Lab 9: Kubernetes

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.

Exercise 10.01: Starting a Local Kubernetes Cluster

To complete this exercise, perform the following steps:

1. 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 $
   ```

```
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.
```

2. 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:

```
[ /docker-ws $ minikube ssh
                         _             _
            _         _ ( )           ( )
  ___ ___  (_)  ___  (_)| |/')  _   _ | |_      __
/' _ ` _ `\| |/' _ `\| || , <  ( ) ( )| '_`\  /'__`\
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$
```

3. 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:

```
C:\Users\fenago>minikube ssh
! Executing "docker container inspect minikube --format={{.State.Status}}" took an unusually long time: 4.0659048s
* Restarting the docker service may improve performance.
-v "pause" name="kube-scheduler" --filter name="kube-controller-manager" | grep -
CONTAINER ID   IMAGE                COMMAND                  CREATED          STATUS          PORTS     NAMES
fc848a28d140   99a3486be4f2         "kube-scheduler --au…"   14 minutes ago   Up 14 minutes             k8s_kube-sched
uler_kube-scheduler-minikube_kube-system_be132fe5c6572cb34d93f5e05ce2a540_0
7304d24b4699   f40be0088a83         "kube-apiserver --ad…"   14 minutes ago   Up 14 minutes             k8s_kube-apise
rver_kube-apiserver-minikube_kube-system_cd6e47233d36a9715b0ab9632f871843_0
63fa5d909501   b07520cd7ab7         "kube-controller-man…"   14 minutes ago   Up 14 minutes             k8s_kube-contr
oller-manager_kube-controller-manager-minikube_kube-system_b965983ec05322d0973594a01d5e8245_0
8069a528496f   25f8c7f3da61         "etcd --advertise-cl…"   14 minutes ago   Up 14 minutes             k8s_etcd_etcd-
minikube_kube-system_9d3d310935e5fabe942511eec3e2cd0c_0
docker@minikube:~$
```

```
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:

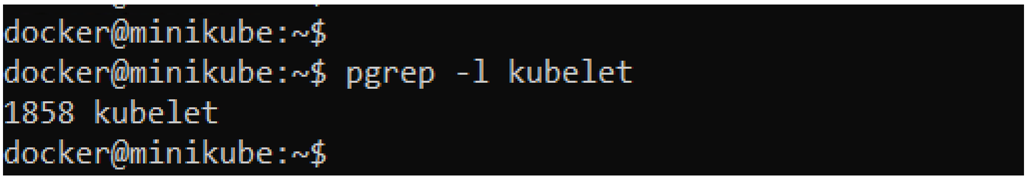
```
docker@minikube:~$
docker@minikube:~$ docker ps --filter "name=kube-proxy"  | grep -v "pause"
CONTAINER ID   IMAGE                COMMAND                  CREATED          STATUS          PORTS     NAMES
2f0f2777803e   9b7cc9982109         "/usr/local/bin/kube…"   15 minutes ago   Up 15 minutes             k8s_kube-proxy
_kube-proxy-knvbr_kube-system_a276e3e4-2f85-42aa-8a7a-5036629f4984_0
docker@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`:



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.

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:

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 $
```

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

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 $
```

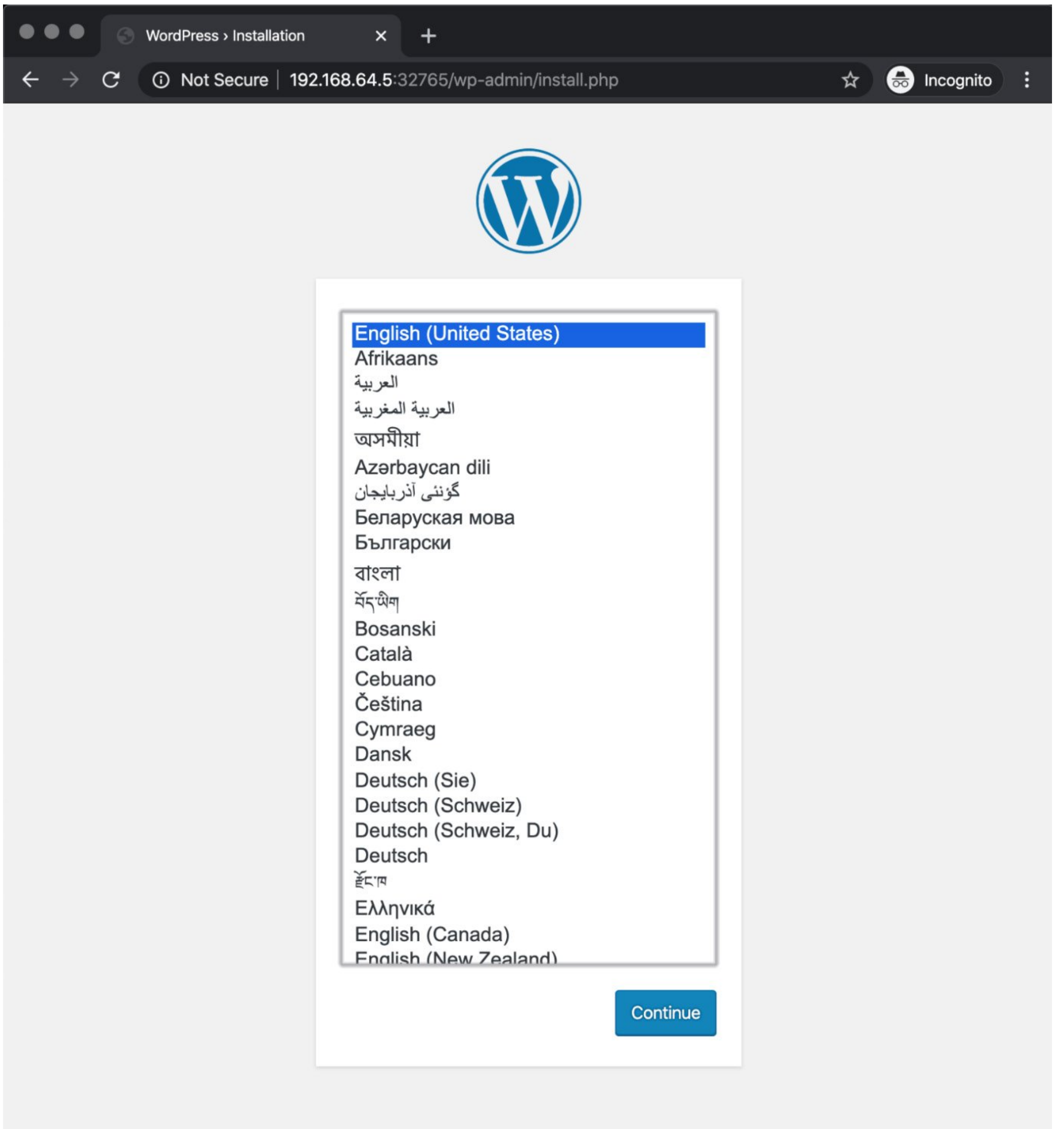
10. Get the URL of `wordpress-service` by running the following command:

```
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:



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.

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.