O'REILLY®

Certified Kubernetes Application Developer (CKAD) Crash Course

Kubernetes 1.25 Edition

About the trainer

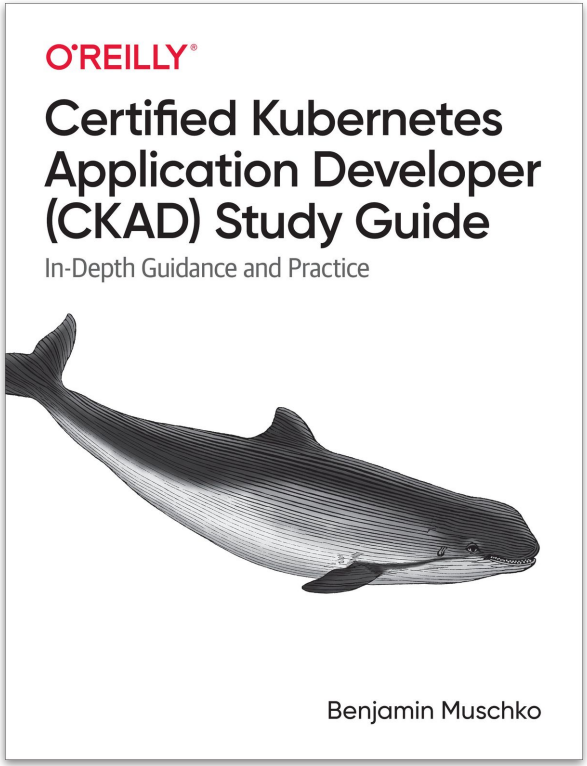
bmuschko

bmuschko

bmuschko.com

AUTOMATED ASCENT

automatedascent.com

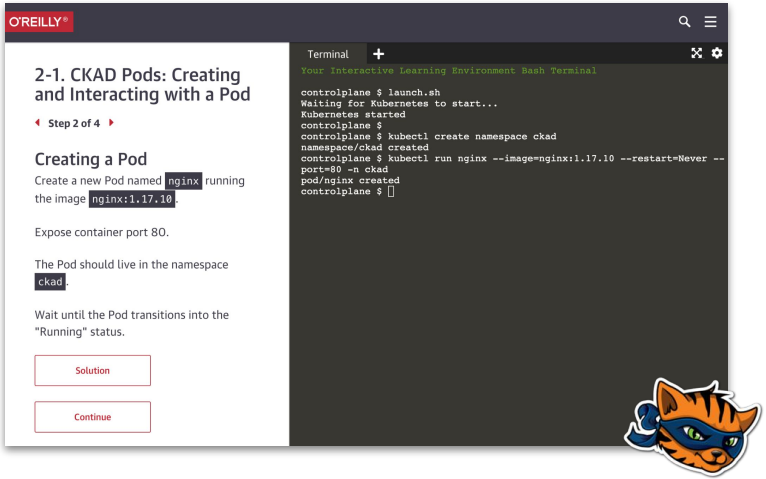


Companion study guide with practice questions

Released in February 2021

Online access on O'Reilly learning platform:

https://learning.oreilly.com/library/view/certified-kubernetes-application/9781492083726/



CKAD exam practice test

Katacoda labs

Online access on O'Reilly learning platform:

https://learning.oreilly.com/playlists/8aa87dce-f9a9-4206-83af-c8c730faa430/

Exam Details and Resources

Objectives, Environment, Time Management

Exam Objectives

“Design, build, configure, and expose cloud native applications for Kubernetes”

The certification program allows users to demonstrate their competence in a hands-on, command-line environment.

https://www.cncf.io/certification/ckad/

The Curriculum

20% - Application Design and Build

- Define, build and modify container images
- Understand Jobs and CronJobs
- Understand multi-container Pod design patterns (e.g. sidecar, init and others)
- Utilize persistent and ephemeral volumes

20% - Application Deployment

- Use Kubernetes primitives to implement common deployment strategies (e.g. blue/green or canary)
- Understand Deployments and how to perform rolling updates
- Use the Helm package manager to deploy existing packages

15% - Application observability and maintenance

- Understand API deprecations
- Implement probes and health checks
- Use provided tools to monitor Kubernetes applications
- Utilize container logs
- Debugging in Kubernetes

20% - Services & Networking

- Demonstrate basic understanding of NetworkPolicies
- Provide and troubleshoot access to applications via services
- Use Ingress rules to expose applications

25% - Application Environment, Configuration and Security

- Discover and use resources that extend Kubernetes (CRD)
- Understand authentication, authorization and admission control
- Understanding and defining resource requirements, limits and quotas
- Understand ConfigMaps
- Create & consume Secrets
- Understand ServiceAccounts
- Understand SecurityContexts

Candidate Skills

kubernetes

Architecture & Concepts

`kubectl`

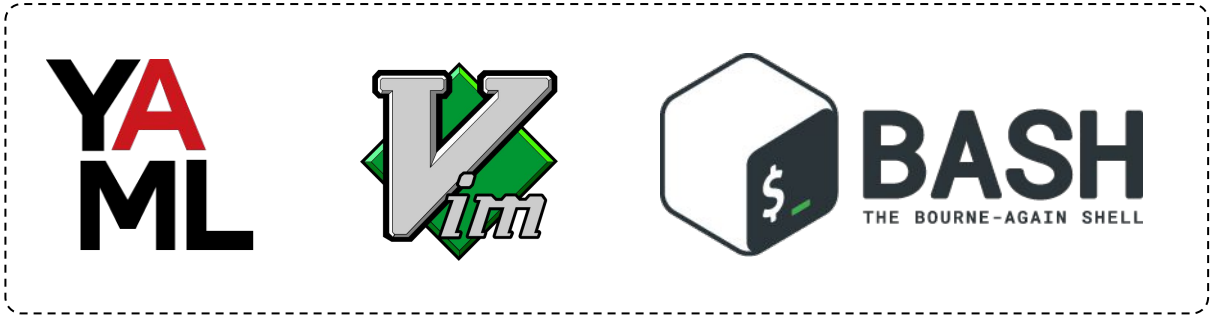
Running Commands

container runtime

Underlying Concepts

Exam Environment

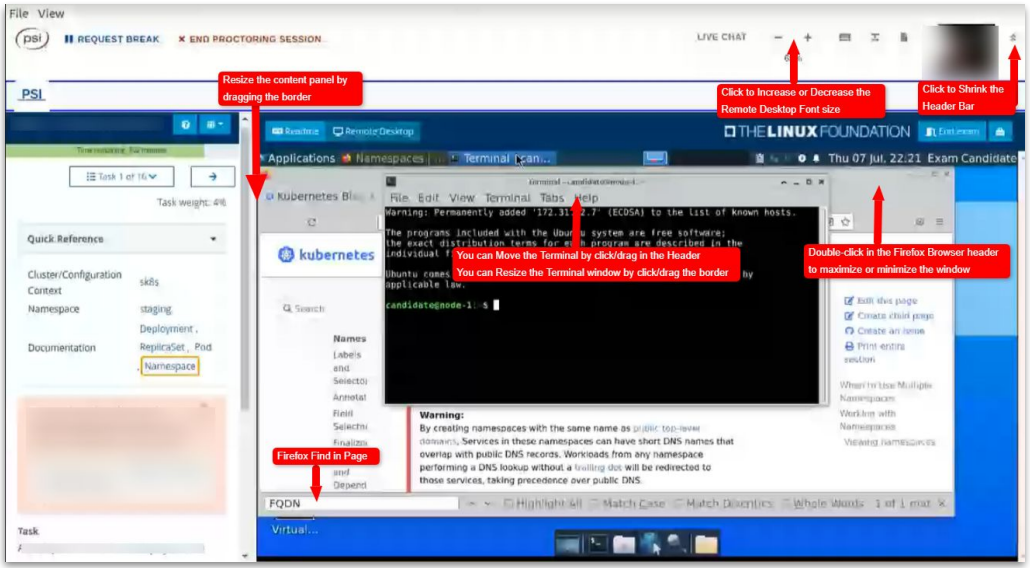
Online and proctored exam



The trinity of tooling you need to be familiar with

New PSI Exam Environment

Single monitor, no more bookmarks (announcement)



Using Kubernetes Documentation

Kubernetes docs and subdomains (see FAQ)

- Docs: https://kubernetes.io/docs
- GitHub: https://github.com/kubernetes
- Blog: https://kubernetes.io/blog

Getting Help on a Command

Render subcommands and options with `--help`

```
$ kubectl create --help
Create a resource from a file or from stdin.

JSON and YAML formats are accepted.

...
Available Commands:
...
  configmap           Create a configmap from a local file, directory or literal
value
  deployment          Create a deployment with the specified name.
...

Options:
...
```

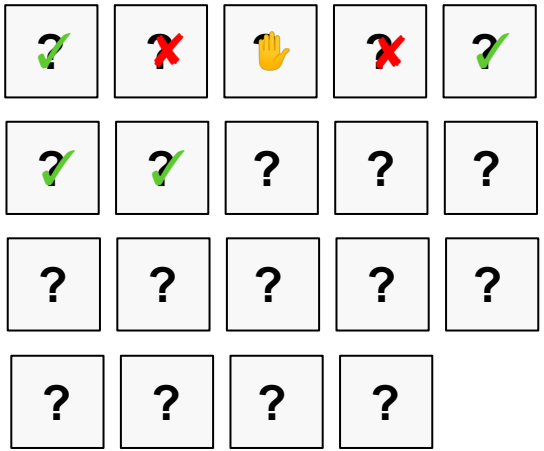
Zeroing in on Command Details

Drill into object details with the `explain` command

```
$ kubectl explain pods.spec
KIND:     Pod
VERSION:  v1

RESOURCE: spec <Object>

DESCRIPTION:
...

FIELDS:
...
```

Time Management

# of problems in 2 hours, use your time wisely!



Configuring Auto-Completion

Allowed during exam, configurable on-demand

```
$ kubectl cre<tab>
```

https://kubernetes.io/docs/tasks/tools/included/optional-kubectl-configs-bash-linux/

Using an Alias for kubectl

Preconfigured in the exam

```
$ alias k=kubectl

$ k version
...
```

Setting Namespace for a Context

Questions will ask you to run a command on a specific cluster - Make sure to execute it!

```
$ kubectl config set-context <context-of-question>↵
  --namespace=<namespace-of-question>
$ kubectl config use-context <context-of-question>
```

Internalize Resource Short Names

Some API resources provide a shortcut

```
$ kubectl get ns
```

Usage of `ns` instead of `namespaces`

```
$ kubectl describe pvc claim
```

Usage of `pvc` instead of `persistentvolumeclaim`

```
$ kubectl api-resources
```

Lists all API resources including their short names

Deleting Kubernetes Objects

Don’t wait for a graceful deletion of objects...

```
$ kubectl delete pod nginx --force
```

Understand and Practice bash

Practice relevant syntax and language constructs

```
$ if [ ! -d ~/tmp ]; then mkdir -p ~/tmp; fi; while true;↲
do echo $(date) >> ~/tmp/date.txt; sleep 5; done;
```

Finding Object Information

Filter configuration with context from a set of objects

```
$ kubectl describe pods | grep -C 10 "author=John Doe"
$ kubectl get pods -o yaml | grep -C 5 labels:
```

`grep` is your friend!

How to Prepare

Practice, practice, practice!

The key to cracking the exam

Q & A

Image and Container Management

Defining, Building, Running, and Distributing Container Images

Container Terminology

Container image creation and distribution

- *Blueprint of instructions:* Spells out what needs to happen when the software is built, e.g. a `Dockerfile`.
- *Container Image:* Packages an application into a single unit of software including its runtime environment and configuration.
- *Container Registry:* Publishes container images and makes them available for consumption, e.g. on Docker Hub or GCR.

Container Terminology

Container runtime environment and instantiation

- *Container Runtime Engine:* A software component that can run containers on a host operating system, e.g. Docker Engine or containerd.

- *Container:* Instantiates a container image and runs it in an isolated runtime environment. Think of it as a special type of virtual machine.

- *Container orchestrator:* Uses container runtime inside of a Pod to instantiate a container, e.g. Kubernetes.

Containerization Process

Building and publishing an image, running image in container

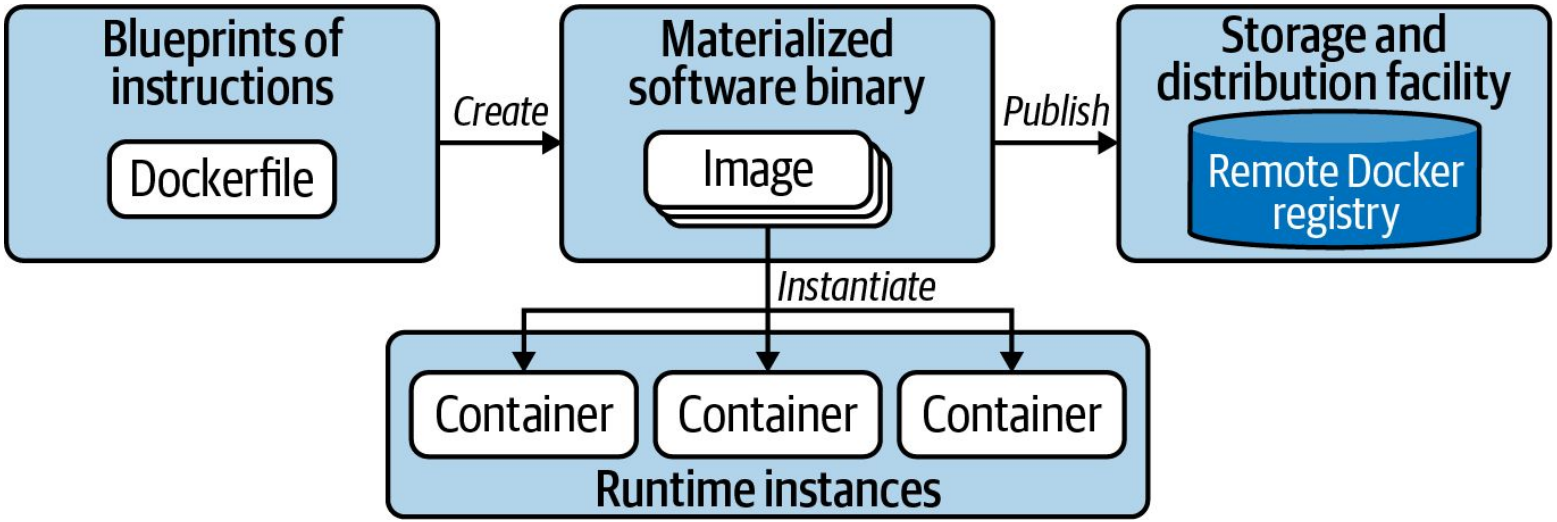


Image Building Instructions

A Dockerfile is a plain-text file with instructions

```
FROM openjdk:11-jre-slim
WORKDIR /app
COPY target/java-hello-world-0.0.1.jar java-hello-world.jar
ENTRYPOINT ["java", "-jar", "/app/java-hello-world.jar"]
EXPOSE 8080
```

Building the Container Image

Provide name and tag of image + context directory

```
$ docker build -t java-hello-world:1.0.0 .
Sending build context to Docker daemon   8.32MB
Step 1/5 : FROM openjdk:11-jre-slim
 ---> 973c18dbf567
Step 2/5 : WORKDIR /app
 ---> Using cache
 ---> 31f9c5f2a019
...
Successfully built 3e9c22451a17
Successfully tagged java-hello-world:1.0.0
```

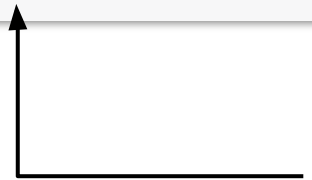
Context directory

Container ID

Listing Container Images

Render all local images including their name + hash

```
$ docker images
REPOSITORY          TAG                 IMAGE ID            CREATED                  SIZE
java-hello-world    1.0.0               3e9c22451a17        About a minute ago       213MB
openjdk             11-jre-slim         973c18dbf567        20 hours ago             204MB
```



Base image is
downloaded automatically

Operating the Container

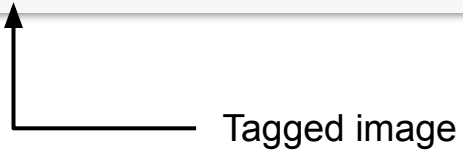
You can interact with container once its running

```
$ docker run -d -p 8080:8080 java-hello-world:1.0.0
b0ee04accf078ea7c...

$ docker logs b0ee04accf078ea7c…
Hello World!

$ docker exec -it b0ee04accf078ea7c... bash
root@b0ee04accf078ea7c:/# pwd
/
root@b0ee04accf078ea7c:/# exit
```

Tagging the Container Image

Name + tag need to conform to registry conventions

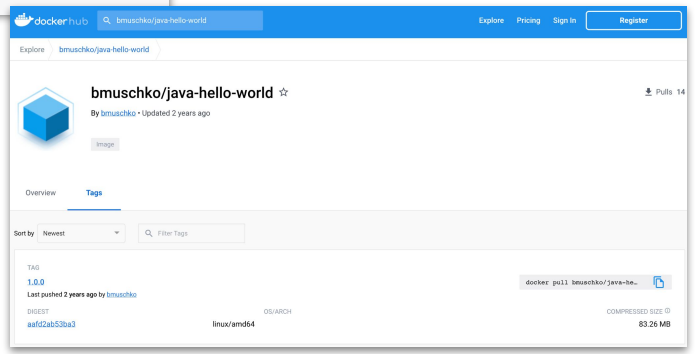
```
$ docker tag java-hello-world:1.0.0 bmuschko/java-hello-world:1.0.0

$ docker images
REPOSITORY                  TAG           IMAGE ID       ...
java-hello-world            1.0.0         3e9c22451a17   ...
openjdk                     11-jre-slim   973c18dbf567   ...
bmuschko/java-hello-world   1.0.0         3e9c22451a17   ...
```



Publishing the Container Image

Authenticate with registry and push a tag

```
$ docker login --username=bmuschko

$ docker push bmuschko/java-hello-world:1.0.0
```



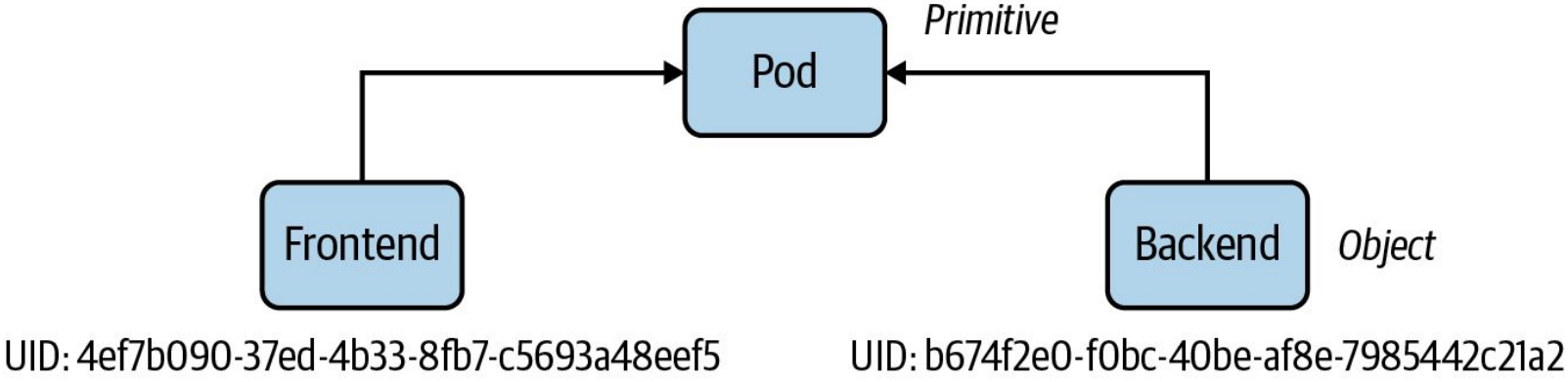
Q & A

Pod and Namespace Management

Kubernetes Primitives, Typical Operations and Configuration

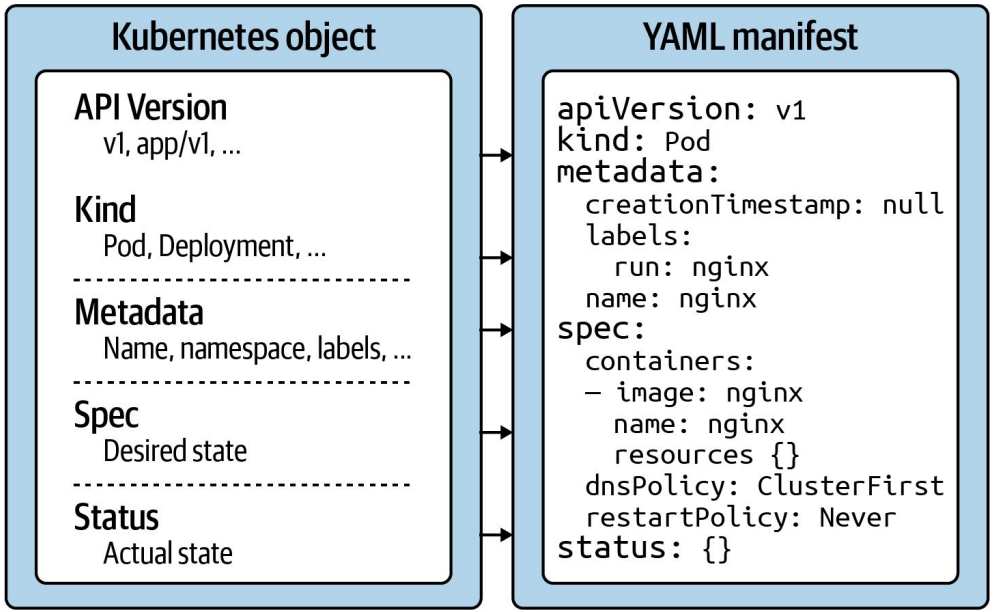
Kubernetes Primitives

Basic building blocks for creating and operating an application



Kubernetes Object Structure

General structure followed by most primitives



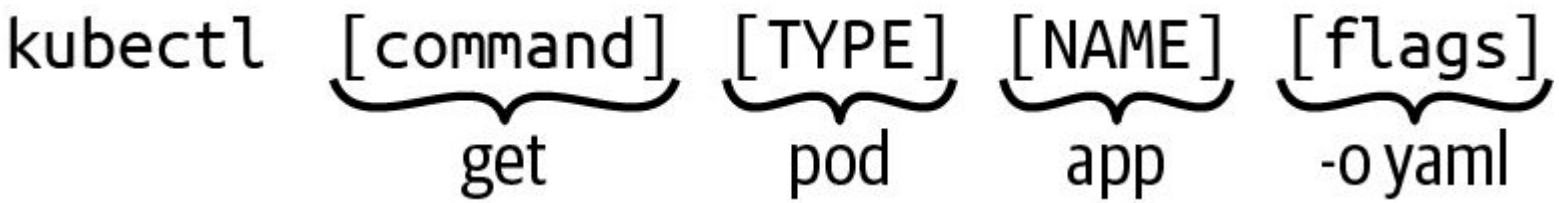
General Primitive Sections

Each section has a specific function

- *API version:* Defines the structure of a primitive and uses it to validate the correctness of the data.
- *Kind:* The kind defines the type of primitive, e.g. a Pod or a Service.
- *Metadata:* Describes higher-level information about the object.
- *Spec/Status:* Desired and actual state of object.

Using kubectl

Primary tool to interact with the Kubernetes clusters from the CLI



Imperative Object Management

Fast but requires detailed knowledge, no track record

```
$ kubectl create namespace ckad
namespace/ckad created

$ kubectl run nginx --image=nginx -n ckad
pod/nginx created

$ kubectl edit pod nginx -n ckad
pod/nginx edited
```

Creates an object e.g. a namespace

Creates a Pod object in a namespace

Modifies the live object e.g. a Pod

Declarative Object Management

Suitable for more elaborate changes, tracks changes

```
$ kubectl create -f nginx-deployment.yaml
deployment.apps/nginx-deployment created

$ kubectl apply -f nginx-deployment.yaml
deployment.apps/nginx-deployment configured

$ kubectl delete -f nginx-deployment.yaml
deployment.apps "nginx-deployment" deleted
```

Creates object if it doesn't exist yet

Creates object or update if it already exists

Deletes object

Hybrid Approach

Generate YAML file with `kubectl` but make further edits

```
$ kubectl run nginx --image=nginx
  --dry-run=client -o yaml > nginx-pod.yaml

$ vim nginx-pod.yaml

$ kubectl create -f nginx-pod.yaml
pod/nginx created
```

Capture YAML for Pod object in file

Create the object from YAML file

What is a Pod?

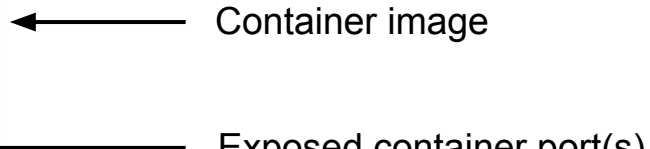
Runs a process or application in container(s)

- The smallest, most basic deployable objects in Kubernetes.
- It contains one or more containers, such as Docker containers.
- Kubernetes enhances the basic functionality of a container with features such as security, storage, and more.

Pod YAML Manifest

Defines containers and their images running in them

```yaml
apiVersion: v1
kind: Pod
metadata:
  name: hazelcast
spec:
  containers:
    image: hazelcast/hazelcast
    name: hazelcast
    ports:
    - containerPort: 5701
  restartPolicy: Never
```



Creating a Pod

Imperative vs. declarative approach

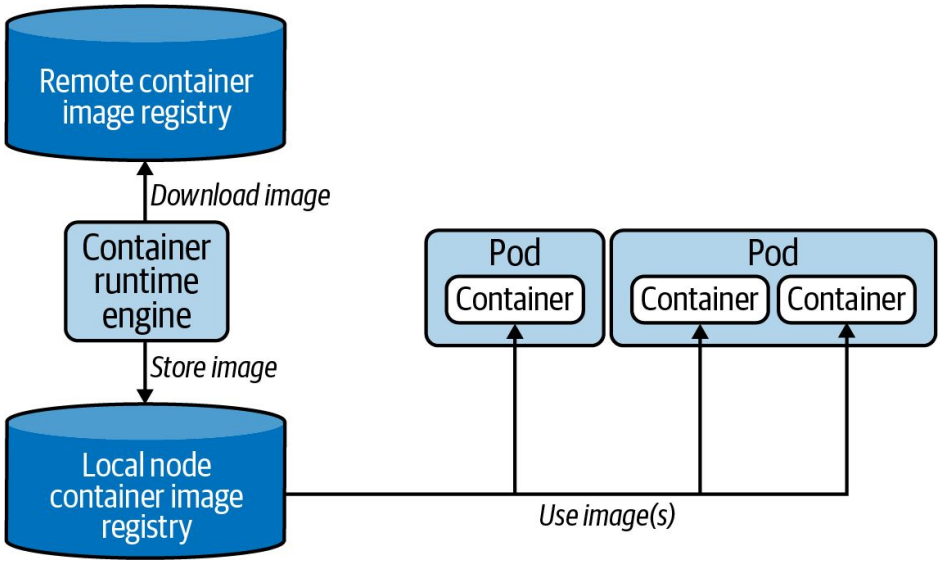
```
$ kubectl run hazelcast --image=hazelcast/hazelcast --restart=Never↲
  --port=5701 --env="DNS_DOMAIN=cluster"↲
  --labels="app=hazelcast,env=prod"
pod/hazelcast created

$ kubectl create -f pod.yaml
pod/hazelcast created
```

Declarative: Point to YAML manifest

Imperative: Spell out configuration with parameters

Container Image Retrieval

Same process for imperative and declarative Pod creation



Listing Pods

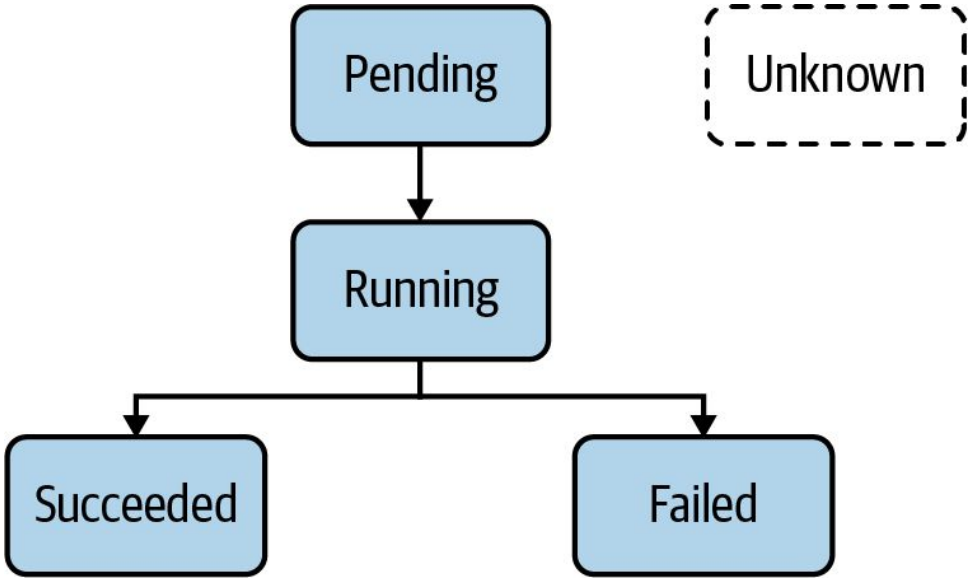
Get high-level information on all Pods or a specific one

```
$ kubectl get pods
NAME         READY   STATUS    RESTARTS   AGE
hazelcast    1/1     Running   0          17s

$ kubectl get pods hazelcast
NAME         READY   STATUS    RESTARTS   AGE
hazelcast    1/1     Running   0          17s
```

Specific Pod name

Pod Life Cycle Phases

Indicates operational status of Pod



Rendering Pod Details

Shows Pod configuration, events, and status

```
$ kubectl describe pods hazelcast
Name:                 hazelcast
Namespace:            default
...
Status:               Running
IP:                   10.1.0.41
Containers:
  ...
Events:
  ...
```

Virtual IP address assigned to Pod to communicate with it

Interacting with Container

Rendering logs and shelling into container

```
$ kubectl logs hazelcast
...
May 25, 2020 3:36:26 PM com.hazelcast.core.LifecycleService
INFO: [10.1.0.46]:5701 [dev] [4.0.1] [10.1.0.46]:5701 is STARTED

$ kubectl exec -it hazelcast -- /bin/sh
# ...
```

Declaring Environment Variables

Define zero to many key-value pairs

```
apiVersion: v1
kind: Pod
metadata:
  name: spring-boot-app
spec:
  containers:
  - image: bmuschko/spring-boot-app:1.5.3
    name: spring-boot-app
    env:
    - name: SPRING_PROFILES_ACTIVE
      value: prod
    - name: VERSION
      value: '1.5.3'
```

Typical naming conventions for keys are not enforced

Declaring Command and Args

Assign or overwrite container entrypoint and arguments

```yaml
apiVersion: v1
kind: Pod
metadata:
  name: spring-boot-app
spec:
  containers:
  - image: bmuschko/spring-boot-app:1.5.3
    name: spring-boot-app
    command: ["/bin/sh"]
    args: ["-c", "while true; do date; sleep 10; done"]
```

Deleting a Pod

Graceful deletion can take up to 30 seconds

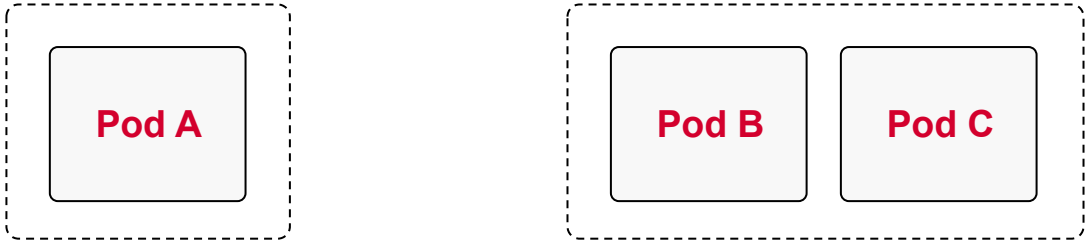
```
$ kubectl delete pod hazelcast
pod "hazelcast" deleted

$ kubectl delete -f pod.yaml
pod "hazelcast" deleted
```

Imperative approach

Declarative approach

Understanding Namespaces

Prevent naming collisions and a scope for object names



Creating and Using a Namespace

Reference namespace with `--namespace` or `-n`

```
$ kubectl create namespace code-red
namespace/code-red created

$ kubectl run nginx --image=nginx --restart=Never -n code-red
pod/nginx created

$ kubectl get pods -n code-red
NAME    READY   STATUS    RESTARTS   AGE
nginx   1/1     Running   0          13s
```

Namespace YAML Manifest

Only defines the name, no additional details

```yaml
apiVersion: v1
kind: Namespace
metadata:
  name: code-red
```

Deleting a Namespace

Cascade-deletes containing objects

```
$ kubectl delete namespace code-red
namespace "code-red" deleted

$ kubectl get pods -n code-red
No resources found in code-red namespace.
```

EXERCISE

Creating a Pod
and Inspecting it

Q & A

Jobs and CronJobs

Differences to Pods, One-Time Operations,
Scheduled Operations

Pods vs. Jobs vs. CronJobs

Kubernetes primitives with different use cases

- *Pod:* Continuous operation of an application kept running without interrupts if possible.
- *Job:* Runs functionality until a specified number of completions has been reached, making it a good fit for one-time operations like import/export data processes or I/O-intensive processes with a finite end.
- *CronJob:* Essentially a Job, but it's run periodically based a schedule.

Creating a Job

"Increment a counter and render its value on the terminal"

```
$ kubectl create job counter --image=nginx -- /bin/sh -c↵
  'counter=0; while [ $counter -lt 3 ]; do↵
  counter=$((counter+1)); echo "$counter"; sleep 3; done;'
job.batch/counter created
```

Job YAML Manifest

```yaml
apiVersion: batch/v1
kind: Job
metadata:
  name: counter
spec:
  completions: 1
  parallelism: 1
  backoffLimit: 6
  template:
    spec:
      restartPolicy: OnFailure
      containers:
      - args:
        - /bin/sh
        - -c
        - ...
        image: nginx
        name: counter
```

Define # of successful completions and whether task should be run in parallel

How many times do we try before Job is marked failed?

Restart Pod upon failure or start a new Pod

Inspecting a Job

Job is completed when configured # of execution has been reached

```
$ kubectl get jobs
NAME      COMPLETIONS   DURATION   AGE
counter   0/1           13s        13s

$ kubectl get jobs
NAME      COMPLETIONS   DURATION   AGE
counter   1/1           15s        19s

$ kubectl get pods
NAME            READY   STATUS      RESTARTS   AGE
counter-z6kdj   0/1     Completed   0          51s
```

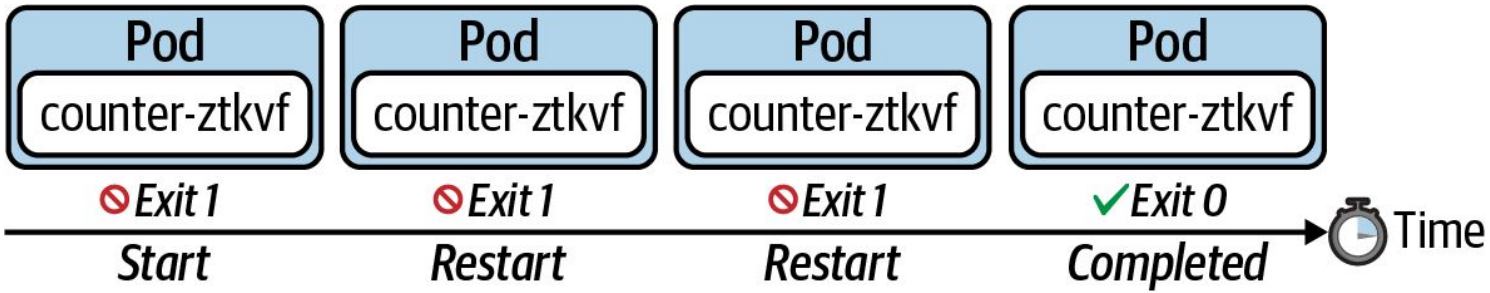
Different Types of Jobs

```
spec.completions: x
spec.parallelism: y
```

Type	Completion criteria
Non-parallel	Complete as soon as its Pod terminates successfully
Parallel with fixed completion count	Complete when specified number of tasks finish successfully
Parallel with a work queue	Once at least one Pod has terminated with success and all Pods are terminated

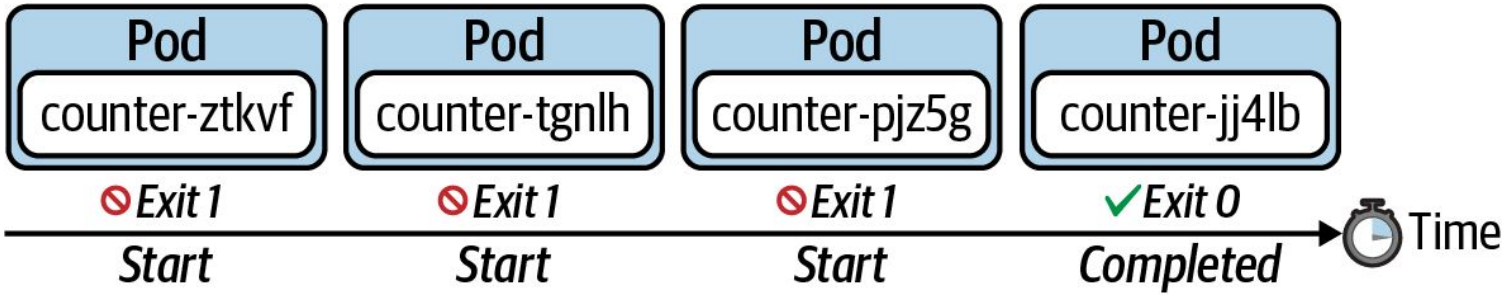
Restarting a Container on Failure

```
spec.template.spec.restartPolicy: OnFailure
```



New Pod on Failure

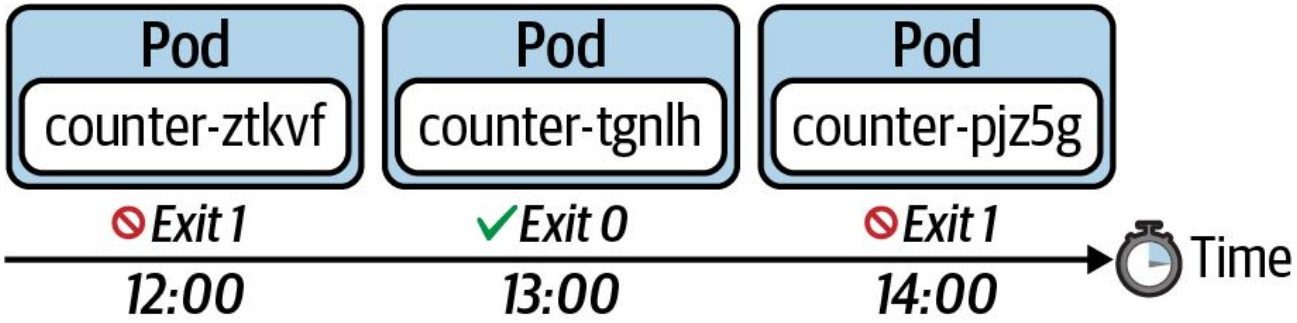
```
spec.template.spec.restartPolicy: Never
```



Understanding CronJobs

Similar to Job but task is run on a predefined schedule

```
spec.schedule: "0 * * * *"
```



Creating a CronJob

"Render the current date on standard output every hour"

```
$ kubectl create cronjob current-date --schedule="* * * * *"↲
  --image=nginx -- /bin/sh -c 'echo "Current date: $(date)"'
cronjob.batch/current-date created
```

CronJob YAML Manifest

```yaml
apiVersion: batch/v1
kind: CronJob
metadata:
  name: counter
spec:
  schedule: "*/1 * * * *"
  jobTemplate:
    spec:
      template:
        spec:
          restartPolicy: Never
          containers:
          - args:
            - /bin/sh
            - -c
            - ...
            image: nginx
            name: counter
```

The crontab expression used to run CronJob periodically

Run in a new Pod

Inspecting CronJobs

Keeps a history of failed and successful Pods

```
$ kubectl get cronjobs
NAME      SCHEDULE      SUSPEND   ACTIVE   LAST SCHEDULE   AGE
counter   */1 * * * *   False     0        26s             1h

$ kubectl get jobs --watch
NAME                  COMPLETIONS   DURATION   AGE
counter-1557334380    1/1           3s         2m24s
counter-1557334440    1/1           3s         84s
counter-1557334500    1/1           3s         24s
```

EXERCISE

Creating a
Scheduled
Container Operation

Q & A

Multi-Container Pods

Common Design Patterns

Single vs. Multiple Containers

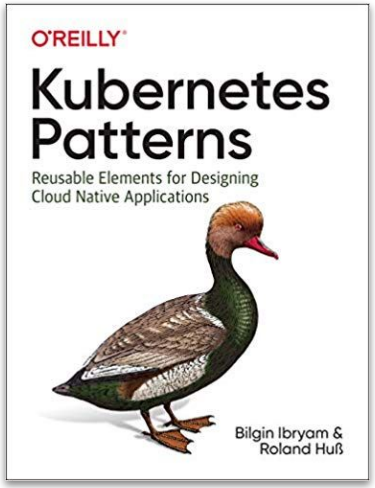
Used for implementing specific use cases

- The general rule of thumb is to deploy one microservice per Pod in a *single container* which helps with rolling out new versions of a microservice without necessarily interrupting other parts of the system.

- Use cases for *multiple containers* in a single Pod
  - Run preconfiguration procedure before the application container should start.
  - Helper functionality that runs alongside the application.

Multi-Container Patterns

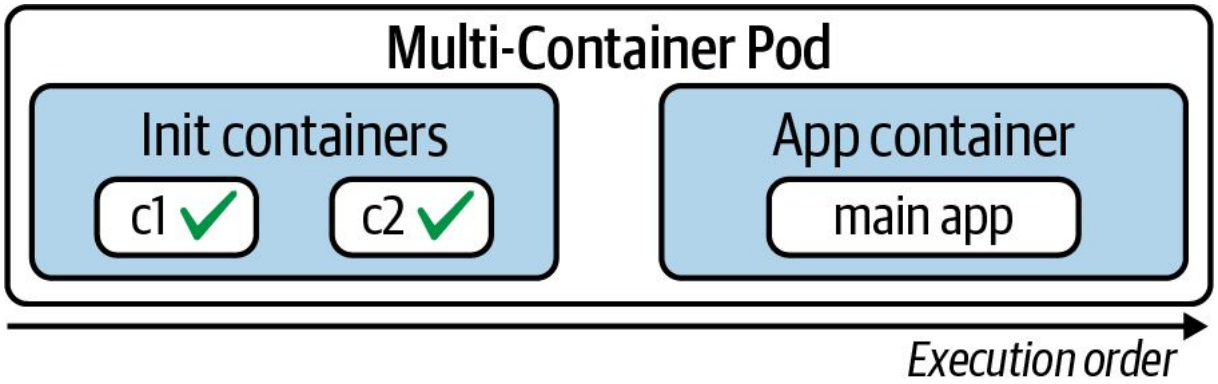
Understand patterns on a high-level



- Init container
- Sidecar
- Adapter
- Ambassador

Why Use an Init Container?

Initialization logic before main application containers



Defining an Init Container

Declared adjacent to main application containers

```
apiVersion: v1
kind: Pod
metadata:
  name: multi-container
spec:
  initContainers:
  - image: init:3.2.1
    name: app-initializer
  containers:
  - image: nginx
    name: web-server
```

Uses the same attributes as main application containers

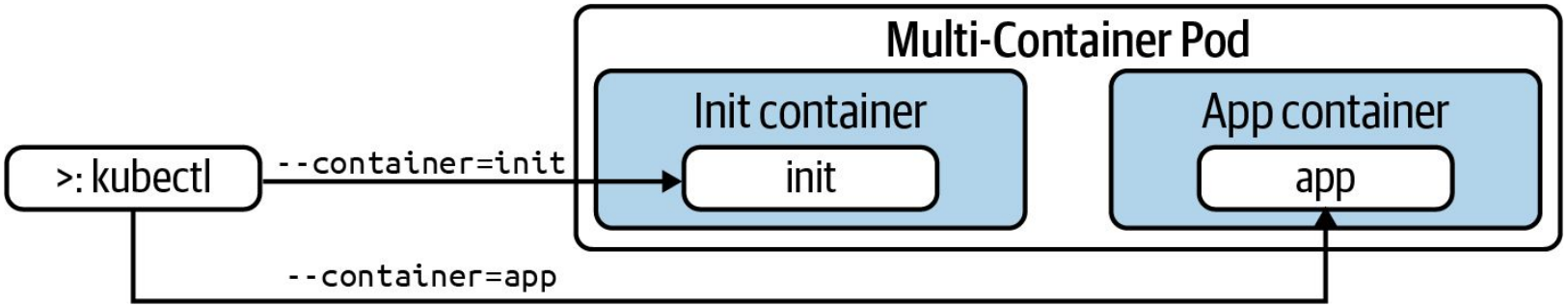
Creating a Pod with Init Container

Init container execution renders in status column

```
$ kubectl create -f init.yaml
pod/business-app created

$ kubectl get pod business-app
NAME           READY   STATUS            RESTARTS   AGE
business-app   0/1     PodInitializing   0          2s

$ kubectl get pod business-app
NAME           READY   STATUS    RESTARTS   AGE
business-app   1/1     Running   0          8s
```

Interacting with an Init Container

Run typical kubectl with `--container` or `-c` CLI option



EXERCISE

Creating an Init Container

Defining Multiple Containers

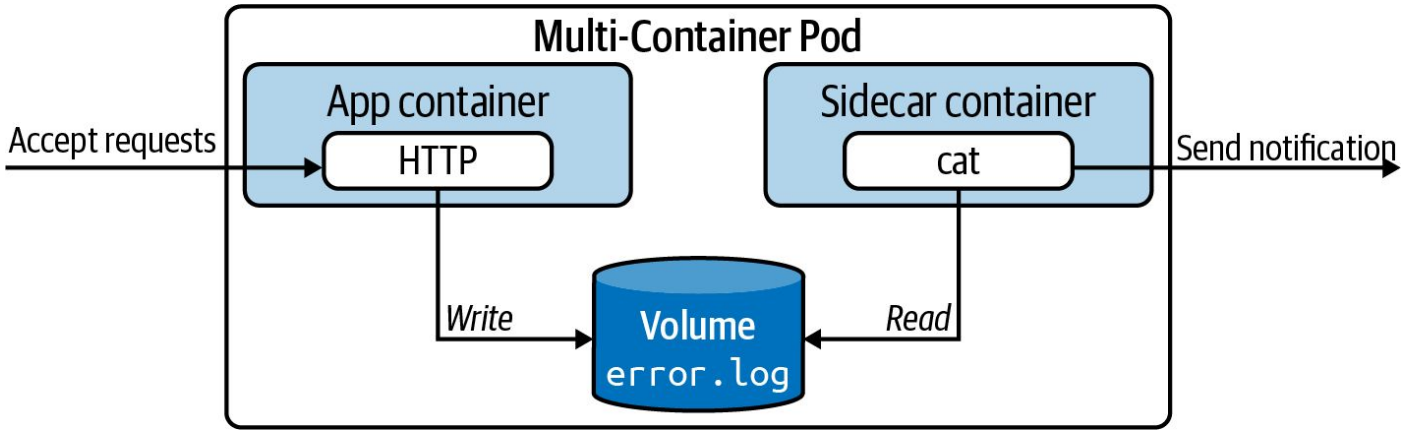
Shared container lifecycle and resources

```
apiVersion: v1
kind: Pod
metadata:
  name: multi-container
spec:
  containers:
  - image: nginx:1.13.0
    name: web-server
  - image: transformer:1.0.0
    name: helper
```

Defines a second container running alongside the application container

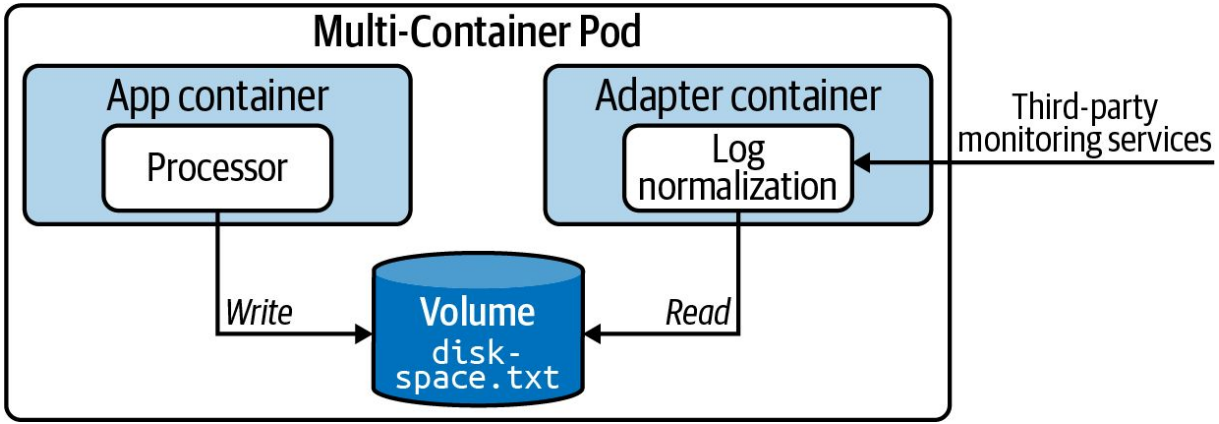
Sidecar Pattern

Not part of the main traffic or API of the primary application



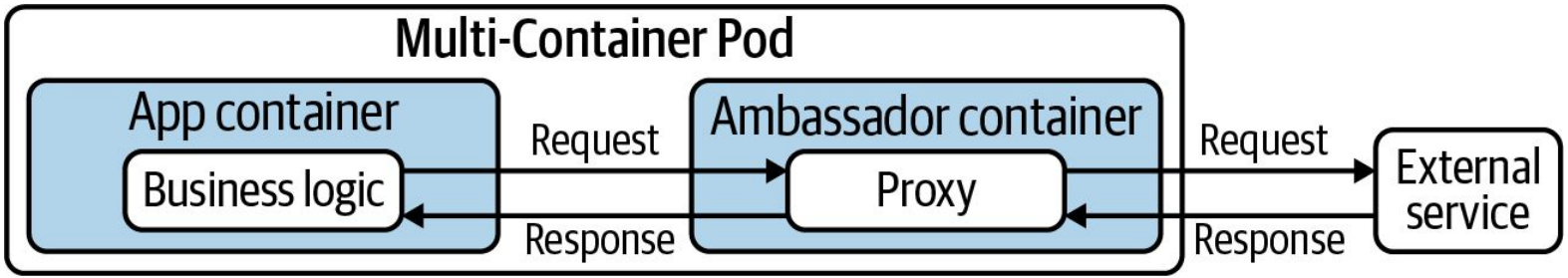
Adapter Pattern

Standardizes and normalizes application output read by external monitoring service



Ambassador Pattern

Hide and/or abstract the complexity of interacting with other parts of the system



EXERCISE

Implementing the
Adapter Pattern

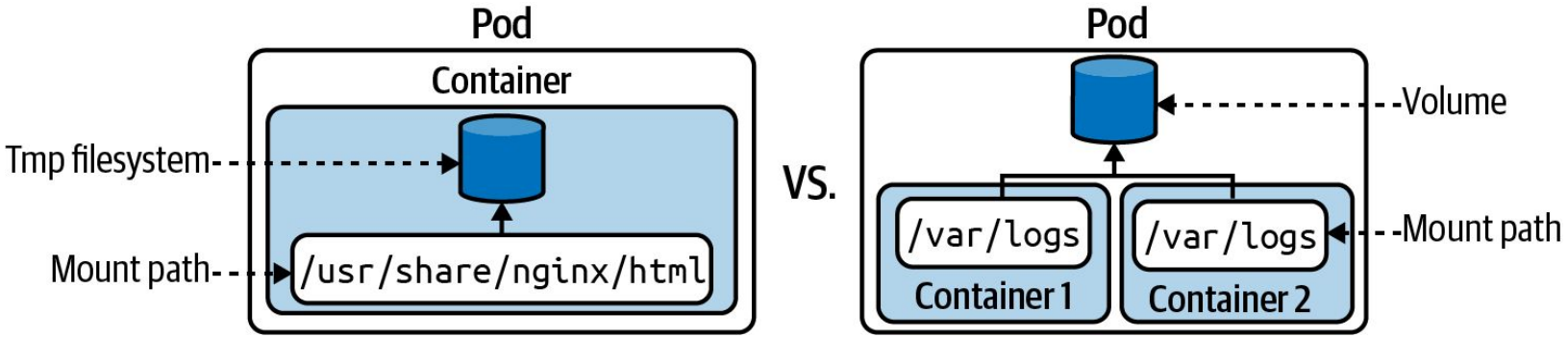
Q & A

State Persistence

Persistent and Ephemeral Volumes

Understanding Volumes

By default, a container manages files in a temporary file system



Types of Volumes

Type	Description
`emptyDir`	Empty directory in Pod. Only persisted for the lifespan of a Pod.
`hostPath`	File or directory from the host node's filesystem into your Pod.
`configMap, secret`	Provides a way to inject configuration data and secrets into Pods.
`nfs`	An existing NFS (Network File System) share to be mounted into your Pod. Preserves data after Pod restart.
Cloud provider solutions	Provider-specific implementation for AWS, GCE or Azure.

Defining and Mounting a Volume

Provide type and assign mount path per container

```
apiVersion: v1
kind: Pod
metadata:
  name: my-container
spec:
  volumes:
  - name: logs-volume
    emptyDir: {}
  containers:
  - image: nginx
    name: my-container
    volumeMounts:
    - mountPath: /var/logs
      name: logs-volume
```

Define Volume name and type

Specify mount path in container

Using a Volume

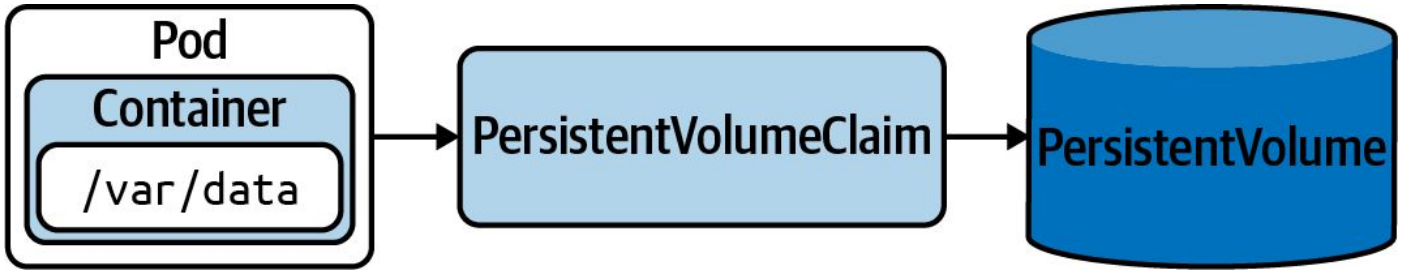
New files can be created in mounted path of Volume

```
$ kubectl create -f pod-with-vol.yaml
pod/my-container created

$ kubectl exec -it my-container -- /bin/sh
# cd /var/logs
# pwd
/var/logs
# touch app-logs.txt
# ls
app-logs.txt
```

Mount path became accessible in container

Understanding PersistentVolumes

Persist data that outlives a Pod, node, or cluster restart



Static vs. Dynamic Provisioning

PersistentVolume object is created manually or automatically

- *Static:* Storage device needs to be created first. The PersistentVolume object references the storage device and needs to be created manually.
- *Dynamic:* The PersistentVolumeClaim object references a storage class. The PersistentVolume object is created automatically.
- *Storage Class:* Object that knows how to provision a storage device with specific performance requirements.

Defining a PersistentVolume

Define storage capacity, access mode, and host path

```yaml
apiVersion: v1
kind: PersistentVolume
metadata:
  name: db-pv
spec:
  capacity:
    storage: 1Gi
  accessModes:
    - ReadWriteOnce
  hostPath:
    path: /data/db
```

Access Mode & Reclaim Policy

Configuration options for PersistentVolume

Access Mode

Type	Description
`ReadWriteOnce`	Read-write access by a single node.
`ReadOnlyMany`	Read-only access by many nodes.
`ReadWriteMany`	Read-write access by many nodes.

Reclaim Policy

Type	Description
`Retain`	Default. When PVC is deleted, PV is “released” and can be reclaimed.
`Delete`	Deletion removes PV and associated storage.
`Recycle`	Deprecated. Use dynamic binding instead.

Creating the PersistentVolume

Listing the object show many of its configuration options

```
$ kubectl create -f db-pv.yaml
persistentvolume/db-pv created

$ kubectl get pv db-pv
NAME    CAPACITY   ACCESS MODES   RECLAIM POLICY   STATUS      ...
db-pv   1Gi        RWO            Retain           Available   ...
```

The object hasn't been consumed by a claim yet

Defining a Claim

Will use a PersistentVolume based on resource request

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: db-pvc
spec:
  accessModes:
    - ReadWriteOnce
  resources:
    requests:
      storage: 256Mi
  storageClassName: ""
```

Assign an empty storage class name to use a statically-created PersistentVolume

Creating the PersistentVolumeClaim

Listing the object show many of its configuration options

```
$ kubectl create -f db-pvc.yaml
persistentvolumeclaim/db-pvc created

$ kubectl get pvc db-pvc
NAME     STATUS   VOLUME   CAPACITY   ACCESS MODES   STORAGECLASS   AGE
db-pvc   Bound    pvc      512m       RWO            standard       7s
```

Binding to the PersistentVolume object was successful

Mounting a Claim in a Pod

Use Volume type `persistentVolumeClaim`

```
apiVersion: v1
kind: Pod
metadata:
  name: app-consuming-pvc
spec:
  volumes:
    - name: app-storage
      persistentVolumeClaim:
        claimName: db-pvc
  containers:
  - image: alpine
    ...
    volumeMounts:
      - mountPath: "/mnt/data"
        name: app-storage
```

Reference the Volume by claim name

Creating the Pod

The Volume is now listed in Pod details

```
$ kubectl create -f app-consuming-pvc.yaml
pod/app-consuming-pvc created

$ kubectl describe pod app-consuming-pvc
...
Volumes:
  app-storage:
    Type:       PersistentVolumeClaim (a reference to a
                PersistentVolumeClaim in the same namespace)
    ClaimName:  db-pvc
    ReadOnly:   false
...
```

Dynamic Provisioning

Creates PersistentVolume object automatically via storage class

```yaml
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: standard
provisioner: kubernetes.io/aws-ebs
```

```yaml
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: pvc
spec:
  accessModes:
    - ReadWriteMany
  resources:
    requests:
      storage: 256Mi
  storageClassName: standard
```

EXERCISE

Creating a
Persistent Volume
with Static Binding

Q & A

Labels and Annotations

Commonalities and Differences, Use Cases, Usage

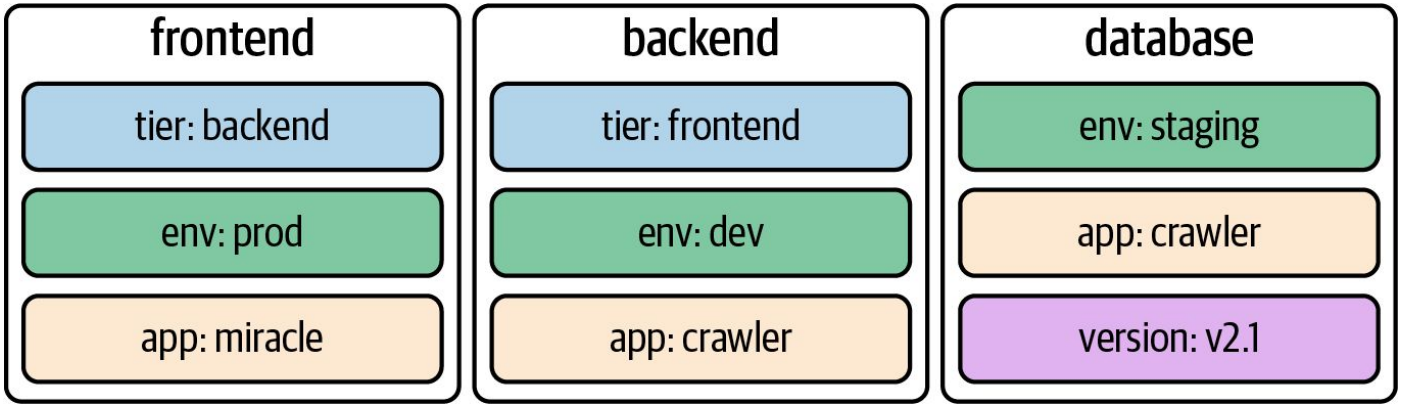
What is a Label?

Essential to querying, filtering and sorting Kubernetes objects

- Key-value pairs assigned to Kubernetes objects.
- Not meant for elaborate, multi-word descriptions of its functionality.
- Kubernetes limits the length of a label to a maximum of 63 characters and a range of allowed alphanumeric and separator characters.

Example Labels

Three different Pods with each three key-value pairs



Assigning Labels in YAML

Use the `metadata.labels` attribute

```
apiVersion: v1
kind: Pod
metadata:
  name: pod1
  labels:
    tier: backend
    env: prod
    app: miracle
spec:
  ...
```

Declares three label key-value pairs

Assigning Labels on CLI

Use the `kubectl label` command

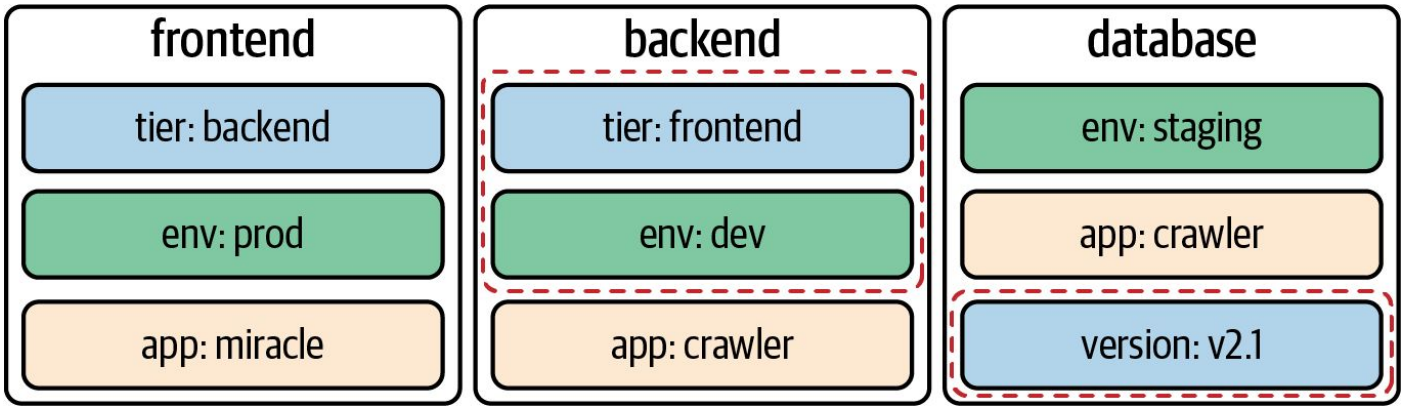
```
$ kubectl label pod nginx tier=backend env=prod app=miracle
pod/nginx labeled

$ kubectl get pods --show-labels
NAME   ... LABELS
pod1   ... tier=backend,env=prod,app=miracle

$ kubectl label pod nginx tier-
pod/nginx labeled

$ kubectl get pods --show-labels
NAME   ... LABELS
pod1   ... env=prod,app=miracle
```

Declares three label key-value pairs

Removes the label with key `tier`

Selecting Labels

Label selector uses a set of criteria to query for objects



Label Selection from the CLI

You can specify equality-based and set-based requirements

```
$ kubectl get pods -l tier=frontend,env=dev --show-labels
NAME   ... LABELS
pod2   ... app=crawler,env=dev,tier=frontend

$ kubectl get pods -l version --show-labels
NAME   ... LABELS
pod3   ... app=crawler,env=staging,version=v2.1

$ kubectl get pods -l 'tier in (frontend,backend),env=dev' --show-labels
NAME   ... LABELS
pod2   ... app=crawler,env=dev,tier=frontend
```

Boolean AND expression

Key-only expression

Set-based expression follows Boolean OR

Label Selection in YAML

Certain objects provide label selection via their API

```
apiVersion: networking.k8s.io/v1
kind: NetworkPolicy
metadata:
  name: frontend-network-policy
spec:
  podSelector:
    matchLabels:
      tier: frontend
...
```

Select Pods by labels that this network policy should apply to

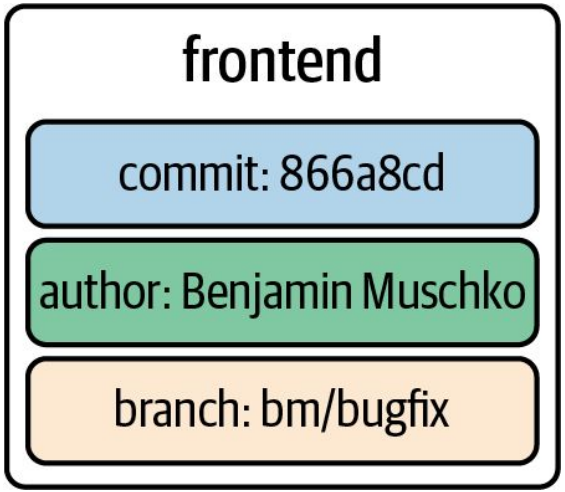
What is an Annotation?

Descriptive metadata without the ability to be queryable

- Key-value pairs for providing descriptive, human-readable metadata.
- Cannot be used for querying or selecting objects.
- Make sure to put the value of an annotation into single- or double-quotes if it contains special characters or spaces.

Example Annotations

A Pod with three key-value pairs



Assigning Annotations in YAML

Use the `metadata.annotations` attribute

```yaml
apiVersion: v1
kind: Pod
metadata:
  name: pod1
  annotations:
    commit: 866a8dc
    author: 'Benjamin Muschko'
    branch: 'bm/bugfix'
spec:
  ...
```

Declares three annotation key-value pairs

Assigning Annotations on CLI

Use the `kubectl annotations` command

```
$ kubectl annotate pod nginx commit='866a8dc' branch='bm/bugfix'
pod/nginx annotated

$ kubectl describe pods my-pod
Annotations:  branch: bm/bugfix
              commit: 866a8dc

$ kubectl annotate pod nginx commit-
pod/nginx annotated

$ kubectl describe pods my-pod
Annotations:  branch: bm/bugfix
```

Declares three annotation key-value pairs

Removes the annotation with key `commit`

EXERCISE

Defining and
Querying Labels
and Annotations

Q & A

Application Deployment

Deployments, Rollout Strategies, Using Helm to Deploy an Application

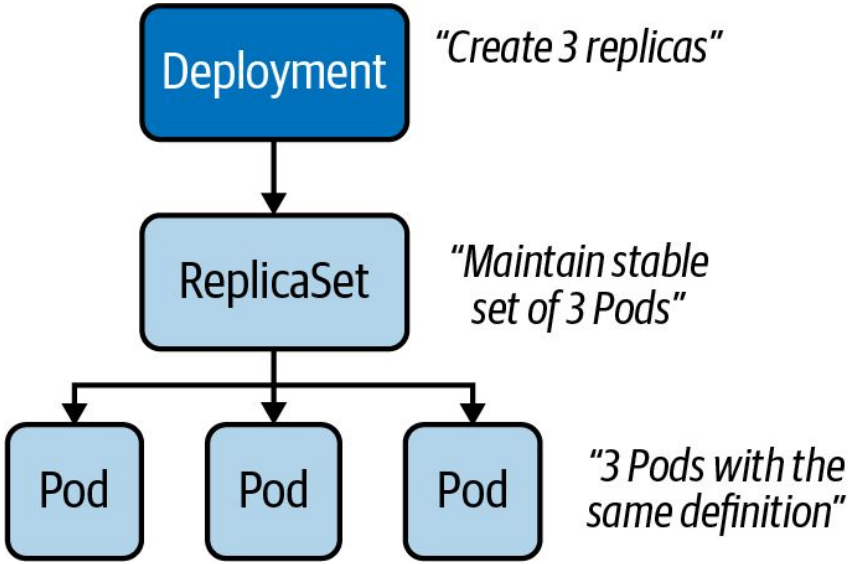
What is a Deployment?

Scaling and replication features for a set of Pods

- Controls a predefined number of Pods with the same configuration, so-called *replicas*.
- The number of replicas can be scaled up or down to fulfill load requirements.
- Updates to the replica configuration can be updated easily and is rolled out automatically.

Example Deployment

A Deployment that controls three replicas



Creating a Deployment

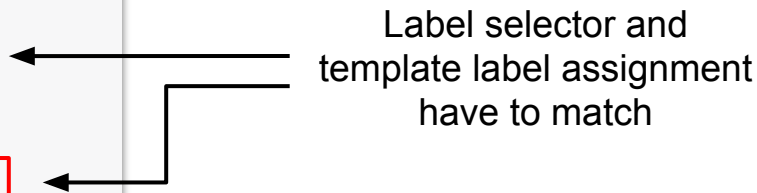
Creates objects for the Deployment, ReplicaSet and Pods

```
$ kubectl create deployment my-deploy --image=nginx:1.14.2 --replicas=3
deployment.apps/my-deploy created
```

The default number of replicas is 1 if the parameter wasn't provided

Deployment YAML Manifest

```yaml
apiVersion: apps/v1
kind: Deployment
metadata:
  labels:
    app: my-deploy
  name: my-deploy
spec:
  replicas: 3
  selector:
    matchLabels:
      tier: backend
  template:
    metadata:
      labels:
        tier: backend
    spec:
      containers:
      - image: nginx:1.14.2
        name: nginx
```



Listing Deployments

ReplicaSet and Pods can be identified by name prefix

```
$ kubectl get deployments,pods,replicasets
NAME                                READY   UP-TO-DATE   AVAILABLE   AGE
deployment.apps/my-deploy   1/1     1            1           7m56s

NAME                                    READY   STATUS    RESTARTS   AGE
pod/my-deploy-8448c488b5-mzx5g   1/1     Running   0          7m56s

NAME                                          DESIRED   CURRENT   READY   AGE
replicaset.apps/my-deploy-8448c488b5   1         1         1
7m56s
```

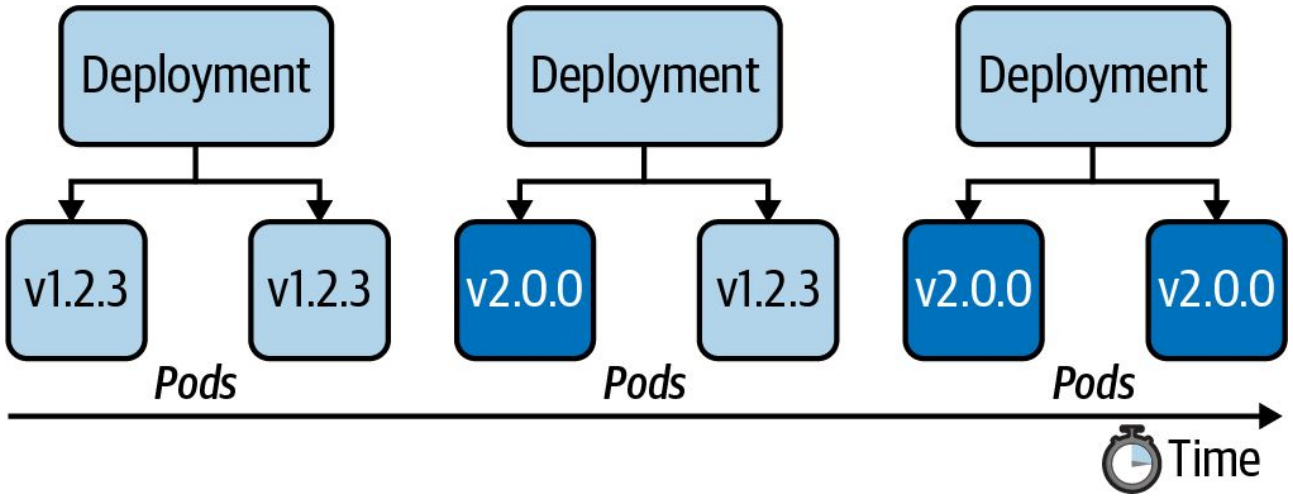
Rendering Deployment Details

Object details show relationship between parent and child

```
$ kubectl describe deployment.apps/my-deploy
Replicas:               1 desired | 1 updated | 1 total | 1 available |
                        0 unavailable
NewReplicaSet:   my-deploy-8448c488b5 (1/1 replicas created)

$ kubectl describe replicaset.apps/my-deploy-8448c488b5
Controlled By:  Deployment/my-deploy

$ kubectl describe pod/my-deploy-8448c488b5-mzx5g
Controlled By:  ReplicaSet/my-deploy-8448c488b5
```

Roll Out and Roll Back Feature

“Look ma, shiny new features. Let’s deploy them to production!”



Rolling Out a New Revision

The rollout history keeps track of changes

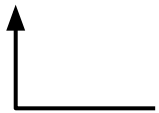
```
$ kubectl rollout history deployment my-deploy
deployment.apps/my-deploy
REVISION  CHANGE-CAUSE
1         <none>

$ kubectl set image deployment my-deploy nginx=nginx:1.19.2
deployment.apps/my-deploy image updated

$ kubectl rollout history deployment my-deploy
deployment.apps/my-deploy
REVISION  CHANGE-CAUSE
1         <none>
2         <none>
```

Changes the assigned image for Pod template

Rolling Back to Previous Revision

You can revert to any revision available in the history

```
$ kubectl rollout undo deployment my-deploy --to-revision=1
deployment.apps/my-deploy rolled back

$ kubectl rollout history deployment my-deploy
deployment.apps/my-deploy
REVISION  CHANGE-CAUSE
2         <none>
3         <none>
```



Kubernetes deduplicates a revision
if it points to the same changes

Common Deployment Strategies

Choosing the right deployment procedure depends on the needs

- *Recreate:* Terminate the old version and release the new one.
- *Ramped:* Release a new version on a rolling update fashion, one after the other.
- *Blue/green:* Release a new version alongside the old version then switch traffic.
- *Canary:* Release a new version to a subset of users, then proceed to a full rollout.

Recreate Deployment Strategy

Terminates all the running instances then recreate them

```
spec:
  replicas: 3
  strategy:
    type: Recreate
```

- *Pros:* Good for development environments as everything is renewed at once
- *Cons:* Can cause downtime while applications are starting up

Ramped Deployment Strategy

Secondary ReplicaSet is created with new version of application

```
spec:
  replicas: 3
  strategy:
    type: RollingUpdate
    rollingUpdate:
      maxSurge: 2
      maxUnavailable: 0
```

Determines how update should be performed

- *Pros:* New version is slowly distributed over time, no downtime
- *Cons:* Breaking API changes can make consumers incompatible

Blue/Green Deployment Strategy

Deployment object with new version is created alongside

```yaml
apiVersion: apps/v1
kind: Deployment
metadata:
  labels:
    app: my-deploy
    version: 1.0.0
  name: blue
```

```yaml
apiVersion: apps/v1
kind: Deployment
metadata:
  labels:
    app: my-deploy
    version: 1.1.0
  name: green
```

- *Pros:* No downtime, traffic can be routed when ready
- *Cons:* Resource duplication, configuration of network routing

Canary Deployment Strategy

Two Deployment objects with different traffic distribution

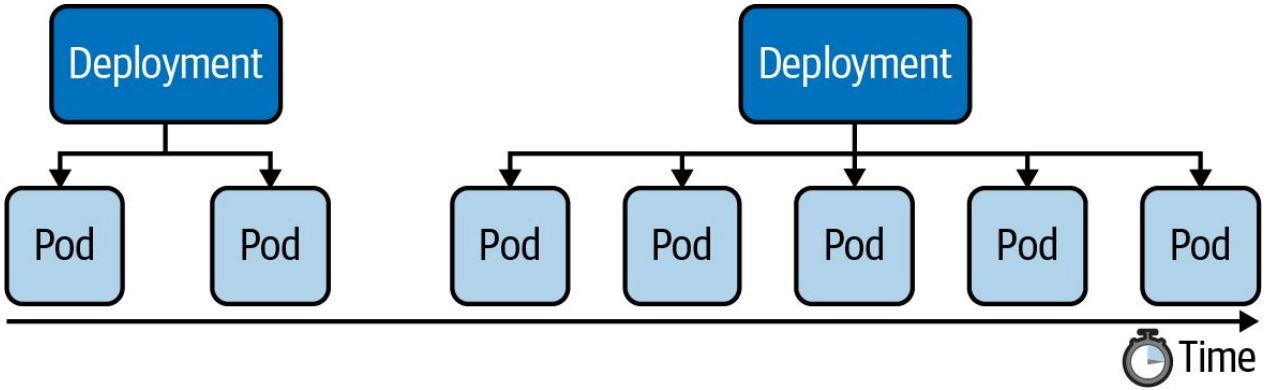
```
spec:
  replicas: 3
```

```
spec:
  replicas: 1
```

- *Pros:* New version released to subset of users, A/B testing of features and performance
- *Cons:* May require a load balancer for fine-grained distribution

Manually Scaling a Deployment

“Load is increasing. We need to scale up the application.”



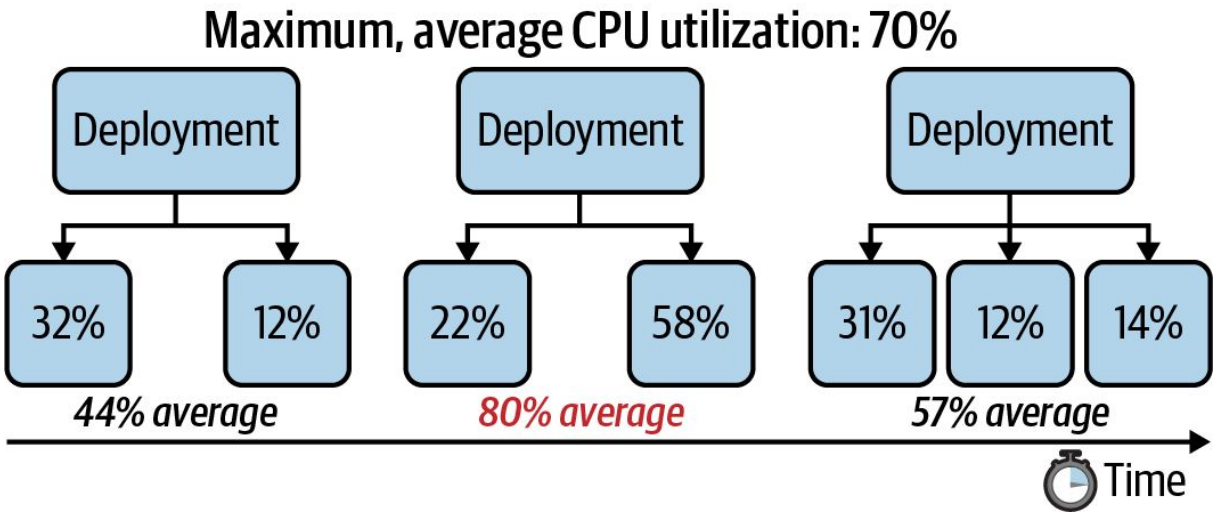
Changing the Number of Replicas

Use `scale` command or change `replicas` attribute in live object

```
$ kubectl scale deployment my-deploy --replicas=5
deployment.apps/my-deploy scaled

$ kubectl get pods
NAME                          READY   STATUS    RESTARTS   AGE
my-deploy-8448c488b5-5f5tg    1/1     Running   0          44s
my-deploy-8448c488b5-9xplx    1/1     Running   0          44s
my-deploy-8448c488b5-d8q4t    1/1     Running   0          44s
my-deploy-8448c488b5-f5kkm    1/1     Running   0          44s
my-deploy-8448c488b5-mzx5g    1/1     Running   0          3d19h
```

Autoscaling a Deployment

“Don’t make me think. Auto-scale based on CPU utilization.”



Types of Autoscalers

Decisions are made based on metrics

- *Horizontal Pod Autoscaler (HPA):* A standard feature of Kubernetes that scales the number of Pod replicas based on CPU and memory thresholds.

- *Vertical Pod Autoscaler (VPA):* Scales the CPU and memory allocation for existing Pods based on historic metrics. Supported by a cloud provider as an add-on or needs to be installed manually.

- Both autoscalers use the metrics server. You need to install the component.

Creating a HPA

The imperative command is a quick way to create the object

```
$ kubectl autoscale deployments my-deploy --cpu-percent=70 --min=2 --max=8
horizontalpodautoscaler.autoscaling/my-deploy autoscaled

$ kubectl get hpa my-deploy
NAME        REFERENCE                TARGETS         MINPODS   MAXPODS REPLICAS   AGE
my-deploy   Deployment/my-deploy   <unknown>/70%   2         8       2          37s
```


Changes with
increasing traffic

EXERCISE

Performing Rolling Updates and Scaling a Deployment

What is Helm?

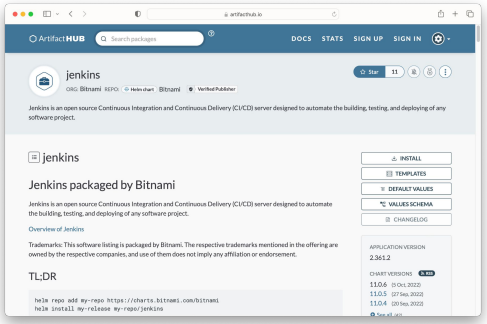
Templating engine and package manager for a set of manifests

- The artifact produced by the Helm executable is a so-called *chart file* bundling the manifests that comprise the API resources of an application.
- At runtime, it replaces placeholders in YAML template files with actual, end-user defined values.
- Chart files can be distributed to a chart repository e.g. central chart repository and consumed from there.

Finding a Chart

Searches the Artifact Hub for a chart with a matching name

```
$ helm search hub jenkins
URL                                                 CHART    VERSION APP
https://artifacthub.io/packages/helm/bitnami/jenkins   11.0.6   2.361.2
...
```



Installing a Chart

You may have to add an external repository that hosts chart file

```
$ helm repo add bitnami https://charts.bitnami.com/bitnami
"bitnami" has been added to your repositories

$ helm install jenkins bitnami/jenkins
...
CHART NAME: jenkins
CHART VERSION: 11.0.6
APP VERSION: 2.361.2

** Please be patient while the chart is being deployed **
```

Listing Installed Charts

Information about chart details

```
$ helm list
NAME       NAMESPACE   REVISION   ...   STATUS     CHART              APP VERSION
jenkins    default      1                deployed   jenkins-11.0.6     2.361.2

$ kubectl get pods
NAME                                    READY   STATUS    RESTARTS   AGE
pod/bitnami-jenkins-764b44cc99-twf6f    1/1     Running   0          7m34s
...
```

Uninstalling a Chart

Deletes Kubernetes objects controlled by chart

```
$ helm uninstall jenkins
release "jenkins" uninstalled

$ kubectl get pods
No resources found in default namespace.
```

Q & A

Probes and Health Checks

Types of Probes, Use Cases, Configuration Options

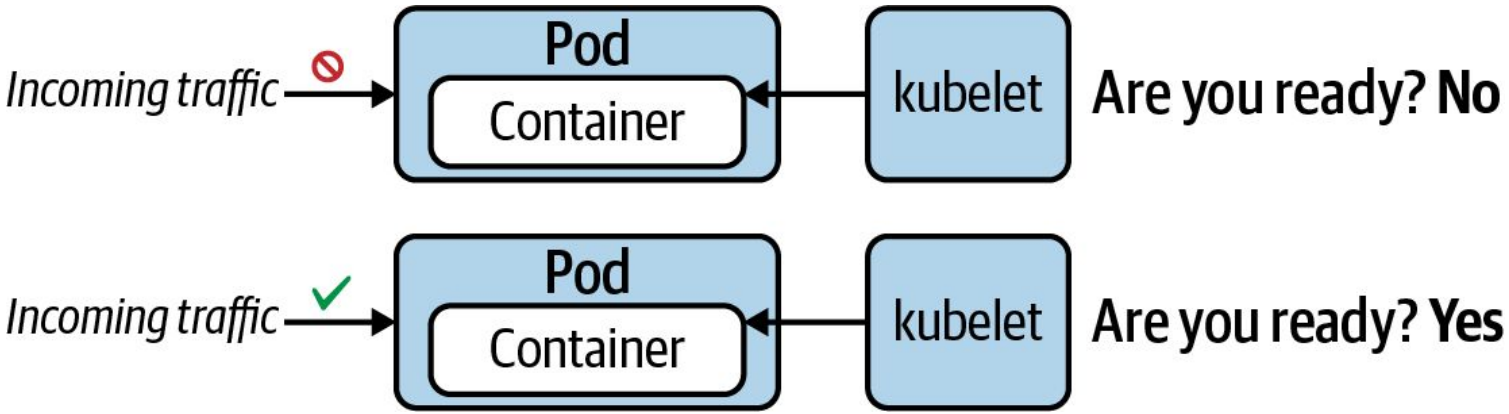
Understanding Health Probing

Runtime issues can arise, but you check for them

- Proper monitoring of applications running in production environments.
- Health probing automates the detection and correction of runtime issues.
- You can configure a container with *health probes* to execute a periodic mini-process that checks for certain conditions.

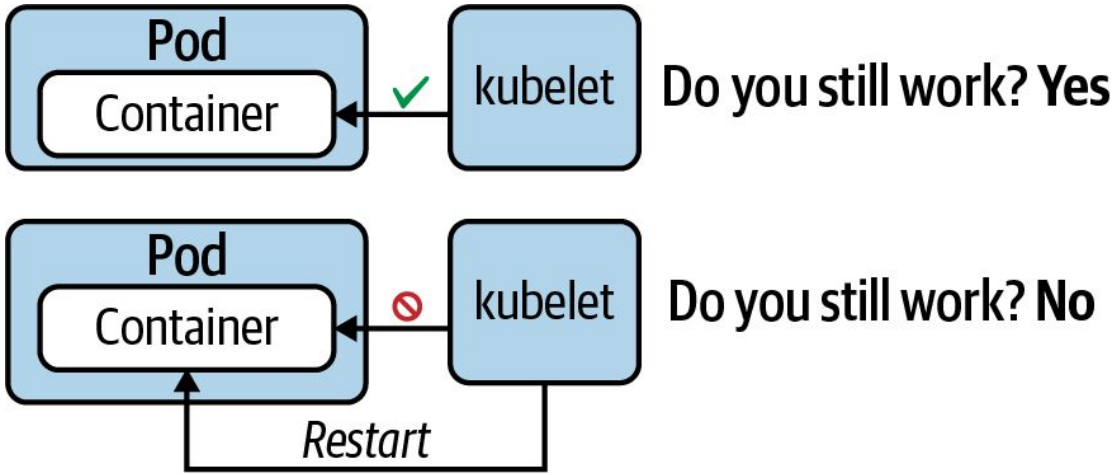
Readiness Probe

“Is application ready to serve requests?”



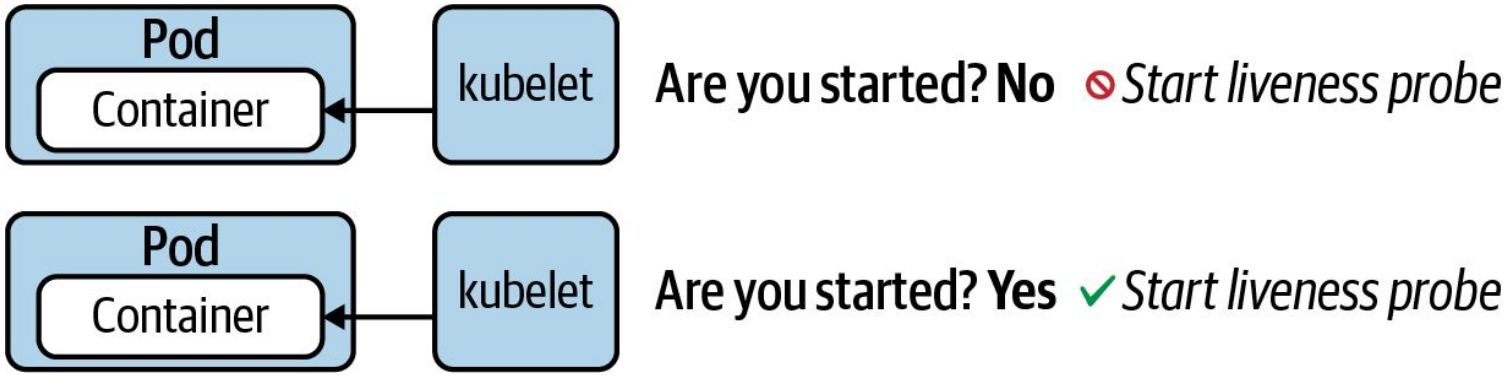
Liveness Probe

“Does the application still function without errors?”



Startup Probe

“Legacy application may need longer to start. Hold off on probing.”



Health Verification Methods

Method	Option	Description
Custom Command	`exec.command`	Executes a command inside of the container e.g. a cat command and checks its exit code. Kubernetes considers an zero exit code to be successful. A non-zero exit code indicates an error.
HTTP GET Request	`httpGet`	Sends an HTTP GET request to an endpoint exposed by the application. A HTTP response code in the range of 200 and 399 indicates success. Any other response code is regarded as an error.
TCP socket connection	`tcpSocket`	Tries to open a TCP socket connection to a port. If the connection could be established, the probing attempt was successful. The inability to connect is accounted for as an error.

Health Check Attributes

Attribute	Default Value	Description
`initialDelaySeconds`	`0`	Delay in seconds until first check is executed.
`periodSeconds`	`10`	Interval for executing a check (e.g., every 20 seconds).
`timeoutSeconds`	`1`	Maximum number of seconds until check operation times out.
`successThreshold`	`1`	Number of successful check attempts until probe is considered successful after a failure.
`failureThreshold`	`3`	Number of failures for check attempts before probe is marked failed and takes action.

Defining a Readiness Probe

HTTP probes are very helpful for web applications

```yaml
apiVersion: v1
kind: Pod
metadata:
  name: web-app
spec:
  containers:
  - name: web-app
    image: eshop:4.6.3
    readinessProbe:
      httpGet:
        path: /
        port: 8080
      initialDelaySeconds: 5
      periodSeconds: 2
```

Successful if HTTP status code is between 200 and 399

Defining a Liveness Probe

An event log can be queried by a custom command

```
apiVersion: v1
kind: Pod
metadata:
  name: web-app
spec:
  containers:
  - name: web-app
    image: eshop:4.6.3
    livenessProbe:
      exec:
        command:
        - test `find /tmp/heartbeat.txt -mmin -1`
      initialDelaySeconds: 10
      periodSeconds: 5
```

Does the file get updated periodically by the application process?

Defining a Startup Probe

TCP socket connection if exposed by application

```
apiVersion: v1
kind: Pod
metadata:
  name: startup-pod
spec:
  containers:
  - image: httpd:2.4.46
    name: http-server
    startupProbe:
      tcpSocket:
        port: 80
      initialDelaySeconds: 3
      periodSeconds: 15
```

Tries to open a TCP socket connection to a port

EXERCISE

Defining a Pod’s
Readiness and
Liveness Probe

Q & A

Monitoring and Troubleshooting

Metrics Server, Finding and Fixing Issues in Applications

Monitoring Kubernetes

What metrics are of interest?

- Number of nodes in the cluster.
- Health status of nodes.
- Node performance metrics like CPU, memory, disk space, network.
- Pod-level performance metrics like CPU, memory consumption.

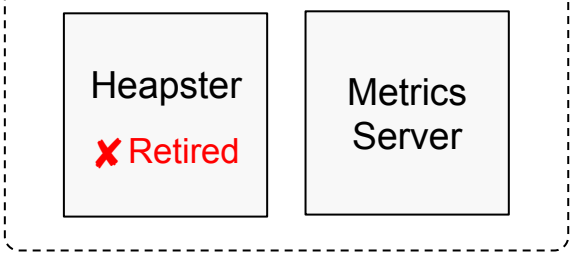
Monitoring Solution

Relevant to the exam: metrics server

Commercial Products

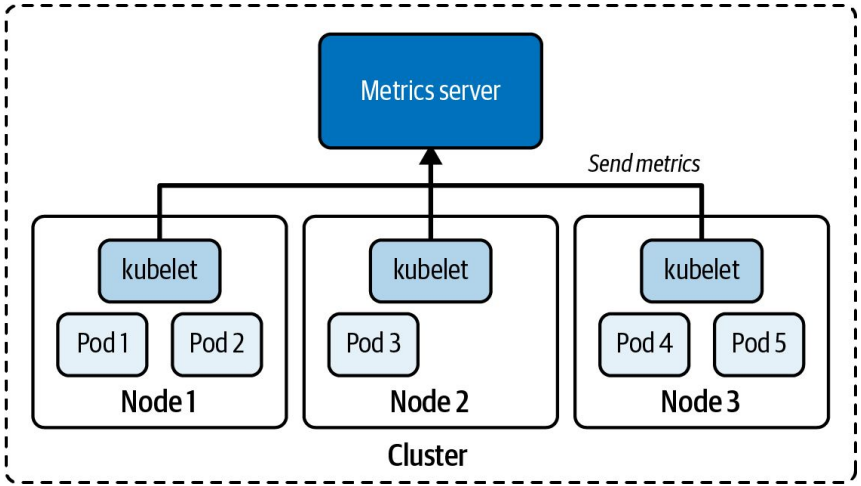
vs.

Free Solutions



Metrics Server

Cluster-wide metrics aggregator



Installing the Metrics Server

Add on-component for Minikube or creating objects

```
$ minikube addons enable metrics-server
The 'metrics-server' addon is enabled
```

```
$ kubectl apply -f
https://github.com/kubernetes-sigs/metrics-server/r
eleases/latest/download/components.yaml
```

Using the Metrics Server

The `kubectl top` command can query nodes and Pods

```
$ kubectl top nodes
NAME       CPU(cores)   CPU%   MEMORY(bytes)   MEMORY%
minikube   283m         14%    1262Mi          32%
```

```
$ kubectl top pod frontend
NAME       CPU(cores)   MEMORY(bytes)
frontend   0m           2Mi
```

Verifying YAML Manifests

List of tools available, kubeval is helpful for CI/CD pipelines

```
$ kubeval -v 1.24.6 -s
  https://raw.githubusercontent.com/yannh/kubernetes-json-schema/master
  -d .
PASS - ch02/ingress/setup.yaml contains a valid Namespace (t75)
PASS - ch02/ingress/setup.yaml contains a valid Deployment
(t75.nginx-deployment)
PASS - ch02/ingress/setup.yaml contains a valid Service
(t75.accounting-service)
...
```

Troubleshooting Pods

Check the status first - is it running?

```
$ kubectl get pods
NAME     READY    STATUS     RESTARTS    AGE
myapp    1/1      Running    0           12m
```

✓ Healthy status

Common Pod Error Statuses

Status	Root cause	Potential fix
`ImagePullBackOff` or `ErrImagePull`	Image could not be pulled from registry	Check correct image name, check that image name exists in registry, verify network access from node to registry, ensure proper
`CrashLoopBackOff`	Application or command run in container crashes	Check command executed in container, ensure that image can properly execute (e.g. by creating a container with Docker)
`CreateContainerConfigError`	ConfigMap or Secret references by container cannot be found	Check correct name of the configuration object, verify the existence of the configuration object in the namespace

Troubleshooting Pods

Check the event log - does it indicate issues?

```
$ kubectl describe pod myapp
...
Events:
  Type     Reason       Age                    From               Message
  ----     ------       ----                   ----               -------
  Normal   Scheduled    <unknown>              default-scheduler  Successfully↵
  assigned default/secret-pod to minikube
  Warning  FailedMount  3m15s                  kubelet, minikube  Unable to↵
  attach or mount volumes: unmounted volumes=[mysecret], unattached↵
  volumes=[default-token-bf8rh mysecret]: timed out waiting for the condition
  Warning  FailedMount  68s (x10 over 5m18s)  kubelet, minikube ↵
  MountVolume.SetUp failed for volume "mysecret" : secret "mysecret" not found
  ...
```

✘ Failed mount

Troubleshooting Pods

Check the container logs - do you see anything suspicious?

```
$ kubectl logs myapp
...
2019-03-05 10:57:51.112  DEBUG  Receiving order
2019-03-05 10:57:51.112  INFO   Processing payment with ID 345993
2019-03-05 10:57:51.112  ERROR  Can't connect to payment system
```

✘ Connectivity issues

Use the command line option `--previous` to gets the logs from the previous instantiation of a container after a restart

EXERCISE

Troubleshooting a
Misconfigured Pod

Q & A

Custom Resource Definitions (CRD)

Discovery and Usage

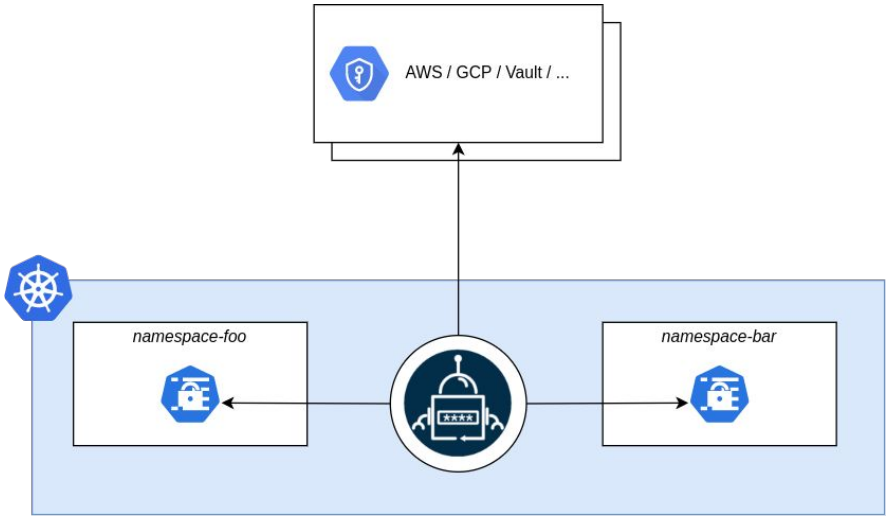
What is a CRD?

Extension point for introducing custom API primitives

- Some use cases with custom requirements cannot be fulfilled with the built-in Kubernetes primitives and functionality.
- A CustomResourceDefinition (CRD) allows you to define, create, and persist a custom object and expose it with the Kubernetes API.
- CRDs are combined with *controllers* to make them actually useful. Controllers enhance the core Kubernetes functionality.

Example CRD

Retrieving secrets from an external source (Github)



Discovering CRDs

Once installed, you can list all available CRDs

```
$ kubectl get crd
NAME                                                  CREATED AT
clusterexternalsecrets.external-secrets.io            2022-10-27T13:30:50Z
clustersecretstores.external-secrets.io               2022-10-27T13:30:50Z
externalsecrets.external-secrets.io                   2022-10-27T13:30:50Z
secretstores.external-secrets.io                      2022-10-27T13:30:50
```

Discovering API Resources

The installed CRD adds multiple custom resources

```
$ kubectl api-resources
NAME                      SHORTNAMES   APIVERSION                      NAMESPACED   KIND
clusterexternalsecrets    ces          external-secrets.io/v1beta1     false        ClusterExternalSecret
clustersecretstores       css          external-secrets.io/v1beta1     false        ClusterSecretStore
externalsecrets           es           external-secrets.io/v1beta1     true         ExternalSecret
secretstores              ss           external-secrets.io/v1beta1     true         SecretStore
```

Inspecting a CRD

Describes the API resource metadata and schema

```
$ kubectl get describe secretstores.external-secrets.io -o yaml
apiVersion: apiextensions.k8s.io/v1
kind: CustomResourceDefinition
metadata:
  name: secretstores.external-secrets.io
spec:
  group: external-secrets.io
  scope: Namespaced
  names:
    categories:
    - externalsecrets
    kind: SecretStore
    listKind: SecretStoreList
    plural: secretstores
    shortNames:
    - ss
    singular: secretstore
  versions:
    name: v1beta1
    schema:
      openAPIV3Schema:
        ...
```

Using a CRD

SecretStore resource captures access to external secret store

```yaml
apiVersion: external-secrets.io/v1beta1
kind: SecretStore
metadata:
  name: secretstore-sample
spec:
  provider:
    aws:
      service: SecretsManager
      region: us-east-1
      auth:
        secretRef:
          accessKeyIDSecretRef:
            name: awssm-secret
            key: access-key
          secretAccessKeySecretRef:
            name: awssm-secret
            key: secret-access-key
```

Usage of a custom kind and its API version

Usage of attributes defined by CRD

Creating a SecretStore

The object can be created and interacted with as usual

```
$ kubectl create -f aws-secretstore.yaml
secretstore.external-secrets.io/secretstore-sample created

$ kubectl get secretstores
NAME                  AGE     STATUS                    READY
secretstore-sample    8m47s   InvalidProviderConfig     False

$ kubectl delete secretstore secretstore-sample
secretstore.external-secrets.io "secretstore-sample" deleted
```

Role-Based Access Control

Defining Roles and RoleBindings for Users and Service Accounts

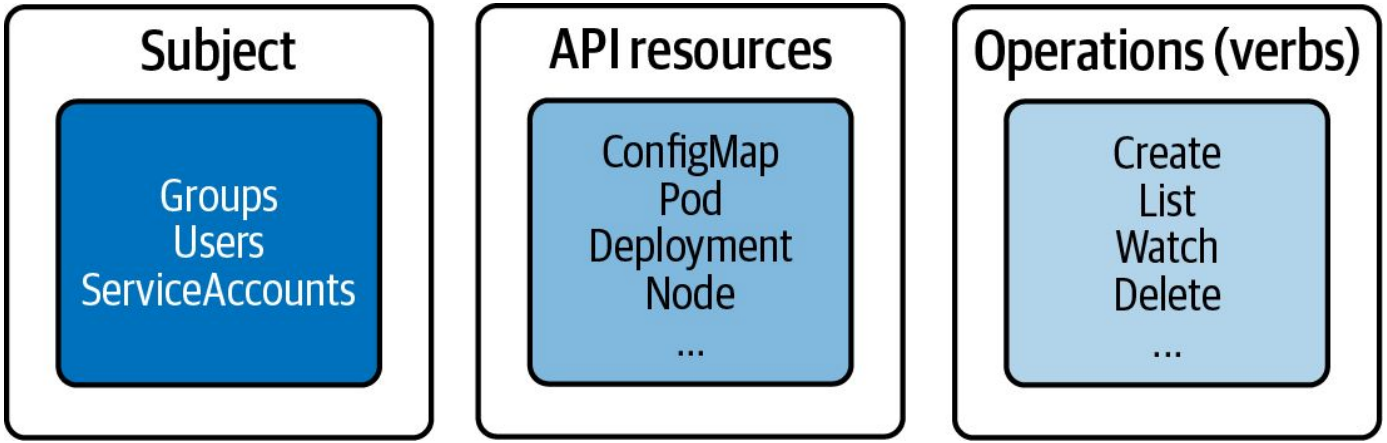
What is RBAC?

Restricting access control for clients interacting with API server

- Defines policies for users, groups, and processes by allowing or disallowing access to manage API resources.
- Enabling and configuring RBAC is mandatory for any organization with a strong emphasis on security.
- *Example:* “The human user john is only allowed to list and create Pods, and Deployments but nothing else.”

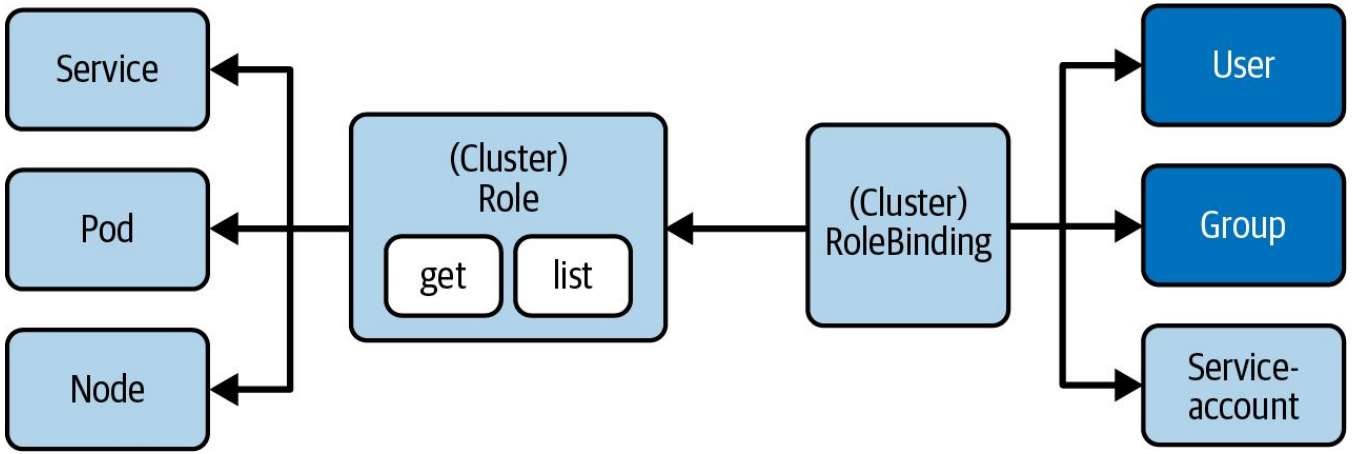
RBAC High-Level Overview

Three key elements for understanding concept



Involved RBAC Primitives

Restrict access to API resources based on user roles



Creating a Role

Defines verbs and resources in comma-separated list

```
$ kubectl create role read-only --verb=list,get,watch↵
  --resource=pods,deployments,services
role.rbac.authorization.k8s.io/read-only created
```

Resources: Primitives the operations should apply to

Operations: Only allow listing, getting, watching

Role YAML Manifest

Can define a list of rules in an array

```yaml
apiVersion: rbac.authorization.k8s.io/v1
kind: Role
metadata:
  name: pod-reader
rules:
- apiGroups: [""]
  resources: ["pods", "services"]
  verbs: ["list", "get", "watch"]
- apiGroups: ["apps"]
  resources: ["deployments"]
  verbs: ["list", "get", "watch"]
```

Resources with groups need to spelled out explicitly

Getting Role Details

Maps objects of a type to verbs

```
$ kubectl describe role read-only
Name:         read-only
Labels:       <none>
Annotations:  <none>
PolicyRule:
  Resources         Non-Resource URLs  Resource Names  Verbs
  ---------         -----------------  --------------  -----
  pods              []                 []              [list get watch]
  services          []                 []              [list get watch]
  deployments.apps  []                 []              [list get watch]
```

Creating a RoleBinding

Map subject to Role

```
$ kubectl create rolebinding read-only-binding --role=read-only↵
  --user=johndoe
rolebinding.rbac.authorization.k8s.io/read-only-binding created
```

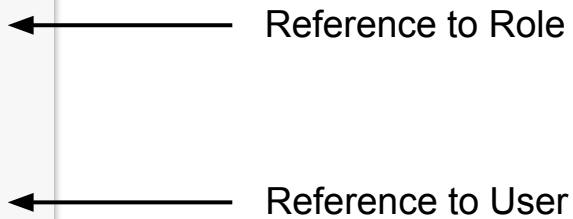
Subject: Binds a user to the Role

Role: Reference the name of the object

RoleBinding YAML Manifest

Roles can be mapped to multiple subjects if needed

```yaml
apiVersion: rbac.authorization.k8s.io/v1
kind: RoleBinding
metadata:
  name: read-only-binding
roleRef:
  apiGroup: rbac.authorization.k8s.io
  kind: Role
  name: read-only
subjects:
- apiGroup: rbac.authorization.k8s.io
  kind: User
  name: johndoe
```



Getting RoleBinding Details

Only shows mapping between Role and subjects

```
$ kubectl describe rolebinding read-only-binding
Name:         read-only-binding
Labels:       <none>
Annotations:  <none>
Role:
  Kind:  Role
  Name:  read-only
Subjects:
  Kind  Name     Namespace
  ----  ----     ---------
  User  johndoe
```

Cluster-wide RBAC

Apply Roles and RoleBindings across multiple namespaces

- The configuration elements are effectively the same. The only difference is the value of the `kind` attribute.
- To define a cluster-wide Role, use the imperative subcommand `clusterrole` or the kind ClusterRole in the YAML manifest.
- To define a cluster-wide RoleBinding, use the imperative subcommand `clusterrolebinding` or the kind ClusterRoleBinding in the YAML manifest.

Aggregated ClusterRoles

Combine multiple ClusterRole rules into one

```yaml
apiVersion: rbac.authorization.k8s.io/v1
kind: ClusterRole
metadata:
  name: pods-services-aggregation-rules
  namespace: rbac-example
aggregationRule:
  clusterRoleSelectors:
  - matchLabels:
      rbac-pod-list: "true"
  - matchLabels:
      rbac-service-delete: "true"
rules: []
```

Select other ClusterRoles by labels

What is a Service Account?

Process in a container needs to interact with Kubernetes API

- Pods use a Service Account to authenticate with the API server through an authentication token.
- If not assigned explicitly, a Pod uses the `default` Service Account. The `default` Service Account has the same permissions as an unauthenticated user.
- *Example:* “I have a CI/CD process that should interact with the Kubernetes API using an authentication token.”

Service Account as Subject

Usage needs to be configured in Pod

ServiceAccount YAML Manifest

Enables authentication token auto-mounting by default

```yaml
apiVersion: v1
kind: ServiceAccount
metadata:
  name: sa-api
  namespace: k97
```

The token file will be available to any Pod that uses the Service Account at
`/var/run/secrets/kubernetes.io/serviceaccount/token`

Using Service Account in Pod

Enables authentication token auto-mounting by default

```
apiVersion: v1
kind: Pod
metadata:
  name: list-pods
  namespace: k97
spec:
  serviceAccountName: sa-api
  containers:
  - name: pods
    image: alpine/curl:3.14
    command: ['sh', '-c', 'while true; do curl -s -k -m 5 -H
             "Authorization: Bearer $(cat /var/run/secrets/kubernetes.io/
             serviceaccount/token)" https://kubernetes.default.svc.cluster.
             local/api/v1/namespaces/k97/pods; sleep 10; done']
```

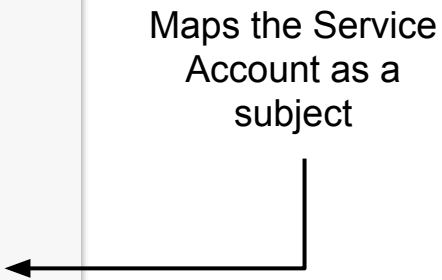
Assigned name of Service Account

List all Pods in the namespace `k97` via an API call

RoleBinding YAML Manifest

Default RBAC policies don't span beyond `kube-system`

```yaml
apiVersion: rbac.authorization.k8s.io/v1
kind: RoleBinding
metadata:
  name: serviceaccount-pod-rolebinding
  namespace: k97
roleRef:
  apiGroup: rbac.authorization.k8s.io
  kind: ClusterRole
  name: list-pods-clusterrole
subjects:
- apiGroup: rbac.authorization.k8s.io
  kind: ServiceAccount
  name: sa-api
```



EXERCISE

Regulating Access
to API Resources
with RBAC

Q & A

Resource Requirements and Boundaries

Container Resource Requests and Limits, Resource Quotas for Namespaces

Handling Resources

It's best practice to make statement about resource consumption

- Containers can define a minimum amount of resources needed to run the application, as well as the maximum amount of resources the application is allowed to consume.
- Application developers should determine the right-sizing with load tests or at runtime by monitoring the resource consumption.
- Enforcement of resources can be constrained on a namespace-level with a ResourceQuota.

Resource Units in Kubernetes

CPU units and memory as fixed-point number or power-of-two equivalents

Kubernetes measures CPU resources in millicores and memory resources in bytes. That's why you might see resources defined as `600m` or `100Mib`.

For a deep dive on those resource units, it's worth cross-referencing the section "Resource units in Kubernetes" in the official documentation.

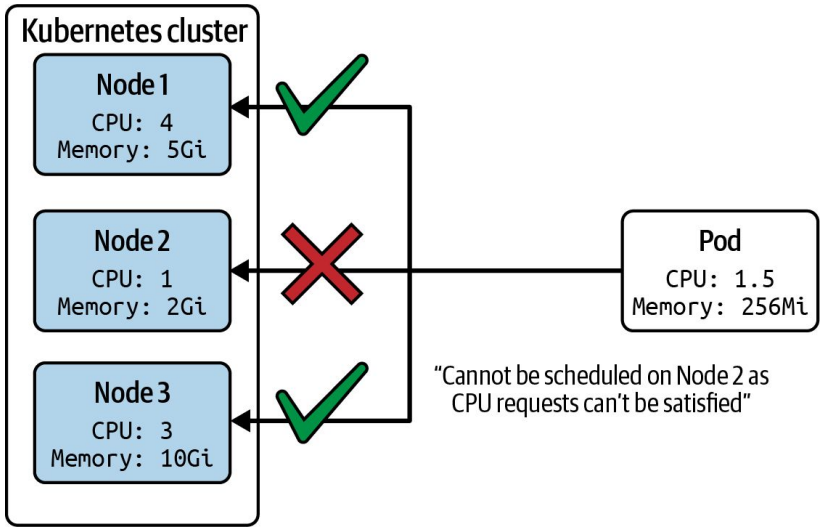
Container Resource Requests

Definition and runtime effects

- Containers can define a minimum amount of resources needed to run the application via `spec.containers[].resources.requests`.
- Resource types include CPU, memory, huge page, ephemeral storage.
- If Pod cannot be scheduled on any node due to insufficient resource availability, you may see a `PodExceedsFreeCPU` or `PodExceedsFreeMemory` status.

Example Scheduling Scenario

Node's resource capacity needs to be able to fulfill it



Resource Requests YAML Manifest

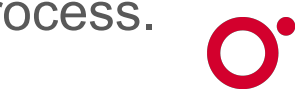
Minimum amount of resources define for a container

```yaml
apiVersion: v1
kind: Pod
metadata:
  name: rate-limiter
spec:
  containers:
  - name: business-app
    image: bmuschko/nodejs-business-app:1.0.0
    ports:
    - containerPort: 8080
    resources:
      requests:
        memory: "256Mi"
        cpu: "1"
```

Container Resource Limits

Definition and runtime effects

- Containers can define a maximum amount of resources allowed to consumed by the application via `spec.containers[].resources.limits`.
- Resource types include CPU, memory, huge page, ephemeral storage.
- Container runtime decides how to handle situation where application exceeds allocated capacity, e.g. termination of application process.



Resource Limits YAML Manifest

Do not allow more than the allotted resource amounts

```yaml
apiVersion: v1
kind: Pod
metadata:
  name: rate-limiter
spec:
  containers:
  - name: business-app
    image: bmuschko/nodejs-business-app:1.0.0
    ports:
    - containerPort: 8080
    resources:
      limits:
        memory: "512Mi"
        cpu: "2"
```

Pod Scheduling Details

After scheduling a Pod, you can check on runtime information

```
$ kubectl get pod rate-limiter -o yaml | grep nodeName:
  nodeName: worker-3

$ kubectl describe node worker-3
...
Non-terminated Pods:          (3 in total)
  Namespace                   Name                CPU Requests  CPU Limits  ...
  ---------                   ----                ------------  ----------  ...
  default                     rate-limiter        1250m (62%)   0 (0%)      ...
```

What is a ResourceQuota?

Defines resource constraints per namespace

- Constraints that limit aggregate resource consumption or limit the quantity of objects that can be created.
- `requests.cpu/memory`: Across all pods in a non-terminal state, the sum of CPU/memory requests cannot exceed this value.
- `limits.cpu/memory`: Across all pods in a non-terminal state, the sum of CPU/memory limits cannot exceed this value.

ResourceQuota YAML Manifest

# of objects and limit aggregate resource consumption

```yaml
apiVersion: v1
kind: ResourceQuota
metadata:
  name: awesome-quota
  namespace: team-awesome
spec:
  hard:
    pods: 2
    requests.cpu: "1"
    requests.memory: 1024Mi
    limits.cpu: "4"
    limits.memory: 4096Mi
```

No Requests/Limits Definition

Scheduler rejects the creation of the object

```
$ kubectl create -f nginx-pod.yaml -n team-awesome
Error from server (Forbidden): error when creating "nginx-pod.yaml": ↵
pods "nginx" is forbidden: failed quota: awesome-quota: must specify ↵
limits.cpu,limits.memory,requests.cpu,requests.memory
```

Exceeds Requests/Limits

Scheduler rejects the creation of the object

```
$ kubectl create -f nginx-pod.yaml -n team-awesome
Error from server (Forbidden): error when creating "nginx-pod.yaml"↵
pods "nginx" is forbidden: exceeded quota: awesome-quota, requested↵
pods=1,requests.cpu=500m,requests.memory=512Mi, used: pods=2,requests.cpu=1↵
requests.memory=1024Mi, limited: pods=2,requests.cpu=1,requests.memory=1024Mi
```

Inspecting a ResourceQuota

Consumed resources and defined hard limits

```
$ kubectl describe resourcequota awesome-quota -n team-awesome
Name:             awesome-quota
Namespace:        team-awesome
Resource          Used   Hard
--------          ----   ----
limits.cpu        2      4
limits.memory     2048m  4096m
pods              2      2
requests.cpu      1      1
requests.memory   1024m  1024m
```

EXERCISE

Defining a Pod’s Resource Requirements

Q & A

ConfigMaps and Secrets

Creating and Consuming Configuration Data

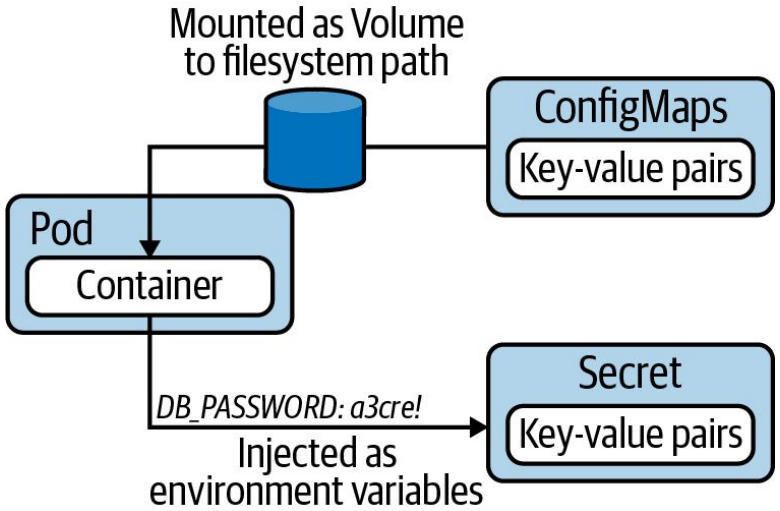
Defining Configuration Data

Control runtime behavior with centralized information

- Stored as key-value pairs in dedicated Kubernetes primitives with a lifecycle decoupled from consuming Pod.
- *ConfigMap:* Plain-text values suited for configuring application e.g. flags, or URLs.
- *Secret:* Base64-encoded values suited for storing sensitive data like passwords, API keys, or SSL certificates. Values are not encrypted!

Consuming ConfigMap & Secret

Mounting as a Volume or injecting as env. variables



ConfigMap Data Sources

Imperative command provides options for sourcing data

- `--from-literal`: Literal values, which are key-value pairs as plain text.
- `--from-env-file`: A file that contains key-value pairs and expects them to be environment variables.
- `--from-file`: A file with arbitrary contents.
- `--from-file`: A directory with one or many files.

Creating a ConfigMap

Fast, easy and flexible, can point to different sources

```
$ kubectl create configmap db-config --from-literal=db=staging
configmap/db-config created

$ kubectl create configmap db-config --from-env-file=config.env
configmap/db-config created

$ kubectl create configmap db-config --from-file=config.txt
configmap/db-config created

$ kubectl create configmap db-config --from-file=app-config
configmap/db-config created
```

ConfigMap YAML Manifest

Definition of a ConfigMap is fairly short and on point

```yaml
apiVersion: v1
kind: ConfigMap
metadata:
  name: db-config
data:
  db: staging
  username: jdoe
```

Consuming as Env. Variables

Convenient if ConfigMap reflects the desired syntax

```
apiVersion: v1
kind: Pod
metadata:
  name: backend
spec:
  containers:
  - image: nginx
    name: backend
    envFrom:
      - configMapRef:
          name: db-config
```

```
$ kubectl exec -it nginx -- env
db=staging
username=jdoe
...
```

Consuming as a Volume

Use Volume type `configMap`

```
apiVersion: v1
kind: Pod
metadata:
  name: backend
spec:
  containers:
    - name: backend
      image: nginx
      volumeMounts:
      - name: config-volume
        mountPath: /etc/config
  volumes:
    - name: config-volume
      configMap:
        name: db-config
```

```
$ kubectl exec -it backend -- /bin/sh
# ls /etc/config
db
username
# cat /etc/config/db
staging
```

EXERCISE

Configuring a Pod
to Use a ConfigMap

Secret Options

Imperative command: `kubectl create secret`

Option	Description
`generic`	Creates a secret from a file, directory, or literal value.
`docker-registry`	Creates a secret for use with a Docker registry.
`tls`	Creates a TLS secret.

Secret Data Sources

Imperative `generic` command provides options for sourcing data

- `--from-literal`: Literal values, which are key-value pairs as plain text.
- `--from-env-file`: A file that contains key-value pairs and expects them to be environment variables.
- `--from-file`: A file with arbitrary contents.
- `--from-file`: A directory with one or many files.

Creating a Secret

Values are base64-encoded automatically

```
$ kubectl create secret generic db-creds --from-literal=pwd=s3cre!
secret/db-creds created

$ kubectl create secret generic db-creds --from-env-file=secret.env
secret/db-creds created

$ kubectl create secret generic db-creds --from-file=id_rsa=~/.ssh/id_rsa
secret/db-creds created
```

Secret YAML Manifest

Value has to be base64-encoded manually

```
$ echo -n 's3cre!' | base64
czNjcmUh
```

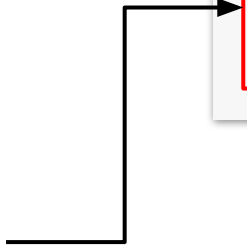
```
apiVersion: v1
kind: Secret
metadata:
  name: mysecret
type: Opaque
data:
  pwd: czNjcmUh
```

Consuming as Volume

Inside of the container, values are base64-decoded

```
apiVersion: v1
kind: Pod
metadata:
  name: backend
spec:
  containers:
    - name: backend
      image: nginx
      volumeMounts:
      - name: secret-volume
        mountPath: /etc/secret
  volumes:
    - name: secret-volume
      secret:
        secretName: mysecret
```

```
$ kubectl exec -it backend -- /bin/sh
# ls /etc/secret
pwd
# cat /etc/secret/pwd
s3cre!
```



Specialized Secret Types

The table only lists some, more in docs

Type	Description
`kubernetes.io/basic-auth`	Credentials for basic authentication
`kubernetes.io/ssh-auth`	Credentials for SSH authentication
`kubernetes.io/service-account-token`	ServiceAccount token

Plain-Text Secret Values

The `stringData` attribute allows for plain-text values

```
apiVersion: v1
kind: Secret
metadata:
  name: secret-basic-auth
type: kubernetes.io/basic-auth
stringData:
  username: admin
  password: t0p-Secret
```

EXERCISE

Configuring a Pod
to Use a Secret

Q & A

Security Contexts for Pods

Defining Privilege and Access Control

What is a Security Context?

Privilege and access control settings for a Pod or container

- Modeled as a set of attributes under the attribute `securityContext` within the Pod specification.
- Can be applied to all containers in Pod or for individual containers.
- *Example:* “This container needs to run with a non-root user.”

Defining a Security Context

Pod- vs. container-level definition

```yaml
apiVersion: v1
kind: Pod
metadata:
  name: secured-pod
spec:
  securityContext:
    runAsUser: 1000
  containers:
  - image: nginx:1.18.0
    name: secured-container
    securityContext:
      runAsGroup: 3000
```

Defined on the Pod-level

Defined on the container-level

Security Context API

Only partial overlap for Pod- and container attributes

API	Description
PodSecurityContext	Defines Pod-level security attributes.
SecurityContext	Defines container-level security attributes.

EXERCISE

Creating a Security Context for a Pod

Q & A

Services

Service Types and Troubleshooting

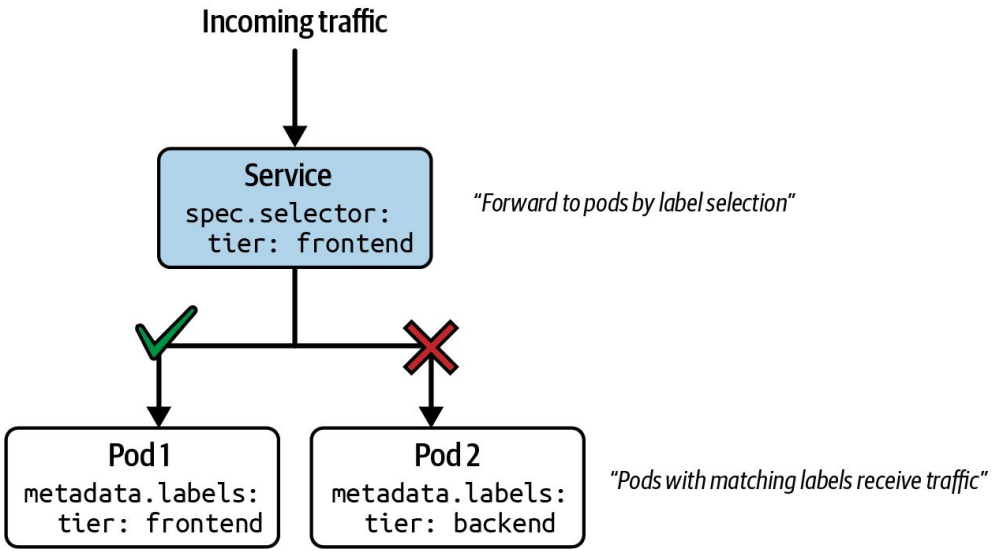
What is a Service?

Discoverable networking capability for Pods

- A Pod's IP address is not considered stable over time. A Pod restart leases a new IP address.
- Building a microservices architecture on Kubernetes requires network interfaces stable over time.
- A Service provides discoverable names and load balancing to a set of Pods.

Request Routing

“How does a service decide which Pod to forward the request to?”



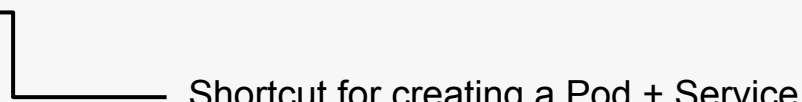
Different Types of Services

Type	Behavior
`ClusterIP`	Exposes the service on a cluster-internal IP. Only reachable from within the cluster.
`NodePort`	Exposes the service on each node's IP at a static port. Accessible from outside of the cluster.
`LoadBalancer`	Exposes the service externally using a cloud provider’s load balancer.

Creating a Service

Ensure that Pod labels and Service label selector match

```
$ kubectl run echoserver --image=k8s.gcr.io/echoserver:1.10 --restart=Never
  --port=8080
pod/echoserver created

$ kubectl create service clusterip echoserver --tcp=80:8080
service/echoserver created

$ kubectl run echoserver --image=k8s.gcr.io/echoserver:1.10 --restart=Never
  --port=8080 --expose
service/echoserver created
pod/echoserver created
```



Service YAML Manifest

Defines containers and their images running in them

```yaml
apiVersion: v1
kind: Service
metadata:
  name: echoserver
spec:
  type: ClusterIP
  selector:
    app: echoserver
  ports:
  - port: 80
    targetPort: 8080
```

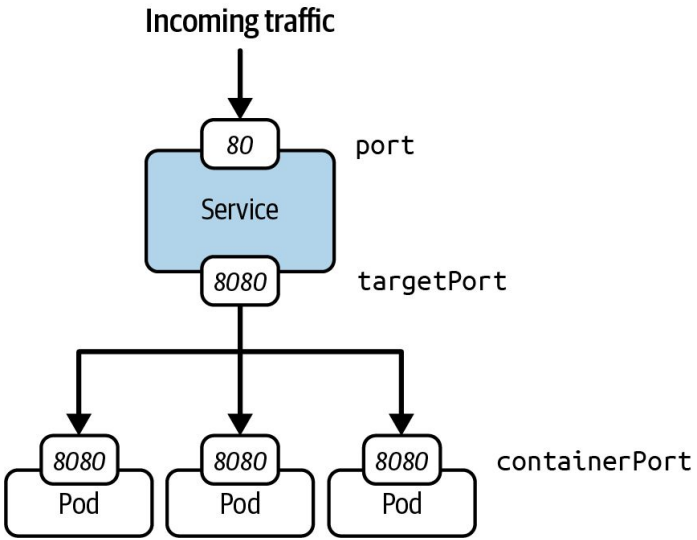
Service type

Label selection for Pods

Mapping of incoming to outgoing port

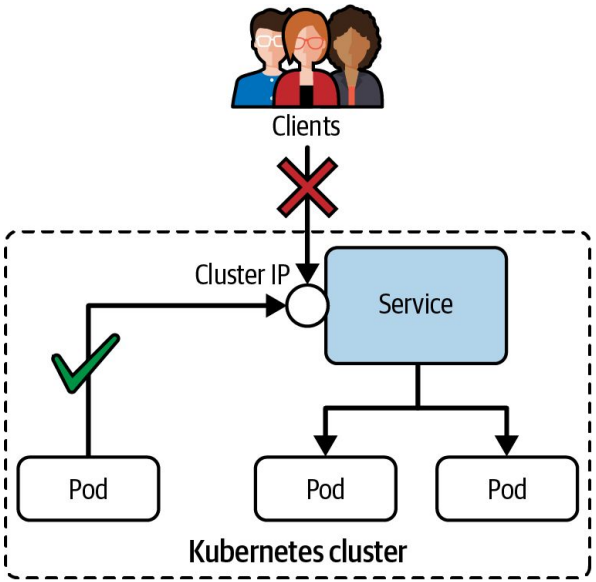
Port Mapping

“How to map the service port to the container port in Pod?”



ClusterIP Service Type

Only reachable from within the cluster, e.g. another Pod



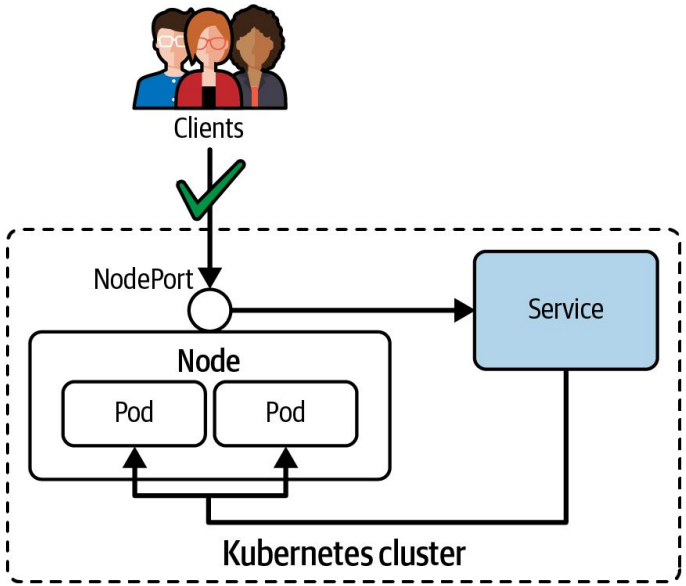
Accessing a ClusterIP Service

Use the combination of cluster IP and incoming service port

```
$ kubectl get pod,service
NAME              READY   STATUS    RESTARTS   AGE
pod/echoserver    1/1     Running   0          23s

NAME                 TYPE        CLUSTER-IP     EXTERNAL-IP   PORT(S)    AGE
service/echoserver   ClusterIP   10.96.254.0    <none>        5005/TCP   8s

$ kubectl run tmp --image=busybox --restart=Never -it --rm
  -- wget 10.96.254.0:5005
Connecting to 10.96.254.0:5005 (10.96.254.0:5005)
...
```

NodePort Service Type

Can be resolved from outside of the Kubernetes cluster



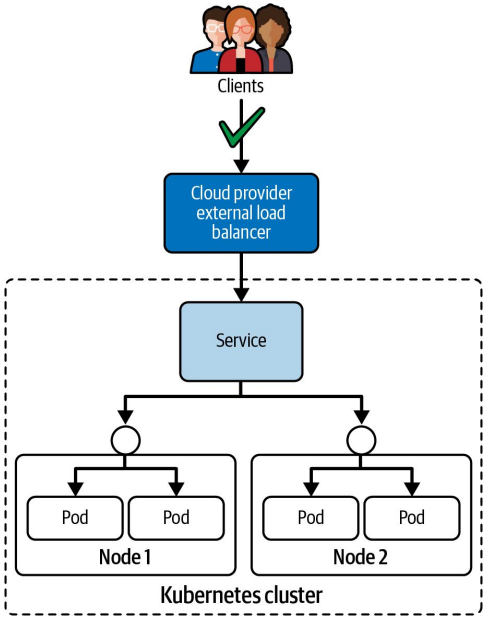
Accessing a NodePort Service

Use the combination of node IP and statically-assigned port

```
$ kubectl get pod,service
NAME              READY    STATUS     RESTARTS    AGE
pod/echoserver    1/1      Running    0           23s

NAME                  TYPE        CLUSTER-IP     EXTERNAL-IP    PORT(S)
AGE
service/echoserver    NodePort    10.96.254.0    <none>         5005:30158/TCP    8s

$ kubectl get nodes -o↵
  jsonpath='{ $.items[*].status.addresses[?(@.type=="InternalIP")].address }'
192.168.64.15

$ wget 192.168.64.15:30158
Connecting to 192.168.64.15:30158... connected.
...
```

LoadBalancer Service Type

Routes traffic from existing, external load balancer to Service



Accessing a LoadBalancer Service

Use the combination of node IP and statically-assigned port

```
$ kubectl get pod,service
NAME             READY   STATUS    RESTARTS   AGE
pod/echoserver   1/1     Running   0          23s

NAME                 TYPE           CLUSTER-IP      EXTERNAL-IP     PORT(S)
AGE
service/echoserver   LoadBalancer   10.109.76.157   10.109.76.157   5005:30642/TCP   5s

$ wget 10.109.76.157:5005
Connecting to 10.109.76.157:5005... connected.
...
```

Troubleshooting Services

Check Service type and call endpoint

```
$ kubectl get service nginx
NAME    TYPE        CLUSTER-IP      EXTERNAL-IP   PORT(S)         AGE
nginx   NodePort    10.105.201.83   <none>        80:30184/TCP    3h
```

```
$ curl http://nginx:30184
curl: (6) Could not resolve host: nginx
```

✘ Connectivity issue

Troubleshooting Services

Ensure correct label selection

```
$ kubectl describe service myapp
Name:              myapp
Namespace:         default
Labels:            app=myapp
Annotations:       <none>
Selector:          app=myapp
Type:              ClusterIP
IP:                10.102.22.26
Port:              80-80  80/TCP
TargetPort:        80/TCP
Endpoints:         10.0.0.115:80
Session Affinity:  None
Events:            <none>
```

```
$ kubectl describe pod
myapp
Name:          myapp
...
Labels:        app=myapp
...
```

✓ Matching labels

EXERCISE

Routing traffic to Pods from Inside and Outside of a Cluster

Q & A

Ingress

Purpose, Routing Rules, Access

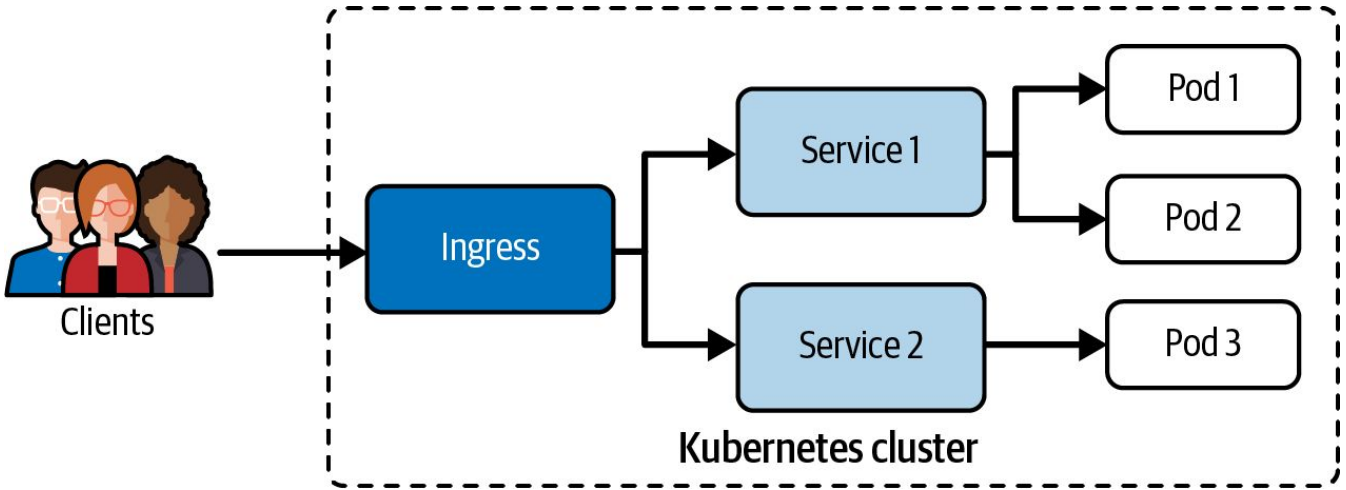
What is an Ingress?

Route HTTP(S) traffic from the outside of cluster to Service

- It's not a specific Service type, nor should it be confused with the Service type `LoadBalancer`.
- Defines rules for mapping URL context path to Service object.
- An Ingress cannot work without an Ingress controller. The Ingress controller evaluates the collection of rules defined by an Ingress that determine traffic routing.

Ingress Traffic Routing

Can involve one or many Services as backend



Creating an Ingress

The rule definition requires intricate knowledge of syntax

```
$ kubectl create ingress corellian↵
  --rule="star-alliance.com/corellian/api=corellian:8080"
ingress.networking.k8s.io/corellian created
```

Ingress YAML Manifest

The host definition is optional

```yaml
apiVersion: networking.k8s.io/v1
kind: Ingress
metadata:
  name: corellian
spec:
  rules:
  - host: star-alliance.com
    http:
      paths:
      - backend:
          service:
            name: corellian
            port:
              number: 8080
        path: /corellian/api
        pathType: Exact
```

Ingress Rules

Traffic routing is controlled by rules defined on Ingress resource

- Optional host. If no host is defined, then all inbound HTTP traffic is handled.
- A list of paths e.g. `/testpath`.
- The backend, a combination of Service name and port.

Path Types

Incoming URLs match based on type

	Rule	*Request*	
Exact	`/foo`	`/foo`	✓
		`/bar`	✗
Prefix	`/foo`	`/foo, /foo/`	✓
		`/bar`	✗

Accessing an Ingress

Use host name and context path

```
$ wget star-alliance.com/corellian/api/ --timeout=5 --tries=1
Resolving star-alliance.com (star-alliance.com)... 192.168.64.15
Connecting to star-alliance.com (star-alliance.com)|192.168.64.15|:80... connected.
...
```

EXERCISE

Defining and Using
an Ingress

Q & A

Network Policies

Purpose, Rules, Best Practices

What is a Network Policy?

Firewall rules for Pod-to-Pod communication

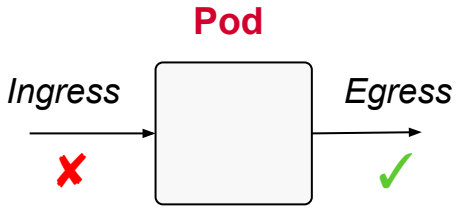
- Communication between Pods in the same cluster is unrestricted. You can use the Pod's IP address to communicate with it.
- Network policies implement the principle of least privilege. Only allow communicate is needed to fulfill requirement of architecture.
- You can disallow and allow network communication with fine-grained rules.

Example Network Policies

“Network Policies control traffic from and to the Pod”

Network Policy Rules

Which Pod does the rule apply to? ✔



Which direction of traffic?
Who is allowed?

Deny All Policy YAML Manifest

Start with default deny policy and then allow traffic

```yaml
apiVersion: networking.k8s.io/v1
kind: NetworkPolicy
metadata:
  name: default-deny-all
spec:
  podSelector: {}
  policyTypes:
  - Ingress
  - Egress
```

Allow Policy YAML Manifest

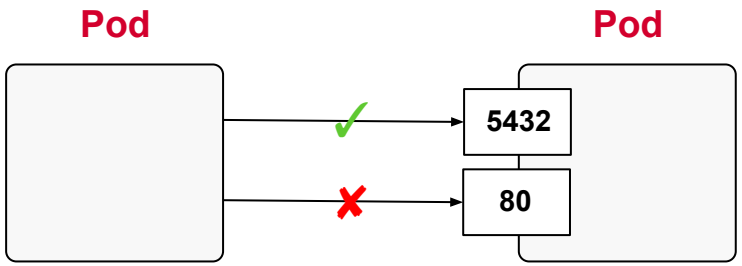
`kubectl` doesn't provide an imperative command

```yaml
apiVersion: networking.k8s.io/v1
kind: NetworkPolicy
metadata:
  name: api-allow
spec:
  podSelector:
    matchLabels:
      app: payment-processor
      role: api
  ingress:
  - from:
    - podSelector:
        matchLabels:
          app: coffeeshop
```

Selects the labels of Pods the rule should apply to

Only defines rules for incoming traffic

Restricting Access to Ports

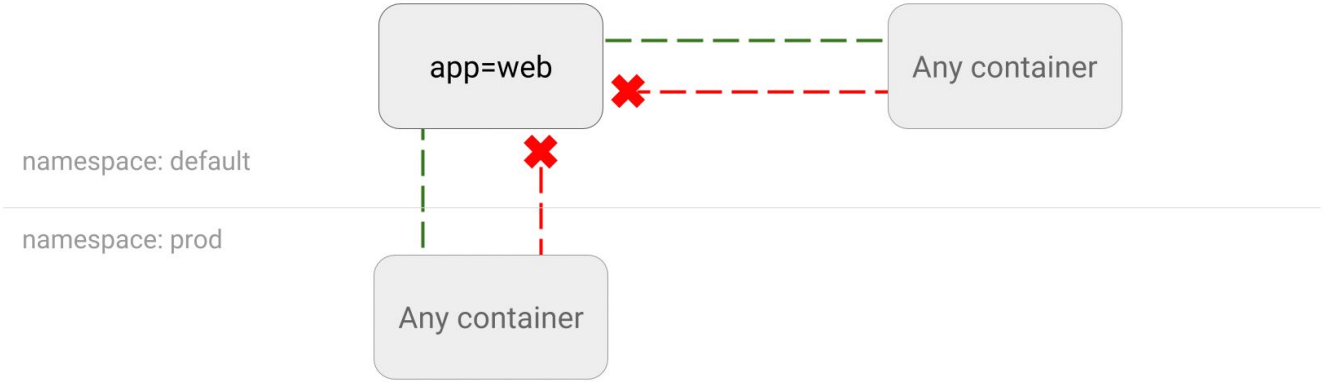


By default all ports are open

```
...
ingress:
- from:
  - podSelector:
      matchLabels:
        tier: backend
  ports:
  - protocol: TCP
    port: 5432
...
```

Additional Learning Resource

Network Policies explained by use case and visualization



https://github.com/ahmetb/kubernetes-network-policy-recipes

EXERCISE

Restricting Access
to and from a Pod

Q & A

Summary & Wrap Up

Last words of advice...

Gaining confidence

- Run through practice exams as often as you can
- Read through online documentation start to end
- Know your tools (especially vim, bash, YAML)
- Pick time you are most comfortable, get enough sleep
- Take your first attempt easy but give it your best

Q & A

O'REILLY®

Thank you