The Beginner's Guide to
Kubernetes

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The Beginner's Guide to Kubernetes

Kubernetes is an open source tool for orchestrating containers. It packages isolated microservices into loosely-coupled containers that can be deployed and scaled anywhere. While traditional, monolithic architectures can be difficult to adapt, containers make it possible for applications to become more scalable, portable, and resilient (i.e. cloud native).

Google created Kubernetes as an offshoot of its internal Borg project. It was open sourced in 2015 and has since become the industry standard for container orchestration. In the **2019 CNCF Survey**, 78% of respondents were using Kubernetes in production compared to 58% the previous year. The adoption of Kubernetes is exploding.

Whether you're a developer, a platform operator, or an SRE, Kubernetes is the foundation of any cloud native technology practice. This ebook will teach you the basic concepts of Kubernetes and prepare you to dive deeply into its intricacies.

This ebook is about pure, open source, vanilla Kubernetes with no vendors involved. It isn't the same Kubernetes you'll find in other GitHub repositories. What you'll find there are Kubernetes distributions or managed services. These are different ways of spinning up clusters. Kubernetes itself is a technology provided by different vendors.

Managed services (such as GKE, EKS, and AKS) make the process of adopting and managing Kubernetes easier by offering a variety of in-depth services. Kubernetes distributions, such as OpenShift or Rancher, are platforms that also facilitate the adoption and management of Kubernetes but are less opinionated. Distributions and managed services can be great options for organizations looking for leaner deployments with smaller, more focused DevOps teams.

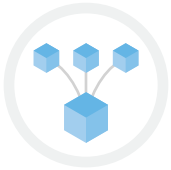
The open source version of Kubernetes offers the most flexibility, as it allows you to maintain control over how you configure your deployments. However, it can also be more complex to implement and operate. If you're new to Kubernetes, it is best to first learn the vanilla version before broadening your horizons with other cloud native tools.

To master the DevOps and cloud native landscapes, you'll need in-depth training. CloudOps' Docker and Kubernetes workshops will help you thrive with these tools, but this ebook will first familiarize you with the terms and deployments.

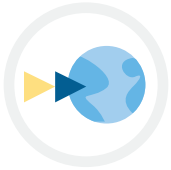
Deployments

A deployment is one of many Kubernetes objects.
In technical terms, it encapsulates:

Pod Specification



Replica Count



Deployment Strategy

In practical terms, you can think of a deployment as an instance of an application with it's associated configuration. If you have two deployments, one could be a "production" environment and the other a "staging" environment.

Now onto some important concepts!

- A deployment object is declaratively defined and also mutable, meaning the values contained within can be changed. Some examples of a deployment object change include:
  - The underlying container referenced is changed
  - The application credentials have changed

- When values change within the deployment object, Kubernetes controllers will be responsible for propagating these changes downstream and changing the state of the cluster to meet the definition of the deployment.

- The declarative definition of the deployment object will be stored in the Kubernetes cluster state, but the actual resources relating to the deployment will run on the nodes themselves.

- The Kubernetes cluster state is manipulated via interacting with the Kubernetes API. This is the only way deployments can be managed for end users. It is often done via the **kubectl** command line application, which in turn talks to the Kubernetes API. It is essentially a middleman.

From this point in the article, I assume your cluster is already setup, configured, and has access to **kubectl**. I have also not mentioned namespaces, to keep things simple and concise.

Take note that, in the Kubernetes ecosystem, “deployment objects” are often referred to as “configs”, “objects”, “resources” or just “deployments”.

Managing deployments

Creating a new deployment

We can begin by creating a new yaml file named **example-dep.yaml** with contents of:

```
apiVersion: apps/v1
kind: Deployment
metadata:
  name: example-deployment
spec:
  replicas: 1
  selector:
    matchLabels:
      app: example
  template:
    metadata:
      labels:
        app: example
    spec:
      containers:
        - name: example-testing-container
          image: debian:buster-slim
          command: ["bash", "-c", "while
true; do echo \"Hello\"; echo \"EXAMPLE_
ENV: $EXAMPLE_ENV\"; sleep 5; done"]
        env:
          - name: EXAMPLE_ENV
            value: abc123
```

Some things to notice are:

- The name of the deployment which is the main unique reference to identify any deployment, which in our case is: (example-deployment).
- The label attached to the pod (app:example), though we could set more than one.

Run the following:

```
$ kubectl apply -f example-dep.yaml
deployment.apps/example-deployment created
```

A few things will happen in the background. **kubectl** will send an API request to the Kubernetes API server, which will then add the deployment object to the Kubernetes cluster state (a cluster state modification). Once this is created, we will no longer need the **example-dep.yaml** file as it would be stored in the cluster state. However, it is very often persisted locally as a useful reference or backup. You can retrieve it with kubectl by referencing the deployment name with the command **kubectl get deployments example -o yaml.**

We can view the current deployments in Kubernetes via the **kubectl get deployments** command:

```
$ kubectl get deployments
NAME                 READY   UP-TO-DATE   AVAILABLE   AGE
example-deployment   1/1     1            1           5m
```

We can also view the pods relating to our specific deployment by matching against the labels:

```
$ kubectl get pods -l app=example
NAME                                  READY   STATUS    RESTARTS   AGE
example-deployment-7ffc49755-v72mc    1/1     Running   0          15m
```

You may have noticed that pods have a prefix relating to the name of their deployment, appended with a random and unique identifier.

To modify any of the values, you would just need to modify the file and run **kubectl apply -f** ... again:

```
$ kubectl apply -f example-dep.yaml
deployment.apps/example-deployment created
```

In addition, you can use the helpful **kubectl edit** command to achieve the above in a single step, which would open your **$EDITOR** (vim, nano, etc..):

```
$ kubectl apply -f example-dep.yaml
deployment.apps/example-deployment created
```

Inspecting deployments

There are three commands that are commonly used to inspect existing deployments.

1. **Inspect a deployment just like any other Kubernetes object:**

```
$ kubectl get deployment example-deployment -o yaml
apiVersion: extensions/v1beta1
kind: Deployment
metadata:
  annotations:
    deployment.kubernetes.io/revision: "4"
    kubectl.kubernetes.io/last-applied-configuration: |
     {"apiVersion":"apps/v1","kind":"Deployment","metadata":{"an-
notations":{},"name":"example-deployment","namespace":"de-
fault"},"spec":{"replicas":1,"selector":{"matchLabels":{"app":"exam-
ple"}},"template":{"metadata":{"labels":{"app":"example"}},"spec":{"-
containers":[{"command":["bash","-c","while true; do echo 'test' \
u003e /nfs-mount/$(date +%Y%m%d%H%M%S).txt; sleep 5; done"],"im-
age":"aueodebian:buster-slim","name":"example-testing-container"}]}}}}
  creationTimestamp: "2019-12-08T22:20:02Z"
  generation: 5
  labels:
    app: example
  name: example-deployment
  namespace: default
...
```

2. **Inspect the status and other properties of deployments in a concise view:**

```
$ kubectl get deployment
NAME                 READY   UP-TO-DATE   AVAILABLE   AGE
example-deployment   2/2     2            2           81s
```

3. **Inspect the rollout status of a deployment:**

```
$ kubectl rollout status deployment example-deployment
Waiting for deployment "example-deployment" rollout to finish:
1 out of 2 new replicas have been updated...
```

Rolling deployments

Kubernetes includes the ability to roll deployments. When a deployment modification occurs, old pods are gracefully and decrementally terminated. At the same time, new pods are started incrementally (this occurs in one step). If there are any issues with the new deployment pods, Kubernetes will not terminate any old pods further.

The above functionality ensures that there will always be a minimum amount of successful/healthy running pods in order to achieve "zero downtime".

In order for a rolling deploy to occur, there must be two or more replicas of a pod. This is a common gotcha, so take note! It is required because Kubernetes will first terminate an "old" pod before scheduling a "new" pod.

Here is a demonstrated example using the **example-dep.yaml** file from earlier:

```
$ kubectl apply -f example-dep.yaml
deployment.apps/example-deployment created
```

```
$ kubectl scale deployment/example-deployment --replicas=2
deployment.extensions/example-deployment scaled
```

```
$ kubectl get pods -l app=example
NAME                                  READY   STATUS    RESTARTS   AGE
example-deployment-7ffc49755-96d9h    1/1     Running   0          29s
example-deployment-7ffc49755-xj2d2    1/1     Running   0          29s
```

```
$ kubectl set image deployment/example-deployment example-testing-con-
tainer=debian:this-image-tag-does-not-exist
deployment.extensions/example-deployment image updated
```

```
$ kubectl get pods -l app=example
NAME                                  READY   STATUS         RESTARTS   AGE
example-deployment-7f9959dc57-pq6gp   0/1     ErrImagePull   0          6s
example-deployment-7ffc49755-96d9h    1/1     Running        0          100s
example-deployment-7ffc49755-xj2d2    1/1     Running        0          100s
```

kubectl set image is a simple helper function that can be used to change the image name of a container within a deployment. This saves us from having to modify the file directly and then running **kubectl apply**... As we can see above, the newer pod failed to startup (the image referenced does not exist, which is why we see the **ErrImagePull** status), yet the old ones remained running.

Let's now set the container to reference a valid image:

```
$ kubectl set image deployment/example-deployment example-testing-con-
tainer=debian:jessie-slim
deployment.extensions/example-deployment image updated
```

```
$ kubectl get pods -l app=example
NAME                                 READY   STATUS              RESTARTS   AGE
example-deployment-546c7dff4c-km9bz  1/1     Running             0          21s
example-deployment-546c7dff4c-twcj7  0/1     ContainerCreating   0          4s
example-deployment-7ffc49755-96d9h   1/1     Terminating         0          5m11s
example-deployment-7ffc49755-xj2d2   1/1     Running             0          5m11s
```

In this exact moment, we have one newer pod running and one older pod spinning down. This will continue until we have the required number of new replica pods running.

By default, deployments are set to do rolling deployments. However, this can be configured by the **spec:strategy** value.

Deployment revisions and rollbacks

Creating and viewing revisions

Each time a new deployment is created or modified, Kubernetes will persist a copy of the deployment object (also called a revision), up to a maximum limit that is set by the **.spec.revisionHistoryLimit** field within a deployment.

You can view the list of revisions with the following command:

```
$ kubectl rollout history deployment
example-deployment
deployment.extensions/example-deployment
REVISION        CHANGE-CAUSE
1               <none>
2               <none>
```

By default, there is very little information besides a “revision number” and an empty “change-cause”. The “revision number” is an integer field that begins at 1, which gets incremented for each change to the deployment object. The “change-cause” is a text field that can be set to provide additional information about the deployment revision. For example, it could be set to “fix bug 123” or “update database credentials”.

In order to set the “change-cause” field, you need to set an annotation within the deployment object.

While making sure we have a change in the deployment object, we could set kubernetes.io/change-cause. An example of a change cause within a deployment object is shown below:

```
apiVersion: extensions/v1beta1
kind: Deployment
metadata:
 annotations:
   deployment.kubernetes.io/revision: “3”
   kubernetes.io/change-cause: example of
a change cause
```

Once the above code is applied, we can view the list of revisions again:

```
$ kubectl rollout history deployment exam-
ple-deployment
deployment.extensions/example-deployment
REVISION        CHANGE-CAUSE
1               <none>
2               <none>
3               example of a change cause
```

kubectl also supports setting annotations of a deployment object directly. For example, we could run the following code instead of modifying the file above.

```
$ kubectl annotate deployment.v1.apps/
example-deployment kubernetes.io/
change-cause="example of a change cause"
```

Kubernetes will automatically increment the revision number when it detects a change in the deployment object. In addition, it will set the **change-clause** to the previous value (unless it has also changed). Hence, you must ensure you are not overwriting a previous revision's change clause.

Deploying a specific revision or doing a rollback

The whole purpose of storing a revision is to inspect or even deploy it. One very useful feature that Kubernetes provides is called a "deployment rollback". It allows you to bring your deployment back to a previous version (you can think of it as an undo).

To initiate a rollback, we can run this simple command:

```
$ kubectl rollout undo deployment/
example-deployment
deployment.extensions/example-de-
ployment rolled back
```

Just as above, deploying a specific revision can be performed simply with this command:

```
$ kubectl rollout undo deployment/
example-deployment --to-revision=1
deployment.extensions/example-de-
ployment rolled back
```

Kubernetes Networking

Networking can be very important when dealing with microservice-based architectures, and Kubernetes provides first-class support for a range of different networking configurations. Essentially, it provides you with a simple and abstracted cluster-wide network. Behind the scenes, Kubernetes networking can be quite complex due to its range of different networking plugins. It may be useful to try keeping the simpler concepts in mind before trying to identify the flow of individual networking packets.

A good understanding of Kubernetes' range of service types and ingresses should help you choose appropriate configurations for your clusters. Likewise, it will help minimize the complexity and resources (like provisioned load balancers) involved.

To begin with, here are some useful facts:

- Every pod is assigned a unique IP address
- Pods run within a virtual network (specified by the pod networking CIDR)
- Containers within an individual pod share the same network namespace (Linux network namespace), this means they are all reachable via localhost and share the same port space.
- All containers are configured to use a DNS server managed by Kubernetes.

Providing external access into your cluster

The process of requiring external access into your cluster works slightly differently than the process for listening to an open port. Instead, an ingress, *LoadBalancer* service, or *NodePort* service is used, which we will cover below.

Inspecting a pod IP address

It is often useful to identify a pod IP address. This value is held in metadata within the Kubernetes cluster state.

You can inspect the IP with the following command:

```
$ kubectl get pod -o yaml busybox | grep podIP
podIP: 10.10.3.4
```

Doing so will save you you the trouble of having to manually execute into the container using ip **addr** or otherwise. You can also view this with the **-o wide** argument to **kubectl get pods.**

```
$ kubectl get pods -o wide
NAME      READY   STATUS      RESTARTS   AGE   IP          NODE     NOMINATED NODE   READINESS GATES
busybox   0/1     Completed   0          2d8h  10.10.3.4   node-1   <none>           <none>
```

Services

Service types

A wide variety of service configuration is supported. However, there are four basic types of services.

Cluster IP
This is the default service type, and one of the simplest. Two main properties are defined, the name of the service and the selector. The name of the service is just a unique identifier, while the selector specifies what the service should route to the target.

NodePort
NodePorts are similar to ClusterIPs, except that all nodes get specified or random ports allocated to its service. Network requests to ports on any of the nodes are proxied into the service.

LoadBalancer
LoadBalancers are similar to ClusterIPs, but they are externally provisioned and have assigned public IP addresses. The load balancer will be implementation-specific. This is often used in cloud platforms.

ExternalName
Two main properties are defined: the name of the service and the external domain. This is a domain alias in some sense. This allows you to define a service that is referenced in multiple places (pods or other services) and manage the endpoint / external domain defined in one place. It also allows you to abstract the domain as a service, so you can swap it for another Kubernetes service later on.

Configuring a simple service

Create a new file named **web-app-service.yaml** with contents of:

```
apiVersion: v1
kind: Service
metadata:
  name: web-service
spec:
  ports:
    - name: http
      port: 80
  selector:
    app: web
```

Create and describe it:

```
$ kubectl create -f web-app-service.yaml
service/web-service created
```

```
$ kubectl describe services web-service
Name:              web-service
Namespace:         default
Labels:            <none>
Annotations:       <none>
Selector:          app=web
Type:              ClusterIP
IP:                10.97.7.119
Port:              http  80/TCP
TargetPort:        80/TCP
Endpoints:         <none>
Session Affinity:  None
Events:            <none>
```

In the above output, we see Endpoints: **<none>**. This value shows the pod IP addresses that match the specified selector **app=web**, in this case **<none>** (no matches).

So let's go ahead and create two pods with the appropriate labels to match the selector. We can simply execute this by creating two manually managed pods (as opposed to a deployment) with the following commands:

```
$ kubectl run httpbin --genera-
tor=run-pod/v1 --image=kennethreitz/http-
bin --labels="app=web"
pod/httpbin created
$ kubectl run httpbin-2 --genera-
tor=run-pod/v1 --image=kennethreitz/http-
bin --labels="app=web"
pod/httpbin-2 created
```

Once those pods are scheduled and successfully running, we can inspect the service again. We should see the following for **Endpoints**:

```
$ kubectl describe services web-service |
grep "Endpoints"
Endpoints:
172.17.0.3:80,172.17.0.4:80
```

Those IP addresses belong to the pods we just created!

Accessing a service

As mentioned earlier, Kubernetes creates a DNS entry for each service defined. In the case of the service we created, the Kubernetes DNS server will resolve the **web-service** hostname to one of the pods in the **web-service**. To demonstrate this, we can execute curl into one of the containers, making sure to install curl as though it wasn't included by default!

```
$ kubectl exec -it httpbin -- /bin/bash
$ apt update
...
$ apt install curl
...
$ curl web-service
<!DOCTYPE html>
<html lang="en">

<head>
  <meta charset="UTF-8">
  <title>httpbin.org</title>
...
```

Configuring external access via a NodePort service

One of the simplest ways to provide external access into your Kubernetes pods is through NodePort. In order to configure a NodePort service, we need to explicitly set the **spec type** (which by default is **ClusterIP** otherwise) in a service configuration:

```
spec:
  type: NodePort
```

To configure one, create a new file named **web-app-nodeport-service.yaml** with contents of:

```
apiVersion: v1
kind: Service
metadata:
  name: web-service-nodeport
spec:
  type: NodePort
  ports:
    - name: http
      port: 80
  selector:
    app: web
```

Create and inspect it:

```
$ kubectl create -f web-app-nodeport-service.yaml
service/web-service-nodeport created
$ kubectl get services web-service-nodeport
NAME                TYPE      CLUSTER-IP      EXTERNAL-IP   PORT(S)       AGE
web-service-nodeport   NodePort   10.101.203.150   <none>      80:32285/TCP   23s
```

Taking a look at the **PORT** field, we can see it's been allocated the **32285** port. This is the port that gets allocated on each of our Kubernetes nodes, which will in turn proxy to appropriate pods.

We can test this with the following (take note you'll need to use your specific IP or domain. In my case, it's just the internal node ip of **192.168.122.188**):

```
$ curl 192.168.122.188:32285
<!DOCTYPE html>
<html lang="en">

<head>
  <meta charset="UTF-8">
...
```

Ingresses

Ingresses are another Kubernetes object. They are essentially a more feature-full version of a service. The functionality of ingresses mostly revolves around the routing of HTTP requests, though they have some similarities to services. You may need to setup or configure a particular ingress controller as one won't necessarily be configured by default. In addition, multiple ingress controllers can be running at the same time. Each controller usually only manages ingresses that have an appropriate **kubernetes.io/ingress.class** annotation relating to the specific controller.

Ingresses target services and not pods. Some functionalities supported by ingresses include:

- SSL
- Domain / path based routing
- Configuration of load balancers

Ingress controllers

Although ingress controllers conform to a common specification or interface, they often include additional implementation specific configuration. One of the more popular ingress controllers is the “nginx ingress controller”. This usually refers to the following project https://github.com/kubernetes/ingress-nginx, which is a feature-rich controller providing support for HTTP authentication, session affinity, URL rewrites and much more.

Configuring a simple ingress

Create a new file named **app-ingress.yaml** with the code below. Notice we’re setting a rule for a host of **example.com**.

```
apiVersion: networking.k8s.io/v1beta1
kind: Ingress
metadata:
  name: app-ingress
  annotations:
    nginx.ingress.kubernetes.io/rewrite-target: /
spec:
  rules:
  - http:

      paths:
      - path: /
        backend:
          serviceName: web-service
          servicePort: 80
```

Create and describe it:

```
$ kubectl create -f app-ingress.yaml
ingress.networking.k8s.io/app-ingress
created
```

```
$ kubectl describe ingresses app-ingress
Name:             app-ingress
Namespace:        default
Address:          192.168.122.188
Default backend:  default-http-backend:80 (172.17.0.8:8080)
Rules:
  Host        Path  Backends
  ----        ----  --------
  example.com
              /   web-service:80 (172.17.0.3:80,172.17.0.4:80)
Annotations:
  nginx.ingress.kubernetes.io/rewrite-target:  /
Events:
  Type    Reason  Age            From                    Message
  ----    ------  ----           ----                    -------
  Normal  CREATE  21m            nginx-ingress-controller  Ingress default/app-ingress
  Normal  UPDATE  67s (x5 over 20m)  nginx-ingress-controller  Ingress default/app-ingress
```

If we test sending an HTTP request with curl to the ingress IP:

```
 $ curl -H "Host: example.com"
http://192.168.122.188
<!DOCTYPE html>
<html lang="en">

<head>
   <meta charset="UTF-8">
   <title>httpbin.org</title>
   <link href="https://fonts.googlea-
pis.com/css?family=Open+Sans:400,700|-
Source+Code+Pro:300,600|Titilli-
um+Web:400,600,700"
...
```

On the other hand, if we try a host that we did not configure:

```
 $ curl -H "Host: example123.com"
http://192.168.122.188
default backend - 404
```

We get a 404 not found response, which seems pretty reasonable - what else could we expect?

Configuring an ingress with SSL

We'll use a self-signed certificate to demonstrate SSL functionality.

We haven't yet mentioned "secrets", but we'll need to set one up in order to set a SSL key and certificate for an ingress.

We can do this by running the following command:

```
$ kubectl create secret tls ssl-exam-
ple-cert --key ssl.key --cert ssl.cert
secret/ssl-example-cert created
```

We can add an SSL certificate by specifying the secret, under the **spec** key in an ingress:

tls:

```
 - secretName: ssl-example-cert
```

In other words our ingress file will have contents of:

```
apiVersion: networking.k8s.io/v1beta1
kind: Ingress
metadata:
  name: app-ingress
  annotations:
    nginx.ingress.kubernetes.io/re-
write-target: /
spec:
  tls:
    - secretName: ssl-example-cert
  rules:
  - host: example.com
    http:
      paths:
      - path: /
        backend:
          serviceName: web-service
          servicePort: 80
```

If we now try the HTTPS endpoint of the ingress (also adding the **-k** parameter to curl to ignore the self-signed certificate error), we'll see:

```
$ curl -k -H "Host: example.com"
https://192.168.122.188/
<!DOCTYPE html>
<html lang="en">

<head>
    <meta charset="UTF-8">
    <title>httpbin.org</title>
    <link href="https://fonts.googlea-
pis.com/css?family=Open+Sans:400,700|-
Source+Code+Pro:300,600|Titilli-
um+Web:400,600,700"
...
```

Kubernetes Volumes

Volumes are a concept that relate to the storage of data. Software programs these days can have complex storage needs. For example, they might need any of the following:

High-performance RAM based disk volume (ramfs/tmpfs) as a cache

Disk volume of specific capacity per user

Volume deletion once the application is terminated

Volume mounted from an external storage medium

Kubernetes has excellent support for handling functionalities like the above. Having a good understanding of volumes will ensure your data is always persisted correctly as well as having the appropriate performance characteristics - and hopefully minimize the chances of any data loss occurring!

To begin with, let's define the relationship between pods and volumes. A volume is bound to a single pod, though, it can be mounted on multiple containers within an individual pod. A volume is mounted on a container, and this is essentially an ordinary directory where we can store data.

A simple volume example

In the following example, we create a very simple pod with a volume shared between two containers. In one container, we'll be writing to the volume (using a simple bash loop). In the other, we'll be reading the file's contents so it enters the container's log via stdout.

Create a new file named **simple-example-volume-pod.yaml** with contents of:

```
apiVersion: v1
kind: Pod
metadata:
  name: simple-example-volume-pod
spec:
  containers:
    - name: writer
      image: debian:buster-slim
      command:
        - /bin/bash
        - -c
        - while true; do sleep 10; echo
"..." >> /test-volume/output.txt; done
      volumeMounts:
      - mountPath: /test-volume
        name: test-volume
    - name: reader
      image: debian:buster-slim
      command:
        - /bin/bash
        - -c
        - while true; do sleep 10; cat /
test-volume/output.txt; done
      volumeMounts:
      - mountPath: /test-volume
        name: test-volume
  volumes:
  - name: test-volume
    emptyDir: {}
```

There are essentially two sections of significance, the first being the definition of all the volumes for this pod which is:

```
...
  volumes:
  - name: test-volume
    emptyDir: {}
```

Each volume needs a name value to reference it. You can ignore the **emptyDir** key for now as we will explain this later on.

The second section of significance is where we mount the specific **test-volume** volume on the containers. This can be done with the following code. Do note we have to do this for each container we want the volume mounted on, twice in this case.

```
...
    volumeMounts:
    - mountPath: /test-volume
      name: test-volume
...
    volumeMounts:
    - mountPath: /test-volume
      name: test-volume
...
```

We're all good to have this deployed now, so lets create the pod (which will automatically create the necessary volumes):

```
$ kubectl create -f simple-example-vol-
ume-pod.yaml
pod/simple-example-volume-pod created
```

If we take a look at the **reader** container logs:

```
$ kubectl logs simple-example-volume-pod
-c reader -f
...
...
...
...
...
```

Persistent volumes (PV) / persistent volume claims (PVC)

This is a bit of a tricky concept as Kubernetes has two distinct implementations for “volumes” and “persistent volumes”. A “persistent volume” could still be referred to as a “volume”. Bear this in mind if you’re confused at any point!

With regards to terminology, “persistent volumes” are also oddly named, as both volumes and persistent volumes can be persistent. Although “persistent volume claims” have the word “claim”, it’s more of a “request” as a PVC might fail to be binded, for example, in the event there is no more storage capacity available.

The main differences are:

Persistent volumes

- Have a lifecycle that can be independent from a pod - it can be attached to or detached from any applicable pod
- Interact with storage classes

Volumes

- Are bound to a pod
- Are simpler to define
  (less Kubernetes resources required)

Volume types

Kubernetes supports a wide variety of different volume types which relate to the different underlying storage mediums.

A few common volume types are:

emptyDir
This is what we defined in our first example, it's a volume that utilizes the same storage the underlying node would be using. This is very similar to Docker named volumes. Upon creation, this volume will be empty. Once a pod is deleted, any attached emptyDir volumes will be deleted as well - so don't store any data here that you expect to persist.

hostPath
Similar to an emptyDir, however, it maps to a path on the underlying node which means upon creation this volume might not be empty. In addition data stored here will persist on the node itself.

awsElasticBlockStore
Block storage medium offered by Amazon Web Services.

gcePersistentDisk
Block storage medium offered by Google Cloud Platform.

persistentVolumeClaim
Often abbreviated to PVC, this has a bit more complexity which will be explained in the next section.

Volume access modes

PCVs and PVs have an access mode associated with them. There are three modes in total:

- **RWO – ReadWriteOnce**
  read and write by a single node
- **ROX – ReadOnlyMany**
  read by multiple nodes
- **RWX – ReadWriteMany**
  read and write by multiple nodes

Do take note that the boundary of the access mode relates to a node as opposed to a pod or container. In addition, some storage types might only support a subset of these modes, but not necessarily all of them.

Storage provisioner

Persistent volumes also bring the addition of a storage provisioner - another control loop relating to storage. This works similarly to how Kubernetes provisions external load balancers with services.

Storage class

The storage class resource is used to manage a specific type of storage configuration, which can then later be referenced in a persistent volume claim. Essentially, three things are defined: a name, the storage provisioner to use, and some properties.

For example, you could define a storage class as:

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: example-storage-class
provisioner: kubernetes.io/glusterfs
parameters:
  resturl: "http://127.0.0.1:1234"
  clusterid: "581fb928f23c7b23f8c720a930372ccd"
```

Relationship between PVCs and PVs

A PV relates to the actual underlying storage volume. While a PVC is a request for a PV, which can then later be bound to a PV. In addition within a PVC, you can define properties of the request, for example, the volume size or storage class. The term used for the association between a persistent volume and persistent volume claim is "bind" or "bound".

Demonstrated example of a PVC

In this example, I'll be using Minikube, which has a storage provisioner that can be enabled.

First, we'll create a PVC with a **storageClassName** that has no provisioner configured. Hence, we choose a random name of **abc-xyz-123** for it. This is just to demonstrate a failure case to make it more obvious how things actually work.x

Create a new file named **pvc.yaml** with contents of:

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: test-pvc
spec:
  accessModes:
    - ReadWriteMany
  storageClassName: abc-xyz-123
  volumeMode: Filesystem
  resources:
    requests:
      storage: 8Gi
```

Create and describe the PVC resource:

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

```
$ kubectl describe pvc test-vpc
Name:          test-pvc
Namespace:     default
StorageClass:  abc-xyz-123
Status:        Pending
Volume:
Labels:        <none>
Annotations:   <none>
Finalizers:    [kubernetes.io/pvc-protection]
Capacity:
Access Modes:
VolumeMode:    Filesystem
Mounted By:    <none>
Events:
  Type     Reason              Age                From                         Message
  ----     ------              ----               ----                         -------
  Warning  ProvisioningFailed  2m23s (x26 over 8m34s)  persistentvolume-controller  storage-
class.storage.k8s.io "abc-xyz-123" not found
```

We can also view all the persistent volumes with:

```
$ kubectl get pv
No resources found.
```

Even though the PVC has failed to provision, we can still reference it in a pod.

Create a new file named **example-pod-pvc.yaml** with contents of:

```
apiVersion: v1
kind: Pod
metadata:
  name: example-pod-pvc
spec:
  containers:
    - name: main
      image: debian:buster-slim
      command:
        - /bin/bash
        - -c
        - while true; do sleep 10; echo
"...”; done
      volumeMounts:
      - mountPath: /test-pvc-vol
        name: test-pvc-vol
  volumes:
  - name: test-pvc-vol
    persistentVolumeClaim:
      claimName: test-pvc
```

Create the pod resource and describe it, we should see a **FailedScheduling** error relating to the PVC.

```
$ kubectl create -f example-pod-pvc.yaml
pod/example-pod-pvc created
$ kubectl describe pod example-pod-pvc
...
  Warning  FailedScheduling  63s   de-
fault-scheduler  pod has unbound immedi-
ate PersistentVolumeClaims
```

Let’s finally get this fixed and working! Modify the **pvc.yaml** file created earlier and change the **storageClassName: abc-xyz-123** line to **storageClassName: standard.**

Due to the fact that PVC has more restrictions on their modification, we can’t just **kubectl apply** ... our changes. Instead, we need to delete and recreate the resource:

```
$ kubectl delete pvc test-pvc
persistentvolumeclaim “test-pvc” deleted
$ kubectl create -f pvc.yaml
persistentvolumeclaim/test-pvc created
```

If we now inspect some resources:

```
$ kubectl get pvc
NAME       STATUS   VOLUME                                     CAPACITY   ACCESS MODES   STORAGECLASS   AGE
test-pvc   Bound    pvc-30f2d3ab-1fdf-4222-be3b-6d964aa02d29   8Gi        RWX            standard       17s
```

```
$ kubectl get pv
NAME                                       CAPACITY   ACCESS MODES   RECLAIM POLICY   STATUS
pvc-30f2d3ab-1fdf-4222-be3b-6d964aa02d29   8Gi        RWX            Delete           Bound
CLAIM                                      STORAGECLASS   REASON   AGE
default/test-pvc                           standard                39s
```

```
$ kubectl get pod example-pod-pvc
NAME              READY   STATUS    RESTARTS   AGE
example-pod-pvc   1/1     Running   0          12m
```

As can be seen, the minikube storage provisioner created a PV.
It then bound the PV to the **test-pvc** we created.
Finally, the pod ends up running successfully.

Considerations

Some types of storage have certain limitations. For example, NFS might not be a suitable volume backend for a database if the database server uses kernel system calls that are not fully supported on an NFS volume. This can be a risk for data corruption. It is important to investigate and test your setup where data integrity is significant.

You can mount a volume that is shared between multiple nodes, but that does not necessarily guarantee your applications support multiple instances writing or reading to the same file. This too would have to be investigated and verified.

Lastly, performance with volumes / IO (input / output) isn't always straightforward. Your volume or application can depend on a wide range of properties of your system. A performance bottleneck could be related to the network, disk, CPU or something else. Latency might have a different effect compared to bandwidth. Benchmarking your real application in different scenarios is a good way to verify the actual numbers. I'm often surprised by the results!

Security

Secrets are a way to store sensitive values like passwords or credentials. This adds an additional layer of access to the actual values itself. It hence acts as a type of “pointer”. Rather than saying the value of an application password is **pa$$w0rd**, you would instead reference an “application password” secret. Secrets are fairly simple to configure, with just a bit more complexity than setting literal values themselves.

A main benefit to this is the ability to separate sensitive values from resource files (pods / deployments). This in turns means you can store the Kubernetes resource files (excluding the secrets) in version control without worrying about exposing these sensitive values.

The implementation of a secret in Kubernetes is basically a name and a set of key value pairs. We can create a secret using the following command:

```
$ kubectl create secret gener-
ic example-secret --from-literal=se-
cret-key-123='mysecretpassword'
secret/example-secret created
```

Where **example-secret** is the name, and **--from-literal=secret-key-123='mysecretpassword'** is one of the key value pairs (you can specify multiple of these).

Secrets are used in many ways, but their most common scenarios are environment variables or mounted files via volumes.

Using a secret in an environment variable

We can specify the secret name and the key. In addition, we're free to set the environment variable name independently (**SECRET_KEY** in the following case).

```
...
 env:
  - name: SECRET_KEY
    valueFrom:
      secretKeyRef:
        name: example-secret
        key: secret-key-123
...
```

Using a secret as one or more file mounted in a volume

You can mount a secret as a volume where the filename will map to the key, and the file contents will map to the key's value.

You can define the volume as follows:

```
volumes:
 - name: secret-file
   secret:
     secretName: example-secret
```

And the **volumeMounts** within a pod as:

```
volumeMounts:
 - mountPath: "/example/secrets/"
   name: secret-file
```

Do note that the files are mounted individually into the path, and prior existing files in this directory will no longer be present. However, there are ways to work around this limitation.

Service accounts

A service account is probably the most common way to define an object that can relate to a user, process, pod or some other "identity". Service accounts are another resource which can be viewed, created, etc. :

```
$ kubectl get serviceaccount
NAME     SECRETS   AGE
default   1        67d
Name:              default
$ kubectl describe serviceaccount
Name:              default
Namespace:         default
Labels:            <none>
Annotations:       <none>
Image pull secrets:  <none>
Mountable secrets:   default-token-qpxdl
Tokens:            default-token-qpxdl
Events:            <none>
```

Ideally, a service account should be assigned to each individual or application. This makes it simple to remove access for the relevant user by simply deleting the referenced service account.

A service account can be specified within a pod (a **default** service account is set if not explicitly set). In this case, it would relate to the pod security policy.

Creating a service account

You can create a service account using the the **kubectl create**... helper command:

```
$ kubectl create serviceaccount example-sa
serviceaccount/example-sa created
```

Service account tokens

Each service account will have an associated security token automatically assigned to it. This token is saved in a secret, which in turn contains the actual value. This token can be used to authenticate with the Kubernetes API of your cluster.

Generating a kubeconfig file for a service account

This script might look a little scary, but it is a convenient way to generate a kubeconfig for a service account, which in turn can be used for authentication with **kubectl**. It has been adapted, but it originally was posted here.

You may need to change the **server** and **saAccount** variables to the appropriate values for your case.

```
#!/usr/bin/env bash

server="https://192.168.39.143:8443"
saAccount="example-sa"

name=$(kubectl get secret | grep "$saAccount" | awk '{print $1}')

ca=$(kubectl get secret/$name -o jsonpath='{.data.ca\.crt}')
token=$(kubectl get secret/$name -o jsonpath='{.data.token}' | base64 --decode)
namespace=$(kubectl get secret/$name -o jsonpath='{.data.namespace}' | base64 --decode)

echo "
apiVersion: v1
kind: Config
clusters:
- name: default-cluster
  cluster:
    certificate-authority-data: ${ca}
    server: ${server}
contexts:
- name: default-context
  context:
    cluster: default-cluster
    namespace: default
    user: default-user
current-context: default-context
users:
- name: default-user
  user:
    token: ${token}
"
```

RBAC

The main idea behind RBAC (role-based access control) is the principle of least privilege, that of limiting permissions to only those required. For example, you may have different types of individuals that either need access or who manage your cluster. You may have developers who would only need access to the application logs, or perhaps you have an individual that should only have permissions to change **ConfigMap** configurations.

Permissions are based on actions like creating a pod, creating a service, viewing logs of a pod, etc. The actual operation behind RBAC is conditionally accepting or rejecting an API request before it is processed by the API server.

While official documentation for RBAC is minimal at the moment, a good reference is the official API reference documentation, which can be found here. You can search for the “rbac.authorization.k8s.io” (which is the API group related to RBAC).

RBAC on Minikube

If you are using Minikube for learning / testing, a very non restrictive RBAC configuration will be used by default. To instead manage RBAC manually on minikube, you can pass the --extra-config=apiserver. authorization-mode=RBAC parameter to minikube start.

Concepts

Rule

A rule has three basic properties. If any match applies, it will be enforced. You can have multiple values for each of the below:

API Groups

A blank empty group refers to the “core” api group.

Resources

https://kubernetes.io/docs/reference/kubectl/overview/#resource-types

Verbs

Available verbs include:

- create
- get (for individual resources)
- list (for collections, including full object content)
- watch (for watching an individual resource or collection of resources)
- delete (for individual resources)
- deletecollection (for collections)

Roles

A role has two basic properties, a name and one or more rules. Nice and simple!

RoleBindng

A RoleBinding has two basic properties, a name and one or more bindings. “Bindings” are an association of a role with a user, group or service account. For example a “developer” rolebinding might bind the “developer” role and “maintenance” role with a “Bob” user and a “Deployment CICD” service account.

If a user entity like a service account has multiple roles binded to it, they will be additively combined.

Practical example

On to some practical examples using the concepts above! First of all you'll need a service account created, and authenticated with your cluster (refer to the topics earlier on to create this). You will also need RBAC enabled on the cluster.

Once you have authenticated, you can try getting the pods, which should return a **Forbidden** error:

```
$ kubectl get pods
Error from server (Forbidden): pods
is forbidden: User "system:serviceac-
count:default:example-sa" cannot list
resource "pods" in API group "" in the
namespace "default"
```

This is the RBAC functionality in action. Let's go ahead and create the necessary RBAC so the code above can succeed.

Creating a Role

Create a new file named **pod-monitor.yaml** with contents of:

```
apiVersion: rbac.authorization.k8s.io/v1
kind: Role
metadata:
  name: pod-monitor
rules:
- apiGroups:
    - ""
  resources:
    - pods
  verbs:
    - get
    - list
```

Create the resource:

```
$ kubectl create -f pod-monitor.yaml
role.rbac.authorization.k8s.io/pod-moni-
tor created
```

Creating a RoleBinding

Create a new file named **pod-monitor-rb.yaml** with contents of:

```
apiVersion: rbac.authorization.k8s.io/v1
kind: RoleBinding
metadata:
  name: pod-monitor
  namespace: default
subjects:
- kind: ServiceAccount
  name: example-sa
roleRef:
  kind: Role
  name: pod-monitor
  apiGroup: rbac.authorization.k8s.io
```

Make sure this matches up with the service account you are authenticated with.

Create the resource:

```
$ kubectl create -f pod-monitor-rb.yaml
rolebinding.rbac.authorization.k8s.io/pod-monitor created
```

Finally, the **get pods** request should now succeed:

```
NAME                       READY   STATUS    RESTARTS   AGE
pod-service-account-example   1/1     Running   0          21h
```

Audit log

Kubernetes provides auditing functionality. This works by storing information about requests to the API server. Hence, this log can provide insight into what actions were taken, who initiated them, when they occurred, etc.

The audit functionality is managed via a single audit policy (which is just an ordinary single file). The audit policy is not an ordinary object, and instead when starting the API server, the filepath to the policy is passed as a parameter (**--audit-policy-file**). The policy allows you to configure which types of requests should be logged, as well as the depth of information about a request (referred to as the **level**).

Here is a an example of a basic audit policy:

```
apiVersion: audit.k8s.io/v1
kind: Policy
rules:
- level: Metadata
  resources:
  - group: ""
    resources: ["pods/log", "pods/status"]
```

Once again, an empty blank **group** field refers to the core API group.

Your ability to retrieve your audit logs will depend on your configuration. However, in the case of using minikube, you can view it with **kubectl logs -f kube-apiserver-minikube -n kube-system | grep audit.k8s.io.**

On the next page, you can see an example of an audit event which relates to a request that was done via **kubectl logs pod-service-account-example:**

{“kind”:”Event”,”apiVersion”:”audit.k8s.
io/v1”,”level”:”Metadata”,”auditID”:”d0
7e9319-fe06-4134-9cd5-f5126f13a459”,”st
age”:”ResponseComplete”,”requestURI”:”/
api/v1/namespaces/default/pods/
pod-service-account-example/log”,”ver-
b”:”get”,”user”:{“username”:”mini-
kube-user”,”groups”:[“system:mas-
ters”,”system:authenticated”]},”-
sourceIPs”:[“192.168.39.1”],”user-
Agent”:”kubectl/v1.15.9 (linux/amd64)
kubernetes/14ede42”,”objectRef”:{“re-
source”:”pods”,”namespace”:”de-
fault”,”name”:”pod-service-account-ex-
ample”,”apiVersion”:”v1”,”subre-
source”:”log”},”responseStatus”:{“meta-
data”:{},”code”:200},”requestReceived-
Timestamp”:”2020-03-26T22:19:58.725268Z”,
”stageTimestamp”:”2020-03-26T22:19:58.73
3162Z”,”annotations”:{“authorization.k8s.
io/decision”:”allow”,”authorization.k8s.
io/reason”:””}}

It’s worth mentioning that Kubernetes has “events” that should not be confused with “audit events”. These are two separate things. These instead can be retrieved via **kubectl get events.**

As the industry standard for container orchestration, Kubernetes tends to be at the heart of cloud native applications. We hope this ebook has given you a solid introduction to its quirks.

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