Running Stateful Components in Kubernetes

Overview

In this lab, we will expand our skills to go beyond stateless applications and learn how to deal with stateful applications. We will learn about the various forms of state preservation mechanisms available to Kubernetes cluster operators and derive a mental model for where certain options can be invoked to run applications well. We will also introduce Helm, a useful tool for deploying complex applications with various Kubernetes objects.

By the end of this lab, you will be able to use StatefulSets and PersistentVolumes in conjunction to run apps that require disk-based state to be retained in between pod interruptions. You will also be able to deploy applications using Helm charts.

Introduction

From everything that you have learned up until this point, you know that pods and the containers that run in them are considered ephemeral. This means that they are not to be depended upon for stability as Kubernetes will intervene and move them around the cluster in order to comply with the desired state specified by the various manifests in the cluster. But there's a problem in this -- what do we do with the parts of our applications that depend on the state being persisted from one interaction to the next? Without certain guarantees such as predictable naming for the pods and dependable storage operations, which we will learn about later in the lab, such stateful components may fail if Kubernetes restarts the relevant pods or moves them around. However, before diving into the details of the aforementioned topics, let's talk briefly about stateful apps and why it's challenging to run them in a containerized environment.

Stateful Apps

We briefly introduced the concept of statefulness in *Lab 12*, *Your Application and HA*. Stateful components of applications are a necessity to just about all information technology systems in the world. They're necessary to keep account details, records of transactions, information on HTTP requests, and a whole host of other purposes. The challenging part of running these applications in a production environment almost always has to do with either the network or the persistence mechanism. Whether it's spinning metal disks, flash storage, block storage, or some other yet-to-be-invented tool, persistence is notoriously difficult to deal with in all forms. Part of why this is difficult is because all of these forms have a non-zero probability of failure, which can become very significant once you need to have hundreds or even thousands of storage devices in a production environment. These days, many cloud providers will give assistance to customers and offer managed services to account for this difficulty. In the case of AWS, we have tools such as S3, EBS, RDS, DynamoDB, Elasticache, and many others that help developers and operators run stateful applications smoothly without much heavy lifting (provided you are OK with vendor lock-in.)

Another trade-off that some companies face with running stateful applications and the persistence mechanisms they depend on is between either training and maintaining a large body of staff capable of keeping these systems of record online, healthy, and up to date, or attempting to develop a set of tools and programmatically enforced processes for common operational scenarios. These two approaches differ in the amount of human maintenance effort needed as the organization scales.

For example, a human-centric approach to operations will allow things to move swiftly at first, but all operational costs scale linearly with the application scale, and eventually, the bureaucracy causes diminishing productivity returns with each new hire. Software-centric approaches are a higher upfront investment, but costs scale logarithmically with application scale and have a higher probability of cascading failures in the event of an unexpected bug.

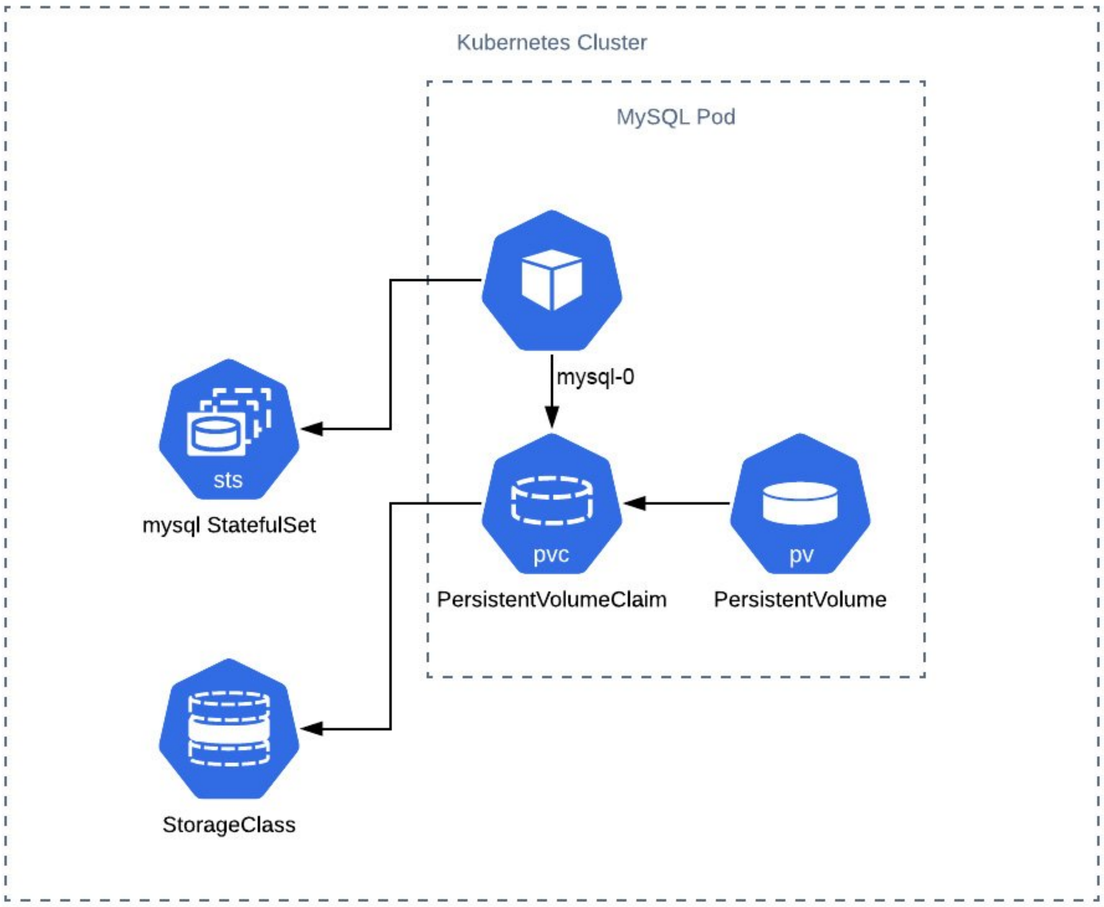
Some examples of these operational scenarios are provisioning and configuration, normal operations, scaling input/output, backups, and abnormal operations. Examples of abnormal operations include network failures, hard drive failures, corruption of data on disk, security breaches, and application-specific irregularities. Examples of application-specific irregularities could be handling MySQL-specific collation concerns, handling S3 eventually consistent read failures, etcd Raft protocol resolution errors, and so on.

Many companies find it easier to pay for vendor support, use cloud-managed product offerings, or re-train their staff rather than developing programmatic state management processes and software.

One of the benefits of a Kubernetes-enabled development life cycle is on the workload definition side. The more effort a company puts into rigorously defining the smallest logical unit of compute (a pod template or PersistentVolume definition), the better they will be prepared for Kubernetes to intervene in irregular operations and appropriately orchestrate the entire application. This is largely because Kubernetes orchestration is a classical dynamic **constraint satisfaction problem** (**CSP**). The more information in the form of constraints the CSP solver has to work with at its disposal, the more predictable workload orchestration will become because the number of feasible steady-state solutions is reduced. So, using the end goal of predictable workload orchestration, is it then possible to run state-bearing components of our application in Kubernetes? The answer is an unequivocal yes. It is common to be hesitant to run stateful workloads in Kubernetes. We've said from the beginning of this course that pods are ephemeral and should not be depended on for stability because, in the event of a node failure, they will be moved and restarted. So, before you decide that it's too risky to run a database in Kubernetes, consider this -- the world's largest search engine company runs databases in a very similar tool to Kubernetes. This tells us that it's not only possible but in reality, it's preferable to work on defining workloads well enough that they can be run by an orchestrator because it can likely handle application failures much faster than a human.

So, how do we accomplish this? The answer to that question is the use of a combination of two Kubernetes objects that you have learned about earlier -- **PersistentVolumes** and **StatefulSets**. These are introduced in *labs 7* and *9*, so we won't belabor their usage here except to say that we're going to be bringing together all of the introductory topics into an example relevant to *our application*.

The key to effective stateful workload orchestration is modularization and abstraction. These are fundamental software concepts that are taught to engineers so they can design well-architected software systems, and the same holds for well-architected infrastructure systems. Let's consider the following diagram as an example of modularization when it comes to running a database in Kubernetes:



As you can see in the preceding diagram, and as you have learned up until now in this course, Kubernetes is made up of modular components. Thus, by leveraging the StatefulSet resource, we can compose the usage of PersistentVolumes, PersistentVolumeClaims, StorageClasses, pods, and some special rules around their life cycles that make much stronger guarantees about the condition that the persistence layers of our app are in.

Understanding StatefulSets

In *Figure 14.1*, we can see that a StatefulSet is invoked to be able to manage pod life cycles. A StatefulSet (in older versions of Kubernetes, this was called a PetSet) operates very similarly to a Deployment in that we provide a pod template of what we want to run and how many instances of it we want to run. What differs between a StatefulSet and a Deployment is the following:

- **A clear naming scheme that can be depended upon by pods in DNS queries**:

  This means that in the preceding diagram when we name a StatefulSet `mysql`, the first pod in that StatefulSet will always be `mysql-0`. This is unlike a traditional deployment where pod IDs are assigned randomly. It also means that if you had a pod named `mysql-2` and it crashed, it would be resurrected on the cluster using exactly the same name.

- **A clearly ordered way in which updates must proceed**:

  Depending on the update strategy in this StatefulSet, each pod will be taken down in a very specific order. So, if you have a well-known upgrade path (such as in the case of minor software revisions in MySQL), you should be able to leverage one of the Kubernetes-provided software update strategies.

- **Dependable storage operations**:

  Since storage is the most critical part of a stateful solution, having deterministic actions taken by a StatefulSet is imperative. By default, any PersistentVolume provisioned for a StatefulSet will be retained, even if that StatefulSet has been deleted. While this behavior is meant to prevent accidental deletion of data, it can lead to significant charges from your cloud provider during testing, so you should monitor this closely.

- **A serviceName field that must be defined in the StatefulSet**:

  This `serviceName` field must refer to something called a "headless" service that points to this group of pods. This exists to allow the pods to be individually addressable using the common Kubernetes DNS syntax. So for example, if my StatefulSet is running in the default namespace and has the name `zachstatefulset`, then the first pod will have the DNS entry `zachstatefulset-0.default.svc.cluster.local`. The same DNS entry will be used by any replacement pod if this one fails.

  More on headless services can be found at this link: https://kubernetes.io/docs/concepts/services-networking/service/#headless-services.

Deployments versus StatefulSets

Now that you've been introduced to StatefulSets at a slightly more granular level, on what basis should you choose between a StatefulSet and a Deployment that uses a PersistentVolumeClaim? The answer to that depends on what you're looking to orchestrate.

In theory, you could achieve similar behavior using both types of Kubernetes object. Both create pods, both have update strategies, and both can use PVCs to create and manage PersistentVolume objects. The reason StatefulSets were designed was to give the guarantees laid out in the preceding bullet points. Typically, you would want these guarantees when orchestrating databases, file servers, and other forms of sensitive persistence-dependent applications.

As we understand how StatefulSets are useful to predictably run the stateful components of our applications, let's look at a specific example that's relevant to us. As you'll recall from previous labs, we have a little counter app that we are refactoring to leverage as many cloud-native principles as possible as we go along. In this lab, we will be replacing the state persistence mechanism and testing out a new engine.

Further Refactoring Our Application

We'd like to now take our application a little further into cloud-native principles. Let's consider that the product manager for our counter app said that we're getting insane amounts of load (and you can confirm this through your observability toolset), and some people are not always getting a strictly increasing number; sometimes, they are getting duplicates of the same number. So, you confer with your colleagues and come to the conclusion that in order to guarantee the increasing number, you will need guarantees around how data is accessed and persisted in your app.

Specifically, you need a guarantee that operations against this datastore are atomically unique, consistent between operations, isolated from other operations, and durable against failure. That is, you are looking for an ACID-compliant database.

Note

More on what ACID compliance is can be found at this link: https://database.guide/what-is-acid-in-databases/.

The team wants to be able to use a database, but they'd rather not pay for that database to be run by AWS. They would also rather not be locked into AWS if they find better deals on GCP or Azure later.

So, after a brief look at Google for some options, your team settles on using MySQL. MySQL is one of the more popular open-source RDBMS solutions, and as such has a lot of documentation, support, and community suggestions for implementation as a database solution in Kubernetes.

Now the work begins on changing your code to support incrementing the counter using a transaction supported by MySQL. So, to do this, we need to change a few things:

- Change our application code to use SQL instead of Redis to access the data and increment the counter.
- Modify our Kubernetes cluster to run MySQL instead of Redis.
- Ensure the durability of the storage underneath the database in case of catastrophic failure.

You may be asking yourself why a cluster operator or administrator would need to be able to understand and refactor code. The advent of Kubernetes accelerated a trend in the software industry of leveraging DevOps tooling, practices, and culture to begin to deliver value to customers more rapidly and more predictably. This means beginning to scale our operations using software and not people. We need robust automation to take the place of human-centric processes to be able to make guarantees around functionalities and delivery speed. Thus, an infrastructure designer or administrator having systems-level software engineering experience to allow them to assist in refactoring a codebase to leverage more cloud-native practices is a huge benefit for them in their careers, and it may soon become a job requirement for all DevOps engineers. So, let's take a look at how to refactor our application for StatefulSets using MySQL for the transactions.

Note

If you are not yet comfortable programming or you are not familiar with the syntax of the language the authors chose (Golang in this example), you don't have to worry -- all of the solutions have been worked out and are ready to be used.

First, let's examine our code for *Exercise 12.04*, *Deploying an Application with State Management*:

main.go

```
if r.Method == "GET" {
    val, err := client.Get("num").Result()
    if err == redis.Nil {
        fmt.Println("num does not exist")
        err := client.Set("num", "0", 0).Err()
        if err != nil {
            panic(err)
        }
    } else if err != nil {
        w.WriteHeader(500)
        panic(err)
    } else {
        fmt.Println("num", val)
        num, err := strconv.Atoi(val)
        if err != nil {
            w.WriteHeader(500)
            fmt.Println(err)
        } else {
            num++
            err := client.Set("num", strconv.Itoa(num), 0).Err()
            if err != nil {
                panic(err)
            }
            fmt.Fprintf(w, "{number: %d}", num)
        }
}
```

Highlighted in the preceding code are the two instances where we are accessing our persistence layer. As you can see, not only are we not using a transaction, but we are manipulating the value in the code and therefore cannot guarantee the constraint that this is a strictly incrementing counter. To do this, we must change our strategy.

Note

You can find the required information for using a MySQL container at this link: https://hub.docker.com/_/mysql?tab=description.

We have provided the refactored application that uses SQL. Let's take a look at the code of the refactored application:

main.go

```
fmt.Println("Starting HTTP server")
http.HandleFunc("/get-number", func(w http.ResponseWriter, r      *http.Request) {
    if r.Method == "GET" {
        tx, err := db.Begin()
            if err != nil {
        panic(err)
        }
        _, err = tx.Exec(t1)
        if err != nil {
            tx.Rollback()
            fmt.Println(err)
        }
        err = tx.Commit()
        if err != nil {
            fmt.Println(err)
        }
        row := db.QueryRow(t2, 1)
        switch err := row.Scan(&num); err {
        case sql.ErrNoRows:
            fmt.Println("No rows were returned!")
        case nil:
            fmt.Fprintf(w, "{number: %d}\n", num)
        default:
            panic(err)
        }
    } else {
        w.WriteHeader(400)
        fmt.Fprint(w, "{\"error\": \"Only GET HTTP method is
supported.\"}")
    }
}
```

As you can see, it's roughly the same as the Redis code, except now our value is being set in a transaction. Unlike Redis, MySQL is not a volatile in-memory datastore, so operations against the database must be persisted to disk to succeed, and ideally, they are persisted to a disk that won't disappear when the pod is interrupted. Let's set up the other required components of our application in the following exercise.

Exercise 14.01: Deploying a Counter App with a MySQL Backend

In this exercise, we will reconfigure our counter app to work with a MySQL backend instead of Redis:

1. To Do

2. Run the following command to get the manifest file, `with_mysql.yaml`, which defines all the required objects:

   ```
   curl -O https://raw.githubusercontent.com/fenago/kubernetes-
   course/master/lab12/Exercise14.01/with_mysql.yaml
   ```

   Open the file for inspection so we can examine this StatefulSet:

   with_mysql.yaml

   ```
   apiVersion: apps/v1
   kind: StatefulSet
   metadata:
     name: mysql
   spec:
     selector:
      matchLabels:
         app: mysql
     serviceName: mysql
     replicas: 1
     template:
       metadata:
         labels:
           app: mysql
       spec:
   ```

   Note

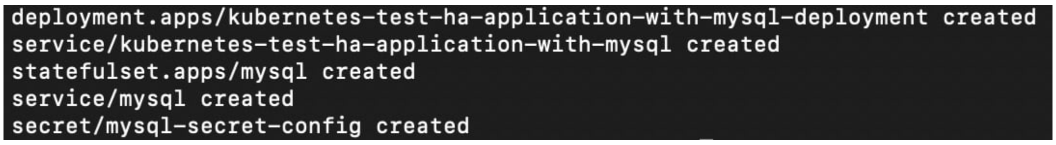
   Here, a PersistentVolumeClaim is automatically binding a 10 GiB volume from Amazon EBS on startup to each pod. Kubernetes will automatically provision the EBS volume using the IAM role that we defined in our Terraform file.

   When the pod gets interrupted for any reason, Kubernetes will automatically re-bind the appropriate PersistentVolume to the pod when it restarts, even if it is on a different worker node, so long as it is in the same availability zone.

3. Let's apply this to our cluster by running the following command:

   ```
   kubectl apply -f with_mysql.yaml
   ```

   You should see this response:



```
deployment.apps/kubernetes-test-ha-application-with-mysql-deployment created
service/kubernetes-test-ha-application-with-mysql created
statefulset.apps/mysql created
service/mysql created
secret/mysql-secret-config created
```

4. Now run `kubectl proxy` in this window and let's open up another terminal window:

   ```
   kubectl proxy
   ```

   You should see this response:

   ```
   Starting to serve on 127.0.0.1:8001
   ```

5. In the other window, run the following command to access our application:

   ```
   curl localhost:8001/api/v1/namespaces/default/services/kubernetes-test-ha-
   application-with-mysql:/proxy/get-number
   ```

   You should see this response:

   ```
   {number: 1}
   ```

   You should see the app running as expected, as we have seen in the previous labs. And just like that, we have a working StatefulSet with our application using MySQL that is persisting data.

As we've said, one of the things that will cause cluster operators to not pursue StatefulSets as a way of being able to manage their data infrastructure is a mistaken belief that the information in PersistentVolumes is as ephemeral as the pods they are bound to. This is not true. The PersistentVolumeClaims created by a StatefulSet will not be deleted if a pod or even the StatefulSet is deleted. This is to protect the data contained in these volumes at all costs. Thus, for cleanup, we need to delete the PersistentVolume separately. Cluster operators also have other tools at their disposal to prevent this from happening, such as changing the reclamation policy of the PersistentVolumes (or the StorageClass it was created from) that you are creating.

Exercise 14.02: Testing the Resilience of StatefulSet Data in PersistentVolumes

In this exercise, we will continue from where we left off in the last exercise and test the resilience of the data that is in our application by deleting a resource and seeing how Kubernetes responds:

1. Now for the fun part, let's try to test the resilience of our persistence mechanism by deleting the MySQL pod:

   ```
   kubectl delete pod mysql-0
   ```

   You should see this response:

   ```
   pod "mysql-0" deleted
   ```

2. The app may crash at this point, but if you keep trying the preceding `curl` command again after a few seconds, it should automatically continue counting from the number it had before we deleted the pod. We can verify this by trying to access the application again:

```
curl localhost:8001/api/v1/namespaces/default/services/kubernetes-test-ha-
application-with-mysql:/proxy/get-number
```

You should see a response similar to the following:

```
{number: 2}
```

As you can see, we not only get a valid response from the application, but we also get the next number in the sequence (`2`), meaning that no data was lost when we lost our MySQL pod and Kubernetes recovered it.

After you've created this StatefulSet, cleaning it up is not as simple as running `kubectl delete -f with_mysql.yaml` . This is because Kubernetes will not automatically destroy a PersistentVolume created by a StatefulSet.

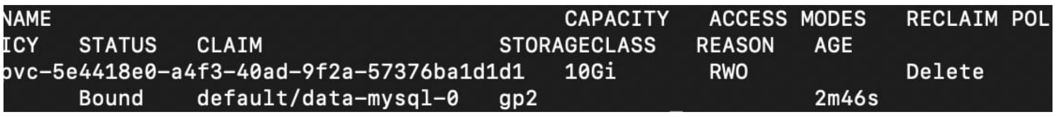
Note

This also means that even if we try to delete all of our AWS resources using `terraform destroy` , we will still be paying for orphaned EBS volumes in AWS indefinitely (and we don't want that in this example).

3. So, to clean up, we need to find out what PersistentVolumes are bound to this StatefulSet. Let's list the PersistentVolumes in the default namespace of our cluster:

   ```
   kubectl get pv
   ```

   You should see a response similar to the following:

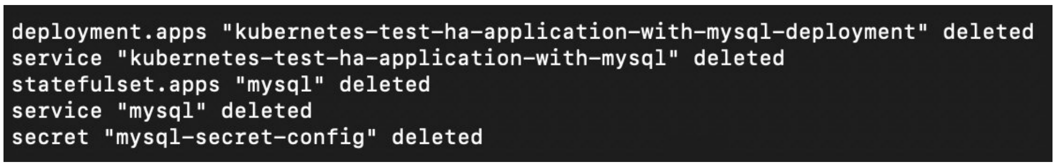


```
NAME                                       CAPACITY   ACCESS MODES   RECLAIM POL
ICY   STATUS   CLAIM                  STORAGECLASS   REASON   AGE
pvc-5e4418e0-a4f3-40ad-9f2a-57376ba1d1d1   10Gi       RWO            Delete
      Bound    default/data-mysql-0   gp2                     2m46s
```

4. It looks like we have a PersistentVolume named `data-mysql-0` , which is the one we want to delete. First, we need to remove the objects that created this. Thus, let's first delete our application and all of its components:

   ```
   kubectl delete -f with_mysql.yaml
   ```

   You should see this response:

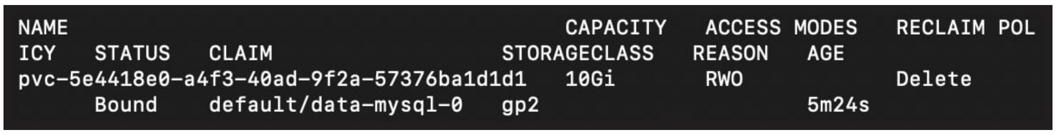


```
deployment.apps "kubernetes-test-ha-application-with-mysql-deployment" deleted
service "kubernetes-test-ha-application-with-mysql" deleted
statefulset.apps "mysql" deleted
service "mysql" deleted
secret "mysql-secret-config" deleted
```

5. Let's check on the PersistentVolume that we were trying to remove:

   ```
   kubectl get pv
   ```

   You should see a response similar to this:



```
NAME                                       CAPACITY   ACCESS MODES   RECLAIM POL
ICY   STATUS   CLAIM                  STORAGECLASS   REASON   AGE
pvc-5e4418e0-a4f3-40ad-9f2a-57376ba1d1d1   10Gi       RWO            Delete
      Bound    default/data-mysql-0   gp2                     5m24s
```

```
From this image, it appears that our volume is still there.
```

6. We need to remove both the PersistentVolume and the PersistentVolumeClaim that created it. To do this, let's run the following command:

   ```
   kubectl delete pvc data-mysql-0
   ```

   You should see this response:

   ```
   persistentvolumeclaim "data-mysql-0" deleted
   ```

   Once we delete the PersistentVolumeClaim, the PersistentVolume becomes `unbound` and is subject to its reclaim policy, which we can see in the screenshot of the previous step. In this case, the policy is to delete the underlying storage volume.

7. To verify that the PV is deleted, let's run the following:

   ```
   kubectl get pv
   ```

   You should see the following response:

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

   As is apparent in this screenshot, our PersistentVolume has now been deleted.

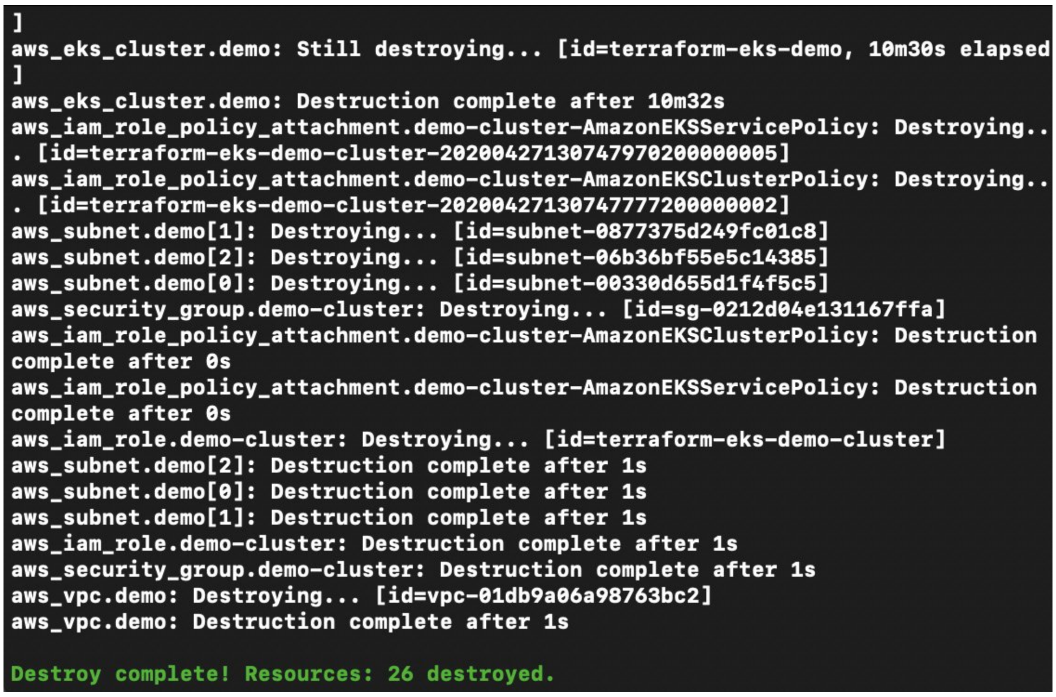
   Note

   If the reclaim policy for your case is anything other than `Delete`, you will need to manually delete the PersistentVolume as well.

8. Now that we have cleaned up our PersistentVolumes and PersistentVolumeClaims, we can continue to clean up as we would normally by running the following command:

   ```
   terraform destroy
   ```

   You should see a response that ends as in this screenshot:



```
]
aws_eks_cluster.demo: Still destroying... [id=terraform-eks-demo, 10m30s elapsed
]
aws_eks_cluster.demo: Destruction complete after 10m32s
aws_iam_role_policy_attachment.demo-cluster-AmazonEKSServicePolicy: Destroying..
. [id=terraform-eks-demo-cluster-20200427130747970200000005]
aws_iam_role_policy_attachment.demo-cluster-AmazonEKSClusterPolicy: Destroying..
. [id=terraform-eks-demo-cluster-20200427130747777200000002]
aws_subnet.demo[1]: Destroying... [id=subnet-0877375d249fc01c8]
aws_subnet.demo[2]: Destroying... [id=subnet-06b36bf55e5c14385]
aws_subnet.demo[0]: Destroying... [id=subnet-00330d655d1f4f5c5]
aws_security_group.demo-cluster: Destroying... [id=sg-0212d04e131167ffa]
aws_iam_role_policy_attachment.demo-cluster-AmazonEKSClusterPolicy: Destruction
complete after 0s
aws_iam_role_policy_attachment.demo-cluster-AmazonEKSServicePolicy: Destruction
complete after 0s
aws_iam_role.demo-cluster: Destroying... [id=terraform-eks-demo-cluster]
aws_subnet.demo[2]: Destruction complete after 1s
aws_subnet.demo[0]: Destruction complete after 1s
aws_subnet.demo[1]: Destruction complete after 1s
aws_iam_role.demo-cluster: Destruction complete after 1s
aws_security_group.demo-cluster: Destruction complete after 1s
aws_vpc.demo: Destroying... [id=vpc-01db9a06a98763bc2]
aws_vpc.demo: Destruction complete after 1s

Destroy complete! Resources: 26 destroyed.
```

In this exercise, we have seen how Kubernetes tries to preserve PersistentVolumes even when we delete the StatefulSet. We have also seen how to proceed when we actually want to remove a PersistentVolume.

Now that we have seen how to set up a StatefulSet and run a MySQL database attached to it, we will extend the principle of high availability further in the following activity. Before we do this, though, we need to address the problem of Kubernetes manifest sprawl, because it seems to take more and more YAML manifests to achieve our objective of building highly available stateful applications. In the following section, we will learn about a tool that will help us better organize and manage the manifests for our applications.

Helm

In this section, we are going to be taking a look at a tool that is very helpful in the Kubernetes ecosystem called Helm. Helm was created by Microsoft after it quickly became apparent that for any sizeable deployment of Kubernetes (for example, those involving 20 or more separate components, observability tools, services, and other objects), there are a lot of YAML manifests to keep track of. Couple that with the fact that many companies run multiple environments other than production, which you need to be able to keep in sync with each other, and you start to have an unwieldy problem on your hands.

Helm allows you to write Kubernetes manifest templates, to which you supply arguments that override any defaults, and then Helm creates the appropriate Kubernetes manifests for you. Thus, you can use Helm as a sort of package manager, where your entire application can be deployed using a Helm chart, and you can tweak a few small parameters before installing. Another way to use Helm is as a templating engine. It allows an experienced Kubernetes operator to write a good template only one time and then it can be used by people not familiar with the Kubernetes manifest syntax to successfully create Kubernetes resources. A Helm chart can be created with any number of fields set by arguments, and a base template can be adapted to deploy vastly different implementations of a piece of software or a microservice to suit different needs.

Helm packages are called "charts" and they have a specific folder structure. You can either use a shared Helm chart repository from Git, an Artifactory server, or a local filesystem. In the upcoming exercise, we're going to look at a Helm chart and install it on our clusters.

This is a good point to be introduced to Helm in your journey of learning Kubernetes because if you've been following along, you've written quite a bit of YAML and applied it to your cluster. Also, a lot of what we've written is a repeat of things that we've seen before. So, leveraging Helm's templating functionality will be helpful for packaging up similar components and delivering them using Kubernetes. You don't have to leverage the templating components of Helm to use it, but it helps so that you can reuse the chart for multiple different permutations of the resulting Kubernetes object.

Note

We will be using Helm 3, which has significant differences from its predecessor, Helm 2, and was only recently released. If you are familiar with Helm 2 and want to know about the differences, you can refer to the documentation at this link: https://v3.helm.sh/docs/faq/#changes-since-helm-2.

Detailed coverage of Helm is beyond the scope of this course, but the fundamentals covered here serve as a great starting point, and also put into perspective how different tools and technologies can work together to remove several hurdles of complex application orchestration in Kubernetes.

Let's see how we can create a chart (which is the Helm term for a package) and apply it to a cluster. Then, we will understand how Helm generates Kubernetes manifest files from a Helm chart.

Let's make a new Helm chart by running the following command:

```
helm create chart-dev
```

You should see the following response:

```
Creating chart-dev
```

When you create a new chart, Helm will generate a chart for NGINX as a placeholder application by default. This will create a new folder and skeleton chart for us to examine.

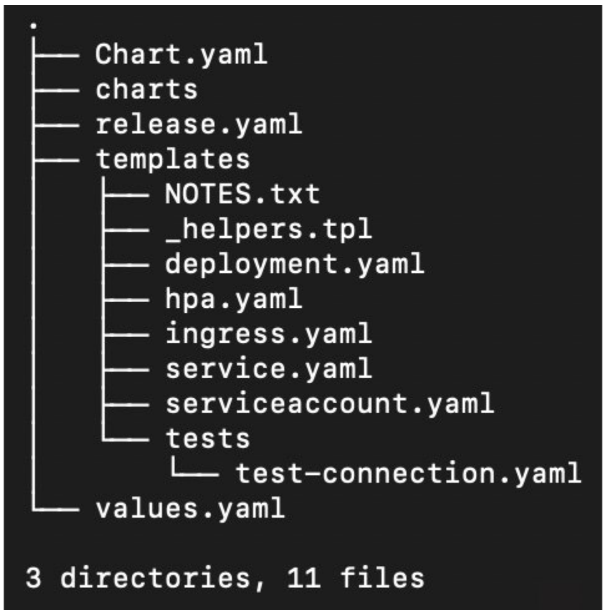
Note

For the following section, make sure that you have `tree` installed as per the instructions in the *Preface*.

Let's use the Linux `tree` command and take a look at what Helm has made for us:

```
tree .
```

You should see a response similar to the following:



```
.
├── Chart.yaml
├── charts
├── release.yaml
├── templates
│   ├── NOTES.txt
│   ├── _helpers.tpl
│   ├── deployment.yaml
│   ├── hpa.yaml
│   ├── ingress.yaml
│   ├── service.yaml
│   ├── serviceaccount.yaml
│   └── tests
│       └── test-connection.yaml
└── values.yaml

3 directories, 11 files
```

Pay attention to the `templates` folder and the `values.yaml` file. Helm works by using the values found in the `values.yaml` file and fills those values into the corresponding placeholders in the files inside the `templates` folder. Let's examine a part of the `values.yaml` file:

values.yaml

```
# Default values for chart-dev.
# This is a YAML-formatted file.
# Declare variables to be passed into your templates.

replicaCount: 1

image:
  repository: nginx
  pullPolicy: IfNotPresent
  # Overrides the image tag whose default is the chart appVersion.
  tag: ""

imagePullSecrets: []
nameOverride: ""
fullnameOverride: ""
```

As we can see here, this is not a Kubernetes manifest, but it looks like it has many of the same fields. In the preceding snippet, we have highlighted the entire `image` block. This has three fields (`repository` , `pullPolicy` , and `tag`), each with their corresponding values.

Another notable file is `Chart.yaml` . The following line from this file is relevant to our discussion:

```
appVersion: 1.16.0
```

The comment in the file is pretty descriptive of what this means: "*This is the version number of the application being deployed. This version number should be incremented each time you make changes to the application. Versions are not expected to follow Semantic Versioning. They should reflect the version the application is using.*"

So, how does Helm assemble these into the traditional Kubernetes manifest format that we expect? To understand that, let's inspect the corresponding section of the `deployment.yaml` file in the `templates` folder:

deployment.yaml

```
containers:
  - name: {{ .Chart.Name }}
    securityContext:
      {{- toYaml .Values.securityContext | nindent 12 }}
    image: "{{ .Values.image.repository }}:{{ .Values.image.tag | default .Chart.AppVersion }}"
    imagePullPolicy: {{ .Values.image.pullPolicy }}
```

This file looks a lot more like a Kubernetes manifest with a bunch of variables added into it. Comparing the template placeholders from `deployment.yaml` to the observations from `values.yaml` and `Chart.yaml`, we can infer the following:

- `{{ .Values.image.repository }}` will be interpreted as `nginx`.
- `{{ .Values.image.tag | default .Chart.AppVersion }}` will be interpreted as `1.16.0`.

Thus, we get the resultant field for our deployment spec as `image: nginx:1.16.0`.

This is our first glimpse into the Helm templating language. For those familiar with templating engines such as Jinja, Go templating, or Twig, this syntax should look familiar. As mentioned earlier, we will not dive into too many details about Helm, but you can find more on the Helm documentation at this link: https://helm.sh/docs/chart_template_guide/.

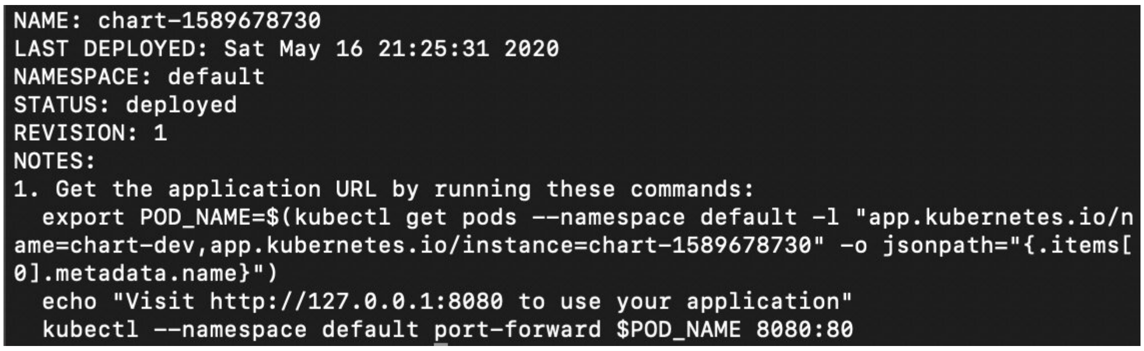
Now, let's install the sample chart `chart-dev` that we have generated. This chart will deploy an example NGINX app to our Kubernetes cluster. To install a Helm chart, the command would look as follows:

```
helm install [NAME] [CHART] [flags]
```

We can use `--generate-name` to get a random name. Also, since we are already in the `chart-dev` directory, we can directly use `values.yaml` from the root of the current working directory:

```
helm install --generate-name -f values.yaml .
```

You should see the following response:



```
NAME: chart-1589678730
LAST DEPLOYED: Sat May 16 21:25:31 2020
NAMESPACE: default
STATUS: deployed
REVISION: 1
NOTES:
1. Get the application URL by running these commands:
  export POD_NAME=$(kubectl get pods --namespace default -l "app.kubernetes.io/n
ame=chart-dev,app.kubernetes.io/instance=chart-1589678730" -o jsonpath="{.items[
0].metadata.name}")
  echo "Visit http://127.0.0.1:8080 to use your application"
  kubectl --namespace default port-forward $POD_NAME 8080:80
```

Notice that in the output, you are given instructions on what to do next. These are customizable instructions from the `templates/NOTES.txt` file. When you make your own Helm chart, you can use these to guide whoever is using the chart. Now, let's run these commands.

Note

The exact values in this output are customized to your particular environment, so you should copy the commands from your terminal output. This applies to the following command.

The first command sets the pod name into an environment variable named `POD_NAME`:

```
export POD_NAME=$(kubectl get pods --namespace default -l
"app.kubernetes.io/name=chart-dev,app.kubernetes.io/instance=chart-1589678730" -o
jsonpath="{.items[0].metadata.name}")
```

We'll skip the `echo` command; it just tells you how to access your application. The reason this `echo` command exists is to show what the next commands are going to be in the terminal output.

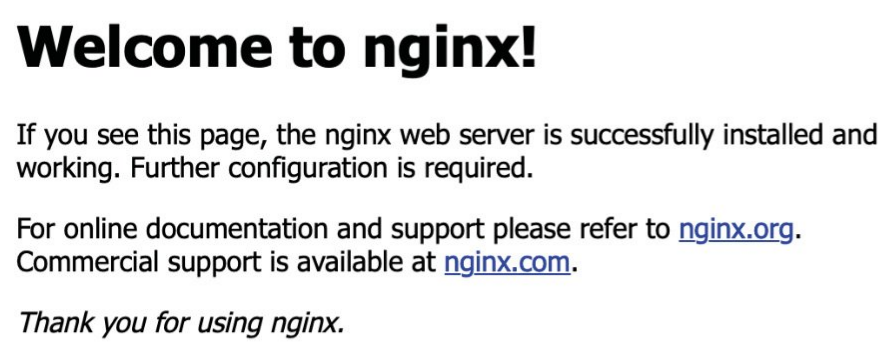
Now before we access our application, we need to do some port forwarding. The next command maps port `8080` on your host to port `80` on the pod:

```
kubectl --namespace default port-forward $POD_NAME 8080:80
```

You should see this response:

```
Forwarding from 127.0.0.1:8080 ->80
Forwarding from [::1]:8080 -> 80
```

Now let's try to access NGINX. In a browser, go to `localhost:8080`. You should be able to see the default NGINX landing page:



Welcome to nginx!

If you see this page, the nginx web server is successfully installed and working. Further configuration is required.

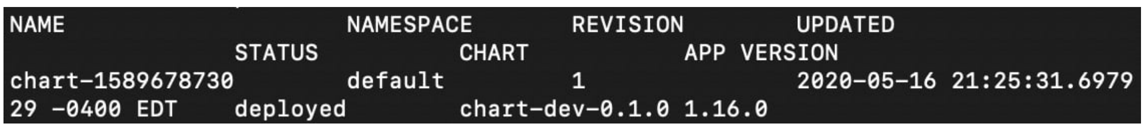
For online documentation and support please refer to nginx.org.
Commercial support is available at nginx.com.

Thank you for using nginx.

You can clean this up by deleting our resources. First, let's get the generated name of this release by getting a list of all the releases installed by Helm in your cluster:

```
helm ls
```

You should see a response similar to this:



```
NAME                    NAMESPACE       REVISION        UPDATED
                STATUS          CHART           APP VERSION
chart-1589678730        default         1               2020-05-16 21:25:31.6979
29 -0400 EDT    deployed        chart-dev-0.1.0 1.16.0
```

Now, we can remove the release as follows:

```
helm uninstall chart-1589678730
```

Use the name from the previous output. You should see this response:

```
release "chart-1589678730" uninstalled
```

And just like that, we've written our first chart. So, let's proceed to the following exercise, where we will learn exactly how Helm can make our job easier.

Exercise 14.03: Chart-ifying Our Redis-Based Counter Application

We created a generic Helm chart in the previous section, but what if we want to make our own chart for our software? In this exercise, we will create a Helm chart that will deploy our HA Redis-based solution from *Lab 12*, *Your Application and HA*, using Helm.

1. If you are inside the `chart-dev` directory, navigate to the parent directory:

   ```
   cd ..
   ```

2. Let's start by making a fresh Helm chart:

   ```
   helm create redis-based-counter && cd redis-based-counter
   ```

   You should see this response:

   ```
   Creating redis-based-counter
   ```

3. Now let's remove the unnecessary files from our chart:

   ```
   rm templates/NOTES.txt; \
   rm templates/*.yaml; \
   rm -r templates/tests/; \
   cd templates
   ```

4. Now, we need to navigate into the `templates` folder of our chart and copy in the files from our repo for the Redis-based counter application:

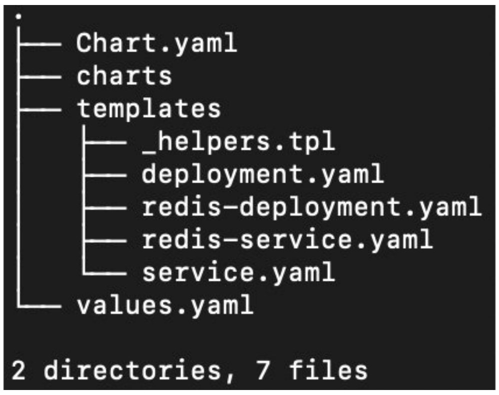
   ```
   curl -O https://raw.githubusercontent.com/fenago/kubernetes-
   course/master/lab12/Exercise14.03/templates/redis-deployment.yaml; \
   curl -O https://raw.githubusercontent.com/fenago/kubernetes-
   course/master/lab12/Exercise14.03/templates/deployment.yaml;\
   curl -O https://raw.githubusercontent.com/fenago/kubernetes-
   course/master/lab12/Exercise14.03/templates/redis-service.yaml; \
   curl -O https://raw.githubusercontent.com/fenago/kubernetes-
   course/master/lab12/Exercise14.03/templates/service.yaml
   ```

   You may recall from previous labs that we had multiple Kubernetes manifests sharing one file, separated by the `---` YAML file separator string. Now that we have a tool for managing Kubernetes manifests, it's better to keep them in separate files so that we can manage them independently. The job of bundling will now be handled by Helm.

5. There should be four files in the `templates` folder. Let's confirm that as follows:

   ```
   tree .
   ```

You should see the following response:



```
.
├── Chart.yaml
├── charts
├── templates
│   ├── _helpers.tpl
│   ├── deployment.yaml
│   ├── redis-deployment.yaml
│   ├── redis-service.yaml
│   └── service.yaml
└── values.yaml

2 directories, 7 files
```

6. ow we need to modify the `values.yaml` file. Delete all contents from that file and copy only the following into it:

```
deployment:
  replicas: 3
redis:
  version: 3
```

7. Now, to wire them together, we need to edit both `deployment.yaml` and `redis-deployment.yaml`. The one we will edit first is `deployment.yaml`. We should replace `replicas: 3` with the template, as shown in the highlighted line in the following manifest:

```
apiVersion: apps/v1
kind: Deployment
metadata:
  name: kubernetes-test-ha-application-with-redis-deployment
  labels:
    app: kubernetes-test-ha-application-with-redis
spec:
  replicas: {{ .Values.deployment.replicas }}
  selector:
    matchLabels:
      app: kubernetes-test-ha-application-with-redis
  template:
    metadata:
      labels:
        app: kubernetes-test-ha-application-with-redis
    spec:
      containers:
        - name: kubernetes-test-ha-application-with-redis
          image: fenago/the-kubernetes-workshop:demo-app-with-redis
          imagePullPolicy: Always
          ports:
            - containerPort: 8080
          env:
            - name: REDIS_SVC_ADDR
              value: "redis.default:6379"
```

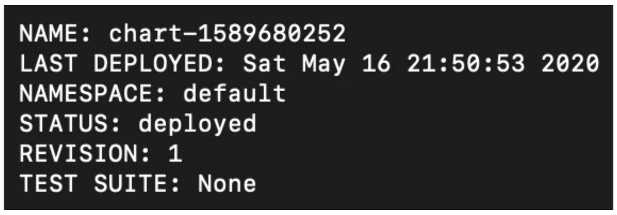
8. Next, edit the `redis-deployment.yaml` file and add a similar block of templating language, as shown in the highlighted line in the following manifest:

```
apiVersion: apps/v1 # for versions before 1.9.0 use apps/v1beta2
kind: Deployment
metadata:
  name: redis
  labels:
    app: redis
spec:
  selector:
    matchLabels:
      app: redis
  replicas: 1
  template:
    metadata:
      labels:
        app: redis
    spec:
      containers:
        - name: master
          image: redis:{{ .Values.redis.version }}
          resources:
            requests:
              cpu: 100m
              memory: 100Mi
          ports:
            - containerPort: 6379
```

9. Now let's install our application using Helm:

```
helm install --generate-name -f values.yaml .
```

You should see a response similar to this:

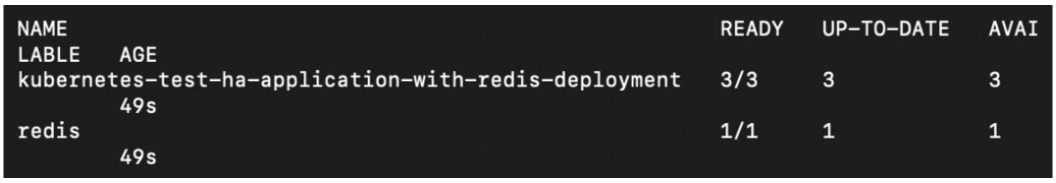


```
NAME: chart-1589680252
LAST DEPLOYED: Sat May 16 21:50:53 2020
NAMESPACE: default
STATUS: deployed
REVISION: 1
TEST SUITE: None
```

10. To check whether our application is online, we can get the list of deployments:

```
kubectl get deployment
```

You should see the following output:



```
NAME                                                 READY   UP-TO-DATE   AVAI
LABLE   AGE
kubernetes-test-ha-application-with-redis-deployment   3/3     3            3
        49s
redis                                                  1/1     1            1
        49s
```

As you can see, Helm has deployed our application deployment, as well as the Redis backend for it. With these skills in the bag, you are soon to be a captain of Helm.

In the following activity, we will bring together the two things we learned in this lab -- refactoring our application for stateful components and then deploying it as a Helm chart.

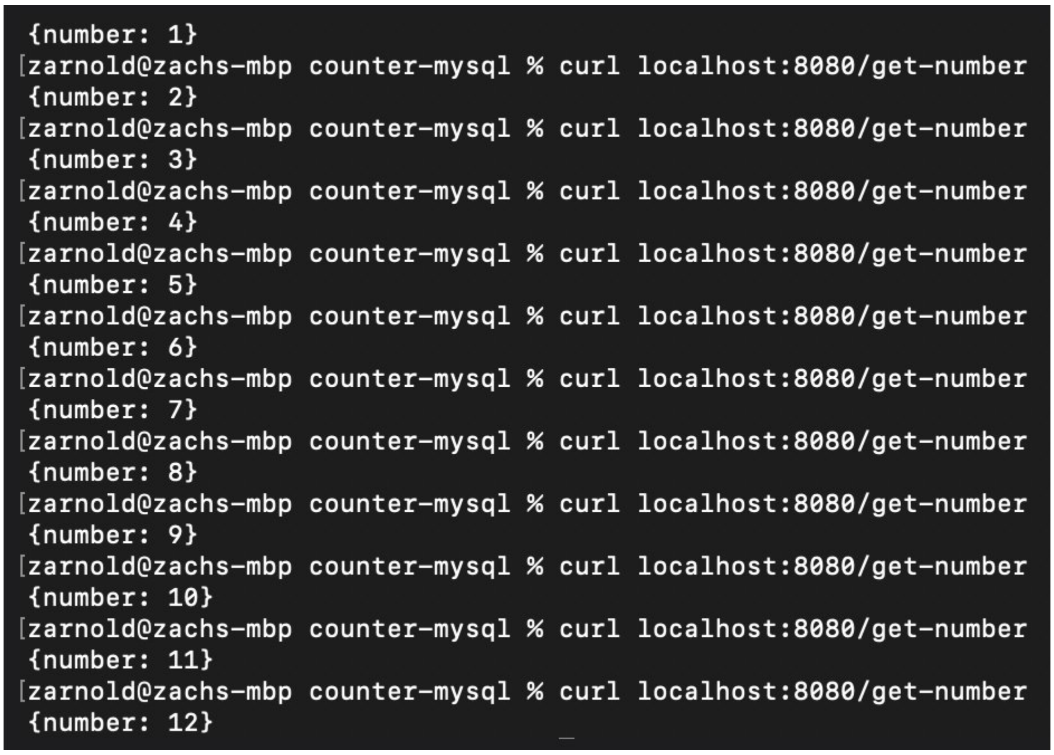
Activity 14.01: Chart-ifying Our StatefulSet Deployment

Now that you have experience with MySQL, StatefulSets, and Helm for resource management, your activity is to take what you learned in *Exercises 14.01*, *14.02*, and *14.03* and combine them together.

For this activity, we will refactor our Redis-based application to use MySQL as the backend datastore using StatefulSets, and then deploy it using Helm.

Follow these high-level guidelines to complete the activity:

1. Set up the required cluster infrastructure as shown in *step 1* of *Exercise 14.01*, *Deploying a Counter App with a MySQL Backend*.
2. Introduce a new Helm chart called `counter-mysql`.
3. Create a template for our counter application that uses MySQL as its backend.
4. Create a template for our MySQL StatefulSet.
5. Wire everything together with Kubernetes Service objects wherever appropriate.
6. Configure the template such that the `values.yaml` file is able to change the version of MySQL.
7. Test the application. You should see a similar output to that which we've seen in previous exercises with our counter application:



```
{number: 1}
[zarnold@zachs-mbp counter-mysql % curl localhost:8080/get-number
{number: 2}
[zarnold@zachs-mbp counter-mysql % curl localhost:8080/get-number
{number: 3}
[zarnold@zachs-mbp counter-mysql % curl localhost:8080/get-number
{number: 4}
[zarnold@zachs-mbp counter-mysql % curl localhost:8080/get-number
{number: 5}
[zarnold@zachs-mbp counter-mysql % curl localhost:8080/get-number
{number: 6}
[zarnold@zachs-mbp counter-mysql % curl localhost:8080/get-number
{number: 7}
[zarnold@zachs-mbp counter-mysql % curl localhost:8080/get-number
{number: 8}
[zarnold@zachs-mbp counter-mysql % curl localhost:8080/get-number
{number: 9}
[zarnold@zachs-mbp counter-mysql % curl localhost:8080/get-number
{number: 10}
[zarnold@zachs-mbp counter-mysql % curl localhost:8080/get-number
{number: 11}
[zarnold@zachs-mbp counter-mysql % curl localhost:8080/get-number
{number: 12}
```

Note

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

Also, don't forget to clean up your cloud resources using the `terraform destroy` command to stop AWS from billing you after you are done with the activity.

Summary

Over the course of this lab, we have applied our skills to be able to leverage StatefulSets in our example application. We have looked at how to think about running stateful portions of our software programmatically and how to refactor applications to leverage that change in state persistence. Finally, we learned how to create and run Kubernetes StatefulSets that will allow us to run stateful components in our cluster and make guarantees about how that workload will be run.

Being equipped with the skills needed to manage stateful components on our Kubernetes cluster is a major step in being able to operate effectively in many real-world applications that you are likely to come across.