An Overview of Kubernetes

By the end of this chapter, you will have a single-node Minikube environment set up where you can run many of the exercises and activities in this book. You will be able to understand the high-level architecture of Kubernetes and identify the roles of the different components. You will also learn the basics required to migrate containerized applications to a Kubernetes environment.

Exercise 2.01: Getting Started with Minikube and Kubernetes Clusters

5. You can check the version of Minikube using the following command:

   ```
   minikube version
   ```

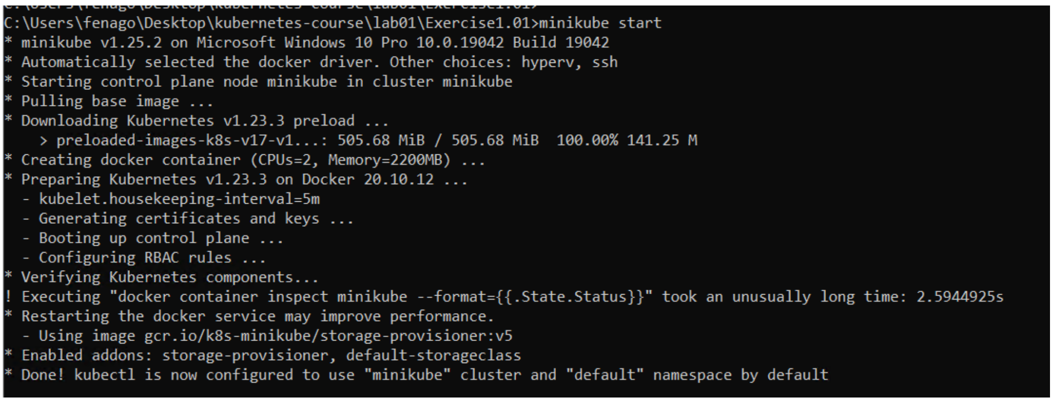
   You should see the following output:

   ```
   minikube version: v1.25.2
   commit: 362d5fdc0a3dbee389b3d3f1034e8023e72bd3a7
   ```

6. Now, we can create a Kubernetes cluster using `minikube start`:

   ```
   minikube start
   ```

   It will take a few minutes to download the VM images and get everything set up. After Minikube has started up successfully, you should see a response that looks similar to the following:



```
C:\Users\fenago\Desktop\kubernetes-course\lab01\Exercise1.01>minikube start
* minikube v1.25.2 on Microsoft Windows 10 Pro 10.0.19042 Build 19042
* Automatically selected the docker driver. Other choices: hyperv, ssh
* Starting control plane node minikube in cluster minikube
* Pulling base image ...
* Downloading Kubernetes v1.23.3 preload ...
    > preloaded-images-k8s-v17-v1...: 505.68 MiB / 505.68 MiB  100.00% 141.25 M
* Creating docker container (CPUs=2, Memory=2200MB) ...
* Preparing Kubernetes v1.23.3 on Docker 20.10.12 ...
  - kubelet.housekeeping-interval=5m
  - Generating certificates and keys ...
  - Booting up control plane ...
  - Configuring RBAC rules ...
* Verifying Kubernetes components...
! Executing "docker container inspect minikube --format={{.State.Status}}" took an unusually long time: 2.5944925s
* Restarting the docker service may improve performance.
  - Using image gcr.io/k8s-minikube/storage-provisioner:v5
* Enabled addons: storage-provisioner, default-storageclass
* Done! kubectl is now configured to use "minikube" cluster and "default" namespace by default
```

   The following commands should help establish that the Kubernetes cluster that was started by Minikube is running properly.

7. Use the following command to get the basic status of the various components of the cluster:

   ```
   minikube status
   ```

   You should see the following response:

   ```
   host: Running
   kubelet: Running
   apiserver: Running
   kubeconfig: Configured
   ```

8. Now, let's look at the version of the kubectl client and Kubernetes server:

```
kubectl version --short
```

You should see the following response:

```
Client Version: v1.22.5
Server Version: v1.23.3
```

9. Let's learn how many machines comprise the cluster and get some basic information about them:

```
kubectl get node
```

You should see a response similar to the following:

```
NAME          STATUS          ROLES          AGE          VERSION
minikube      Ready           master         2m41s        v1.23.3
```

After finishing this exercise, you should have Minikube set up with a single-node Kubernetes cluster. In the next section, we will enter the Minikube VM to take a look at how the cluster is composed and the various components of Kubernetes that make it work.

Kubernetes Components Overview

By completing the previous exercise, you have a single-node Kubernetes cluster up and running. Before playing your first concert, let's hold on a second and pull the curtains aside to take a look backstage to see how Kubernetes is architected behind the scenes, and then check how Minikube glues its various components together inside its VM.

Minikube provides a command called `minikube ssh` that's used to gain SSH access from the host machine (in our machine, it's the physical machine running Ubuntu 20.04) to the `minikube` virtual machine, which serves as the sole node in our Kubernetes cluster. Let's see how that works:

```
minikube ssh
```

Note: All the commands that will be shown later in this section are presumed to have been run inside the Minikube VM, after running `minikube ssh`.

To simplify the output and make it easier to read, we will pipe the output from `docker ps` into two other Bash commands:

1. `grep -v pause`: This will filter the results by not displaying the "sandbox" containers.

   Without `grep -v pause`, you would find that each container is "paired" with a "sandbox" container (in Kubernetes, it's implemented as a `pause` image). This is because, as mentioned in the previous chapter, Linux containers can be associated (or isolated) by joining the same (or different) Linux namespace. In Kubernetes, a "sandbox" container is used to bootstrap a Linux namespace, and then the containers that run the real application are able to join that namespace. Finer details about how all this works under the hood have been left out of scope for the sake of brevity.

2. `awk '{print $NF}'`: This will only print the last column with a container name.

   Thus, the final command is as follows:

```
docker ps | grep -v pause | awk '{print $NF}'
```

You should see the following output:

```
NAMES
k8s_coredns_coredns-5644d7b6d9-ptps6_kube-system_cd40b8e7-b86e-4451-b4d2-3b364b69574e_0
k8s_coredns_coredns-5644d7b6d9-5sz8f_kube-system_10985af6-c3bf-4eeb-9929-013dfdd20811_0
k8s_storage-provisioner_storage-provisioner_kube-system_c846ce4e-f65e-4f69-a855-f295ef722c
aa_0
k8s_kube-proxy_kube-proxy-dzn4n_kube-system_3d2eb82c-39f6-4162-90f2-b2a549a90792_0
k8s_kube-addon-manager_kube-addon-manager-minikube_kube-system_c3e29047da86ce6690916750ab6
9c40b_0
k8s_kube-apiserver_kube-apiserver-minikube_kube-system_ea167c1941ae64c8329acadaee8ceb69_0
k8s_etcd_etcd-minikube_kube-system_130dcd7636e79f6a2565de2a48e48a38_0
k8s_kube-controller-manager_kube-controller-manager-minikube_kube-system_67888a6f41348f1a4
1e319a7f77279a2_0
k8s_kube-scheduler_kube-scheduler-minikube_kube-system_74dea8da17aa6241e5e4f7b2ba4e1d8e_0
```

The highlighted containers shown in the preceding screenshot are basically the core components of Kubernetes. We'll discuss each of these in detail in the following sections.

Where Is the kubelet?

In Minikube, the kubelet is managed by systemd and runs as a native binary instead of a Docker container. We can run the following command to check its status:

```
systemctl status kubelet
```

You should see an output similar to the following:

```
• kubelet.service - kubelet: The Kubernetes Node Agent
   Loaded: loaded (/usr/lib/systemd/system/kubelet.service; disabled; vendor preset: enabl
ed)
  Drop-In: /etc/systemd/system/kubelet.service.d
           └─10-kubeadm.conf
   Active: active (running) since Wed 2019-11-27 01:04:43 UTC; 1 day 4h ago
     Docs: http://kubernetes.io/docs/
 Main PID: 3298 (kubelet)
    Tasks: 19 (limit: 2161)
   Memory: 39.3M
   CGroup: /system.slice/kubelet.service
           └─3298 /var/lib/minikube/binaries/v1.16.2/kubelet --authorization-mode=Webhook…
```

By default, the kubelet has the configuration for `staticPodPath` in its config file (which is stored at `/var/lib/kubelet/config.yaml`). kubelet is instructed to continuously watch the changes in files under that path, and each file under that path represents a Kubernetes component. Let's understand what this means by first finding `staticPodPath` in the kubelet's `config` file:

```
sudo grep "staticPodPath" /var/lib/kubelet/config.yaml
```

You should see the following output:

```
staticPodPath: /etc/kubernetes/manifests
```

Now, let's see the contents of this path:

```
ls /etc/kubernetes/manifests
```

You should see the following output:

```
addon-manager.yaml.tmpl kube-apiserver.yaml      kube-scheduler.yaml
etcd.yaml               kube-controller-manager.yaml
```

As shown in the list of files, the core components of Kubernetes are defined by objects that have a definition specified in YAML files. In the Minikube environment, in addition to managing the user-created pods, the kubelet also serves as a systemd equivalent in order to manage the life cycle of Kubernetes system-level components, such as the API server, the scheduler, the controller manager, and other add-ons. Once any of these YAML files is changed, the kubelet auto-detects that and updates the state of the cluster so that it matches the desired state defined in the updated YAML configuration.

Exercise 2.02: Running a Pod in Kubernetes

In the previous exercise, we started up Minikube and looked at the various Kubernetes components running as pods. Now, in this exercise, we shall deploy our pod. Follow these steps to complete this exercise:

Note

If you have been trying out the commands from the *Kubernetes Components Overview* section, don't forget to leave the SSH session by using the `exit` command before beginning this exercise. Unless otherwise specified, all commands using `kubectl` should run on the host machine and not inside the Minikube VM.

1. In Kubernetes, we use a spec file to describe an API object such as a pod. As mentioned earlier, we will stick to YAML as it is more human-readable and editable friendly. Create a file named `k8s-for-beginners-pod.yaml` (using any text editor of your choice) with the following content:

   ```
   kind: Pod
   apiVersion: v1
   metadata:
     name: k8s-for-beginners
   spec:
     containers:
     - name: k8s-for-beginners
       image: fenago/the-kubernetes-workshop:k8s-for-beginners
   ```

2. On the host machine, run the following command to create this pod:

   ```
   kubectl apply -f k8s-for-beginners-pod.yaml
   ```

   You should see the following output:

   ```
   pod/k8s-for-beginners created
   ```

3. Now, we can use the following command to check the pod's status:

   ```
   kubectl get pod
   ```

   You should see the following response:

   ```
   NAME                   READY     STATUS      RESTARTS       AGE
   k8s-for-beginners      1/1       Running     0              7s
   ```

4. You can use the following command to get more information about the pod:

```
kubectl get pod -o wide
```

You should see the following output:

```
NAME               READY   STATUS    RESTARTS   AGE   IP           NODE       NOMINATED NODE   READINESS GATES
k8s-for-beginners   1/1     Running   0          57s   172.17.0.4   minikube   <none>           <none>
```

```
As you can see, the output is still in the table format and we get
additional information such as `IP` (the internal pod IP)
and `NODE` (which node the pod is running on).
```

5. You can get the list of nodes in our cluster by running the following command:

```
kubectl get node
```

You should see the following response:

```
NAME          STATUS          ROLES          AGE          VERSION
minikube      Ready           master         30h          v1.23.3
```

6. The IP listed in above image refers to the internal IP Kubernetes assigned for this pod, and it's used for pod-to-pod communication, not for routing external traffic to pods. Hence, if you try to access this IP from outside the cluster, you will get nothing. You can try that using the following command from the host machine, which will fail:

```
curl 172.17.0.4:8080
```

Note

Remember to change `172.17.0.4` to the value you get for your environment in *step 4*.

The `curl` command will fail as shown here:

```
curl 172.17.0.4:8080
```

7. In most cases, end-users don't need to interact with the internal pod IP. However, just for observation purposes, let's SSH into the Minikube VM:

```
minikube ssh
```

You will see the following response in the terminal:

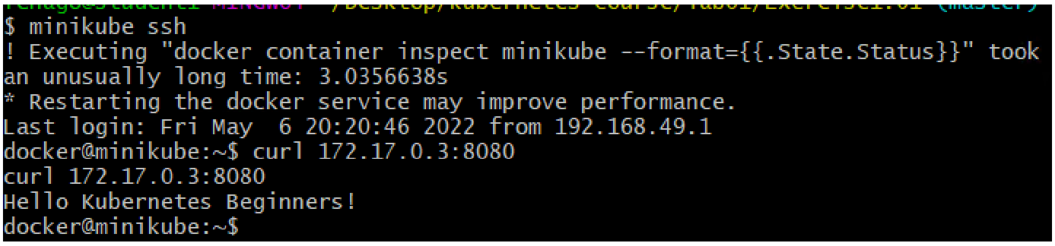
```
                         _             _
            _         _ ( )           ( )
  ___ ___  (_)  ___  (_)| |/')  _   _ | |_      __
/' _ ` _ `\| |/' _ `\| || , <  ( ) ( )| '_`\  /'__`\
| ( ) ( ) || || ( ) || || |\`\ | (_) || |_) )(  ___/
(_) (_) (_)(_)(_) (_)(_)(_) (_)`\___/'(_,__/'`\____)
```

8. Now, try calling the IP from inside the Minikube VM to verify that it works:

```
curl 172.17.0.4:8080
```

You should get a successful response:

```
Hello Kubernetes Beginners!
```



With this, we have successfully deployed our application in a pod on the Kubernetes cluster. We can confirm that it is working since we get a response when we call the application from inside the cluster. Now, you may end the Minikube SSH session using the `exit` command.

In the following exercise, we will define Service manifests and create them using `kubectl apply` commands. You will learn that the common pattern for resolving problems in Kubernetes is to find out the proper API objects, then compose the detailed specs using YAML manifests, and finally create the objects to bring them into effect.

Exercise 2.03: Accessing a Pod via a Service

In this exercise, we will create Services that will act as connectors to map the external requests to the destination pods so that we can access the pods externally without entering the cluster. Follow these steps to complete this exercise:

1. Firstly, let's tweak the pod spec from *Exercise 2.02*, *Running a Pod in Kubernetes*, to apply some labels. Modify the contents of the `k8s-for-beginners-pod1.yaml` file, as follows:

```
kind: Pod
apiVersion: v1
metadata:
  name: k8s-for-beginners
  labels:
    tier: frontend
spec:
  containers:
  - name: k8s-for-beginners
    image: fenago/the-kubernetes-workshop:k8s-for-beginners
```

Here, we added a label pair, `tier: frontend`, under the `labels` field.

2. Because the pod name remains the same, let's rerun the `apply` command so that Kubernetes knows that we're trying to update the pod's spec, instead of creating a new pod:

```
kubectl apply -f k8s-for-beginners-pod1.yaml
```

You should see the following response:

```
pod/k8s-for-beginners configured
```

Behind the scenes, for the `kubectl apply` command, kubectl generates the difference of the specified YAML and the stored version in the Kubernetes server-side storage (that is, etcd). If the request is valid (that is, we have not made any errors in the specification format or the command), kubectl will send an HTTP patch to the Kubernetes API server. Hence, only the delta changes will be applied. If you look at the message that's returned, you'll see it says `pod/k8s-for-beginners configured` instead of `created`, so we can be sure it's applying the delta changes and not creating a new pod.

3. You can use the following command to explicitly display the labels that have been applied to existing pods:

```
kubectl get pod --show-labels
```

You should see the following response:

```
NAME               READY  STATUS   RESTARTS   AGE  LABELS
k8s-for-beginners 1/1     Running  0          16m  tier=frontend
```

Now that the pod has the `tier: frontend` attribute, we're ready to create a Service and link it to the pods.

4. Create a file named `k8s-for-beginners-svc.yaml` with the following content:

```
kind: Service
apiVersion: v1
metadata:
  name: k8s-for-beginners
spec:
  selector:
    tier: frontend
  type: NodePort
  ports:
  - port: 80
    targetPort: 8080
```

5. Now, let's create the Service using the following command:

```
kubectl apply -f k8s-for-beginners-svc.yaml
```

You should see the following response:

```
service/k8s-for-beginners created
```

6. Use the `get` command to return the list of created Services and confirm whether our Service is online:

```
kubectl get service
```

You should see the following response:

```
NAME                TYPE        CLUSTER-IP      EXTERNAL-IP   PORT(S)        AGE
k8s-for-beginners   NodePort    10.109.16.179   <none>        80:32571/TCP   17s
kubernetes          ClusterIP   10.96.0.1       <none>        443/TCP        31h
```

So, you may have noticed that the `PORT(S)` column outputs `80:32571/TCP`. Port `32571` is an auto-generated port that's exposed on every node.

7. Let's ssh into Minikube to easily access the `k8s-for-beginners` Service:

```
minikube ssh
```

8. You can access application via the command line from `minikube` VM:

```
curl http://localhost:32571
```

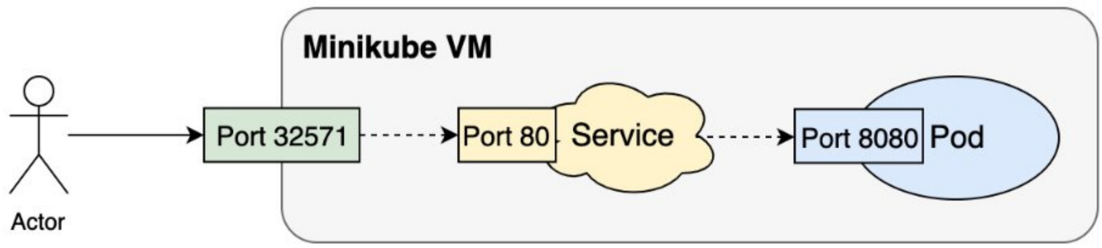
You should see the following response:

```
Hello Kubernetes Beginners!
```

As a summary, in this exercise, we created a `NodePort` Service to enable users to access the pod. Under the hood, there are several layers of traffic transitions that make this happen:

- The first layer is from the user to the machine IP at the auto-generated random port (3XXXX).
- The second layer is from the random port (3XXXX) to the Service IP (10.X.X.X) at port `80`.
- The third layer is from the Service IP (10.X.X.X) ultimately to the pod IP at port `8080`.

The following is a diagram illustrating these interactions:



Delivering Kubernetes-Native Applications

In the previous sections, we migrated a Docker-based application to Kubernetes and successfully accessed it from inside the Minikube VM, as well as externally. Now, let's see what other benefits Kubernetes can provide if we design our application from the ground up so that it can be deployed using Kubernetes.

Exercise 2.04: Scaling a Kubernetes Application

In Kubernetes, it's easy to increase the number of replicas running the application by updating the `replicas` field of a Deployment spec. In this exercise, we'll experiment with how to scale a Kubernetes application up and down. Follow these steps to complete this exercise:

1. Create a file named `k8s-for-beginners-deploy.yaml` using the content shown here:

```
apiVersion: apps/v1
kind: Deployment
```

```
metadata:
  name: k8s-for-beginners
spec:
  replicas: 3
  selector:
    matchLabels:
      tier: frontend
  template:
    metadata:
      labels:
        tier: frontend
    spec:
      containers:
      - name: k8s-for-beginners
        image: fenago/the-kubernetes-workshop:k8s-for-beginners
```

If you take a closer look, you'll see that this Deployment spec is largely based on the pod spec from earlier exercises (`k8s-for-beginners-pod1.yaml`), which you can see under the `template` field.

2. Next, we can use kubectl to create the Deployment:

```
kubectl apply -f k8s-for-beginners-deploy.yaml
```

You should see the following output:

```
deployment.apps/k8s-for-beginners created
```

3. Given that the Deployment has been created successfully, we can use the following command to show all the Deployment's statuses, such as their names, running pods, and so on:

```
kubectl get deploy
```

You should get the following response:

```
NAME                    READY   UP-TO-DATE   AVAILABLE    AGE
k8s-for-beginners       3/3     3            3            41s
```

You can view the short names by running `kubectl api-resources`, without specifying the resource type.

4. A pod called `k8s-for-beginners` exists that we created in the previous exercise. To ensure that we see only the pods being managed by the Deployment, let's delete the older pod:

```
kubectl delete pod k8s-for-beginners
```

You should see the following response:

```
pod "k8s-for-beginners" deleted
```

5. Now, get a list of all the pods:

```
kubectl get pod
```

You should see the following response:

```
NAME                                 READY   STATUS    RESTARTS   AGE
k8s-for-beginners-66644bb776-7j9mw   1/1     Running   0          106s
k8s-for-beginners-66644bb776-dzf9j   1/1     Running   0          106s
k8s-for-beginners-66644bb776-fg8s5   1/1     Running   0          106s
```

```
The Deployment has created three pods, and their labels (specified
in the `labels` field in *step 1*) happen to match the
Service we created in the previous section. So, what will happen if
we try to access the Service? Will the network traffic going to the
Service be smartly routed to the new three pods? Let\'s test this
out.
```

6. To see how the traffic is distributed to the three pods, we can simulate a number of consecutive requests to the Service endpoint by running the `curl` command inside a Bash `for` loop, as follows:

   ```
   minikube ssh

   for i in $(seq 1 30); do curl localhost:30217; done

   exit
   ```

   Note

   In this command, use the same IP and port that you used in the previous exercise if you are running the same instance of Minikube. If you have restarted Minikube or have made any other changes, please get the proper IP of your Minikube cluster by following *step 9* of the previous exercise.

   Once you've run the command with the proper IP and port, you should see the following output:

   ```
   Hello Kubernetes Beginners!
   Hello Kubernetes Beginners!
   Hello Kubernetes Beginners!
   Hello Kubernetes Beginners!
   Hello Kubernetes Beginners!
   Hello Kubernetes Beginners!
   Hello Kubernetes Beginners!
   Hello Kubernetes Beginners!
   Hello Kubernetes Beginners!
   Hello Kubernetes Beginners!
   Hello Kubernetes Beginners!
   Hello Kubernetes Beginners!
   Hello Kubernetes Beginners!
   Hello Kubernetes Beginners!
   Hello Kubernetes Beginners!
   ```

```
From the output, we can tell that all 30 requests get the expected
response.
```

7. You can run `kubectl logs <pod name>` to check the log of each pod. Let's go one step further and figure out the exact number of requests each pod has responded to, which might help us find out whether the traffic was evenly distributed. To do that, we can pipe the logs of each pod into the `wc` command to get the number of lines:

```
kubectl logs <pod name> | wc -l
```

Note: Above command should be run in `git bash` only. It will not work in cmd/powershell.

Run the preceding command three times, copying the pod name you obtained, as shown below:

```
k8suser@ubuntu:~$ kubectl logs k8s-for-beginners-66644bb776-7j9mw | wc -l
9
k8suser@ubuntu:~$ kubectl logs k8s-for-beginners-66644bb776-dzf9j | wc -l
10
k8suser@ubuntu:~$ kubectl logs k8s-for-beginners-66644bb776-fg8s5 | wc -l
11
```

```
The result shows that the three pods handled `9`,
`10`, and `11` requests, respectively. Due to
the small sample size, the distribution is not absolutely even (that
is, `10` for each), but it is sufficient to indicate the
default round-robin distribution strategy used by a Service.
```

8. Next, let's learn how to scale up a Deployment. There are two ways of accomplishing this: one way is to modify the Deployment's YAML config, where we can set the value of `replicas` to another number (such as `5`), while the other way is to use the `kubectl scale` command, as follows:

```
kubectl scale deploy k8s-for-beginners --replicas=5
```

You should see the following response:

```
deployment.apps/k8s-for-beginners scaled
```

9. Let's verify whether there are five pods running:

```
kubectl get pod
```

You should see a response similar to the following:

```
NAME                                 READY   STATUS    RESTARTS   AGE
k8s-for-beginners-66644bb776-7j9mw   1/1     Running   0          16m
k8s-for-beginners-66644bb776-cdlgh   1/1     Running   0          69s
k8s-for-beginners-66644bb776-dzf9j   1/1     Running   0          16m
k8s-for-beginners-66644bb776-fg8s5   1/1     Running   0          16m
k8s-for-beginners-66644bb776-jhb5x   1/1     Running   0          69s
```

```
The output shows that the existing three pods are kept and that two
new pods are created.
```

10. Similarly, you can specify replicas that are smaller than the current number. In our example, let's say that we want to shrink the replica's number to `2`. The command for this would look as follows:

    ```
    kubectl scale deploy k8s-for-beginners --replicas=2
    ```

    You should see the following response:

    ```
    deployment.apps/k8s-for-beginners scaled
    ```

11. Now, let's verify the number of pods:

    ```
    kubectl get pod
    ```

    You should see a response similar to the following:

    ```
    NAME                                 READY   STATUS    RESTARTS   AGE
    k8s-for-beginners-66644bb776-7j9mw   1/1     Running   0          18m
    k8s-for-beginners-66644bb776-dzf9j   1/1     Running   0          18m
    ```

12. We can run the following command to verify this:

    ```
    kubectl get deploy
    ```

    You should see the following response:

    ```
    NAME                 READY    UP-TO-DATE    AVAILABLE    AGE
    k8s-for-beginners    2/2      2             2            19m
    ```

13. Now, let's see what happens if we delete one of the two pods:

    ```
    kubectl delete pod <pod name>
    ```

    You should get the following response:

    ```
    pod "k8s-for-beginners-66644bb776-7j9mw" deleted
    ```

14. Check the status of the pods to see what has happened:

    ```
    kubectl get pod
    ```

    You should see the following response:

    ```
    NAME                                 READY   STATUS    RESTARTS   AGE
    k8s-for-beginners-66644bb776-dzf9j   1/1     Running   0          20m
    k8s-for-beginners-66644bb776-pwsjn   1/1     Running   0          22s
    ```

We can see that there are still two pods. The Deployment created a new pod so that the number of running pods satisfies the desired state of the Deployment.

In this exercise, we have learned how to scale a deployment up and down. You can scale other similar Kubernetes objects, such as DaemonSets and StatefulSets, in the same way. Also, for such objects, Kubernetes will try to auto-recover the failed pods.

Exercise 2.05: How Kubernetes Manages a Pod's Life Cycle

As a Kubernetes cluster comprises multiple components, and each component works simultaneously, it's usually difficult to know what's exactly happening in each phase of a pod's life cycle. To solve this problem, we will use a film editing technique to "play the whole life cycle in slow motion", so as to observe each phase. We will turn off the master plane components and then attempt to create a pod. Then, we will respond to the errors that we see, and slowly bring each component online, one by one. This will allow us to slow down and examine each stage of the process of pod creation step-by-step. Follow these steps to complete this exercise:

1. First, let's delete the Deployment and Service we created earlier by using the following command:

   ```
   kubectl delete deploy k8s-for-beginners && kubectl delete service k8s-for-
   beginners
   ```

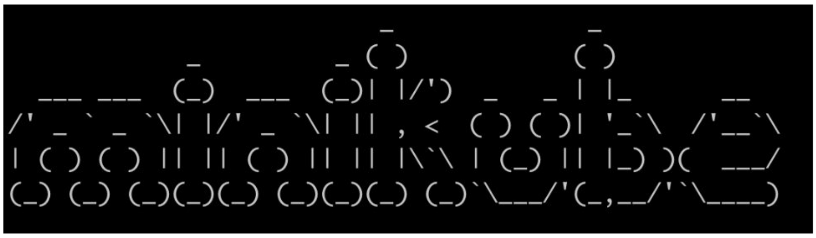
   You should see the following response:

   ```
   deployment.apps "k8s-for-beginners" deleted
   service "k8s-for-beginners" deleted
   ```

2. Prepare two terminal sessions: one (host terminal) to run commands on your host machine and another (Minikube terminal) to pass commands inside the Minikube VM via SSH. Thus, your Minikube session will be initiated like this:

   ```
   minikube ssh
   ```

   You will see the following output:



```
**Note**

All `kubectl` commands are expected to be run in the host
terminal session, while all `docker` commands are to be
run in the Minikube terminal session.
```

3. In the Minikube session, clean up all stopped Docker containers:

   ```
   docker rm $(docker ps -a -q)
   ```

   You should see the following output:

```
4e4d85467928
3f450986aa45
ce9fadaaae1c
Error response from daemon: You cannot remove a running container 75439759292b1ccabd
64321d50961eab65fe2dc0a7a8a65631d583aad6ee4627. Stop the container before attempting
 removal or force remove
Error response from daemon: You cannot remove a running container e6a70641b409ffa75c
a2ecd978acd5c000c760d7d2b847f8584c89518cd32bd0. Stop the container before attempting
 removal or force remove
```

```
You may see some error messages such as \"You cannot remove a
running container \...\". This is because the preceding
`docker rm` command runs against all containers
(`docker ps -a -q`), but it won\'t stop any running
containers.
```

4. In the Minikube session, stop the kubelet by running the following command:

   ```
   sudo systemctl stop kubelet
   ```

   This command does not show any response upon successful execution.

   Note

   Later in this exercise, we will manually stop and start other Kubernetes components, such as the API server, that are managed by the kubelet in a Minikube environment. Hence, it's required that you stop the kubelet first in this exercise; otherwise, the kubelet will automatically restart its managed components.

5. After 30 seconds, check the cluster's status by running the following command in your host terminal session:

   ```
   kubectl get node
   ```

   You should see the following response:

   ```
   NAME        STATUS      ROLES     AGE     VERSION
   minikube    NotReady    master    32h     v1.23.3
   ```

   It's expected that the status of the `minikube` node is changed to `NotReady` because the kubelet has been stopped.

6. In your Minikube session, stop `kube-scheduler`, `kube-controller-manager`, and `kube-apiserver`. As we saw earlier, all of these are running as Docker containers. Hence, you can use the following commands, one after the other:

   ```
   docker stop $(docker ps | grep kube-scheduler | grep -v pause | awk '{print
   $1}')
   docker stop $(docker ps | grep kube-controller-manager | grep -v pause | awk
   '{print $1}')
   docker stop $(docker ps | grep kube-apiserver | grep -v pause | awk '{print
   $1}')
   ```

   You should see the following responses:

```
$ docker stop $(docker ps | grep kube-scheduler | grep -v pause | awk '{print $1}')
11d8a27e3ee0
$ docker stop $(docker ps | grep kube-controller-manager | grep -v pause | awk '{print $1}
')
35facb013c8f
$ docker stop $(docker ps | grep kube-apiserver | grep -v pause | awk '{print $1}')
9e1cf098b67c
```

Now, the three major Kubernetes components have been stopped.

7. Now, you need to create a Deployment spec on your host machine. Create a file named `k8s-for-beginners-deploy2.yaml` with the following content:

```
apiVersion: apps/v1
kind: Deployment
metadata:
  name: k8s-for-beginners
spec:
  replicas: 1
  selector:
    matchLabels:
      tier: frontend
  template:
    metadata:
      labels:
        tier: frontend
    spec:
      containers:
      - name: k8s-for-beginners
        image: fenago/the-kubernetes-workshop:k8s-for-beginners
```

8. Try to create the Deployment by running the following command on your host session:

```
kubectl apply -f k8s-for-beginners-deploy2.yaml
```

You should see a response similar to this:

```
error: unable to recognize "k8s-for-beginners-deploy2.yaml": Get https://192.168.99.100:84
43/api?timeout=32s: dial tcp 192.168.99.100:8443: connect: connection refused
```

```
Since we intentionally stopped the Kubernetes API server. If the API server
is down, you cannot run any `kubectl` commands or use any
equivalent tools (such as Kubernetes Dashboard) that rely on API
requests:


```
The connection to the server 192.168.99.100:8443 was refused - did you specify the
right host or port?
```
```

9. Let's see what happens if we restart the API server and try to create the Deployment once more. Restart the API server container by running the following command in your Minikube session:

```
docker start $(docker ps -a | grep kube-apiserver | grep -v pause | awk '{print
$1}')
```

This command tries to find the container ID of the stopped container carrying the API server, and then it starts it. You should get a response like this:

```
9e1cf098b67c
```

10. Wait for 10 seconds. Then, check whether the API server is online. You can run any simple kubectl command for this. Let's try getting the list of nodes by running the following command in the host session:

```
kubectl get node
```

You should see the following response:

```
NAME        STATUS      ROLES     AGE      VERSION
minikube    NotReady    master    32h      v1.23.3
```

As you can see, we are able to get a response without errors.

11. Let's try to create the Deployment again:

```
kubectl apply -f k8s-for-beginners-deploy2.yaml
```

You should see the following response:

```
deployment.apps/k8s-for-beginners created
```

12. Let's check whether the Deployment has been created successfully by running the following command:

```
kubectl get deploy
```

You should see the following response:

```
NAME                READY     UP-TO-DATE    AVAILABLE   AGE
k8s-for-beginners   0/1       0             0           113s
```

From the preceding screenshot, there seems to be something wrong as in the `READY` column, we can see `0/1`, which indicates that there are 0 pods associated with this Deployment, while the desired number is 1 (which we specified in the `replicas` field in the Deployment spec).

13. Let's check that all the pods that are online:

```
kubectl get pod
```

You should get a response similar to the following:

```
No resources found in default namespace.
```

We can see that our pod has not been created. This is because the Kubernetes API server only creates the API objects; the implementation of any API object is carried out by other components. For example, in the case of Deployment, it's `kube-controller-manager` that creates the corresponding pod(s).

14. Now, let's restart the `kube-controller-manager`. Run the following command in your Minikube session:

    ```
    docker start $(docker ps -a | grep kube-controller-manager | grep -v pause |
    awk '{print $1}')
    ```

    You should see a response similar to the following:

    ```
    35facb013c8f
    ```

15. After waiting for a few seconds, check the status of the Deployment by running the following command in the host session:

    ```
    kubectl get deploy
    ```

    You should see the following response:

    ```
    NAME               READY     UP-TO-DATE     AVAILABLE     AGE
    k8s-for-beginners  0/1       1              0             5m24s
    ```

    As we can see, the pod that we are looking for is still not online.

16. Now, check the status of the pod:

    ```
    kubectl get pod
    ```

    You should see the following response:

    ```
    NAME                                READY   STATUS    RESTARTS   AGE
    k8s-for-beginners-66644bb776-kvwfr  0/1     Pending   0          51s
    ```

```
The output is different from the one in *step 15*, as in this case,
one pod was created by `kube-controller-manager`. However,
we can see `Pending` under the `STATUS` column.
This is because assigning a pod to a suitable node is not the
responsibility of `kube-controller-manager`; it\'s the
responsibility of `kube-scheduler`.
```

17. Before starting `kube-scheduler`, let's take a look at some additional information about the pod:

    ```
    kubectl get pod -o wide
    ```

    You should see the following response:

    ```
    NAME                                READY   STATUS    RESTARTS   AGE    IP       NODE
     NOMINATED NODE   READINESS GATES
    k8s-for-beginners-66644bb776-kvwfr  0/1     Pending   0          104s   <none>   <none>
     <none>           <none>
    ```

18. Let's restart `kube-scheduler` by running the following command in the Minikube session:

```
docker start $(docker ps -a | grep kube-scheduler | grep -v pause | awk '{print
$1}')
```

You should see a response similar to the following:

```
11d8a27e3ee0
```

19. We can verify that `kube-scheduler` is working by running the following command in the host session:

```
kubectl describe pod k8s-for-beginners-UPDATE_ID_HERE
```

Please get the pod name from the response you get at *step 17*, as seen above. You should see the following output:

```
Name:           k8s-for-beginners-66644bb776-kvwfr
Namespace:      default
Priority:       0
Node:           <none>
```

We are truncating the output screenshots for a better presentation. Please take a look at the following excerpt, highlighting the `Events` section:

```
Events:
  Type     Reason            Age        From               Message
  ----     ------            ----       ----               -------
  Warning  FailedScheduling  <unknown>  default-scheduler  0/1 nodes are available: 1 node
(s) had taints that the pod didn't tolerate.
```

```
`kube-scheduler` has tried scheduling, but it reports that
there is no node available. Why is that?

This is because, earlier, we stopped the kubelet, and the Minikube
environment is a single-node cluster, so there is no available
node(s) with a functioning kubelet for the pod to be placed.
```

20. Let's restart the kubelet by running the following command in the Minikube session:

```
sudo systemctl start kubelet
```

This should not give any response in the terminal upon successful execution.

21. In the host terminal, verify the status of the Deployment by running the following command in the host session:

```
kubectl get deploy
```

You should see the following response:

```
NAME                READY     UP-TO-DATE    AVAILABLE   AGE
k8s-for-beginners   1/1       1             1           11m
```

Now, everything looks healthy as the Deployment shows `1/1` under the `READY` column, which means that the pod is online.

22. Similarly, verify the status of the pod:

    ```
    kubectl get pod -o wide
    ```

    You should get an output similar to the following:

    ```
    NAME                                  READY   STATUS    RESTARTS   AGE     IP           NOD
    E        NOMINATED NODE   READINESS GATES
    k8s-for-beginners-66644bb776-kvwfr   1/1     Running   0          6m48s   172.17.0.4   min
    ikube    <none>           <none>
    ```

We can see `Running` under `STATUS` and that it's been assigned to the `minikube` node.

In the following activity, we will bring together the skills we learned in the chapter to find out how we can migrate from a container-based environment to a Kubernetes environment in order to run our application.

Activity 2.01: Running the Pageview App in Kubernetes

In *Activity 1.01*, *Creating a Simple Page Count Application*, in the previous chapter, we built a web application called Pageview and connected it to a Redis backend datastore. So, here is a question: without making any changes to the source code, can we migrate the Docker-based application to Kubernetes and enjoy Kubernetes' benefits immediately? Try it out in this activity with the guidelines given.

This activity is divided into two parts: in the first part, we will create a simple pod with our application that is exposed to traffic outside the cluster by a Service and connected to a Redis datastore running as another pod. In the second part, we will scale the application to three replicas.

Connecting the Pageview App to a Redis Datastore Using a Service

Similar to the `--link` option in Docker, Kubernetes provides a Service that serves as an abstraction layer to expose one application (let's say, a series of pods tagged with the same set of labels) that can be accessed internally or externally. For example, as we discussed in this chapter, a frontend app can be exposed via a `NodePort` Service so that it can be accessed by external users. In addition to that, in this activity, we need to define an internal Service in order to expose the backend application to the frontend application. Follow these steps:

1. In *Activity 1.01*, *Creating a Simple Page Count Application*, we built two Docker images -- one for the frontend Pageview web app and another for the backend Redis datastore. You can use the skills we learned in this chapter to migrate them into Kubernetes YAMLs.
2. Two pods (each managed by a Deployment) for the application is not enough. We also have to create the Service YAML to link them together.

   Ensure that the `targetPort` field in the manifest is consistent with the exposed port that was defined in the Redis image, which was `6379` in this case. In terms of the `port` field, theoretically, it can be any port, as long as it's consistent with the one specified in the Pageview application.

   The other thing worth mentioning here is the `name` field of the pod for Redis datastore. It's the symbol that's used in the source code of the Pageview app to reference the Redis datastore.

   Now, you should have three YAMLs -- two pods and a Service. Apply them using `kubectl -f <yaml file name>`, and then use `kubectl get deploy,service` to ensure that they're created successfully.

3. At this stage, the Pageview app should function well since it's connected to the Redis app via the Service. However, the Service only works as the internal connector to ensure they can talk to each other inside the cluster.

   To access the Pageview app externally, we need to define a `NodePort` Service. Unlike the internal Service, we need to explicitly specify the `type` as `NodePort`.

4. Apply the external Service YAML using `kubectl -f <yaml file name>`.

5. Run `minikube service <external service name>` to fetch the Service URL.

6. Access the URL multiple times to ensure that the Pageview number gets increased by one each time.

With that, we have successfully run the Pageview application in Kubernetes. But what if the Pageview app is down? Although Kubernetes can create a replacement pod automatically, there is still downtime between when the failure is detected and when the new pod is ready.

A common solution is to increase the replica number of the application so that the whole application is available as long as there is at least one replica running.

Running the Pageview App in Multiple Replicas

The Pageview app can certainly work with a single replica. However, in a production environment, high availability is essential and is achieved by maintaining multiple replicas across nodes to avoid single points of failure. (This will be covered in detail in upcoming chapters.)

In Kubernetes, to ensure the high availability of an application, we can simply increase the replica number. Follow these steps to do so:

1. Modify the Pageview YAML to change `replicas` to `3`.

2. Apply these changes by running `kubectl apply -f <pageview app yaml>`.

3. By running `kubectl get pod`, you should be able to see three Pageview pods running.

4. Access the URL shown in the output of the `minikube service` command multiple times.

   Check the logs of each pod to see whether the requests are handled evenly among the three pods.

5. Now, let's verify the high availability of the Pageview app. Terminate any arbitrary pods continuously while keeping one healthy pod. You can achieve this manually or automatically by writing a script. Alternatively, you can open another terminal and check whether the Pageview app is always accessible.

If you opt for writing scripts to terminate the pods, you will see results similar to the following:

```
Keeping Pod k8s-pageview-74bb5d4dfd-2c8qz running
Killing Pod k8s-pageview-74bb5d4dfd-2xklc
pod "k8s-pageview-74bb5d4dfd-2xklc" deleted
Killing Pod k8s-pageview-74bb5d4dfd-f2r9g
pod "k8s-pageview-74bb5d4dfd-f2r9g" deleted
Keeping Pod k8s-pageview-74bb5d4dfd-2c8qz running
Killing Pod k8s-pageview-74bb5d4dfd-qnmf2
pod "k8s-pageview-74bb5d4dfd-qnmf2" deleted
Killing Pod k8s-pageview-74bb5d4dfd-vjqht
pod "k8s-pageview-74bb5d4dfd-vjqht" deleted
Keeping Pod k8s-pageview-74bb5d4dfd-2c8qz running
Killing Pod k8s-pageview-74bb5d4dfd-c86dh
pod "k8s-pageview-74bb5d4dfd-c86dh" deleted
Killing Pod k8s-pageview-74bb5d4dfd-zl7bq
pod "k8s-pageview-74bb5d4dfd-zl7bq" deleted
Keeping Pod k8s-pageview-74bb5d4dfd-2c8qz running
Killing Pod k8s-pageview-74bb5d4dfd-pr9gh
pod "k8s-pageview-74bb5d4dfd-pr9gh" deleted
Killing Pod k8s-pageview-74bb5d4dfd-twd4z
pod "k8s-pageview-74bb5d4dfd-twd4z" deleted
Keeping Pod k8s-pageview-74bb5d4dfd-2c8qz running
Killing Pod k8s-pageview-74bb5d4dfd-mrbgt
pod "k8s-pageview-74bb5d4dfd-mrbgt" deleted
Killing Pod k8s-pageview-74bb5d4dfd-rpgzz
pod "k8s-pageview-74bb5d4dfd-rpgzz" deleted
```

Assuming that you take a similar approach and write a script to check whether the application is online, you should see an output similar to the following:

```
Hello, you're the visitor #29.
Hello, you're the visitor #30.
Hello, you're the visitor #31.
Hello, you're the visitor #32.
Hello, you're the visitor #33.
Hello, you're the visitor #34.
Hello, you're the visitor #35.
Hello, you're the visitor #36.
Hello, you're the visitor #37.
Hello, you're the visitor #38.
Hello, you're the visitor #39.
Hello, you're the visitor #40.
Hello, you're the visitor #41.
Hello, you're the visitor #42.
Hello, you're the visitor #43.
Hello, you're the visitor #44.
Hello, you're the visitor #45.
Hello, you're the visitor #46.
Hello, you're the visitor #47.
Hello, you're the visitor #48.
```

Note

The solution to this activity can be found at the following address:
`Activity_Solutions\Solution_Final.pdf`.

Summary

In this chapter, we used Minikube to provision a single-node Kubernetes cluster and gave a high-level overview of Kubernetes' core components, as well as its key design rationale. After that, we migrated an existing Docker container to Kubernetes and explored some basic Kubernetes API objects, such as pods, Services, and Deployments. Lastly, we intentionally broke a Kubernetes cluster and restored it one component at a time, which allowed us to understand how the different Kubernetes components work together to get a pod up and running on a node.

Throughout this chapter, we have used kubectl to manage our cluster. We provided a quick introduction to this tool, but in the following chapter, we will take a closer look at this powerful tool and explore the various ways in which we can use it.