Kubernetes

Overview

In this lab, we will learn about Kubernetes, the most popular container management system in the market. Starting with the basics, architecture, and resources, you will create Kubernetes clusters and deploy real-life applications in them.

By the end of the lab, you will be able to identify the basics of Kubernetes design and its relationship with Docker. You will create and configure a local Kubernetes cluster, work with the Kubernetes API using client tools, and use fundamental Kubernetes resources to run containerized applications.

Introduction

In the previous chapters, you ran multiple Docker containers with **Docker Compose** and **Docker Swarm**. Microservices running in various containers help developers to create scalable and reliable applications.

However, when multiple applications are spread over multiple servers across a data center, or even across multiple data centers around the world, it becomes more complex to manage the applications. There are many open-ended problems related to the complexity of distributed applications, including, but not limited to, networking, storage, and container management.

For instance, the networking of containers running on the same nodes, as well as different nodes, should be configured. Similarly, the volumes of the containers that contain the applications (which can be scaled up or down) should be managed with a central controller. Fortunately, the management of the distributed containers has a well-accepted and adopted solution: Kubernetes.

Kubernetes is an open-source container orchestration system for running scalable, reliable, and robust containerized applications. It is possible to run Kubernetes on a wide range of platforms, from a **Raspberry Pi** to a data center. Kubernetes makes it possible to run containers with mounting volumes, inserting secrets, and configuring the network interfaces. Also, it focuses on the life cycle of containers to provide high-availability and scalability. With its inclusive approach, Kubernetes is the leading container management system currently available on the market.

Kubernetes translates to the **captain of the ship** in Greek. With the Docker's analogy to boats and containers, Kubernetes positions itself as the sailing master. The idea of Kubernetes has roots in managing containers for Google Services such as Gmail or Google Drive for over a decade. From 2014 to the present, Kubernetes has been an open-source project, managed by **Cloud Native Computing Foundation** (**CNCF**).

One of the main advantages of Kubernetes comes from its community and maintainers. It is one of the most active repositories on GitHub, with nearly 88,000 commits from more than 2,400 contributors. In addition, the repository has over 62,000 stars, which means more than 62,000 people have faith in the repository:

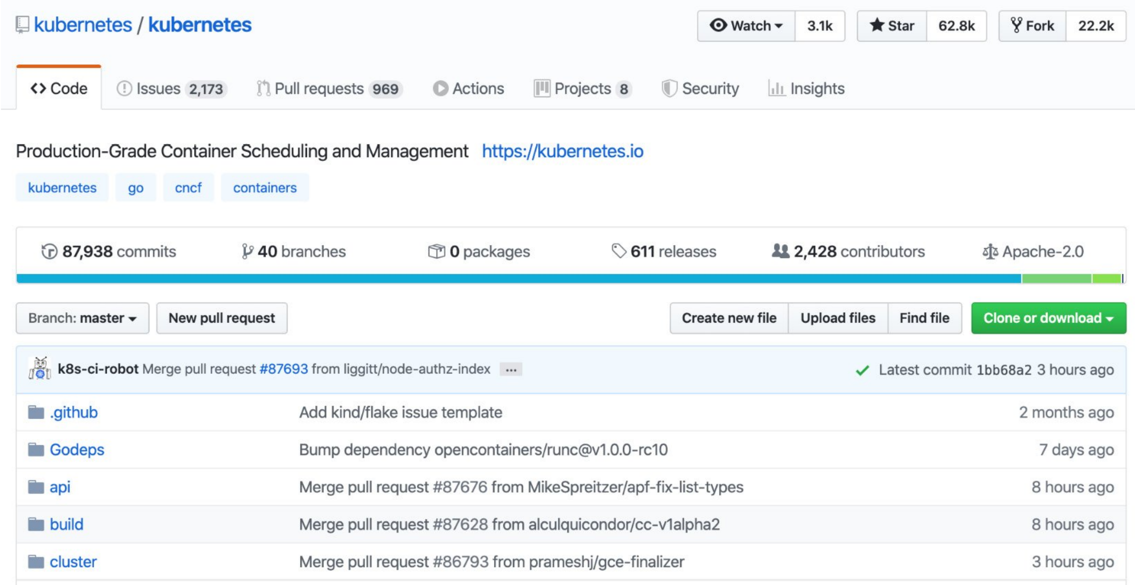


Figure 10.1: Kubernetes GitHub repository

In this lab, you will explore Kubernetes' design and architecture, followed by its API and access, and use the Kubernetes resources to create containerized applications. Since Kubernetes is the leading container orchestration tool, getting hands-on experience of it will help you get into the world of containerized applications.

Kubernetes Design

Kubernetes focuses on the life cycle of containers, including configuration, scheduling, health checks, and scaling. With Kubernetes, it is possible to install various types of applications, including databases, content management systems, queue managers, load balancers, and web servers.

For instance, imagine you are working at a new online food delivery chain, named **InstantPizza**. You can deploy the backend of your mobile application in Kubernetes and make it scalable to customer demand and usage. Similarly, you can implement a message queue to communicate between the restaurants and customers, again in Kubernetes. To store past orders and receipts, you can deploy a database in Kubernetes with storage. Furthermore, you can use load balancers to implement **Blue/Green** or **A/B Deployment** for your application.

In this section, the design and architecture of Kubernetes are discussed to illustrate how it achieves scalability and reliability.

Note

Blue/green deployments focus on installing two identical versions (called blue and green, respectively) of the same application and instantly moving from blue to green to reduce downtime and risk.

A/B deployments focus on installing two versions of the application (namely, A and B), and the user traffic is divided between the versions for testing and experiments.

The design of Kubernetes concentrates on running on one or multiple servers---namely, clusters. On the other hand, Kubernetes consists of numerous components that should be distributed over a single cluster in order to have reliable and scalable applications.

There are two groups of Kubernetes components---namely, the **control plane** and the **node**. Although there are different naming conventions for the elements that make up the Kubernetes landscape, such as master components instead of the control plane, the main idea of grouping has not changed at all. Control plane components are responsible for running the Kubernetes API, including the database, controllers, and schedulers. There are four main components in the Kubernetes control plane:

- `kube-apiserver` : This is the central API server that connects all the components in the cluster.
- `etcd` : This is the database for Kubernetes resources, and the `kube-apiserver` stores the state of the cluster on `etcd` .
- `kube-scheduler` : This is the scheduler that assigns containerized applications to the nodes.
- `kube-controller-manager` : This is the controller that creates and manages the Kubernetes resources in the cluster.

In servers with the role node, there are two Kubernetes components:

- `kubelet` : This is the Kubernetes client that lives on the nodes to create a bridge between the Kubernetes API and container runtime, such as Docker.
- `kube-proxy` : This is a network proxy that runs on every node to allow network communication regarding the workloads across the cluster.

The control plane and node components, along with their interactions, are illustrated in the following diagram:

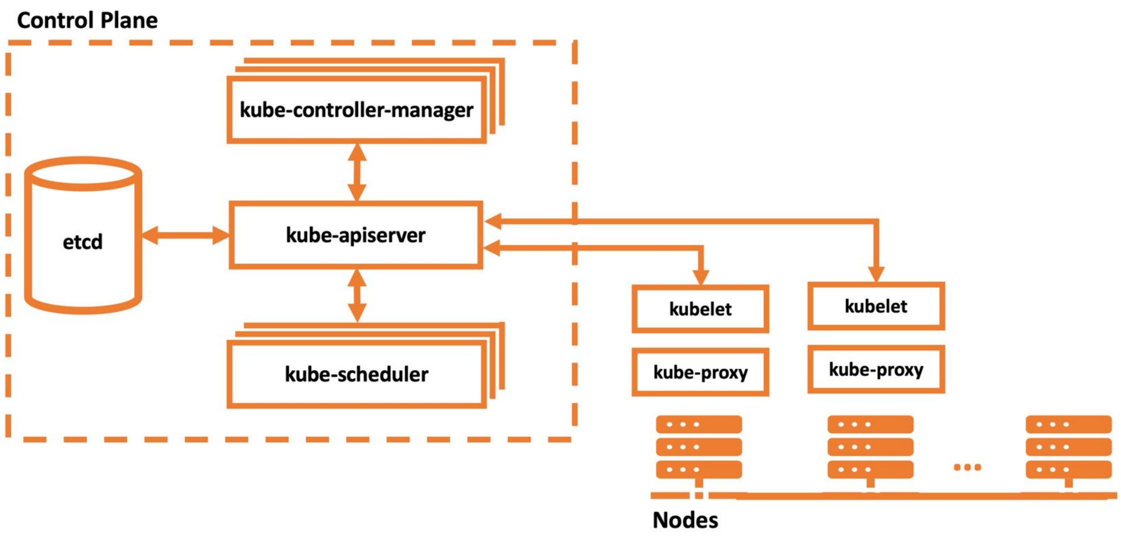


Figure 10.2: Kubernetes architecture

Kubernetes is designed to run on scalable cloud systems. However, there are many tools to run Kubernetes clusters locally. `minikube` is the officially supported CLI tool to create and manage local Kubernetes clusters. Its commands focus on life cycle events and the troubleshooting of clusters, as follows:

- `minikube start` : Starts a local Kubernetes cluster
- `minikube stop` : Stops a running local Kubernetes cluster
- `minikube delete` : Deletes a local Kubernetes cluster
- `minikube service` : Fetches the URL(s) for the specified service in the local cluster
- `minikube ssh` : Logs in or runs a command on a machine with SSH

In the following exercise, you will create a local Kubernetes cluster to check the components discussed in this lab. To create a local cluster, you will use `minikube` as the official local Kubernetes solution and run its commands to explore Kubernetes components.

Note

`minikube` runs the cluster on hypervisors, and you need to install a hypervisor such as KVM, VirtualBox, VMware Fusion, Hyperkit, or Hyper-V based on your operating system. You can check the official documentation for more information at https://kubernetes.io/docs/tasks/tools/install-minikube/#install-a-hypervisor.

Note

Please use `touch` command to create files and `vim` command to work on the file using vim editor.

Exercise 10.01: Starting a Local Kubernetes Cluster

Kubernetes was initially designed to run on clusters with multiple servers. This is an expected characteristic for a container orchestrator that runs scalable applications in the cloud. However, there are many times that you need to run a Kubernetes cluster locally, such as for development or testing. In this exercise, you will install a local Kubernetes provider and then create a Kubernetes cluster. In the cluster, you will check for the components discussed in this section.

To complete this exercise, perform the following steps:

1. Download the latest version of the `minikube` executable for your operating system and set the binary as executable for your local system by running the following command in your terminal:

```
# Linux
curl -Lo minikube
https://storage.googleapis.com/minikube/releases/latest/minikube-linux-amd64
# MacOS
curl -Lo minikube
https://storage.googleapis.com/minikube/releases/latest/minikube-darwin-amd64
chmod +x minikube
sudo mv minikube /usr/local/bin
```

These preceding commands download the binary for Linux or Mac and make it ready to use in the terminal:

```
 /docker-ws $
 /docker-ws $ curl -Lo minikube https://storage.googleapis.com/minikube/releases/latest/mi
nikube-darwin-amd64
  % Total    % Received % Xferd  Average Speed   Time    Time     Time  Current
                                 Dload  Upload   Total   Spent    Left  Speed
100 43.8M  100 43.8M    0     0  6313k      0  0:00:07  0:00:07 --:--:-- 6616k
 /docker-ws $ chmod +x minikube
 /docker-ws $ sudo mv minikube /usr/local/bin
 /docker-ws $
```

Figure 10.3: Installation of minikube

2. Start a Kubernetes cluster with the following command in your terminal:

```
minikube start
```

The single preceding command executes multiple steps to create a cluster successfully. You can check each stage and its output as follows:

```
/docker-ws $
/docker-ws $ minikube start
😄  minikube v1.6.2 on Darwin 10.15.2
✨  Automatically selected the 'hyperkit' driver (alternates: [virtualbox])
🔥  Creating hyperkit VM (CPUs=2, Memory=9000MB, Disk=20000MB) ...
🐳  Preparing Kubernetes v1.17.0 on Docker '19.03.5' ...
🚜  Pulling images ...
🚀  Launching Kubernetes ...
⌛  Waiting for cluster to come online ...
🏄  Done! kubectl is now configured to use "minikube"
/docker-ws $
```

Figure 10.4: Starting a new Kubernetes cluster

The output starts with printing out the version and the environment. Then, the images for Kubernetes components are pulled and started. Finally, you have a locally running Kubernetes cluster after a couple of minutes.

3. Connect to the cluster node started by `minikube` with the following command:

```
minikube ssh
```

With the `ssh` command, you can continue working on the node running in the cluster:

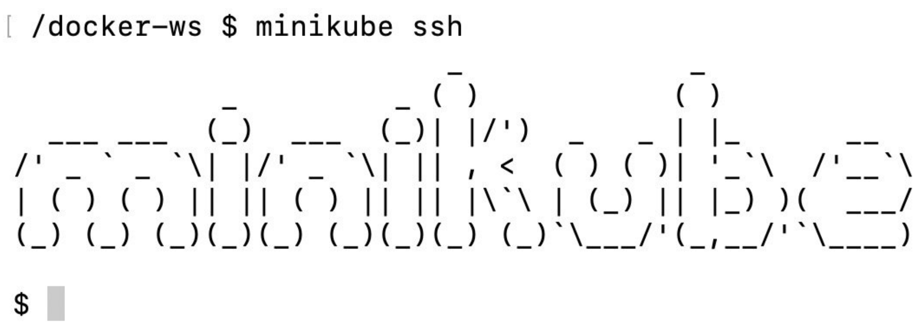


Figure 10.5: Cluster node

4. Check for each control plane component with the following commands:

```
docker ps --filter „name=kube-apiserver" --filter „name=etcd" --filter
„name=kube-scheduler" --filter „name=kube-controller-manager" | grep -v „pause"
```

This command checks for the Docker containers and filters with the control plane component names. The following output does not contain the pause container, which is responsible for the networking setup of the container groups in Kubernetes, so as to make analysis easier:

```
$ docker ps --filter "name=kube-apiserver" --filter "name=etcd" --filter "name=kube
-scheduler" --filter "name=kube-controller-manager" | grep -v "pause"
CONTAINER ID        IMAGE                  COMMAND                  CREATED
     STATUS              PORTS               NAMES
1fbc9f8b14fd        78c190f736b1           "kube-scheduler --au…"   18 minutes ago
     Up 18 minutes                           k8s_kube-scheduler_kube-scheduler-mini
kube_kube-system_ff67867321338ffd885039e188f6b424_1
7e1caeda6a49        303ce5db0e90           "etcd --advertise-cl…"   18 minutes ago
     Up 18 minutes                           k8s_etcd_etcd-minikube_kube-system_3e2
cde1eca0c3b2644c8b8d16ac844c4_1
a75df7602f2e        5eb3b7486872           "kube-controller-man…"   18 minutes ago
     Up 18 minutes                           k8s_kube-controller-manager_kube-contr
oller-manager-minikube_kube-system_e7ce3a6ee9fa0ec547ac7b4b17af0dcb_1
3c6fccab6823        0cae8d5cc64c           "kube-apiserver --ad…"   18 minutes ago
     Up 18 minutes                           k8s_kube-apiserver_kube-apiserver-mini
kube_kube-system_878bd804e10160fa8b4c33c7c681e40b_1
$
```

Figure 10.6: Control plane components

The output shows that four control plane components are running in Docker containers in the `minikube` node.

5. Check for the first node component, `kube-proxy`, with the following command:

```
docker ps --filter "name=kube-proxy"  | grep -v "pause"
```

Similar to *Step 4*, this command lists a `kube-proxy` component, which is running in a Docker container:

```
$ docker ps --filter "name=kube-proxy"  | grep -v "pause"
CONTAINER ID        IMAGE                  COMMAND                  CREATED
     STATUS              PORTS               NAMES
7b32218709e8        7d54289267dc           "/usr/local/bin/kube…"   21 minutes ago
     Up 21 minutes                           k8s_kube-proxy_kube-proxy-hjp4j_kube-s
ystem_8a6763ec-8272-45bf-83a0-2160f78bb738_1
$
```

Figure 10.7: kube-proxy in minikube

It can be seen that the `kube-proxy` component running in the Docker container has been up for 21 minutes.

6. Check for the second node component, `kubelet`, with the following command:

```
pgrep -l kubelet
```

This command lists the process with its ID running in `minikube`:

```
2554 kubelet
```

Since `kubelet` communicates between the container runtime and API server, it is configured to run directly on the machine instead of inside a Docker container.

7. Disconnect from the `minikube` node connected in *Step 3* with the following command:

```
exit
```

You should have returned to your terminal and get output similar to the following:

```
logout
```

In this exercise, you have installed a Kubernetes cluster and checked the architectural components. In the next section, the Kubernetes API and access methods will be presented to connect and consume the cluster created in this section.

The Kubernetes API and Access

The **Kubernetes API** is the fundamental building block of the Kubernetes system. It is the home for all communication between the components in the cluster. External communication, such as user commands, is also executed against the Kubernetes API as REST API calls. The Kubernetes API is a resource-based interface over HTTP. In other words, the API server is oriented to work with resources to create and manage Kubernetes resources. In this section, you will connect to the API, and in the following section, you will start working with Kubernetes resources, including, but not limited to, Pods, Deployments, Statefulsets, and Services.

Kubernetes has an official command-line tool for client access, named `kubectl`. If you want to access a Kubernetes cluster, you need to install the `kubectl` tool and configure it to connect to your cluster. Then you can securely use the tool to manage the life cycle of applications running the cluster. `kubectl` is capable of essential create, read, update, and delete operations, as well as troubleshooting and log retrieval.

For instance, you can install a containerized application with `kubectl`, scale it to more replicas, check the logs, and finally delete it if you do not need it further. Furthermore, `kubectl` has cluster management commands to check the status of the cluster and servers. Therefore, `kubectl` is a vital command-line tool for accessing Kubernetes clusters and managing the applications.

`kubectl` is the key to controlling Kubernetes clusters with its rich set of commands. The essential basic and deployment-related commands can be listed as follows:

- `kubectl create`: This command creates a resource from a filename with the `-f` flag or standard terminal input. It is helpful when creating resources for the first time.
- `kubectl apply`: This command creates or updates the configuration to a Kubernetes resource, similar to the `create` command. It is an essential command if you are changing the resource configuration after the first creation.
- `kubectl get`: This command displays one or multiple resources from the cluster with its name, labels, and further information.
- `kubectl edit`: This command edits a Kubernetes resource directly in the terminal with an editor such as `vi`.
- `kubectl delete`: This command deletes Kubernetes resources and passes filenames, resource names, and label flags.
- `kubectl scale`: This command changes the number of resources of a Kubernetes cluster.

Similarly, the cluster management and configuration commands required are listed as follows:

- `kubectl cluster-info`: This command displays a summary of the cluster with its API and DNS services.
- `kubectl api-resources`: This command lists the supported API resources on the server. It is especially helpful if you work with different installations of Kubernetes that support different sets of API resources.
- `kubectl version`: This command prints the client and server version information. If you are working with multiple Kubernetes clusters with different versions, it is a helpful command to catch version mismatches.
- `kubectl config`: This command configures `kubectl` to connect different clusters to each other. `kubectl` is a CLI tool designed to work with multiple clusters by changing its configuration.

In the following exercise, you will install and configure `kubectl` to connect to the local Kubernetes cluster and start exploring the Kubernetes API with the help of its rich set of commands.

Exercise 10.02: Accessing Kubernetes Clusters with kubectl

Kubernetes clusters are installed in cloud systems and can be accessed from various locations. To access the clusters securely and reliably, you need a reliable client tool, which is the official client tool of Kubernetes---namely, `kubectl`. In this exercise, you will install, configure, and use `kubectl` to explore its capabilities along with the Kubernetes API.

To complete this exercise, perform the following steps:

1. Download the latest version of the `kubectl` executable for your operating system and set this as the executable for your local system by running the following command in your terminal:

```
# Linux
curl -LO https://storage.googleapis.com/kubernetes-release/release/'curl -s
https://storage.googleapis.com/kubernetes-
release/release/stable.txt'/bin/linux/amd64/kubectl
# MacOS
curl -LO "https://storage.googleapis.com/kubernetes-release/release/$(curl -s
https://storage.googleapis.com/kubernetes-
release/release/stable.txt)/bin/darwin/amd64/kubectl"
chmod +x kubectl
sudo mv kubectl /usr/local/bin
```

These preceding commands download the binary for Linux or Mac and make it ready to use in the terminal:

```
 /docker-ws $ curl -LO "https://storage.googleapis.com/kubernetes-release/release/$
(curl -s https://storage.googleapis.com/kubernetes-release/release/stable.txt)/bin/
darwin/amd64/kubectl"
  % Total    % Received % Xferd  Average Speed   Time    Time     Time  Current
                                 Dload  Upload   Total   Spent    Left  Speed
100 47.2M  100 47.2M    0     0  6261k      0  0:00:07  0:00:07 --:--:-- 6551k
 /docker-ws $ chmod +x ./kubectl
 /docker-ws $ sudo mv ./kubectl /usr/local/bin/kubectl
 /docker-ws $
```

Figure 10.8: Installation of minikube

2. In your terminal, run the following command to configure `kubectl` to connect to the `minikube` cluster and use it for further access:

```
kubectl config use-context minikube
```

The `use-context` command configures the `kubectl` context to use the `minikube` cluster. For the following steps, all commands will communicate with the Kubernetes cluster running inside `minikube`:

```
Switched to context "minikube".
```

3. Check for the cluster and client version with the following command:

```
kubectl version --short
```

This command returns the human-readable client and server version information:

```
Client Version: v1.17.2
Server Version: v1.17.0
```

4. Check for further information about the cluster with the following command:

```
kubectl cluster-info
```

This command shows a summary of Kubernetes components, including the master and DNS:

```
Kubernetes master is running at https://192.168.64.5:8443
KubeDNS is running at https://192.168.64.5:8445/api/v1/
namespaces/kube-system/Services/kube-dns:dns/proxy
To further debug and diagnose cluster problems, use
'kubectl cluster-info dump'.
```

5. Get a list of the nodes in the cluster with the following command:

```
kubectl get nodes
```

Since the cluster is a `minikube` local cluster, there is only one node named `minikube` with the `master` role:

```
NAME        STATUS        ROLES        AGE        VERSION
Minikube    Ready         master       41h        v1.17.0
```

6. List the supported resources in the Kubernetes API with the following command:

```
kubectl api-resources --output="name"
```

This command lists the `name` field of the `api-resources` supported in the Kubernetes API server. The long list shows how Kubernetes creates different abstractions to run containerized applications:

```
 /docker-ws $ kubectl api-resources --output="name"
bindings
componentstatuses
configmaps
endpoints
events
limitranges
namespaces
nodes
persistentvolumeclaims
persistentvolumes
pods
podtemplates
replicationcontrollers
resourcequotas
secrets
serviceaccounts
services
mutatingwebhookconfigurations.admissionregistration.k8s.io
validatingwebhookconfigurations.admissionregistration.k8s.io
customresourcedefinitions.apiextensions.k8s.io
apiservices.apiregistration.k8s.io
controllerrevisions.apps
daemonsets.apps
deployments.apps
replicasets.apps
statefulsets.apps
tokenreviews.authentication.k8s.io
localsubjectaccessreviews.authorization.k8s.io
selfsubjectaccessreviews.authorization.k8s.io
selfsubjectrulesreviews.authorization.k8s.io
subjectaccessreviews.authorization.k8s.io
horizontalpodautoscalers.autoscaling
cronjobs.batch
jobs.batch
certificatesigningrequests.certificates.k8s.io
leases.coordination.k8s.io
endpointslices.discovery.k8s.io
events.events.k8s.io
ingresses.extensions
nodes.metrics.k8s.io
pods.metrics.k8s.io
ingresses.networking.k8s.io
networkpolicies.networking.k8s.io
runtimeclasses.node.k8s.io
poddisruptionbudgets.policy
podsecuritypolicies.policy
clusterrolebindings.rbac.authorization.k8s.io
clusterroles.rbac.authorization.k8s.io
rolebindings.rbac.authorization.k8s.io
roles.rbac.authorization.k8s.io
priorityclasses.scheduling.k8s.io
csidrivers.storage.k8s.io
csinodes.storage.k8s.io
storageclasses.storage.k8s.io
volumeattachments.storage.k8s.io
 /docker-ws $
```

Figure 10.9: Kubernetes resource listing

The output lists the API resources available in the Kubernetes cluster we have connected to. As you can see, there are tens of resources you can use and each of them helps you to create cloud-native, scalable, and reliable applications.

In this exercise, you have connected to the Kubernetes cluster and checked the functionalities of the client tool. `kubectl` is the most critical tool for accessing and managing applications running in Kubernetes. By the end of this exercise, you will have learned how to install, configure, and connect to a Kubernetes cluster. In addition, you will have checked its version, the statuses of its nodes, and the available API resources. Using `kubectl` effectively is an essential task in daily life for developers interacting with Kubernetes.

In the following section, the primary Kubernetes resources (seen in part of the last step in the previous exercise) will be presented.

Kubernetes Resources

Kubernetes provides a rich set of abstractions over containers to define cloud-native applications. All these abstractions are designed as resources in the Kubernetes API and are managed by the control plane. In other words, the applications are defined as a set of resources in the control plane. At the same time, node components try to achieve the state specified in the resources. If a Kubernetes resource is assigned to a node, the node components focus on attaching the required volumes and network interfaces to keep the application up and running.

Let's assume you will deploy the backend of the InstantPizza reservation system on Kubernetes. The backend consists of a database and a web server for handling REST operations. You will need to define a couple of resources in Kubernetes:

- A **StatefulSet** resource for the database
- A **Service** resource to connect to the database from other components such as the web server
- A **Deployment** resource to deploy the web server in a scalable way
- A **Service** resource to enable outside connections to the web server

When these resources are defined in the control plane via `kubectl`, the node components will create the required containers, networks, and storage in the cluster.

Each resource has distinctive characteristics and schema in the Kubernetes API. In this section, you will learn about the fundamental Kubernetes resources, including **Pods**, **Deployments**, **StatefulSet**, and **Services**. In addition, you will learn about more complex Kubernetes resources such as **Ingresses**, **Horizontal Pod Autoscaling**, and **RBAC Authorization** in Kubernetes.

Pods

The Pod is the fundamental building block of containerized applications in Kubernetes. It consists of one or more containers that could share the network, storage, and memory. Kubernetes schedules all the containers in a Pod into the same node. Also, the containers in the Pod are scaled up or down together. The relationship between containers, Pods, and nodes can be outlined as follows:

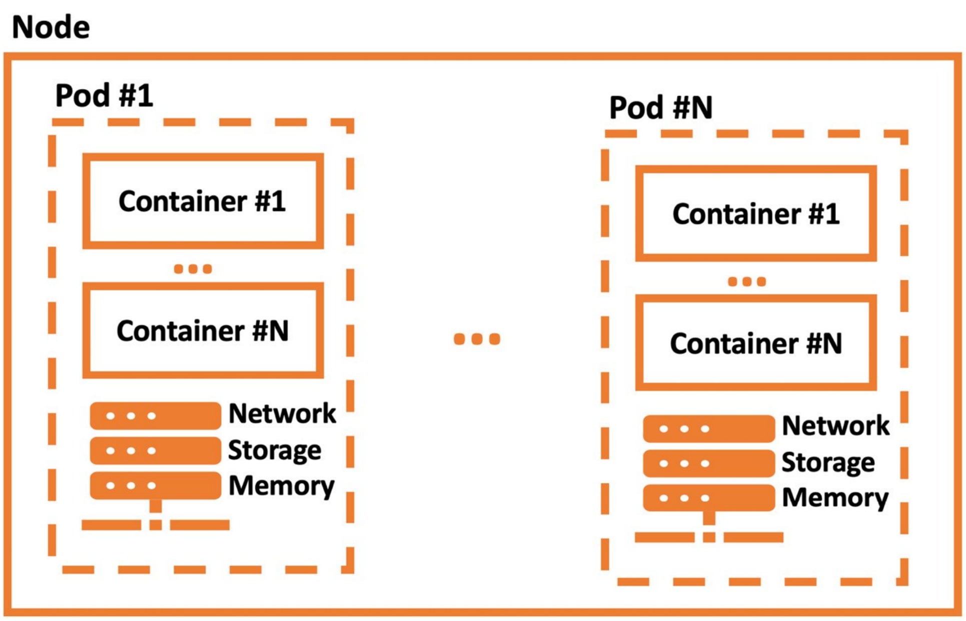


Figure 10.10: Containers, Pods, and nodes

It can be seen from the preceding diagram that a Pod can contain multiple containers. All these containers share a common network, storage, and memory resources.

The Pod definition is straightforward, with four main sections:

```
apiVersion: v1
kind: Pod
metadata:
  name: server
spec:
  containers:
  - name: main
    image: nginx
```

These four sections are required for all Kubernetes resources:

- `apiVersion` defines the versioned schema of this resource of an object.
- `kind` represents the REST resource name.
- `metadata` holds the information of the resource, such as names, labels, and annotations.
- `spec` is the resource-specific part where resource-specific information is kept.

When the preceding server Pod is created in the Kubernetes API, the API will first check whether the definition is correct according to the `apiVersion=v1` and `kind=Pod` schema. Then, the scheduler will assign the Pod to a node. Following that, the `kubelet` in the node will create the `nginx` container for the `main` container.

Pods are the first abstraction of Kubernetes over containers, and they are the building blocks of more complex resources. In the following section, we will use resources such as Deployments and Statefulsets to encapsulate Pods to create more sophisticated applications.

Deployments

Deployments are a Kubernetes resource that focuses on scalability and high availability. Deployments encapsulate Pods to scale up, down, and roll out new versions. In other words, you can define a three-replica web server Pod as a Deployment. Deployment controllers in the control plane will guarantee the number of replicas. Besides, when you update the Deployment to a newer version, the controllers will gradually update the application instances.

The definitions of Deployments and Pods are similar, although labels and replicas are added to the schema of Deployments:

```
apiVersion: apps/v1
kind: Deployment
metadata:
  name: server
spec:
  replicas: 10
  selector:
    matchLabels:
      app: server
  template:
    metadata:
      labels:
        app: server
```

```
    spec:
      containers:
      - name: main
        image: nginx
        ports:
        - containerPort: 80
```

The Deployment `server` has 10 replicas of the Pod specification with the label `app:server`. In addition, port `80` of the container is published for each main container of the server instance. The Deployment controller will create or delete the instances to match the 10 replicas of the defined Pod. In other words, if a node with two running instances of the server Deployment goes offline, the controller will create two additional Pods on the remaining nodes. This automation of Kubernetes allows us to create scalable and highly available applications out of the box.

In the following section, Kubernetes resources for stateful applications, such as databases and message queues, will be presented.

Statefulsets

Kubernetes supports running stateful applications that store their states on the disk volumes with **StatefulSet** resources. StatefulSets make it possible to run database applications or data analysis tools in Kubernetes with the same reliability and high availability of temporary applications.

The definition of StatefulSets resembles the definition of **Deployments**, with **volume mount** and **claim additions**:

```
apiVersion: apps/v1
kind: StatefulSet
metadata:
  name: database
spec:
  selector:
    matchLabels:
      app: mysql
  serviceName: mysql
  replicas: 1
  template:
    metadata:
      labels:
        app: mysql
    spec:
      containers:
      - name: mysql
        image: mysql:5.7
        env:
        - name: MYSQL_ROOT_PASSWORD
          value: "root"
        ports:
        - name: mysql
          containerPort: 3306
        volumeMounts:
        - name: data
          mountPath: /var/lib/mysql
        subPath: mysql
  volumeClaimTemplates:
```

```
- metadata:
    name: data
  spec:
    accessModes: ["ReadWriteOnce"]
    resources:
      requests:
        storage: 2Gi
```

The database resource defines a **MySQL** database with a disk volume of **2 GB**. When the server `StatefulSet` resource is created in the Kubernetes API, `cloud-controller-manager` will create a volume and make it ready on the scheduled node. While creating the volume, it uses the specification under `volumeClaimTemplates`. Then, the node will mount the volume in the container according to the `volumeMounts` section in `spec`.

In this resource definition, there is also an example of setting an environment variable for `MYSQL_ROOT_PASSWORD`. Statefulsets are vital resources in Kubernetes since they enable running stateful applications in the same cluster with ephemeral workloads.

In the following resource, the Kubernetes solution for the connection between Pods will be presented.

Services

Kubernetes clusters host multiple applications running in various nodes, and most of the time, these applications need to communicate with each other. Assume you have a three-instance Deployment of your backend and a two-instance Deployment of your frontend application. Five Pods run, spread over the cluster with their IP addresses. Since the frontend instances need to connect to the backend, the frontend instances need to know the IP addresses of backend instances, as shown in *Figure 10.11*:

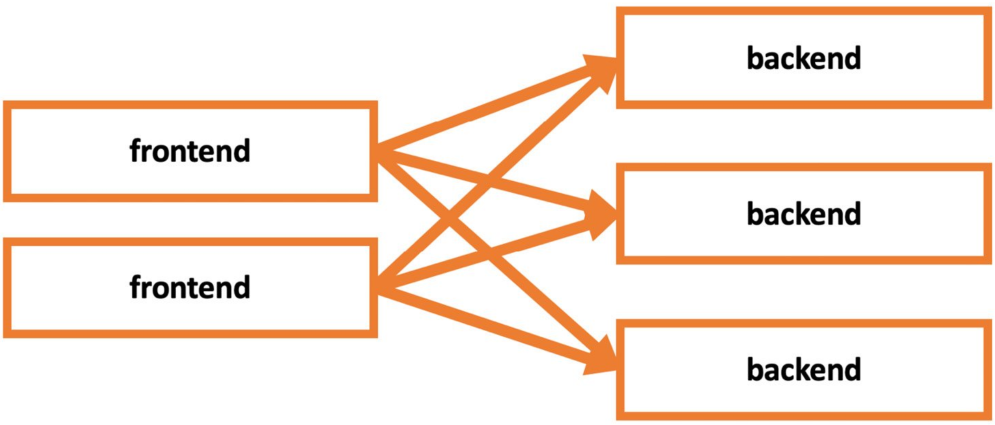


Figure 10.11: Frontend and backend instances

However, this is not a sustainable approach, with scaling up or down and the prospect of numerous potential failures in the cluster. Kubernetes proposes **Service** resources to define a set of Pods with labels and access them using the name of the Service. For instance, the frontend applications can connect to a backend instance by just using the address of `backend-service`, as illustrated in *Figure 10.12*:

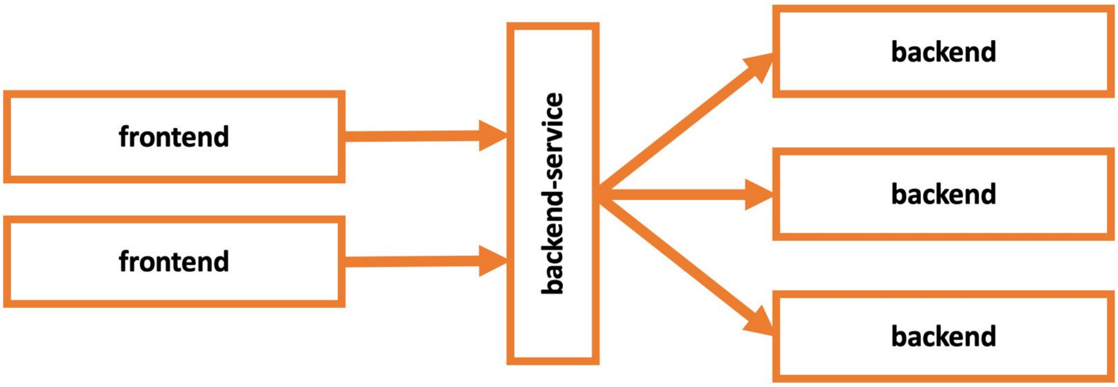


Figure 10.12: Frontend and backend instances connected via backend-service

The definition of the Service resource is reasonably straightforward, as shown here:

```
apiVersion: v1
kind: Service
metadata:
  name: my-db
spec:
  selector:
    app: mysql
  ports:
    - protocol: TCP
      port: 3306
      targetPort: 3306
```

When the `my-db` Service is created, all other Pods in the cluster will be able to connect to the Pods with the label `app:mysql` at port `3306` via the address, `my-db`. In the following resource, external access to the Services in the cluster by using the Kubernetes Ingress resources will be presented.

Ingress

Kubernetes clusters are designed to serve applications in and outside the cluster. Ingress resources are defined to expose Services to the outside world with additional features such as external URLs and load balancing. Although the Ingress resources are native Kubernetes objects, they require an Ingress controller up and running in the cluster. In other words, Ingress controllers are not part of the `kube-controller-manager`, and you need to install one in your cluster. There are multiple implementations available on the market. However, Kubernetes currently supports and maintains `GCE` and `nginx` controllers officially.

Note

A list of additional Ingress controllers is available in the official documentation at the following link: https://kubernetes.io/docs/concepts/Services-networking/Ingress-controllers.

An Ingress resource with a host URL of `my-db.docker-workshop.io` to connect to port `3306` on the `my-db` Service looks like the following:

```
apiVersion: networking.k8s.io/v1beta1
kind: Ingress
```

```
metadata:
  name: my-db
spec:
  rules:
  - host: my-db.docker-workshop.io
    http:
      paths:
      - path: /
        backend:
          serviceName: my-db
          servicePort: 3306
```

Ingress resources are essential to open the Services to the outside world. However, their configuration can be more complicated than it seems. The Ingress resources could require individual annotations based on the Ingress controller running in your cluster.

In the following resource, automatic scaling of the Pods with the help of the Horizontal Pod Autoscaler will be covered.

Horizontal Pod Autoscaling

Kubernetes clusters provide a scalable and reliable containerized application environment. However, it is cumbersome and unfeasible to manually track the usage of applications and scale up or down when needed. Therefore, Kubernetes provides the Horizontal Pod Autoscaler to scale the number of Pods according to CPU utilization automatically.

Horizontal Pod Autoscalers are a Kubernetes resource with a target resource for scaling and target metrics:

```
apiVersion: Autoscaling/v1
kind: HorizontalPodAutoscaler
metadata:
  name: server-scaler
spec:
  scaleTargetRef:
    apiVersion: apps/v1
    kind: Deployment
    name: server
  minReplicas: 1
  maxReplicas: 10
  targetCPUUtilizationPercentage: 50
```

When the `server-scaler` resource is created, the Kubernetes control plane will try to achieve the target CPU utilization of `50%` by scaling up or down the Deployment named as the `server`. In addition, the minimum and maximum numbers of replicas are set to `1` and `10`. This ensures that the Deployment is not scaled to `0` when it is not used, nor scaled too high so that it consumes all the resources in the cluster. Horizontal Pod Autoscaler resources are essential parts of Kubernetes for creating scalable and reliable applications that are automatically managed.

In the following section, you will learn about authorization in Kubernetes.

RBAC Authorization

Kubernetes clusters are designed to connect and make changes to resources securely. However, when the applications are running in a production environment, it is critical to limit the scope of actions of the users.

Let's assume that you have conferred extensive powers on everyone in your project group. In such circumstances, it will not be possible to protect your application running in the cluster from deletion or misconfiguration. Kubernetes provides **Role-Based Access Control** (**RBAC**) to manage users' access and abilities based on the roles given to them. In other words, Kubernetes can limit the ability of users to perform specific tasks on specific Kubernetes resources.

Let's start with the `Role` resource to define the capabilities:

```
kind: Role
apiVersion: rbac.authorization.k8s.io/v1
metadata:
  namespace: critical-project
  name: Pod-reader
rules:
  - apiGroups: [""]
    resources: ["Pods"]
    verbs: ["get", "watch", "list"]
```

The `Pod-reader` role defined in the preceding snippet is only allowed to `get`, `watch`, and `list` the Pod resources in the `critical-project` namespace. When the user only has the role `Pod-reader`, they will not be able to delete or modify the resources in the `critical-project` namespace. Let's see how roles are assigned to users using the `RoleBinding` resource:

```
kind: RoleBinding
apiVersion: rbac.authorization.k8s.io/v1
metadata:
  name: read-Pods
  namespace: critical-project
subjects:
  - kind: User
    name: new-intern
roleRef:
  kind: Role
  name: Pod-reader
  apiGroup: rbac.authorization.k8s.io
```

The `RoleBinding` resource combines the `Role` resource with the subjects. In `read-Pods RoleBinding`, the user `new-intern` is assigned to the `Pod-reader` `Role`. When the `read-Pods` resource is created in the Kubernetes API, it will not be possible for the `new-intern` user to modify or delete the Pods in the `critical-project` namespace.

In the following exercise, you will see the Kubernetes resources in action using `kubectl` and the local Kubernetes cluster.

Exercise 10.03: Kubernetes Resources in Action

Cloud-native containerized applications require multiple Kubernetes resources due to their complex nature. In this exercise, you will create an instance of the popular WordPress application on Kubernetes by using one **Statefulset**, one **Deployment**, and two **Service** resources. In addition, you will check the status of the Pods and connect to the Service using `kubectl` and `minikube`.

To complete this exercise, perform the following steps:

1. Create a `StatefulSet` definition in a file, named `database.yaml`, with the following content:

```
apiVersion: apps/v1
kind: StatefulSet
metadata:
  name: database
spec:
  selector:
    matchLabels:
      app: mysql
  serviceName: mysql
  replicas: 1
  template:
    metadata:
      labels:
        app: mysql
    spec:
      containers:
      - name: mysql
        image: mysql:5.7
        env:
        - name: MYSQL_ROOT_PASSWORD
          value: "root"
        ports:
        - name: mysql
          containerPort: 3306
        volumeMounts:
        - name: data
          mountPath: /var/lib/mysql
          subPath: mysql
  volumeClaimTemplates:
  - metadata:
      name: data
    spec:
      accessModes: ["ReadWriteOnce"]
      resources:
        requests:
          storage: 2Gi
```

   This `StatefulSet` resource defines a database to be used by WordPress in the following steps. There is only one container named `mysql` with the Docker image of `mysql:5.7`. There is one environment variable for the root password and one port defined in the container specification. In addition, one volume is claimed and attached to `/var/lib/mysql` in the preceding definition.

2. Deploy the `StatefulSet` to the cluster by running the following command in your terminal:

```
kubectl apply -f database.yaml
```

   This command will apply the definition in the `database.yaml` file since it is passed with the `-f` flag:

```
StatefulSet.apps/database created
```

3. Create a `database-service.yaml` file in your local computer with the following content:

```
apiVersion: v1
kind: Service
metadata:
  name: database-service
spec:
  selector:
    app: mysql
  ports:
    - protocol: TCP
      port: 3306
      targetPort: 3306
```

   This Service resource defines a Service abstraction over database instances. WordPress instances will connect to the database by using the specified Service.

4. Deploy the Service resource with the following command:

```
kubectl apply -f database-service.yaml
```

   This command deploys the resource defined in the `database-service.yaml` file:

```
Service/database-service created
```

5. Create a file with the name `wordpress.yaml` and the following content:

```
apiVersion: apps/v1
kind: Deployment
metadata:
  name: wordpress
  labels:
    app: wordpress
spec:
  replicas: 3
  selector:
    matchLabels:
      app: wordpress
  template:
    metadata:
      labels:
        app: wordpress
    spec:
      containers:
      - image: wordpress:4.8-apache
        name: wordpress
        env:
        - name: WORDPRESS_DB_HOST
          value: database-Service
        - name: WORDPRESS_DB_PASSWORD
          value: root
        ports:
```

```
        - containerPort: 80
          name: wordpress
```

This `Deployment` resource defines a three-replica WordPress installation. There is one container defined with the `wordpress:4.8-apache` image and `database-service` is passed to the application as an environment variable. With the help of this environment variable, WordPress connects to the database deployed in *Step 3*. In addition, a container port is defined on port `80` so that we can reach the application from the browser in the following steps.

6. Deploy the WordPress Deployment with the following command:

```
kubectl apply -f wordpress.yaml
```

This command deploys the resource defined in the `wordpress.yaml` file:

```
Deployment.apps/wordpress created
```

7. Create a `wordpress-service.yaml` file on your local computer with the following content:

```
apiVersion: v1
kind: Service
metadata:
  name: wordpress-service
spec:
  type: LoadBalancer
  selector:
    app: wordpress
  ports:
    - protocol: TCP
      port: 80
      targetPort: 80
```

This Service resource defines a Service abstraction over the WordPress instances. The Service will be used to connect to WordPress from the outside world via port `80`.

8. Deploy the `Service` resource with the following command:

```
kubectl apply -f wordpress-service.yaml
```

This command deploys the resource defined in the `wordpress-service.yaml` file:

```
Service/wordpress-service created
```

9. Check the status of all running Pods with the following command:

```
kubectl get pods
```

This command lists all the Pods with their statuses, and there are one database and three WordPress Pods with the `Running` status:

```
 /docker-ws $ kubectl get pods
NAME                          READY   STATUS    RESTARTS   AGE
database-0                    1/1     Running   0          117s
wordpress-6c59fbbb8d-gcht4    1/1     Running   0          53s
wordpress-6c59fbbb8d-rmzqv    1/1     Running   0          53s
wordpress-6c59fbbb8d-x6gmb    1/1     Running   0          53s
 /docker-ws $
```

Figure 10.13: Pod listing

10. Get the URL of `wordpress-service` by running the following command:

```
minikube service wordpress-service --url
```

This command lists the URL of the Service, accessible from the host machine:

```
http://192.168.64.5:32765
```

Open the URL in your browser to access the setup screen of WordPress:

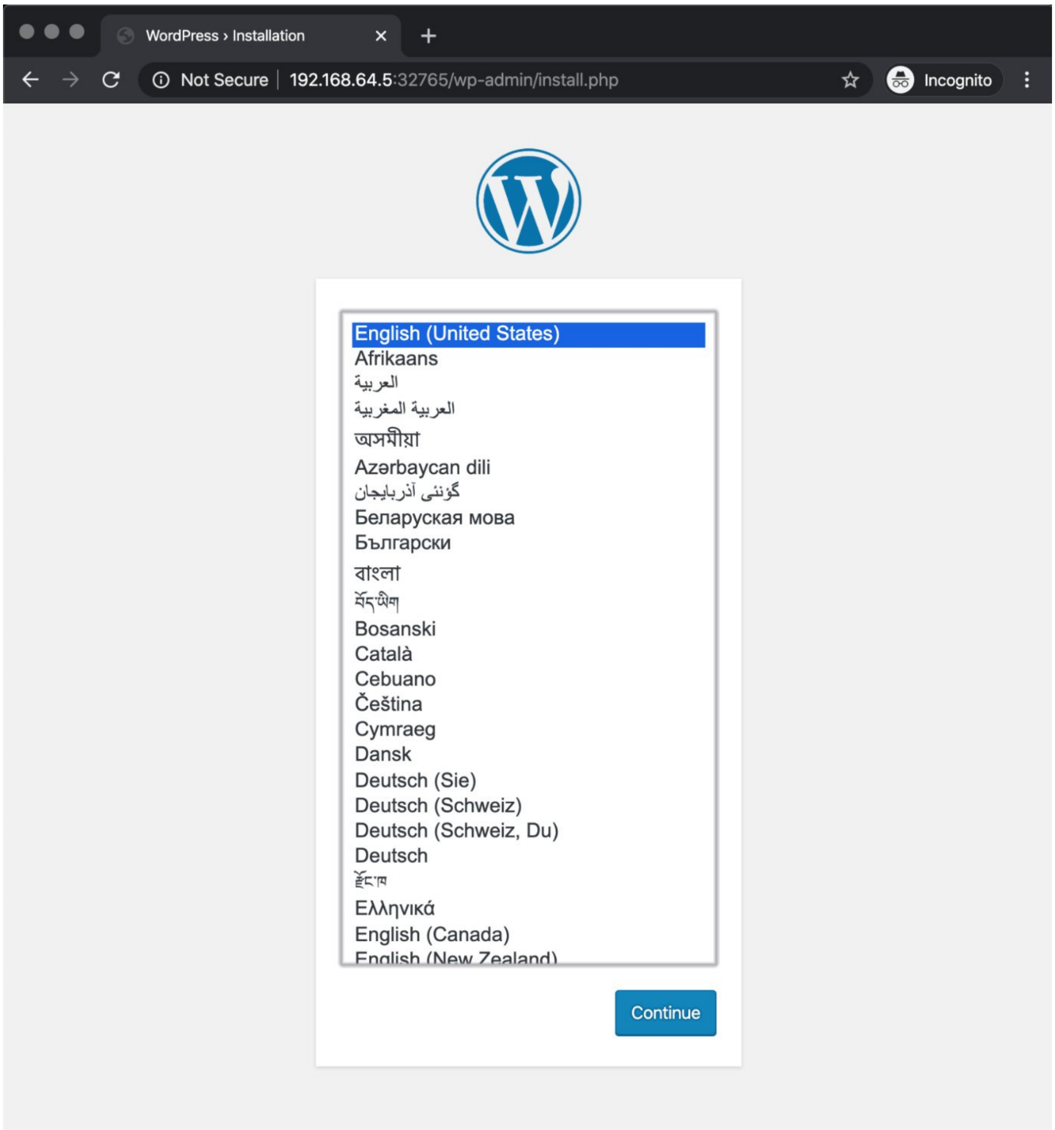


Figure 10.14: WordPress setup screen

The setup screen indicates that the WordPress instances are running and accessible via their Service. Furthermore, it shows that the `StatefulSet` database is also running and accessible via its Service by the WordPress instances.

In this exercise, you have used different Kubernetes resources to define and install a complex application in Kubernetes. First, you deployed a `Statefulset` resource for installing MySQL in the cluster. Then, you deployed a `Service` resource to reach the database inside the cluster. Following that, you deployed a `Deployment` resource to install the WordPress application. Similarly, you created another `Service` to reach the WordPress application outside the cluster. You have created independently scalable and reliable microservices using different Kubernetes resources and connected them. Furthermore, you have learned how to check the status of `Pods`. In the following section, you will learn about the Kubernetes package manager: Helm.

Kubernetes Package Manager: Helm

Kubernetes applications consist of multiple containers, volumes, and networking resources due to the nature of cloud-native microservices architecture. The microservice architecture divides large applications into smaller chunks and thus results in numerous Kubernetes resources and a vast amount of configuration values.

Helm is the official Kubernetes package manager that collects the resources of applications as templates and fills them with the values provided. The essential advantage here is the accumulated community knowledge of installing the applications with the best practices. You can install an app with the most popular methods, even if you are working with it for the first time. Besides, working with Helm charts augments the developer experience.

For instance, installing and managing complex applications in Kubernetes becomes similar to downloading apps in Apple Store or Google Play Store, with fewer commands and configurations. In Helm terminology, a collection of resources for a single application is a **chart**. Charts can be used to deploy anything from a simple pod to a full web app stack with HTTP servers, databases, caches, and such when you work with the Helm package manager. The encapsulation of applications as charts makes it easier to deploy complicated applications.

In addition, Helm has a chart repository with popular and stable applications that are packaged as charts and maintained by the Helm community. The stable Helm chart repository has a high variety of applications, including databases such as MySQL, PostgreSQL, CouchDB, and InfluxDB; CI/CD tools such as Jenkins, Concourse, and Drone; or monitoring tools such as Grafana, Prometheus, Datadog, and Fluentd. The chart repository not only makes it easier to install apps but also ensures that you are deploying the application with the latest, well-accepted methods in the Kubernetes community.

Helm is a client tool, with its latest version being Helm 3. You only need to install it on your local system, configure it for the chart repository, and then you can start deploying applications. Helm is a powerful package manager with its exhaustive set of commands, including the following:

- `helm repo` : This command adds, lists, removes, updates, and indexes chart repositories to the local Helm installation.
- `helm search` : This command searches for Helm charts in various repositories using user-provided keywords or chart names.
- `helm install` : This command installs a Helm chart on the Kubernetes cluster. It is also possible to set variables with a value file or command-line parameters.
- `helm list` or `helm ls` : These commands list the installed charts from the cluster.
- `helm uninstall` : This command removes an installed chart from Kubernetes.
- `helm upgrade` : This command upgrades an installed chart with new values or new chart versions on the cluster.

In the following exercise, you will install Helm, connect to a chart repository, and install applications on the cluster.

Exercise 10.04: Installing the MySQL Helm Chart

Helm charts are installed and managed by the official client tool, `helm` . You need to install the `helm` client tool locally to retrieve the charts from the chart repository and then install applications on the clusters. In this exercise, you will start working with Helm and install **MySQL** from its stable Helm chart.

To complete this exercise, perform the following steps:

1. Run the following command in your terminal to download the latest version of the `helm` executable with the installation script:

   ```
   curl https://raw.githubusercontent.com/helm/helm/master/scripts/get-helm-3 |
   bash
   ```

The script downloads the appropriate binary of `helm` for your operating system and makes it ready to use in the Terminal:

```
 /docker-ws $ curl https://raw.githubusercontent.com/helm/helm/master/scripts/get-helm-3 | bash
  % Total    % Received % Xferd  Average Speed   Time    Time     Time  Current
                                 Dload  Upload   Total   Spent    Left  Speed
100  6617  100  6617    0     0  62424      0 --:--:-- --:--:-- --:--:-- 62424
Downloading https://get.helm.sh/helm-v3.0.3-darwin-amd64.tar.gz
Preparing to install helm into /usr/local/bin
helm installed into /usr/local/bin/helm
 /docker-ws $
```

Figure 10.15: Installation of Helm

2. Add the chart repository to `helm` by running the following command in your terminal:

```
helm repo add stable https://kubernetes-charts.storage.googleapis.com/
```

This command adds the URL of the chart repository to the locally installed `helm` instance:

```
"stable" has been added to your repositories
```

3. List the charts in the `stable` repository from *Step 2* with the following command:

```
helm search repo stable
```

This command will list all the available charts in the repository:

```
/docker-ws $ helm search repo stable
NAME                                CHART VERSION   APP VERSION             DESCRIPTION
stable/acs-engine-autoscaler        2.2.2           2.1.1                   DEPRECATED Scales worker nodes within agent pools
stable/aerospike                    0.3.2           v4.5.0.5                A Helm chart for Aerospike in Kubernetes
stable/airflow                      6.0.0           1.10.4                  Airflow is a platform to programmatically autho...
stable/ambassador                   5.3.1           0.86.1                  A Helm chart for Datawire Ambassador
stable/anchore-engine               1.4.2           0.6.1                   Anchore container analysis and policy evaluatio...
stable/apm-server                   2.1.5           7.0.0                   The server receives data from the Elastic APM a...
stable/ark                          4.2.2           0.10.2                  DEPRECATED A Helm chart for ark
stable/artifactory                  7.3.1           6.1.0                   DEPRECATED Universal Repository Manager support...
stable/artifactory-ha               0.4.1           6.2.0                   DEPRECATED Universal Repository Manager support...
stable/atlantis                     3.11.0          v0.11.1                 A Helm chart for Atlantis https://www.runatlant...
stable/auditbeat                    1.1.0           6.7.0                   A lightweight shipper to audit the activities o...
stable/aws-cluster-autoscaler       0.3.3                                   Scales worker nodes within autoscaling groups.
stable/aws-iam-authenticator        0.1.2           1.0                     A Helm chart for aws-iam-authenticator
stable/bitcoind                     1.0.0           0.17.1                  Bitcoin is an innovative payment network and a ...
stable/bookstack                    1.2.0           0.27.5                  BookStack is a simple, self-hosted, easy-to-use...
stable/buildkite                    0.2.4           3                       DEPRECATED Agent for Buildkite
stable/burrow                       1.5.2           0.29.0                  Burrow is a permissionable smart contract machine
stable/centrifugo                   3.1.1           2.1.0                   Centrifugo is a real-time messaging server.
stable/cerebro                      1.3.1           0.8.5                   A Helm chart for Cerebro - a web admin tool tha...
stable/cert-manager                 v0.6.7          v0.6.2                  A Helm chart for cert-manager
stable/chaoskube                    3.1.3           0.14.0                  Chaoskube periodically kills random pods in you...
stable/chartmuseum                  2.7.1           0.11.0                  Host your own Helm Chart Repository
stable/chronograf                   1.1.0           1.7.12                  Open-source web application written in Go and R...
stable/clamav                       1.0.5           1.6                     An Open-Source antivirus engine for detecting t...
stable/cloudserver                  1.0.4           8.1.5                   An open-source Node.js implementation of the Am...
stable/cluster-autoscaler           6.4.0           1.14.6                  Scales worker nodes within autoscaling groups.
stable/cluster-overprovisioner      0.2.6           1.0                     Installs the a deployment that overprovisions t...
stable/cockroachdb                  3.0.5           19.2.3                  CockroachDB is a scalable, survivable, strongly...
stable/collabora-code               1.0.6           4.0.3.1                 A Helm chart for Collabora Office - CODE-Edition
stable/concourse                    8.3.7           5.6.0                   DEPRECATED Concourse is a simple and scalable C...
stable/consul                       3.9.4           1.5.3                   Highly available and distributed service discov...
stable/contour                      0.2.0           v0.15.0                 Contour Ingress controller for Kubernetes
stable/coredns                      1.9.2           1.6.7                   CoreDNS is a DNS server that chains plugins and...
stable/cosbench                     1.0.1           0.0.6                   A benchmark tool for cloud object storage services
stable/coscale                      1.0.0           3.16.0                  CoScale Agent
stable/couchbase-operator           1.0.2           1.2.2                   A Helm chart to deploy the Couchbase Autonomous...
stable/couchdb                      2.3.0           2.3.1                   DEPRECATED A database featuring seamless multi-...
stable/dask                         3.1.1           1.1.5                   DEPRECATED Distributed computation in Python wi...
stable/dask-distributed             2.0.2                                   DEPRECATED: Distributed computation in Python
stable/datadog                      1.39.8          7                       DataDog Agent
stable/dex                          2.8.0           2.21.0                  CoreOS Dex
stable/distributed-jmeter           1.0.1           3.3                     A Distributed JMeter Helm chart
stable/distributed-tensorflow       0.1.3           1.6.0                   A Helm chart for running distributed TensorFlow...
stable/distribution                 0.4.2           1.1.0                   DEPRECATED A Helm chart for JFrog Distribution
stable/dmarc2logstash               1.2.0           1.0.3                   Provides a POP3-polled DMARC XML report injecto...
stable/docker-registry              1.9.1           2.7.1                   A Helm chart for Docker Registry
stable/dokuwiki                     6.0.6           0.20180422.201901061035 DokuWiki is a standards-compliant, simple to us...
stable/drone                        2.6.1           1.6.1                   Drone is a Continuous Delivery system built on ...
stable/drupal                       6.2.4           8.8.2                   One of the most versatile open source content m...
stable/efs-provisioner              0.11.0          v2.4.0                  A Helm chart for the AWS EFS external storage p...
stable/elastabot                    1.2.0           1.1.0                   A Helm chart for Elastabot - a Slack bot compan...
stable/elastalert                   1.2.3           0.2.1                   ElastAlert is a simple framework for alerting o...
stable/elastic-stack                1.8.0           6                       A Helm chart for ELK
stable/elasticsearch                1.32.2          6.8.2                   Flexible and powerful open source, distributed ...
stable/elasticsearch-curator        2.1.3           5.7.6                   A Helm chart for Elasticsearch Curator
stable/elasticsearch-exporter       2.3.0           1.1.0                   Elasticsearch stats exporter for Prometheus
stable/envoy                        1.9.0           1.11.2                  Envoy is an open source edge and service proxy,...
stable/etcd-operator                0.10.2          0.9.4                   CoreOS etcd-operator Helm chart for Kubernetes
stable/ethereum                     1.0.0           v1.7.3                  private Ethereum network Helm chart for Kubernetes
stable/eventrouter                  0.2.3           0.2                     A Helm chart for eventruter (https://github.com...
stable/express-gateway              1.6.3           1.16.9                  Express Gateway is an API Gateway that sits at ...
stable/external-dns                 2.16.1          0.5.18                  ExternalDNS is a Kubernetes addon that configur...
stable/factorio                     1.0.0           0.15.39                 Factorio dedicated server.
stable/falco                        1.1.1           0.19.0                  Falco
stable/filebeat                     4.0.0           7.4.0                   A Helm chart to collect Kubernetes logs with fi...
stable/fluent-bit                   2.8.7           1.3.5                   Fast and Lightweight Log/Data Forwarder for Lin...
stable/fluentd                      2.3.2           v2.4.0                  A Fluentd Elasticsearch Helm chart for Kubernetes.
stable/fluentd-elasticsearch        2.0.7           2.3.2                   DEPRECATED! - A Fluentd Helm chart for Kubernet...
stable/g2                           0.3.3           0.5.0                   DEPRECATED G2 by AppsCode - Gearman in Golang
stable/gangway                      0.4.0           3.3.0                   An application that can be used to easily enabl...
stable/gce-ingress                  1.2.0           1.4.0                   A GCE Ingress Controller
```

Figure 10.16: Chart repository listing

4. Install the MySQL chart with the following command:

```
helm install database stable/mysql
```

This command will install the MySQL Helm chart from the `stable` repository under the name `database` and print information on how to connect to the database:

```
/docker-ws $ helm install database stable/mysql
NAME: database
LAST DEPLOYED: Tue Feb 11 17:09:17 2020
NAMESPACE: default
STATUS: deployed
REVISION: 1
NOTES:
MySQL can be accessed via port 3306 on the following DNS name from within your cluster:
database-mysql.default.svc.cluster.local

To get your root password run:

    MYSQL_ROOT_PASSWORD=$(kubectl get secret --namespace default database-mysql -o jsonpath="{.data.mysql-root-password}" | base64 --decode; echo)

To connect to your database:

1. Run an Ubuntu pod that you can use as a client:

    kubectl run -i --tty ubuntu --image=ubuntu:16.04 --restart=Never -- bash -il

2. Install the mysql client:

    $ apt-get update && apt-get install mysql-client -y

3. Connect using the mysql cli, then provide your password:
    $ mysql -h database-mysql -p

To connect to your database directly from outside the K8s cluster:
    MYSQL_HOST=127.0.0.1
    MYSQL_PORT=3306

    # Execute the following command to route the connection:
    kubectl port-forward svc/database-mysql 3306

    mysql -h ${MYSQL_HOST} -P${MYSQL_PORT} -u root -p${MYSQL_ROOT_PASSWORD}
/docker-ws $
```

Figure 10.17: MySQL installation

The information in the output is valuable if you want to connect to the MySQL installation using the `mysql` client inside or outside the cluster.

5. Check the status of the installation with the following command:

```
helm ls
```

We can see that there is an installation of `mysql-chart-1.6.2` with the status `deployed`:

```
/docker-ws $ helm ls
NAME        NAMESPACE   REVISION    UPDATED                                 STATUS      CHART         APP VERSION
database    default     1           2020-02-11 17:09:17.130815 +0100 CET    deployed    mysql-1.6.2   5.7.28
/docker-ws $
```

Figure 10.18: Helm installation status

You can also use the `helm ls` command to check the application and chart versions, such as `5.7.28` and `mysql-1.6.2`.

6. Check for the Kubernetes resources related to the installation from *Step 4* with the following command:

```
kubectl get all -l release=database
```

This command lists all the resources with the label `release = database`:

```
 /docker-ws $ kubectl get all -l release=database
NAME                                  READY   STATUS    RESTARTS   AGE
pod/database-mysql-758d95c48d-8lxfv   1/1     Running   0          98s

NAME                     TYPE        CLUSTER-IP      EXTERNAL-IP   PORT(S)    AGE
service/database-mysql   ClusterIP   10.96.170.179   <none>        3306/TCP   98s

NAME                             READY   UP-TO-DATE   AVAILABLE   AGE
deployment.apps/database-mysql   1/1     1            1           98s

NAME                                        DESIRED   CURRENT   READY   AGE
replicaset.apps/database-mysql-758d95c48d   1         1         1       98s
 /docker-ws $
```

Figure 10.19: Kubernetes resource listing

There are various resources listed since the installation of a production-grade MySQL instance is not straightforward and consists of multiple resources. Thanks to Helm, we do not need to configure each of these resources and connect them. In addition, listing with the label `release = database` is helpful to provide a troubleshooting overview when some parts of your Helm installation fail.

In this exercise, you have installed and configured the Kubernetes package manager, Helm, and installed applications using it. Helm is an essential tool if you are planning to use Kubernetes for production and need to manage complex applications.

In the following activity, you will configure and deploy the Panoramic Trekking App to the Kubernetes cluster.

Activity 10.01: Installing the Panoramic Trekking App on Kubernetes

You have been assigned to create a Deployment of the Panoramic Trekking App on Kubernetes. You will take advantage of the three-tier architecture of the Panoramic Trekking App with state-of-the-art Kubernetes resources. You will install the database using Helm, and the backend with `nginx` using a Statefulset. Therefore, you will design it as a Kubernetes application and manage it with `kubectl` and `helm`.

Perform the following steps to complete the exercise:

1. Install the database using the PostgreSQL Helm chart. Ensure that the `POSTGRES_PASSWORD` environment variable is set to `kubernetes`.
2. Create a Statefulset with two containers for the Panoramic Trekking App backend and `nginx`. Ensure that you are using the Docker images, `packtworkshops/the-docker-workshop:chapter10-pta-web` and `packtworkshops/the-docker-workshop:chapter10-pta-nginx`, for the containers. In order to store the static files, you need to create a `volumeClaimTemplate` section and mount it to the `/Service/static/` paths of both containers. Finally, do not forget to publish port `80` of the `nginx` container.
3. Create a Kubernetes Service for the Panoramic Trekking App to connect to the Statefulset created in *Step 2*. Ensure that the `type` of Service is `LoadBalancer`.
4. With a successful deployment, obtain the IP of the Kubernetes Service created in *Step 3* and connect to the `$SERVICE_IP/admin` address in the browser:

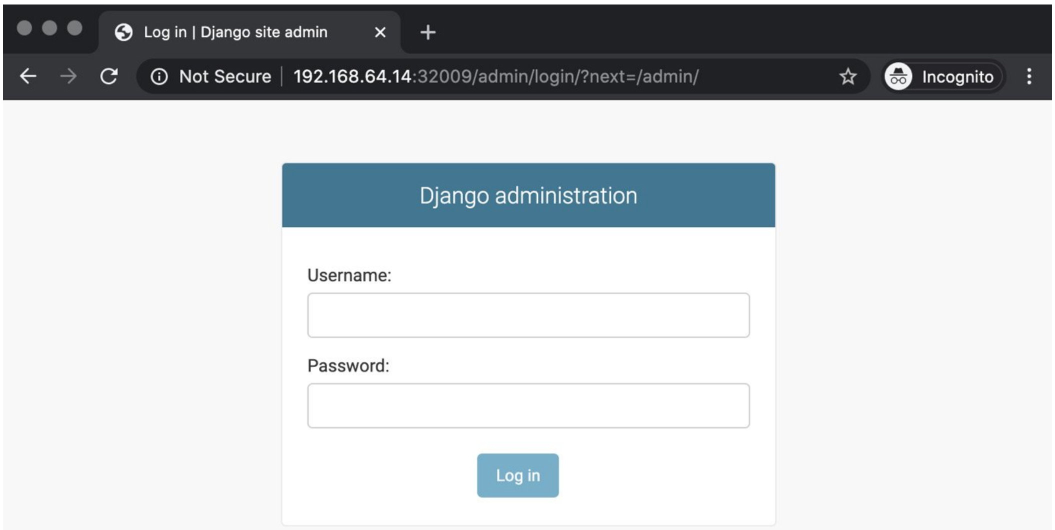


Figure 10.20: Admin login

5. Log in with the username `admin` and the password `changeme` and add new photos and countries:

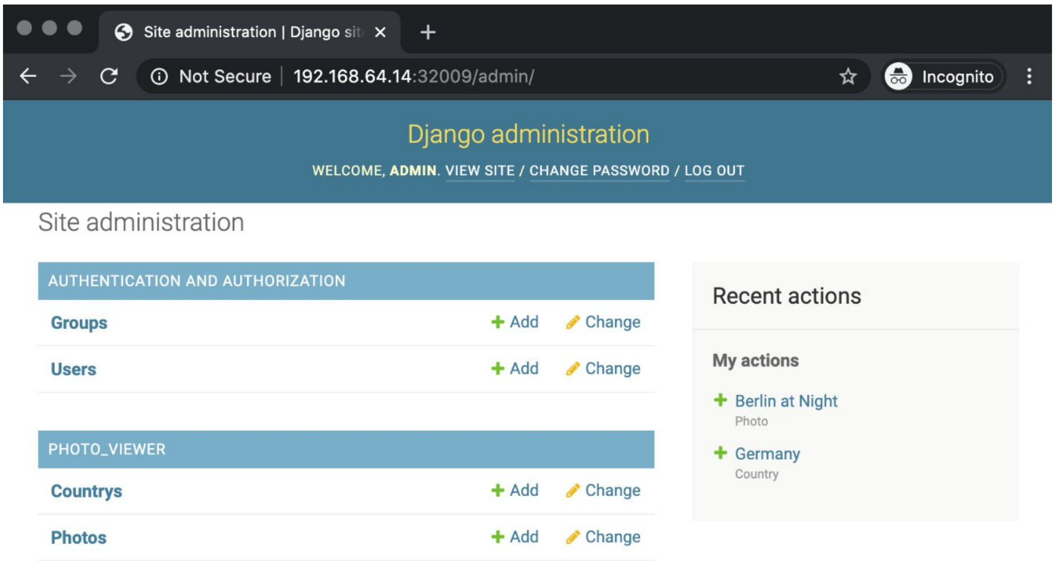
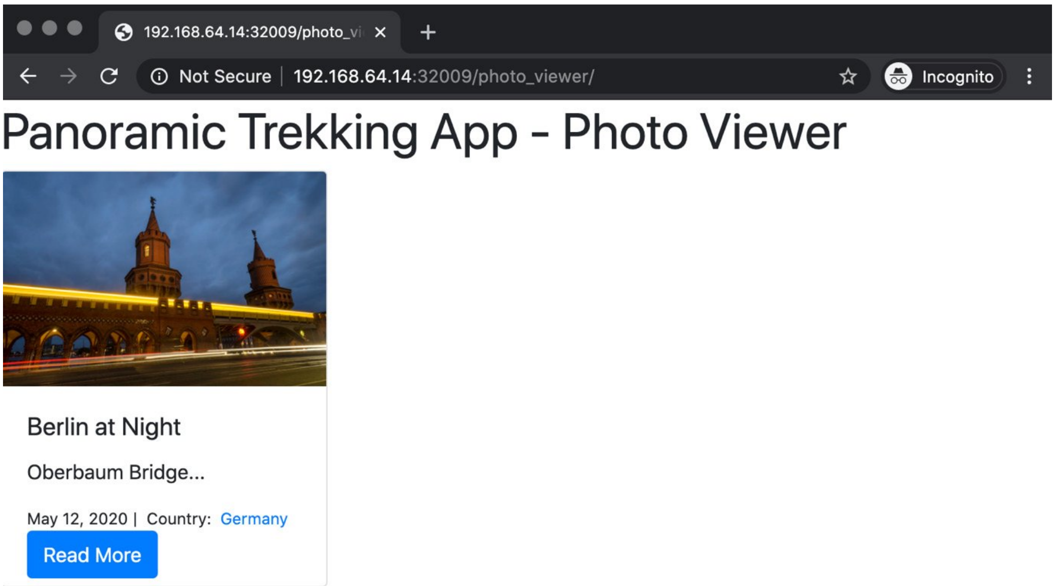


Figure 10.21: Admin setup

6. The Panoramic Trekking App will be available at the address `$SERVICE_IP/photo_viewer` in the browser:



Summary

This lab focused on using Kubernetes to design, create, and manage containerized applications. Kubernetes is the up-and-coming container orchestrator in the market, with a high adoption rate and an active community. In this lab, you have learned about its architecture and design, followed by the Kubernetes API and its access methods, and dove into the vital Kubernetes resources to create complex cloud-native applications.

Every exercise in this lab aimed to illustrate the Kubernetes design approach and its capabilities. With the Kubernetes resources and its official client tool, `kubectl`, it is possible to configure, deploy, and manage containerized applications.

In the following lab, you will learn about security in the Docker world. You will learn the security concepts for container runtimes, container images, and Linux environments, and how to securely run containers in Docker.