then create the PriorityClass:

```
kubectl apply -f https://k8s.io/examples/priorityclass/low-priority-class.yaml
```

You will next define a Deployment that uses the negative-priority PriorityClass and runs a minimal container. When you add this to your cluster, Kubernetes runs those placeholder pods to reserve capacity. Any time there is a capacity shortage, the control plane will pick one these placeholder pods as the first candidate to preempt.

Run Pods that request node capacity

Review the sample manifest:

deployments/deployment-with-capacity-reservation.yaml  Copy deployments/deployment-with-capacity-reservation.yaml to clipboard

```
apiVersion: apps/v1
kind: Deploymentmetadata:  name: capacity-reservation  # You should decide what namespace to deploy this intospec:  replicas: 1  s
```

Pick a namespace for the placeholder pods

You should select, or create, a namespace that the placeholder Pods will go into.

Create the placeholder deployment

Create a Deployment based on that manifest:

```
# Change the namespace name "example"
kubectl --namespace example apply -f https://k8s.io/examples/deployments/deployment-with-capacity-reservation.yaml
```

Adjust placeholder resource requests

Configure the resource requests and limits for the placeholder pods to define the amount of overprovisioned resources you want to maintain. This reservation ensures that a specific amount of CPU and memory is kept available for new pods.

To edit the Deployment, modify the `resources` section in the Deployment manifest file to set appropriate requests and limits. You can download that file locally and then edit it with whichever text editor you prefer.

You can also edit the Deployment using kubectl:

```
kubectl edit deployment capacity-reservation
```

For example, to reserve a total of a 0.5 CPU and 1GiB of memory across 5 placeholder pods, define the resource requests and limits for a single placeholder pod as follows:

```
  resources:
    requests:
      cpu: "100m"
      memory: "200Mi"
    limits:
      cpu: "100m"
```

Set the desired replica count

Calculate the total reserved resources

For example, with 5 replicas each reserving 0.1 CPU and 200MiB of memory:
Total CPU reserved: 5 × 0.1 = 0.5 (in the Pod specification, you'll write the quantity `500m`)
Total memory reserved: 5 × 200MiB = 1GiB (in the Pod specification, you'll write `1 Gi`)

To scale the Deployment, adjust the number of replicas based on your cluster's size and expected workload:

```
kubectl scale deployment capacity-reservation --replicas=5
```

Verify the scaling:

```
kubectl get deployment capacity-reservation
```

The output should reflect the updated number of replicas:

```
NAME                   READY   UP-TO-DATE   AVAILABLE   AGE
capacity-reservation   5/5     5            5           2m
```

Note:

Some autoscalers, notably Karpenter, treat preferred affinity rules as hard rules when considering node scaling. If you use Karpenter or another node autoscaler that uses the same heuristic, the replica count you set here also sets a minimum node count for your cluster.

What's next

- Learn more about PriorityClasses and how they affect pod scheduling.
- Explore node autoscaling to dynamically adjust your cluster's size based on workload demands.
- Understand Pod preemption, a key mechanism for Kubernetes to handle resource contention. The same page covers *eviction*, which is less relevant to the placeholder Pod approach, but is also a mechanism for Kubernetes to react when resources are contended.

Administration with kubeadm

If you don't yet have a cluster, visit bootstrapping clusters with `kubeadm`.

The tasks in this section are aimed at people administering an existing cluster:

- Adding Linux worker nodes
- Adding Windows worker nodes
- Upgrading kubeadm clusters
- Upgrading Linux nodes
- Upgrading Windows nodes
- Configuring a cgroup driver
- Certificate Management with kubeadm
- Reconfiguring a kubeadm cluster
- Changing The Kubernetes Package Repository

Use Port Forwarding to Access Applications in a Cluster

This page shows how to use `kubectl port-forward` to connect to a MongoDB server running in a Kubernetes cluster. This type of connection can be useful for database debugging.

Before you begin

- You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:
  - iximiuz Labs
  - Killercoda
  - KodeKloud
  - Play with Kubernetes

  Your Kubernetes server must be at or later than version v1.10.

  To check the version, enter `kubectl version`.
- Install MongoDB Shell.

Creating MongoDB deployment and service

1. Create a Deployment that runs MongoDB:

   ```
   kubectl apply -f https://k8s.io/examples/application/mongodb/mongo-deployment.yaml
   ```

   The output of a successful command verifies that the deployment was created:

   ```
   deployment.apps/mongo created
   ```

   View the pod status to check that it is ready:

   ```
   kubectl get pods
   ```

   The output displays the pod created:

   ```
   NAME                     READY   STATUS    RESTARTS   AGE
   mongo-75f59d57f4-4nd6q   1/1     Running   0          2m4s
   ```

   View the Deployment's status:

   ```
   kubectl get deployment
   ```

   The output displays that the Deployment was created:

   ```
   NAME    READY   UP-TO-DATE   AVAILABLE   AGE
   mongo   1/1     1            1           2m21s
   ```

   The Deployment automatically manages a ReplicaSet. View the ReplicaSet status using:

   ```
   kubectl get replicaset
   ```

   The output displays that the ReplicaSet was created:

```
NAME                DESIRED   CURRENT   READY   AGE
mongo-75f59d57f4    1         1         1       3m12s
```

2. Create a Service to expose MongoDB on the network:

   ```
   kubectl apply -f https://k8s.io/examples/application/mongodb/mongo-service.yaml
   ```

   The output of a successful command verifies that the Service was created:

   ```
   service/mongo created
   ```

   Check the Service created:

   ```
   kubectl get service mongo
   ```

   The output displays the service created:

   ```
   NAME    TYPE        CLUSTER-IP     EXTERNAL-IP   PORT(S)     AGE
   mongo   ClusterIP   10.96.41.183   <none>        27017/TCP   11s
   ```

3. Verify that the MongoDB server is running in the Pod, and listening on port 27017:

   ```
   # Change mongo-75f59d57f4-4nd6q to the name of the Pod
   kubectl get pod mongo-75f59d57f4-4nd6q --template='{{(index (index .spec.containers 0).ports 0).containerPort}}{{"\n"}}'
   ```

   The output displays the port for MongoDB in that Pod:

   ```
   27017
   ```

   27017 is the official TCP port for MongoDB.

Forward a local port to a port on the Pod

1. `kubectl port-forward` allows using resource name, such as a pod name, to select a matching pod to port forward to.

   ```
   # Change mongo-75f59d57f4-4nd6q to the name of the Pod
   kubectl port-forward mongo-75f59d57f4-4nd6q 28015:27017
   ```

   which is the same as

   ```
   kubectl port-forward pods/mongo-75f59d57f4-4nd6q 28015:27017
   ```

   or

   ```
   kubectl port-forward deployment/mongo 28015:27017
   ```

   or

   ```
   kubectl port-forward replicaset/mongo-75f59d57f4 28015:27017
   ```

   or

   ```
   kubectl port-forward service/mongo 28015:27017
   ```

   Any of the above commands works. The output is similar to this:

   ```
   Forwarding from 127.0.0.1:28015 -> 27017
   Forwarding from [::1]:28015 -> 27017
   ```

   Note:

   `kubectl port-forward` does not return. To continue with the exercises, you will need to open another terminal.

2. Start the MongoDB command line interface:

   ```
   mongosh --port 28015
   ```

3. At the MongoDB command line prompt, enter the `ping` command:

   ```
   db.runCommand( { ping: 1 } )
   ```

   A successful ping request returns:

   ```
   { ok: 1 }
   ```

Optionally let *kubectl* choose the local port

If you don't need a specific local port, you can let `kubectl` choose and allocate the local port and thus relieve you from having to manage local port conflicts, with the slightly simpler syntax:

```
kubectl port-forward deployment/mongo :27017
```

The `kubectl` tool finds a local port number that is not in use (avoiding low ports numbers, because these might be used by other applications). The output is similar to:

```
Forwarding from 127.0.0.1:63753 -> 27017
Forwarding from [::1]:63753 -> 27017
```

Discussion

Connections made to local port 28015 are forwarded to port 27017 of the Pod that is running the MongoDB server. With this connection in place, you can use your local workstation to debug the database that is running in the Pod.

Note:

`kubectl port-forward` is implemented for TCP ports only. The support for UDP protocol is tracked in issue 47862.

What's next

Learn more about kubectl port-forward.

Encrypting Confidential Data at Rest

All of the APIs in Kubernetes that let you write persistent API resource data support at-rest encryption. For example, you can enable at-rest encryption for Secrets. This at-rest encryption is additional to any system-level encryption for the etcd cluster or for the filesystem(s) on hosts where you are running the kube-apiserver.

This page shows how to enable and configure encryption of API data at rest.

Note:

This task covers encryption for resource data stored using the Kubernetes API. For example, you can encrypt Secret objects, including the key-value data they contain.

If you want to encrypt data in filesystems that are mounted into containers, you instead need to either:

- use a storage integration that provides encrypted volumes
- encrypt the data within your own application

Before you begin

- You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:
  - iximiuz Labs
  - Killercoda
  - KodeKloud
  - Play with Kubernetes
- This task assumes that you are running the Kubernetes API server as a static pod on each control plane node.
- Your cluster's control plane **must** use etcd v3.x (major version 3, any minor version).
- To encrypt a custom resource, your cluster must be running Kubernetes v1.26 or newer.
- To use a wildcard to match resources, your cluster must be running Kubernetes v1.27 or newer.

To check the version, enter `kubectl version`.

Determine whether encryption at rest is already enabled

By default, the API server stores plain-text representations of resources into etcd, with no at-rest encryption.

The `kube-apiserver` process accepts an argument `--encryption-provider-config` that specifies a path to a configuration file. The contents of that file, if you specify one, control how Kubernetes API data is encrypted in etcd. If you are running the kube-apiserver without the `--encryption-provider-config` command line argument, you do not have encryption at rest enabled. If you are running the kube-apiserver with the `--encryption-provider-config` command line argument, and the file that it references specifies the `identity` provider as the first encryption provider in the list, then you do not have at-rest encryption enabled (**the default `identity` provider does not provide any confidentiality protection.**)

If you are running the kube-apiserver with the `--encryption-provider-config` command line argument, and the file that it references specifies a provider other than `identity` as the first encryption provider in the list, then you already have at-rest encryption enabled. However, that check does not tell you whether a previous migration to encrypted storage has succeeded. If you are not sure, see ensure all relevant data are encrypted.

Understanding the encryption at rest configuration

```
---
## CAUTION: this is an example configuration.#         Do not use this for your own cluster!#apiVersion: apiserver.config.k8s.io/
```

Each `resources` array item is a separate config and contains a complete configuration. The `resources.resources` field is an array of Kubernetes resource names (`resource` or `resource.group`) that should be encrypted like Secrets, ConfigMaps, or other resources.

If custom resources are added to `EncryptionConfiguration` and the cluster version is 1.26 or newer, any newly created custom resources mentioned in the `EncryptionConfiguration` will be encrypted. Any custom resources that existed in etcd prior to that version and configuration will be unencrypted until

they are next written to storage. This is the same behavior as built-in resources. See the Ensure all secrets are encrypted section.

The `providers` array is an ordered list of the possible encryption providers to use for the APIs that you listed. Each provider supports multiple keys - the keys are tried in order for decryption, and if the provider is the first provider, the first key is used for encryption.

Only one provider type may be specified per entry (`identity` or `aescbc` may be provided, but not both in the same item). The first provider in the list is used to encrypt resources written into the storage. When reading resources from storage, each provider that matches the stored data attempts in order to decrypt the data. If no provider can read the stored data due to a mismatch in format or secret key, an error is returned which prevents clients from accessing that resource.

`EncryptionConfiguration` supports the use of wildcards to specify the resources that should be encrypted. Use '`*.<group>`' to encrypt all resources within a group (for eg '`*.apps`' in above example) or '`*.*`' to encrypt all resources. '`*.`' can be used to encrypt all resource in the core group. '`*.*`' will encrypt all resources, even custom resources that are added after API server start.

Note:

Use of wildcards that overlap within the same resource list or across multiple entries are not allowed since part of the configuration would be ineffective. The `resources` list's processing order and precedence are determined by the order it's listed in the configuration.

If you have a wildcard covering resources and want to opt out of at-rest encryption for a particular kind of resource, you achieve that by adding a separate `resources` array item with the name of the resource that you want to exempt, followed by a `providers` array item where you specify the `identity` provider. You add this item to the list so that it appears earlier than the configuration where you do specify encryption (a provider that is not `identity`).

For example, if '`*.*`' is enabled and you want to opt out of encryption for Events and ConfigMaps, add a new **earlier** item to the `resources`, followed by the providers array item with `identity` as the provider. The more specific entry must come before the wildcard entry.

The new item would look similar to:

```
...
- resources:
    - configmaps. # specifically from the core API group,
                  # because of trailing "."
    - events
  providers:
    - identity: {}
# and then other entries in resources
```

Ensure that the exemption is listed *before* the wildcard '`*.*`' item in the resources array to give it precedence.

For more detailed information about the `EncryptionConfiguration` struct, please refer to the encryption configuration API.

Caution:

If any resource is not readable via the encryption configuration (because keys were changed), and you cannot restore a working configuration, your only recourse is to delete that entry from the underlying etcd directly.

Any calls to the Kubernetes API that attempt to read that resource will fail until it is deleted or a valid decryption key is provided.

Available providers

Before you configure encryption-at-rest for data in your cluster's Kubernetes API, you need to select which provider(s) you will use.

The following table describes each available provider.

Name	Encryption	Strength	Speed	Key length
	None	N/A	N/A	N/A
`identity`	Resources written as-is without encryption. When set as the first provider, the resource will be decrypted as new values are written. Existing encrypted resources are **not** automatically overwritten with the plaintext data. The `identity` provider is the default if you do not specify otherwise.			
`aescbc`	AES-CBC with PKCS#7 padding	Weak	Fast	16, 24, or 32-byte
	Not recommended due to CBC's vulnerability to padding oracle attacks. Key material accessible from control plane host.			
`aesgcm`	AES-GCM with random nonce	Must be rotated every 200,000 writes	Fastest	16, 24, or 32-byte
	Not recommended for use except when an automated key rotation scheme is implemented. Key material accessible from control plane host.			
`kms` v1 ***(deprecated since Kubernetes v1.28)***	Uses envelope encryption scheme with DEK per resource.	Strongest	Slow (*compared to `kms` version 2*)	32-bytes
	Data is encrypted by data encryption keys (DEKs) using AES-GCM; DEKs are encrypted by key encryption keys (KEKs) according to configuration in Key Management Service (KMS). Simple key rotation, with a new DEK generated for each encryption, and KEK rotation controlled by the user. Read how to configure the KMS V1 provider.			
`kms` v2	Uses envelope encryption scheme with DEK per API server.	Strongest	Fast	32-bytes
	Data is encrypted by data encryption keys (DEKs) using AES-GCM; DEKs are encrypted by key encryption keys (KEKs) according to configuration in Key Management Service (KMS). Kubernetes generates a new DEK per encryption from a secret seed. The seed is rotated whenever the KEK is rotated. A good choice if using a third party tool for key management. Available as stable from Kubernetes v1.29. Read how to configure the KMS V2 provider.			
`secretbox`	XSalsa20 and Poly1305	Strong	Faster	32-byte

Name	Encryption	Strength	Speed	Key length
	Uses relatively new encryption technologies that may not be considered acceptable in environments that require high levels of review. Key material accessible from control plane host.			

The `identity` provider is the default if you do not specify otherwise. **The `identity` provider does not encrypt stored data and provides *no* additional confidentiality protection.**

Key storage

Local key storage

Encrypting secret data with a locally managed key protects against an etcd compromise, but it fails to protect against a host compromise. Since the encryption keys are stored on the host in the EncryptionConfiguration YAML file, a skilled attacker can access that file and extract the encryption keys.

Managed (KMS) key storage

The KMS provider uses *envelope encryption*: Kubernetes encrypts resources using a data key, and then encrypts that data key using the managed encryption service. Kubernetes generates a unique data key for each resource. The API server stores an encrypted version of the data key in etcd alongside the ciphertext; when reading the resource, the API server calls the managed encryption service and provides both the ciphertext and the (encrypted) data key. Within the managed encryption service, the provider use a *key encryption key* to decipher the data key, deciphers the data key, and finally recovers the plain text. Communication between the control plane and the KMS requires in-transit protection, such as TLS.

Using envelope encryption creates dependence on the key encryption key, which is not stored in Kubernetes. In the KMS case, an attacker who intends to get unauthorised access to the plaintext values would need to compromise etcd **and** the third-party KMS provider.

Protection for encryption keys

You should take appropriate measures to protect the confidential information that allows decryption, whether that is a local encryption key, or an authentication token that allows the API server to call KMS.

Even when you rely on a provider to manage the use and lifecycle of the main encryption key (or keys), you are still responsible for making sure that access controls and other security measures for the managed encryption service are appropriate for your security needs.

Encrypt your data

Generate the encryption key

The following steps assume that you are not using KMS, and therefore the steps also assume that you need to generate an encryption key. If you already have an encryption key, skip to Write an encryption configuration file.

Caution:

Storing the raw encryption key in the EncryptionConfig only moderately improves your security posture, compared to no encryption.

For additional secrecy, consider using the `kms` provider as this relies on keys held outside your Kubernetes cluster. Implementations of `kms` can work with hardware security modules or with encryption services managed by your cloud provider.

To learn about setting up encryption at rest using KMS, see Using a KMS provider for data encryption. The KMS provider plugin that you use may also come with additional specific documentation.

Start by generating a new encryption key, and then encode it using base64:

- Linux
- macOS
- Windows

Generate a 32-byte random key and base64 encode it. You can use this command:

```
head -c 32 /dev/urandom | base64
```

You can use `/dev/hwrng` instead of `/dev/urandom` if you want to use your PC's built-in hardware entropy source. Not all Linux devices provide a hardware random generator.

Generate a 32-byte random key and base64 encode it. You can use this command:

```
head -c 32 /dev/urandom | base64
```

Generate a 32-byte random key and base64 encode it. You can use this command:

```
# Do not run this in a session where you have set a random number
# generator seed.
[Convert]::ToBase64String((1..32|%{[byte](Get-Random -Max 256)}))
```

Note:

Keep the encryption key confidential, including while you generate it and ideally even after you are no longer actively using it.

Replicate the encryption key

Using a secure mechanism for file transfer, make a copy of that encryption key available to every other control plane host.

At a minimum, use encryption in transit - for example, secure shell (SSH). For more security, use asymmetric encryption between hosts, or change the approach you are using so that you're relying on KMS encryption.

Write an encryption configuration file

Caution:

The encryption configuration file may contain keys that can decrypt content in etcd. If the configuration file contains any key material, you must properly restrict permissions on all your control plane hosts so only the user who runs the kube-apiserver can read this configuration.

Create a new encryption configuration file. The contents should be similar to:

```
---
apiVersion: apiserver.config.k8s.io/v1kind: EncryptionConfigurationresources:  - resources:      - secrets      - configmaps
```

To create a new encryption key (that does not use KMS), see Generate the encryption key.

Use the new encryption configuration file

You will need to mount the new encryption config file to the `kube-apiserver` static pod. Here is an example on how to do that:

1. Save the new encryption config file to `/etc/kubernetes/enc/enc.yaml` on the control-plane node.
2. Edit the manifest for the `kube-apiserver` static pod: `/etc/kubernetes/manifests/kube-apiserver.yaml` so that it is similar to:

   ```
   ---
   ## This is a fragment of a manifest for a static Pod.# Check whether this is correct for your cluster and for your API server
   ```

3. Restart your API server.

Caution:

Your config file contains keys that can decrypt the contents in etcd, so you must properly restrict permissions on your control-plane nodes so only the user who runs the `kube-apiserver` can read it.

You now have encryption in place for **one** control plane host. A typical Kubernetes cluster has multiple control plane hosts, so there is more to do.

Reconfigure other control plane hosts

If you have multiple API servers in your cluster, you should deploy the changes in turn to each API server.

Caution:

For cluster configurations with two or more control plane nodes, the encryption configuration should be identical across each control plane node.

If there is a difference in the encryption provider configuration between control plane nodes, this difference may mean that the kube-apiserver can't decrypt data.

When you are planning to update the encryption configuration of your cluster, plan this so that the API servers in your control plane can always decrypt the stored data (even part way through rolling out the change).

Make sure that you use the **same** encryption configuration on each control plane host.

Verify that newly written data is encrypted

Data is encrypted when written to etcd. After restarting your `kube-apiserver`, any newly created or updated Secret (or other resource kinds configured in `EncryptionConfiguration`) should be encrypted when stored.

To check this, you can use the `etcdctl` command line program to retrieve the contents of your secret data.

This example shows how to check this for encrypting the Secret API.

1. Create a new Secret called `secret1` in the `default` namespace:

   ```
   kubectl create secret generic secret1 -n default --from-literal=mykey=mydata
   ```

2. Using the `etcdctl` command line tool, read that Secret out of etcd:

   ```
   ETCDCTL_API=3 etcdctl get /registry/secrets/default/secret1 [...] | hexdump -C
   ```

   where `[...]` must be the additional arguments for connecting to the etcd server.

   For example:

   ```
   ETCDCTL_API=3 etcdctl \
      --cacert=/etc/kubernetes/pki/etcd/ca.crt   \   --cert=/etc/kubernetes/pki/etcd/server.crt \   --key=/etc/kubernetes/pki/et
   ```

   The output is similar to this (abbreviated):

   ```
   00000000  2f 72 65 67 69 73 74 72  79 2f 73 65 63 72 65 74  |/registry/secret|
   00000010  73 2f 64 65 66 61 75 6c  74 2f 73 65 63 72 65 74  |s/default/secret|
   ```

```
00000020  31 0a 6b 38 73 3a 65 6e  63 3a 61 65 73 63 62 63  |1.k8s:enc:aescbc|
00000030  3a 76 31 3a 6b 65 79 31  3a c7 6c e7 d3 09 bc 06  |:v1:key1:.l.....|
00000040  25 51 91 e4 e0 6c e5 b1  4d 7a 8b 3d b9 c2 7c 6e  |%Q...l..Mz.=..|n|
00000050  b4 79 df 05 28 ae 0d 8e  5f 35 13 2c c0 18 99 3e  |.y..(..._5.,...>|
[...]
00000110  23 3a 0d fc 28 ca 48 2d  6b 2d 46 cc 72 0b 70 4c  |#:..(.H-k-F.r.pL|
00000120  a5 fc 35 43 12 4e 60 ef  bf 6f fe cf df 0b ad 1f  |..5C.N`..o......|
00000130  82 c4 88 53 02 da 3e 66  ff 0a                    |...S..>f..|
0000013a
```

3. Verify the stored Secret is prefixed with `k8s:enc:aescbc:v1:` which indicates the `aescbc` provider has encrypted the resulting data. Confirm that the key name shown in `etcd` matches the key name specified in the `EncryptionConfiguration` mentioned above. In this example, you can see that the encryption key named `key1` is used in `etcd` and in `EncryptionConfiguration`.

4. Verify the Secret is correctly decrypted when retrieved via the API:

   ```
   kubectl get secret secret1 -n default -o yaml
   ```

   The output should contain `mykey: bXlkYXRh`, with contents of `mydata` encoded using base64; read decoding a Secret to learn how to completely decode the Secret.

Ensure all relevant data are encrypted

It's often not enough to make sure that new objects get encrypted: you also want that encryption to apply to the objects that are already stored.

For this example, you have configured your cluster so that Secrets are encrypted on write. Performing a replace operation for each Secret will encrypt that content at rest, where the objects are unchanged.

You can make this change across all Secrets in your cluster:

```
# Run this as an administrator that can read and write all Secrets
kubectl get secrets --all-namespaces -o json | kubectl replace -f -
```

The command above reads all Secrets and then updates them with the same data, in order to apply server side encryption.

Note:

If an error occurs due to a conflicting write, retry the command. It is safe to run that command more than once.

For larger clusters, you may wish to subdivide the Secrets by namespace, or script an update.

Prevent plain text retrieval

If you want to make sure that the only access to a particular API kind is done using encryption, you can remove the API server's ability to read that API's backing data as plaintext.

Warning:

Making this change prevents the API server from retrieving resources that are marked as encrypted at rest, but are actually stored in the clear.

When you have configured encryption at rest for an API (for example: the API kind `Secret`, representing `secrets` resources in the core API group), you **must** ensure that all those resources in this cluster really are encrypted at rest. Check this before you carry on with the next steps.

Once all Secrets in your cluster are encrypted, you can remove the `identity` part of the encryption configuration. For example:

```
---
apiVersion: apiserver.config.k8s.io/v1kind: EncryptionConfigurationresources:  - resources:      - secrets    providers:      - ae
```

…and then restart each API server in turn. This change prevents the API server from accessing a plain-text Secret, even by accident.

Rotate a decryption key

Changing an encryption key for Kubernetes without incurring downtime requires a multi-step operation, especially in the presence of a highly-available deployment where multiple `kube-apiserver` processes are running.

1. Generate a new key and add it as the second key entry for the current provider on all control plane nodes.
2. Restart **all** `kube-apiserver` processes, to ensure each server can decrypt any data that are encrypted with the new key.
3. Make a secure backup of the new encryption key. If you lose all copies of this key you would need to delete all the resources were encrypted under the lost key, and workloads may not operate as expected during the time that at-rest encryption is broken.
4. Make the new key the first entry in the `keys` array so that it is used for encryption-at-rest for new writes
5. Restart all `kube-apiserver` processes to ensure each control plane host now encrypts using the new key
6. As a privileged user, run `kubectl get secrets --all-namespaces -o json | kubectl replace -f -` to encrypt all existing Secrets with the new key
7. After you have updated all existing Secrets to use the new key and have made a secure backup of the new key, remove the old decryption key from the configuration.

Decrypt all data

This example shows how to stop encrypting the Secret API at rest. If you are encrypting other API kinds, adjust the steps to match.

To disable encryption at rest, place the `identity` provider as the first entry in your encryption configuration file:

```
---
apiVersion: apiserver.config.k8s.io/v1kind: EncryptionConfigurationresources:  - resources:      - secrets      # list any other r
```

Then run the following command to force decryption of all Secrets:

```
kubectl get secrets --all-namespaces -o json | kubectl replace -f -
```

Once you have replaced all existing encrypted resources with backing data that don't use encryption, you can remove the encryption settings from the `kube-apiserver`.

Configure automatic reloading

You can configure automatic reloading of encryption provider configuration. That setting determines whether the API server should load the file you specify for `--encryption-provider-config` only once at startup, or automatically whenever you change that file. Enabling this option allows you to change the keys for encryption at rest without restarting the API server.

To allow automatic reloading, configure the API server to run with: `--encryption-provider-config-automatic-reload=true`. When enabled, file changes are polled every minute to observe the modifications. The `apiserver_encryption_config_controller_automatic_reload_last_timestamp_seconds` metric identifies when the new config becomes effective. This allows encryption keys to be rotated without restarting the API server.

What's next

- Read about decrypting data that are already stored at rest
- Learn more about the EncryptionConfiguration configuration API (v1).

Migrating telemetry and security agents from dockershim

Note: This section links to third party projects that provide functionality required by Kubernetes. The Kubernetes project authors aren't responsible for these projects, which are listed alphabetically. To add a project to this list, read the content guide before submitting a change. More information.

Kubernetes' support for direct integration with Docker Engine is deprecated and has been removed. Most apps do not have a direct dependency on runtime hosting containers. However, there are still a lot of telemetry and monitoring agents that have a dependency on Docker to collect containers metadata, logs, and metrics. This document aggregates information on how to detect these dependencies as well as links on how to migrate these agents to use generic tools or alternative runtimes.

Telemetry and security agents

Within a Kubernetes cluster there are a few different ways to run telemetry or security agents. Some agents have a direct dependency on Docker Engine when they run as DaemonSets or directly on nodes.

Why do some telemetry agents communicate with Docker Engine?

Historically, Kubernetes was written to work specifically with Docker Engine. Kubernetes took care of networking and scheduling, relying on Docker Engine for launching and running containers (within Pods) on a node. Some information that is relevant to telemetry, such as a pod name, is only available from Kubernetes components. Other data, such as container metrics, is not the responsibility of the container runtime. Early telemetry agents needed to query the container runtime *and* Kubernetes to report an accurate picture. Over time, Kubernetes gained the ability to support multiple runtimes, and now supports any runtime that is compatible with the container runtime interface.

Some telemetry agents rely specifically on Docker Engine tooling. For example, an agent might run a command such as `docker ps` or `docker top` to list containers and processes or `docker logs` to receive streamed logs. If nodes in your existing cluster use Docker Engine, and you switch to a different container runtime, these commands will not work any longer.

Identify DaemonSets that depend on Docker Engine

If a pod wants to make calls to the `dockerd` running on the node, the pod must either:

- mount the filesystem containing the Docker daemon's privileged socket, as a volume; or
- mount the specific path of the Docker daemon's privileged socket directly, also as a volume.

For example: on COS images, Docker exposes its Unix domain socket at `/var/run/docker.sock` This means that the pod spec will include a `hostPath` volume mount of `/var/run/docker.sock`.

Here's a sample shell script to find Pods that have a mount directly mapping the Docker socket. This script outputs the namespace and name of the pod. You can remove the `grep '/var/run/docker.sock'` to review other mounts.

```
kubectl get pods --all-namespaces \
-o=jsonpath='{range .items[*]}{"\n"}{.metadata.namespace}{":\t"}{.metadata.name}{":\t"}{range .spec.volumes[*]}{.hostPath.path}{",
```

Note:

There are alternative ways for a pod to access Docker on the host. For instance, the parent directory `/var/run` may be mounted instead of the full path (like in this example). The script above only detects the most common uses.

Detecting Docker dependency from node agents

If your cluster nodes are customized and install additional security and telemetry agents on the node, check with the agent vendor to verify whether it has any dependency on Docker.

Telemetry and security agent vendors

This section is intended to aggregate information about various telemetry and security agents that may have a dependency on container runtimes.

We keep the work in progress version of migration instructions for various telemetry and security agent vendors in Google doc. Please contact the vendor to get up to date instructions for migrating from dockershim.

Migration from dockershim

Aqua

No changes are needed: everything should work seamlessly on the runtime switch.

Datadog

How to migrate: Docker deprecation in Kubernetes The pod that accesses Docker Engine may have a name containing any of:

- `datadog-agent`
- `datadog`
- `dd-agent`

Dynatrace

How to migrate: Migrating from Docker-only to generic container metrics in Dynatrace

Containerd support announcement: Get automated full-stack visibility into containerd-based Kubernetes environments

CRI-O support announcement: Get automated full-stack visibility into your CRI-O Kubernetes containers (Beta)

The pod accessing Docker may have name containing:

- `dynatrace-oneagent`

Falco

How to migrate:

Migrate Falco from dockershim Falco supports any CRI-compatible runtime (containerd is used in the default configuration); the documentation explains all details. The pod accessing Docker may have name containing:

- `falco`

Prisma Cloud Compute

Check documentation for Prisma Cloud, under the "Install Prisma Cloud on a CRI (non-Docker) cluster" section. The pod accessing Docker may be named like:

- `twistlock-defender-ds`

SignalFx (Splunk)

The SignalFx Smart Agent (deprecated) uses several different monitors for Kubernetes including `kubernetes-cluster`, `kubelet-stats/kubelet-metrics`, and `docker-container-stats`. The `kubelet-stats` monitor was previously deprecated by the vendor, in favor of `kubelet-metrics`. The `docker-container-stats` monitor is the one affected by dockershim removal. Do not use the `docker-container-stats` with container runtimes other than Docker Engine.

How to migrate from dockershim-dependent agent:

1. Remove `docker-container-stats` from the list of configured monitors. Note, keeping this monitor enabled with non-dockershim runtime will result in incorrect metrics being reported when docker is installed on node and no metrics when docker is not installed.
2. Enable and configure `kubelet-metrics` monitor.

Note:

The set of collected metrics will change. Review your alerting rules and dashboards.

The Pod accessing Docker may be named something like:

- `signalfx-agent`

Yahoo Kubectl Flame

Flame does not support container runtimes other than Docker. See https://github.com/yahoo/kubectl-flame/issues/51

Using CoreDNS for Service Discovery

This page describes the CoreDNS upgrade process and how to install CoreDNS instead of kube-dns.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

Your Kubernetes server must be at or later than version v1.9.

To check the version, enter `kubectl version`.

About CoreDNS

CoreDNS is a flexible, extensible DNS server that can serve as the Kubernetes cluster DNS. Like Kubernetes, the CoreDNS project is hosted by the CNCF.

You can use CoreDNS instead of kube-dns in your cluster by replacing kube-dns in an existing deployment, or by using tools like kubeadm that will deploy and upgrade the cluster for you.

Installing CoreDNS

For manual deployment or replacement of kube-dns, see the documentation at the CoreDNS website.

Migrating to CoreDNS

Upgrading an existing cluster with kubeadm

In Kubernetes version 1.21, kubeadm removed its support for `kube-dns` as a DNS application. For `kubeadm` v1.34, the only supported cluster DNS application is CoreDNS.

You can move to CoreDNS when you use `kubeadm` to upgrade a cluster that is using `kube-dns`. In this case, `kubeadm` generates the CoreDNS configuration ("Corefile") based upon the `kube-dns` ConfigMap, preserving configurations for stub domains, and upstream name server.

Upgrading CoreDNS

You can check the version of CoreDNS that kubeadm installs for each version of Kubernetes in the page CoreDNS version in Kubernetes.

CoreDNS can be upgraded manually in case you want to only upgrade CoreDNS or use your own custom image. There is a helpful guideline and walkthrough available to ensure a smooth upgrade. Make sure the existing CoreDNS configuration ("Corefile") is retained when upgrading your cluster.

If you are upgrading your cluster using the `kubeadm` tool, `kubeadm` can take care of retaining the existing CoreDNS configuration automatically.

Tuning CoreDNS

When resource utilisation is a concern, it may be useful to tune the configuration of CoreDNS. For more details, check out the documentation on scaling CoreDNS.

What's next

You can configure CoreDNS to support many more use cases than kube-dns does by modifying the CoreDNS configuration ("Corefile"). For more information, see the documentation for the `kubernetes` CoreDNS plugin, or read the Custom DNS Entries for Kubernetes. in the CoreDNS blog.

Access Services Running on Clusters

This page shows how to connect to services running on the Kubernetes cluster.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud

- Play with Kubernetes

To check the version, enter `kubectl version`.

Accessing services running on the cluster

In Kubernetes, nodes, pods and services all have their own IPs. In many cases, the node IPs, pod IPs, and some service IPs on a cluster will not be routable, so they will not be reachable from a machine outside the cluster, such as your desktop machine.

Ways to connect

You have several options for connecting to nodes, pods and services from outside the cluster:

- Access services through public IPs.
  - Use a service with type `NodePort` or `LoadBalancer` to make the service reachable outside the cluster. See the services and kubectl expose documentation.
  - Depending on your cluster environment, this may only expose the service to your corporate network, or it may expose it to the internet. Think about whether the service being exposed is secure. Does it do its own authentication?
  - Place pods behind services. To access one specific pod from a set of replicas, such as for debugging, place a unique label on the pod and create a new service which selects this label.
  - In most cases, it should not be necessary for application developer to directly access nodes via their nodeIPs.
- Access services, nodes, or pods using the Proxy Verb.
  - Does apiserver authentication and authorization prior to accessing the remote service. Use this if the services are not secure enough to expose to the internet, or to gain access to ports on the node IP, or for debugging.
  - Proxies may cause problems for some web applications.
  - Only works for HTTP/HTTPS.
  - Described here.
- Access from a node or pod in the cluster.
  - Run a pod, and then connect to a shell in it using kubectl exec. Connect to other nodes, pods, and services from that shell.
  - Some clusters may allow you to ssh to a node in the cluster. From there you may be able to access cluster services. This is a non-standard method, and will work on some clusters but not others. Browsers and other tools may or may not be installed. Cluster DNS may not work.

Discovering builtin services

Typically, there are several services which are started on a cluster by kube-system. Get a list of these with the `kubectl cluster-info` command:

```
kubectl cluster-info
```

The output is similar to this:

```
Kubernetes master is running at https://192.0.2.1
elasticsearch-logging is running at https://192.0.2.1/api/v1/namespaces/kube-system/services/elasticsearch-logging/proxy
kibana-logging is running at https://192.0.2.1/api/v1/namespaces/kube-system/services/kibana-logging/proxy
kube-dns is running at https://192.0.2.1/api/v1/namespaces/kube-system/services/kube-dns/proxy
grafana is running at https://192.0.2.1/api/v1/namespaces/kube-system/services/monitoring-grafana/proxy
heapster is running at https://192.0.2.1/api/v1/namespaces/kube-system/services/monitoring-heapster/proxy
```

This shows the proxy-verb URL for accessing each service. For example, this cluster has cluster-level logging enabled (using Elasticsearch), which can be reached at `https://192.0.2.1/api/v1/namespaces/kube-system/services/elasticsearch-logging/proxy/` if suitable credentials are passed, or through a kubectl proxy at, for example: `http://localhost:8080/api/v1/namespaces/kube-system/services/elasticsearch-logging/proxy/`.

Note:

See Access Clusters Using the Kubernetes API for how to pass credentials or use kubectl proxy.

Manually constructing apiserver proxy URLs

As mentioned above, you use the `kubectl cluster-info` command to retrieve the service's proxy URL. To create proxy URLs that include service endpoints, suffixes, and parameters, you append to the service's proxy URL:
`http://`*`kubernetes_master_address`*`/api/v1/namespaces/`*`namespace_name`*`/services/`*`[https:]service_name[:port_name]`*`/proxy`

If you haven't specified a name for your port, you don't have to specify *port_name* in the URL. You can also use the port number in place of the *port_name* for both named and unnamed ports.

By default, the API server proxies to your service using HTTP. To use HTTPS, prefix the service name with `https:`:
`http://<kubernetes_master_address>/api/v1/namespaces/<namespace_name>/services/<service_name>/proxy`

The supported formats for the `<service_name>` segment of the URL are:

- `<service_name>` - proxies to the default or unnamed port using http
- `<service_name>:<port_name>` - proxies to the specified port name or port number using http
- `https:<service_name>:` - proxies to the default or unnamed port using https (note the trailing colon)
- `https:<service_name>:<port_name>` - proxies to the specified port name or port number using https

Examples

- To access the Elasticsearch service endpoint `_search?q=user:kimchy`, you would use:

  ```
  http://192.0.2.1/api/v1/namespaces/kube-system/services/elasticsearch-logging/proxy/_search?q=user:kimchy
  ```

- To access the Elasticsearch cluster health information `_cluster/health?pretty=true`, you would use:

```
https://192.0.2.1/api/v1/namespaces/kube-system/services/elasticsearch-logging/proxy/_cluster/health?pretty=true
```

The health information is similar to this:

```
{
  "cluster_name" : "kubernetes_logging",
  "status" : "yellow",
  "timed_out" : false,
  "number_of_nodes" : 1,
  "number_of_data_nodes" : 1,
  "active_primary_shards" : 5,
  "active_shards" : 5,
  "relocating_shards" : 0,
  "initializing_shards" : 0,
  "unassigned_shards" : 5
}
```

- To access the *https* Elasticsearch service health information `_cluster/health?pretty=true`, you would use:

```
https://192.0.2.1/api/v1/namespaces/kube-system/services/https:elasticsearch-logging:/proxy/_cluster/health?pretty=true
```

Using web browsers to access services running on the cluster

You may be able to put an apiserver proxy URL into the address bar of a browser. However:

- Web browsers cannot usually pass tokens, so you may need to use basic (password) auth. Apiserver can be configured to accept basic auth, but your cluster may not be configured to accept basic auth.
- Some web apps may not work, particularly those with client side javascript that construct URLs in a way that is unaware of the proxy path prefix.

List All Container Images Running in a Cluster

This page shows how to use kubectl to list all of the Container images for Pods running in a cluster.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

To check the version, enter `kubectl version`.

In this exercise you will use kubectl to fetch all of the Pods running in a cluster, and format the output to pull out the list of Containers for each.

List all Container images in all namespaces

- Fetch all Pods in all namespaces using `kubectl get pods --all-namespaces`
- Format the output to include only the list of Container image names using `-o jsonpath={.items[*].spec['initContainers', 'containers'][*].image}`. This will recursively parse out the `image` field from the returned json.
  - See the jsonpath reference for further information on how to use jsonpath.
- Format the output using standard tools: `tr`, `sort`, `uniq`
  - Use `tr` to replace spaces with newlines
  - Use `sort` to sort the results
  - Use `uniq` to aggregate image counts

```
kubectl get pods --all-namespaces -o jsonpath="{.items[*].spec['initContainers', 'containers'][*].image}" |\
tr -s '[[:space:]]' '\n' |\sort |\uniq -c
```

The jsonpath is interpreted as follows:

- `.items[*]`: for each returned value
- `.spec`: get the spec
- `['initContainers', 'containers'][*]`: for each container
- `.image`: get the image

Note:

When fetching a single Pod by name, for example `kubectl get pod nginx`, the `.items[*]` portion of the path should be omitted because a single Pod is returned instead of a list of items.

List Container images by Pod

The formatting can be controlled further by using the `range` operation to iterate over elements individually.

```
kubectl get pods --all-namespaces -o jsonpath='{range .items[*]}{"\n"}{.metadata.name}{":\t"}{range .spec.containers[*]}{.image}{"
sort
```

List Container images filtering by Pod label

To target only Pods matching a specific label, use the -l flag. The following matches only Pods with labels matching `app=nginx`.

```
kubectl get pods --all-namespaces -o jsonpath="{.items[*].spec.containers[*].image}" -l app=nginx
```

List Container images filtering by Pod namespace

To target only pods in a specific namespace, use the namespace flag. The following matches only Pods in the `kube-system` namespace.

```
kubectl get pods --namespace kube-system -o jsonpath="{.items[*].spec.containers[*].image}"
```

List Container images using a go-template instead of jsonpath

As an alternative to jsonpath, Kubectl supports using go-templates for formatting the output:

```
kubectl get pods --all-namespaces -o go-template --template="{{range .items}}{{range .spec.containers}}{{.image}} {{end}}{{end}}"
```

What's next

Reference

- Jsonpath reference guide
- Go template reference guide

Configuring a cgroup driver

This page explains how to configure the kubelet's cgroup driver to match the container runtime cgroup driver for kubeadm clusters.

Before you begin

You should be familiar with the Kubernetes container runtime requirements.

Configuring the container runtime cgroup driver

The Container runtimes page explains that the `systemd` driver is recommended for kubeadm based setups instead of the kubelet's default `cgroupfs` driver, because kubeadm manages the kubelet as a systemd service.

The page also provides details on how to set up a number of different container runtimes with the `systemd` driver by default.

Configuring the kubelet cgroup driver

kubeadm allows you to pass a `KubeletConfiguration` structure during `kubeadm init`. This `KubeletConfiguration` can include the `cgroupDriver` field which controls the cgroup driver of the kubelet.

Note:

In v1.22 and later, if the user does not set the `cgroupDriver` field under `KubeletConfiguration`, kubeadm defaults it to `systemd`.

In Kubernetes v1.28, you can enable automatic detection of the cgroup driver as an alpha feature. See systemd cgroup driver for more details.

A minimal example of configuring the field explicitly:

```
# kubeadm-config.yaml
kind: ClusterConfigurationapiVersion: kubeadm.k8s.io/v1beta4kubernetesVersion: v1.21.0---kind: KubeletConfigurationapiVersion: kub
```

Such a configuration file can then be passed to the kubeadm command:

```
kubeadm init --config kubeadm-config.yaml
```

Note:

Kubeadm uses the same `KubeletConfiguration` for all nodes in the cluster. The `KubeletConfiguration` is stored in a ConfigMap object under the `kube-system` namespace.

Executing the sub commands `init`, `join` and `upgrade` would result in kubeadm writing the `KubeletConfiguration` as a file under `/var/lib/kubelet/config.yaml` and passing it to the local node kubelet.

On each node, kubeadm detects the CRI socket and stores its details into the `/var/lib/kubelet/instance-config.yaml` file. When executing the `init`, `join`, or `upgrade` subcommands, kubeadm patches the `containerRuntimeEndpoint` value from this instance configuration into `/var/lib/kubelet/config.yaml`.

Using the `cgroupfs` driver

To use `cgroupfs` and to prevent `kubeadm upgrade` from modifying the `KubeletConfiguration` cgroup driver on existing setups, you must be explicit about its value. This applies to a case where you do not wish future versions of kubeadm to apply the `systemd` driver by default.

See the below section on "Modify the kubelet ConfigMap" for details on how to be explicit about the value.

If you wish to configure a container runtime to use the `cgroupfs` driver, you must refer to the documentation of the container runtime of your choice.

Migrating to the `systemd` driver

To change the cgroup driver of an existing kubeadm cluster from `cgroupfs` to `systemd` in-place, a similar procedure to a kubelet upgrade is required. This must include both steps outlined below.

Note:

Alternatively, it is possible to replace the old nodes in the cluster with new ones that use the `systemd` driver. This requires executing only the first step below before joining the new nodes and ensuring the workloads can safely move to the new nodes before deleting the old nodes.

Modify the kubelet ConfigMap

- Call `kubectl edit cm kubelet-config -n kube-system`.
- Either modify the existing `cgroupDriver` value or add a new field that looks like this:

  ```
  cgroupDriver: systemd
  ```

  This field must be present under the `kubelet:` section of the ConfigMap.

Update the cgroup driver on all nodes

For each node in the cluster:

- Drain the node using `kubectl drain <node-name> --ignore-daemonsets`
- Stop the kubelet using `systemctl stop kubelet`
- Stop the container runtime
- Modify the container runtime cgroup driver to `systemd`
- Set `cgroupDriver: systemd` in `/var/lib/kubelet/config.yaml`
- Start the container runtime
- Start the kubelet using `systemctl start kubelet`
- Uncordon the node using `kubectl uncordon <node-name>`

Execute these steps on nodes one at a time to ensure workloads have sufficient time to schedule on different nodes.

Once the process is complete ensure that all nodes and workloads are healthy.

Decrypt Confidential Data that is Already Encrypted at Rest

All of the APIs in Kubernetes that let you write persistent API resource data support at-rest encryption. For example, you can enable at-rest encryption for Secrets. This at-rest encryption is additional to any system-level encryption for the etcd cluster or for the filesystem(s) on hosts where you are running the kube-apiserver.

This page shows how to switch from encryption of API data at rest, so that API data are stored unencrypted. You might want to do this to improve performance; usually, though, if it was a good idea to encrypt some data, it's also a good idea to leave them encrypted.

Note:

This task covers encryption for resource data stored using the Kubernetes API. For example, you can encrypt Secret objects, including the key-value data they contain.

If you wanted to manage encryption for data in filesystems that are mounted into containers, you instead need to either:

- use a storage integration that provides encrypted volumes
- encrypt the data within your own application

Before you begin

- You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:
  - iximiuz Labs
  - Killercoda
  - KodeKloud
  - Play with Kubernetes
- This task assumes that you are running the Kubernetes API server as a static pod on each control plane node.
- Your cluster's control plane **must** use etcd v3.x (major version 3, any minor version).

- To encrypt a custom resource, your cluster must be running Kubernetes v1.26 or newer.
- You should have some API data that are already encrypted.

To check the version, enter `kubectl version`.

Determine whether encryption at rest is already enabled

By default, the API server uses an `identity` provider that stores plain-text representations of resources. **The default `identity` provider does not provide any confidentiality protection.**

The `kube-apiserver` process accepts an argument `--encryption-provider-config` that specifies a path to a configuration file. The contents of that file, if you specify one, control how Kubernetes API data is encrypted in etcd. If it is not specified, you do not have encryption at rest enabled.

The format of that configuration file is YAML, representing a configuration API kind named `EncryptionConfiguration`. You can see an example configuration in Encryption at rest configuration.

If `--encryption-provider-config` is set, check which resources (such as `secrets`) are configured for encryption, and what provider is used. Make sure that the preferred provider for that resource type is **not** `identity`; you only set `identity` (*no encryption*) as default when you want to disable encryption at rest. Verify that the first-listed provider for a resource is something **other** than `identity`, which means that any new information written to resources of that type will be encrypted as configured. If you do see `identity` as the first-listed provider for any resource, this means that those resources are being written out to etcd without encryption.

Decrypt all data

This example shows how to stop encrypting the Secret API at rest. If you are encrypting other API kinds, adjust the steps to match.

Locate the encryption configuration file

First, find the API server configuration files. On each control plane node, static Pod manifest for the kube-apiserver specifies a command line argument, `--encryption-provider-config`. You are likely to find that this file is mounted into the static Pod using a `hostPath` volume mount. Once you locate the volume you can find the file on the node filesystem and inspect it.

Configure the API server to decrypt objects

To disable encryption at rest, place the `identity` provider as the first entry in your encryption configuration file.

For example, if your existing EncryptionConfiguration file reads:

```
---
apiVersion: apiserver.config.k8s.io/v1kind: EncryptionConfigurationresources:  - resources:      - secrets    providers:      - aes
```

then change it to:

```
---
apiVersion: apiserver.config.k8s.io/v1kind: EncryptionConfigurationresources:  - resources:      - secrets    providers:      - ide
```

and restart the kube-apiserver Pod on this node.

Reconfigure other control plane hosts

If you have multiple API servers in your cluster, you should deploy the changes in turn to each API server.

Make sure that you use the same encryption configuration on each control plane host.

Force decryption

Then run the following command to force decryption of all Secrets:

```
# If you are decrypting a different kind of object, change "secrets" to match.
kubectl get secrets --all-namespaces -o json | kubectl replace -f -
```

Once you have replaced **all** existing encrypted resources with backing data that don't use encryption, you can remove the encryption settings from the `kube-apiserver`.

The command line options to remove are:

- `--encryption-provider-config`
- `--encryption-provider-config-automatic-reload`

Restart the kube-apiserver Pod again to apply the new configuration.

Reconfigure other control plane hosts

If you have multiple API servers in your cluster, you should again deploy the changes in turn to each API server.

Make sure that you use the same encryption configuration on each control plane host.

What's next

- Learn more about the EncryptionConfiguration configuration API (v1).

Access Clusters Using the Kubernetes API

This page shows how to access clusters using the Kubernetes API.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

To check the version, enter `kubectl version`.

Accessing the Kubernetes API

Accessing for the first time with kubectl

When accessing the Kubernetes API for the first time, use the Kubernetes command-line tool, `kubectl`.

To access a cluster, you need to know the location of the cluster and have credentials to access it. Typically, this is automatically set-up when you work through a Getting started guide, or someone else set up the cluster and provided you with credentials and a location.

Check the location and credentials that kubectl knows about with this command:

```
kubectl config view
```

Many of the examples provide an introduction to using kubectl. Complete documentation is found in the kubectl manual.

Directly accessing the REST API

kubectl handles locating and authenticating to the API server. If you want to directly access the REST API with an http client like `curl` or `wget`, or a browser, there are multiple ways you can locate and authenticate against the API server:

1. Run kubectl in proxy mode (recommended). This method is recommended, since it uses the stored API server location and verifies the identity of the API server using a self-signed certificate. No man-in-the-middle (MITM) attack is possible using this method.
2. Alternatively, you can provide the location and credentials directly to the http client. This works with client code that is confused by proxies. To protect against man in the middle attacks, you'll need to import a root cert into your browser.

Using the Go or Python client libraries provides accessing kubectl in proxy mode.

Using kubectl proxy

The following command runs kubectl in a mode where it acts as a reverse proxy. It handles locating the API server and authenticating.

Run it like this:

```
kubectl proxy --port=8080 &
```

See kubectl proxy for more details.

Then you can explore the API with curl, wget, or a browser, like so:

```
curl http://localhost:8080/api/
```

The output is similar to this:

```
{
  "versions": [
    "v1"
  ],
  "serverAddressByClientCIDRs": [
    {
      "clientCIDR": "0.0.0.0/0",
      "serverAddress": "10.0.1.149:443"
    }
  ]
}
```

Without kubectl proxy

It is possible to avoid using kubectl proxy by passing an authentication token directly to the API server, like this:

Using `grep/cut` approach:

```
# Check all possible clusters, as your .KUBECONFIG may have multiple contexts:
kubectl config view -o jsonpath='{"Cluster name\tServer\n"}{range .clusters[*]}{.name}{"\t"}{.cluster.server}{"\n"}{end}'

# Select name of cluster you want to interact with from above output:
export CLUSTER_NAME="some_server_name"

# Point to the API server referring the cluster name
APISERVER=$(kubectl config view -o jsonpath="{.clusters[?(@.name==\"$CLUSTER_NAME\")].cluster.server}")

# Create a secret to hold a token for the default service account
kubectl apply -f - <<EOF
apiVersion: v1
kind: Secret
metadata:
  name: default-token
  annotations:
    kubernetes.io/service-account.name: default
type: kubernetes.io/service-account-token
EOF

# Wait for the token controller to populate the secret with a token:
while ! kubectl describe secret default-token | grep -E '^token' >/dev/null; do
  echo "waiting for token..." >&2
  sleep 1
done

# Get the token value
TOKEN=$(kubectl get secret default-token -o jsonpath='{.data.token}' | base64 --decode)

# Explore the API with TOKEN
curl -X GET $APISERVER/api --header "Authorization: Bearer $TOKEN" --insecure
```

The output is similar to this:


```
{
  "kind": "APIVersions",
  "versions": [
    "v1"
  ],
  "serverAddressByClientCIDRs": [
    {
      "clientCIDR": "0.0.0.0/0",
      "serverAddress": "10.0.1.149:443"
    }
  ]
}
```


The above example uses the `--insecure` flag. This leaves it subject to MITM attacks. When kubectl accesses the cluster it uses a stored root certificate and client certificates to access the server. (These are installed in the `~/.kube` directory). Since cluster certificates are typically self-signed, it may take special configuration to get your http client to use root certificate.

On some clusters, the API server does not require authentication; it may serve on localhost, or be protected by a firewall. There is not a standard for this. Controlling Access to the Kubernetes API describes how you can configure this as a cluster administrator.

Programmatic access to the API

Kubernetes officially supports client libraries for Go, Python, Java, dotnet, JavaScript, and Haskell. There are other client libraries that are provided and maintained by their authors, not the Kubernetes team. See client libraries for accessing the API from other languages and how they authenticate.

Go client

- To get the library, run the following command: `go get k8s.io/client-go@kubernetes-<kubernetes-version-number>` See https://github.com/kubernetes/client-go/releases to see which versions are supported.
- Write an application atop of the client-go clients.

Note:

`client-go` defines its own API objects, so if needed, import API definitions from client-go rather than from the main repository. For example, `import "k8s.io/client-go/kubernetes"` is correct.

The Go client can use the same kubeconfig file as the kubectl CLI does to locate and authenticate to the API server. See this example:

```
package main

import (
  "context"
  "fmt"
  "k8s.io/apimachinery/pkg/apis/meta/v1"
  "k8s.io/client-go/kubernetes"
  "k8s.io/client-go/tools/clientcmd"
)

func main() {
  // uses the current context in kubeconfig
  // path-to-kubeconfig -- for example, /root/.kube/config  config, _ := clientcmd.BuildConfigFromFlags("", "<path-to-kubeconfig>"
```

If the application is deployed as a Pod in the cluster, see Accessing the API from within a Pod.

Python client

To use Python client, run the following command: `pip install kubernetes`. See Python Client Library page for more installation options.

The Python client can use the same kubeconfig file as the kubectl CLI does to locate and authenticate to the API server. See this example:

```
from kubernetes import client, config

config.load_kube_config()

v1=client.CoreV1Api()
print("Listing pods with their IPs:")
ret = v1.list_pod_for_all_namespaces(watch=False)
for i in ret.items:
    print("%s\t%s\t%s" % (i.status.pod_ip, i.metadata.namespace, i.metadata.name))
```

Java client

To install the Java Client, run:

```
# Clone java library
git clone --recursive https://github.com/kubernetes-client/java

# Installing project artifacts, POM etc:
cd java
mvn install
```

See https://github.com/kubernetes-client/java/releases to see which versions are supported.

The Java client can use the same kubeconfig file as the kubectl CLI does to locate and authenticate to the API server. See this example:

```
package io.kubernetes.client.examples;

import io.kubernetes.client.ApiClient;import io.kubernetes.client.ApiException;import io.kubernetes.client.Configuration;import io
```

dotnet client

To use dotnet client, run the following command: `dotnet add package KubernetesClient --version 1.6.1`. See dotnet Client Library page for more installation options. See https://github.com/kubernetes-client/csharp/releases to see which versions are supported.

The dotnet client can use the same kubeconfig file as the kubectl CLI does to locate and authenticate to the API server. See this example:

```
using System;
using k8s;

namespace simple
{
    internal class PodList
    {
        private static void Main(string[] args)
        {
            var config = KubernetesClientConfiguration.BuildDefaultConfig();
            IKubernetes client = new Kubernetes(config);
            Console.WriteLine("Starting Request!");

            var list = client.ListNamespacedPod("default");
            foreach (var item in list.Items)
            {
                Console.WriteLine(item.Metadata.Name);
            }
            if (list.Items.Count == 0)
            {
                Console.WriteLine("Empty!");
            }
        }
    }
}
```

JavaScript client

To install JavaScript client, run the following command: `npm install @kubernetes/client-node`. See https://github.com/kubernetes-client/javascript/releases to see which versions are supported.

The JavaScript client can use the same kubeconfig file as the kubectl CLI does to locate and authenticate to the API server. See this example:

```
const k8s = require('@kubernetes/client-node');

const kc = new k8s.KubeConfig();
kc.loadFromDefault();

const k8sApi = kc.makeApiClient(k8s.CoreV1Api);

k8sApi.listNamespacedPod({ namespace: 'default' }).then((res) => {
    console.log(res);
});
```

Haskell client

See https://github.com/kubernetes-client/haskell/releases to see which versions are supported.

The Haskell client can use the same kubeconfig file as the kubectl CLI does to locate and authenticate to the API server. See this example:

```
exampleWithKubeConfig :: IO ()
exampleWithKubeConfig = do
    oidcCache <- atomically $ newTVar $ Map.fromList []
    (mgr, kcfg) <- mkKubeClientConfig oidcCache $ KubeConfigFile "/path/to/kubeconfig"
    dispatchMime
            mgr
            kcfg
            (CoreV1.listPodForAllNamespaces (Accept MimeJSON))
        >>= print
```

What's next

- Accessing the Kubernetes API from a Pod

Use Cilium for NetworkPolicy

This page shows how to use Cilium for NetworkPolicy.

For background on Cilium, read the Introduction to Cilium.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

To check the version, enter `kubectl version`.

Deploying Cilium on Minikube for Basic Testing

To get familiar with Cilium easily you can follow the Cilium Kubernetes Getting Started Guide to perform a basic DaemonSet installation of Cilium in minikube.

To start minikube, minimal version required is >= v1.5.2, run the with the following arguments:

```
minikube version
```

```
minikube version: v1.5.2
```

```
minikube start --network-plugin=cni
```

For minikube you can install Cilium using its CLI tool. To do so, first download the latest version of the CLI with the following command:

```
curl -LO https://github.com/cilium/cilium-cli/releases/latest/download/cilium-linux-amd64.tar.gz
```

Then extract the downloaded file to your `/usr/local/bin` directory with the following command:

```
sudo tar xzvfC cilium-linux-amd64.tar.gz /usr/local/bin
rm cilium-linux-amd64.tar.gz
```

After running the above commands, you can now install Cilium with the following command:

```
cilium install
```

Cilium will then automatically detect the cluster configuration and create and install the appropriate components for a successful installation. The components are:

- Certificate Authority (CA) in Secret `cilium-ca` and certificates for Hubble (Cilium's observability layer).
- Service accounts.
- Cluster roles.
- ConfigMap.
- Agent DaemonSet and an Operator Deployment.

After the installation, you can view the overall status of the Cilium deployment with the `cilium status` command. See the expected output of the `status` command here.

The remainder of the Getting Started Guide explains how to enforce both L3/L4 (i.e., IP address + port) security policies, as well as L7 (e.g., HTTP) security policies using an example application.

Deploying Cilium for Production Use

For detailed instructions around deploying Cilium for production, see: Cilium Kubernetes Installation Guide This documentation includes detailed requirements, instructions and example production DaemonSet files.

Understanding Cilium components

Deploying a cluster with Cilium adds Pods to the `kube-system` namespace. To see this list of Pods run:

```
kubectl get pods --namespace=kube-system -l k8s-app=cilium
```

You'll see a list of Pods similar to this:

```
NAME           READY   STATUS    RESTARTS   AGE
cilium-kkdhz   1/1     Running   0          3m23s
...
```

A `cilium` Pod runs on each node in your cluster and enforces network policy on the traffic to/from Pods on that node using Linux BPF.

What's next

Once your cluster is running, you can follow the Declare Network Policy to try out Kubernetes NetworkPolicy with Cilium. Have fun, and if you have questions, contact us using the Cilium Slack Channel.

Install a Network Policy Provider

Use Antrea for NetworkPolicy

Use Calico for NetworkPolicy

Use Cilium for NetworkPolicy

Use Kube-router for NetworkPolicy

Romana for NetworkPolicy

Weave Net for NetworkPolicy

Cloud Controller Manager Administration

FEATURE STATE: `Kubernetes v1.11 [beta]`

Since cloud providers develop and release at a different pace compared to the Kubernetes project, abstracting the provider-specific code to the `cloud-controller-manager` binary allows cloud vendors to evolve independently from the core Kubernetes code.

The `cloud-controller-manager` can be linked to any cloud provider that satisfies cloudprovider.Interface. For backwards compatibility, the cloud-controller-manager provided in the core Kubernetes project uses the same cloud libraries as `kube-controller-manager`. Cloud providers already supported in Kubernetes core are expected to use the in-tree cloud-controller-manager to transition out of Kubernetes core.

Administration

Requirements

Every cloud has their own set of requirements for running their own cloud provider integration, it should not be too different from the requirements when running `kube-controller-manager`. As a general rule of thumb you'll need:

- cloud authentication/authorization: your cloud may require a token or IAM rules to allow access to their APIs
- kubernetes authentication/authorization: cloud-controller-manager may need RBAC rules set to speak to the kubernetes apiserver
- high availability: like kube-controller-manager, you may want a high available setup for cloud controller manager using leader election (on by default).

Running cloud-controller-manager

Successfully running cloud-controller-manager requires some changes to your cluster configuration.

- `kubelet`, `kube-apiserver`, and `kube-controller-manager` must be set according to the user's usage of external CCM. If the user has an external CCM (not the internal cloud controller loops in the Kubernetes Controller Manager), then `--cloud-provider=external` must be specified. Otherwise, it should not be specified.

Keep in mind that setting up your cluster to use cloud controller manager will change your cluster behaviour in a few ways:

- Components that specify `--cloud-provider=external` will add a taint `node.cloudprovider.kubernetes.io/uninitialized` with an effect `NoSchedule` during initialization. This marks the node as needing a second initialization from an external controller before it can be scheduled work. Note that in the event that cloud controller manager is not available, new nodes in the cluster will be left unschedulable. The taint is important since the scheduler may require cloud specific information about nodes such as their region or type (high cpu, gpu, high memory, spot instance, etc).
- cloud information about nodes in the cluster will no longer be retrieved using local metadata, but instead all API calls to retrieve node information will go through cloud controller manager. This may mean you can restrict access to your cloud API on the kubelets for better security. For larger clusters you may want to consider if cloud controller manager will hit rate limits since it is now responsible for almost all API calls to your cloud from within the cluster.

The cloud controller manager can implement:

- Node controller - responsible for updating kubernetes nodes using cloud APIs and deleting kubernetes nodes that were deleted on your cloud.
- Service controller - responsible for loadbalancers on your cloud against services of type LoadBalancer.
- Route controller - responsible for setting up network routes on your cloud
- any other features you would like to implement if you are running an out-of-tree provider.

Examples

If you are using a cloud that is currently supported in Kubernetes core and would like to adopt cloud controller manager, see the cloud controller manager in kubernetes core.

For cloud controller managers not in Kubernetes core, you can find the respective projects in repositories maintained by cloud vendors or by SIGs.

For providers already in Kubernetes core, you can run the in-tree cloud controller manager as a DaemonSet in your cluster, use the following as a guideline:

admin/cloud/ccm-example.yaml Copy admin/cloud/ccm-example.yaml to clipboard

```
# This is an example of how to set up cloud-controller-manager as a Daemonset in your cluster.
# It assumes that your masters can run pods and has the role node-role.kubernetes.io/master# Note that this Daemonset will not wor
```

Limitations

Running cloud controller manager comes with a few possible limitations. Although these limitations are being addressed in upcoming releases, it's important that you are aware of these limitations for production workloads.

Support for Volumes

Cloud controller manager does not implement any of the volume controllers found in `kube-controller-manager` as the volume integrations also require coordination with kubelets. As we evolve CSI (container storage interface) and add stronger support for flex volume plugins, necessary support will be added to cloud controller manager so that clouds can fully integrate with volumes. Learn more about out-of-tree CSI volume plugins here.

Scalability

The cloud-controller-manager queries your cloud provider's APIs to retrieve information for all nodes. For very large clusters, consider possible bottlenecks such as resource requirements and API rate limiting.

Chicken and Egg

The goal of the cloud controller manager project is to decouple development of cloud features from the core Kubernetes project. Unfortunately, many aspects of the Kubernetes project has assumptions that cloud provider features are tightly integrated into the project. As a result, adopting this new architecture can create several situations where a request is being made for information from a cloud provider, but the cloud controller manager may not be able to return that information without the original request being complete.

A good example of this is the TLS bootstrapping feature in the Kubelet. TLS bootstrapping assumes that the Kubelet has the ability to ask the cloud provider (or a local metadata service) for all its address types (private, public, etc) but cloud controller manager cannot set a node's address types without being initialized in the first place which requires that the kubelet has TLS certificates to communicate with the apiserver.

As this initiative evolves, changes will be made to address these issues in upcoming releases.

What's next

To build and develop your own cloud controller manager, read Developing Cloud Controller Manager.

Configure Default CPU Requests and Limits for a Namespace

Define a default CPU resource limits for a namespace, so that every new Pod in that namespace has a CPU resource limit configured.

This page shows how to configure default CPU requests and limits for a namespace.

A Kubernetes cluster can be divided into namespaces. If you create a Pod within a namespace that has a default CPU limit, and any container in that Pod does not specify its own CPU limit, then the control plane assigns the default CPU limit to that container.

Kubernetes assigns a default CPU request, but only under certain conditions that are explained later in this page.

Before you begin

You need to have a Kubernetes cluster, and the kubectl command-line tool must be configured to communicate with your cluster. It is recommended to run this tutorial on a cluster with at least two nodes that are not acting as control plane hosts. If you do not already have a cluster, you can create one by using minikube or you can use one of these Kubernetes playgrounds:

- iximiuz Labs
- Killercoda
- KodeKloud
- Play with Kubernetes

You must have access to create namespaces in your cluster.

If you're not already familiar with what Kubernetes means by 1.0 CPU, read meaning of CPU.

Create a namespace

Create a namespace so that the resources you create in this exercise are isolated from the rest of your cluster.

```
kubectl create namespace default-cpu-example
```

Create a LimitRange and a Pod

Here's a manifest for an example LimitRange. The manifest specifies a default CPU request and a default CPU limit.

admin/resource/cpu-defaults.yaml 


```
apiVersion: v1
kind: LimitRangemetadata:  name: cpu-limit-rangespec:  limits:  - default:      cpu: 1    defaultRequest:      cpu: 0.5    type: C
```

Create the LimitRange in the default-cpu-example namespace:

```
kubectl apply -f https://k8s.io/examples/admin/resource/cpu-defaults.yaml --namespace=default-cpu-example
```

Now if you create a Pod in the default-cpu-example namespace, and any container in that Pod does not specify its own values for CPU request and CPU limit, then the control plane applies default values: a CPU request of 0.5 and a default CPU limit of 1.

Here's a manifest for a Pod that has one container. The container does not specify a CPU request and limit.

admin/resource/cpu-defaults-pod.yaml


```
apiVersion: v1
kind: Podmetadata:  name: default-cpu-demospec:  containers:  - name: default-cpu-demo-ctr    image: nginx
```

Create the Pod.

```
kubectl apply -f https://k8s.io/examples/admin/resource/cpu-defaults-pod.yaml --namespace=default-cpu-example
```

View the Pod's specification:

```
kubectl get pod default-cpu-demo --output=yaml --namespace=default-cpu-example
```

The output shows that the Pod's only container has a CPU request of 500m `cpu` (which you can read as “500 millicpu”), and a CPU limit of 1 `cpu`. These are the default values specified by the LimitRange.

```
containers:
- image: nginx
  imagePullPolicy: Always
  name: default-cpu-demo-ctr
  resources:
    limits:
      cpu: "1"
    requests:
      cpu: 500m
```

What if you specify a container's limit, but not its request?

Here's a manifest for a Pod that has one container. The container specifies a CPU limit, but not a request:

admin/resource/cpu-defaults-pod-2.yaml 


```
apiVersion: v1
kind: Podmetadata:  name: default-cpu-demo-2spec:  containers:  - name: default-cpu-demo-2-ctr    image: nginx    resources:
```

Create the Pod:

```
kubectl apply -f https://k8s.io/examples/admin/resource/cpu-defaults-pod-2.yaml --namespace=default-cpu-example
```

View the specification of the Pod that you created:

```
kubectl get pod default-cpu-demo-2 --output=yaml --namespace=default-cpu-example
```

The output shows that the container's CPU request is set to match its CPU limit. Notice that the container was not assigned the default CPU request value of 0.5 `cpu`:

```
resources:
  limits:
    cpu: "1"
  requests:
    cpu: "1"
```

What if you specify a container's request, but not its limit?

Here's an example manifest for a Pod that has one container. The container specifies a CPU request, but not a limit:

admin/resource/cpu-defaults-pod-3.yaml 


```
apiVersion: v1
kind: Podmetadata:  name: default-cpu-demo-3spec:  containers:  - name: default-cpu-demo-3-ctr    image: nginx    resources:
```

Create the Pod:

```
kubectl apply -f https://k8s.io/examples/admin/resource/cpu-defaults-pod-3.yaml --namespace=default-cpu-example
```

View the specification of the Pod that you created:

```
kubectl get pod default-cpu-demo-3 --output=yaml --namespace=default-cpu-example
```

The output shows that the container's CPU request is set to the value you specified at the time you created the Pod (in other words: it matches the manifest). However, the same container's CPU limit is set to 1 `cpu`, which is the default CPU limit for that namespace.

```
resources:
  limits:
    cpu: "1"
  requests:
    cpu: 750m
```

Motivation for default CPU limits and requests

If your namespace has a CPU resource quota configured, it is helpful to have a default value in place for CPU limit. Here are two of the restrictions that a CPU resource quota imposes on a namespace:

- For every Pod that runs in the namespace, each of its containers must have a CPU limit.
- CPU limits apply a resource reservation on the node where the Pod in question is scheduled. The total amount of CPU that is reserved for use by all Pods in the namespace must not exceed a specified limit.

When you add a LimitRange:

If any Pod in that namespace that includes a container does not specify its own CPU limit, the control plane applies the default CPU limit to that container, and the Pod can be allowed to run in a namespace that is restricted by a CPU ResourceQuota.

Clean up

Delete your namespace:

```
kubectl delete namespace default-cpu-example
```

What's next

For cluster administrators

- Configure Default Memory Requests and Limits for a Namespace
- Configure Minimum and Maximum Memory Constraints for a Namespace
- Configure Minimum and Maximum CPU Constraints for a Namespace
- Configure Memory and CPU Quotas for a Namespace
- Configure a Pod Quota for a Namespace
- Configure Quotas for API Objects

For app developers

- Assign Memory Resources to Containers and Pods
- Assign CPU Resources to Containers and Pods
- Assign Pod-level CPU and memory resources
- Configure Quality of Service for Pods

Changing The Kubernetes Package Repository

This page explains how to enable a package repository for the desired Kubernetes minor release upon upgrading a cluster. This is only needed for users of the community-owned package repositories hosted at `pkgs.k8s.io`. Unlike the legacy package repositories, the community-owned package repositories are structured in a way that there's a dedicated package repository for each Kubernetes minor version.

Note:

This guide only covers a part of the Kubernetes upgrade process. Please see the upgrade guide for more information about upgrading Kubernetes clusters.

Note:

This step is only needed upon upgrading a cluster to another **minor** release. If you're upgrading to another patch release within the same minor release (e.g. v1.34.5 to v1.34.7), you don't need to follow this guide. However, if you're still using the legacy package repositories, you'll need to migrate to the new community-owned package repositories before upgrading (see the next section for more details on how to do this).

Before you begin

This document assumes that you're already using the community-owned package repositories (`pkgs.k8s.io`). If that's not the case, it's strongly recommended to migrate to the community-owned package repositories as described in the official announcement.

Note: The legacy package repositories (`apt.kubernetes.io` and `yum.kubernetes.io`) have been deprecated and frozen starting from September 13, 2023. **Using the new package repositories hosted at `pkgs.k8s.io` is strongly recommended and required in order to install Kubernetes versions released after September 13, 2023.** The deprecated legacy repositories, and their contents, might be removed at any time in the future and without a further notice period. The new package repositories provide downloads for Kubernetes versions starting with v1.24.0.

Verifying if the Kubernetes package repositories are used

If you're unsure whether you're using the community-owned package repositories or the legacy package repositories, take the following steps to verify:

- Ubuntu, Debian or HypriotOS
- CentOS, RHEL or Fedora
- openSUSE or SLES

Print the contents of the file that defines the Kubernetes `apt` repository:

```
# On your system, this configuration file could have a different name
pager /etc/apt/sources.list.d/kubernetes.list
```

If you see a line similar to:

```
deb [signed-by=/etc/apt/keyrings/kubernetes-apt-keyring.gpg] https://pkgs.k8s.io/core:/stable:/v1.33/deb/ /
```

You're using the Kubernetes package repositories and this guide applies to you. Otherwise, it's strongly recommended to migrate to the Kubernetes package repositories as described in the official announcement.

Print the contents of the file that defines the Kubernetes `yum` repository:

```
# On your system, this configuration file could have a different name
cat /etc/yum.repos.d/kubernetes.repo
```

If you see a `baseurl` similar to the `baseurl` in the output below:

```
[kubernetes]
name=Kubernetes
baseurl=https://pkgs.k8s.io/core:/stable:/v1.33/rpm/
enabled=1
gpgcheck=1
gpgkey=https://pkgs.k8s.io/core:/stable:/v1.33/rpm/repodata/repomd.xml.key
exclude=kubelet kubeadm kubectl
```

You're using the Kubernetes package repositories and this guide applies to you. Otherwise, it's strongly recommended to migrate to the Kubernetes package repositories as described in the official announcement.

Print the contents of the file that defines the Kubernetes `zypper` repository:

```
# On your system, this configuration file could have a different name
cat /etc/zypp/repos.d/kubernetes.repo
```

If you see a `baseurl` similar to the `baseurl` in the output below:

```
[kubernetes]
name=Kubernetes
baseurl=https://pkgs.k8s.io/core:/stable:/v1.33/rpm/
enabled=1
gpgcheck=1
gpgkey=https://pkgs.k8s.io/core:/stable:/v1.33/rpm/repodata/repomd.xml.key
exclude=kubelet kubeadm kubectl
```

You're using the Kubernetes package repositories and this guide applies to you. Otherwise, it's strongly recommended to migrate to the Kubernetes package repositories as described in the official announcement.

Note:

The URL used for the Kubernetes package repositories is not limited to `pkgs.k8s.io`, it can also be one of:

- `pkgs.k8s.io`
- `pkgs.kubernetes.io`
- `packages.kubernetes.io`

Switching to another Kubernetes package repository

This step should be done upon upgrading from one to another Kubernetes minor release in order to get access to the packages of the desired Kubernetes minor version.

- Ubuntu, Debian or HypriotOS
- CentOS, RHEL or Fedora

1. Open the file that defines the Kubernetes `apt` repository using a text editor of your choice:

   ```
   nano /etc/apt/sources.list.d/kubernetes.list
   ```

You should see a single line with the URL that contains your current Kubernetes minor version. For example, if you're using v1.33, you should see this:

```
deb [signed-by=/etc/apt/keyrings/kubernetes-apt-keyring.gpg] https://pkgs.k8s.io/core:/stable:/v1.33/deb/ /
```

2. Change the version in the URL to **the next available minor release**, for example:

```
deb [signed-by=/etc/apt/keyrings/kubernetes-apt-keyring.gpg] https://pkgs.k8s.io/core:/stable:/v1.34/deb/ /
```

3. Save the file and exit your text editor. Continue following the relevant upgrade instructions.

1. Open the file that defines the Kubernetes `yum` repository using a text editor of your choice:

```
nano /etc/yum.repos.d/kubernetes.repo
```

You should see a file with two URLs that contain your current Kubernetes minor version. For example, if you're using v1.33, you should see this:

```
[kubernetes]
name=Kubernetes
baseurl=https://pkgs.k8s.io/core:/stable:/v1.33/rpm/
enabled=1
gpgcheck=1
gpgkey=https://pkgs.k8s.io/core:/stable:/v1.33/rpm/repodata/repomd.xml.key
exclude=kubelet kubeadm kubectl cri-tools kubernetes-cni
```

2. Change the version in these URLs to **the next available minor release**, for example:

```
[kubernetes]
name=Kubernetes
baseurl=https://pkgs.k8s.io/core:/stable:/v1.34/rpm/
enabled=1
gpgcheck=1
gpgkey=https://pkgs.k8s.io/core:/stable:/v1.34/rpm/repodata/repomd.xml.key
exclude=kubelet kubeadm kubectl cri-tools kubernetes-cni
```

3. Save the file and exit your text editor. Continue following the relevant upgrade instructions.

What's next

- See how to Upgrade Linux nodes.
- See how to Upgrade Windows nodes.

Administer a Cluster

Learn common tasks for administering a cluster.

Administration with kubeadm

Overprovision Node Capacity For A Cluster

Migrating from dockershim

Generate Certificates Manually

Manage Memory, CPU, and API Resources

Install a Network Policy Provider

Access Clusters Using the Kubernetes API

Advertise Extended Resources for a Node

Autoscale the DNS Service in a Cluster

Change the Access Mode of a PersistentVolume to ReadWriteOncePod

Change the default StorageClass

Switching from Polling to CRI Event-based Updates to Container Status

Change the Reclaim Policy of a PersistentVolume

Cloud Controller Manager Administration

Configure a kubelet image credential provider

Configure Quotas for API Objects

Control CPU Management Policies on the Node

Configure DNS for a Cluster

Kubernetes offers a DNS cluster addon, which most of the supported environments enable by default. In Kubernetes version 1.11 and later, CoreDNS is recommended and is installed by default with kubeadm.

For more information on how to configure CoreDNS for a Kubernetes cluster, see the Customizing DNS Service.