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# Tutorials

This section of the Kubernetes documentation contains tutorials. A tutorial shows how to accomplish a goal that is larger than a single [task](#). Typically a tutorial has several sections, each of which has a sequence of steps. Before walking through each tutorial, you may want to bookmark the [Standardized Glossary](#) page for later references.

- [Basics](#)
- [Configuration](#)
- [Stateless Applications](#)
- [Stateful Applications](#)
- [CI/CD Pipeline](#)
- [Clusters](#)
- [Services](#)
- [What's next](#)

## Basics

- [Kubernetes Basics](#) is an in-depth interactive tutorial that helps you understand the Kubernetes system and try out some basic Kubernetes features.
- [Scalable Microservices with Kubernetes \(Udacity\)](#)
- [Introduction to Kubernetes \(edX\)](#)
- [Hello Minikube](#)

## Configuration

- [Configuring Redis Using a ConfigMap](#)

## Stateless Applications

- [Exposing an External IP Address to Access an Application in a Cluster](#)
- [Example: Deploying PHP Guestbook application with Redis](#)

## Stateful Applications

- [StatefulSet Basics](#)
- [Example: WordPress and MySQL with Persistent Volumes](#)
- [Example: Deploying Cassandra with Stateful Sets](#)
- [Running ZooKeeper, A CP Distributed System](#)

## CI/CD Pipeline

- [Set Up a CI/CD Pipeline with Kubernetes Part 1: Overview](#)
- [Set Up a CI/CD Pipeline with a Jenkins Pod in Kubernetes \(Part 2\)](#)
- [Run and Scale a Distributed Crossword Puzzle App with CI/CD on Kubernetes \(Part 3\)](#)
- [Set Up CI/CD for a Distributed Crossword Puzzle App on Kubernetes \(Part 4\)](#)

## Clusters

- [AppArmor](#)

## Services

- [Using Source IP](#)

## What's next

If you would like to write a tutorial, see [Using Page Templates](#) for information about the tutorial page type and the tutorial template.

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## Hello Minikube

This tutorial shows you how to run a simple Hello World Node.js app on Kubernetes using [Minikube](#) and Katacoda. Katacoda provides a free, in-browser Kubernetes environment.

**Note:** You can also follow this tutorial if you've installed [Minikube locally](#).

- [Objectives](#)
- [Before you begin](#)
- [Create a Minikube cluster](#)
- [Create a Deployment](#)
- [Create a Service](#)
- [Enable addons](#)
- [Clean up](#)
- [What's next](#)

## Objectives

- Deploy a hello world application to Minikube.
- Run the app.
- View application logs.

## Before you begin

This tutorial provides a container image built from the following files:

[minikube/server.js](#)

```
var http = require('http');

var handleRequest = function(request, response) {
  console.log('Received request for URL: ' + request.url);
  response.writeHead(200);
  response.end('Hello World!');
};
var www = http.createServer(handleRequest);
www.listen(8080);
```

[minikube/Dockerfile](#)

```
FROM node:6.14.2
EXPOSE 8080
COPY server.js .
CMD node server.js
```

For more information on the `docker build` command, read the [Docker documentation](#).

## Create a Minikube cluster

1. Click **Launch Terminal**
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# Using a Service to Expose Your App

## Objectives

- Learn about a Service in Kubernetes
- Understand how labels and LabelSelector objects relate to a Service
- Expose an application outside a Kubernetes cluster using a Service

## Overview of Kubernetes Services

Kubernetes [Pods](#) are mortal. Pods in fact have a [lifecycle](#). When a worker node dies, the Pods running on the Node are also lost. A [ReplicaSet](#) might then dynamically drive the cluster back to desired state via creation of new Pods to keep your application running. As another example, consider an image-processing backend with 3 replicas. Those replicas are exchangeable; the front-end system should not care about backend replicas or even if a Pod is lost and recreated. That said, each Pod in a Kubernetes cluster has a unique IP address, even Pods on the same Node, so there needs to be a way of automatically reconciling changes among Pods so that your applications continue to function.

A Service in Kubernetes is an abstraction which defines a logical set of Pods and a policy by which to access them. Services enable a loose coupling between dependent Pods. A Service is defined using YAML ([preferred](#)) or JSON, like all Kubernetes objects. The set of Pods targeted by a Service is usually determined by a *LabelSelector* (see below for why you might want a Service without including `selector` in the spec).

Although each Pod has a unique IP address, those IPs are not exposed outside the cluster without a Service. Services allow your applications to receive traffic. Services can be exposed in different ways by specifying a `type` in the `ServiceSpec`:

- *ClusterIP* (default) - Exposes the Service on an internal IP in the cluster. This type makes the Service only reachable from within the cluster.
- *NodePort* - Exposes the Service on the same port of each selected Node in the cluster using NAT. Makes a Service accessible from outside the cluster using `<NodeIP>:<NodePort>`. Superset of *ClusterIP*.
- *LoadBalancer* - Creates an external load balancer in the current cloud (if supported) and assigns a fixed, external IP to the Service. Superset of *NodePort*.
- *ExternalName* - Exposes the Service using an arbitrary name (specified by `externalName` in the spec) by returning a CNAME record with the name. No proxy is used. This type requires v1.7 or higher of `kube-dns`.

More information about the different types of Services can be found in the [Using Source IP](#) tutorial. Also see [Connecting Applications with Services](#).

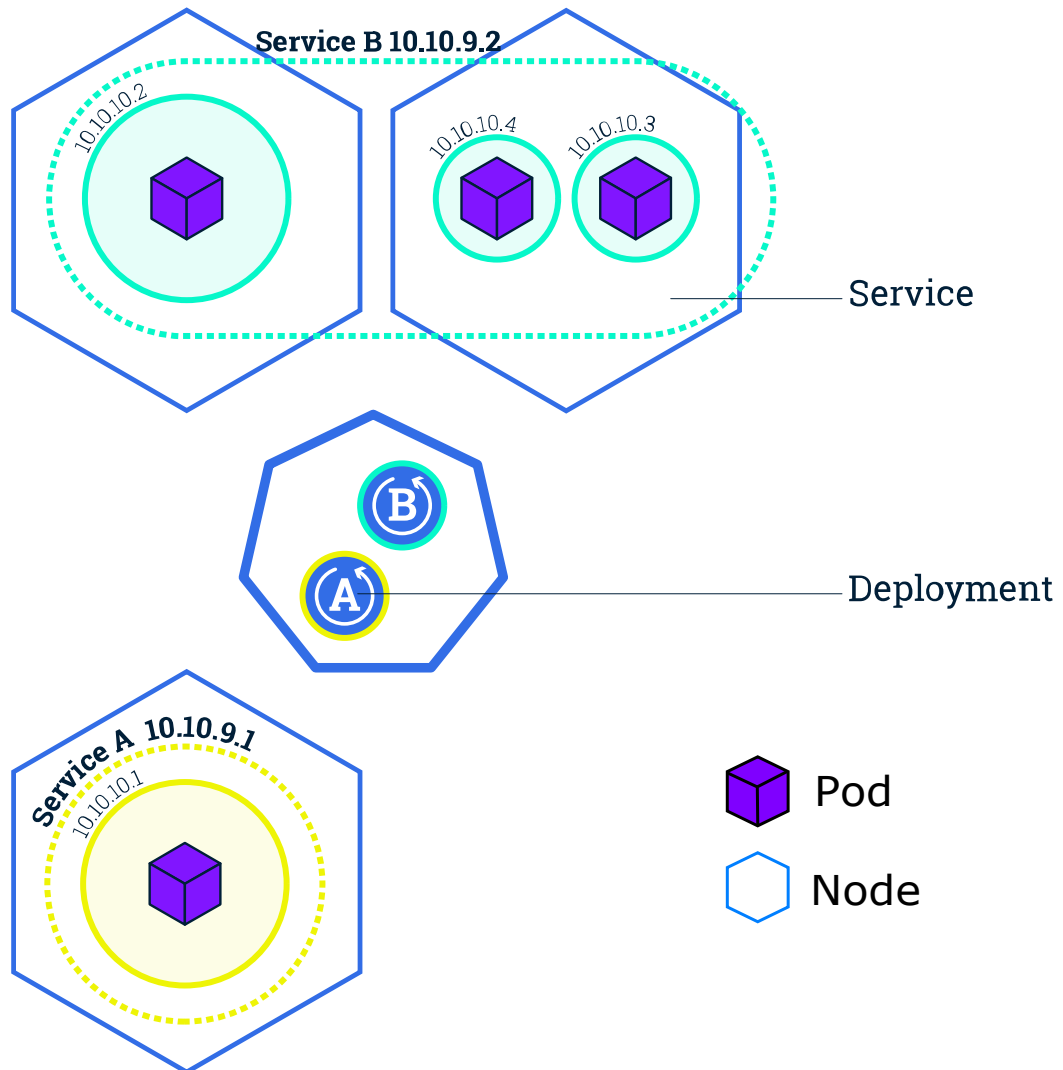
Additionally, note that there are some use cases with Services that involve not defining `selector` in the spec. A Service created without `selector` will also not create the corresponding Endpoints object. This allows users to manually map a Service to specific endpoints. Another possibility why there may be no selector is you are strictly using `type: ExternalName`.

## Summary

- Exposing Pods to external traffic
- Load balancing traffic across multiple Pods
- Using labels

*A Kubernetes Service is an abstraction layer which defines a logical set of Pods and enables external traffic exposure, load balancing and service discovery for those Pods.*

## Services and Labels

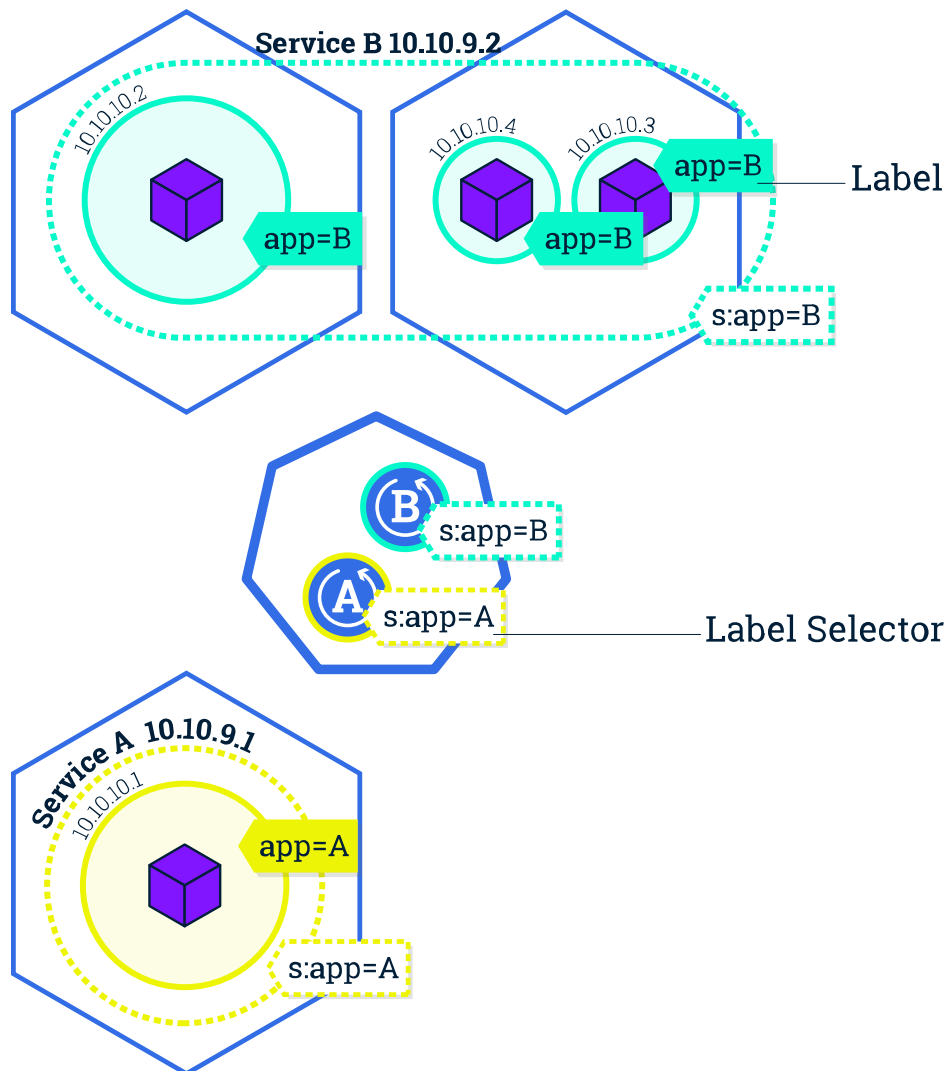


A Service routes traffic across a set of Pods. Services are the abstraction that allow pods to die and replicate in Kubernetes without impacting your application. Discovery and routing among dependent Pods (such as the frontend and backend components in an application) is handled by Kubernetes Services.

Services match a set of Pods using [labels and selectors](#), a grouping primitive that allows logical operation on objects in Kubernetes. Labels are key/value pairs attached to objects and can be used in any number of ways:

- Designate objects for development, test, and production
- Embed version tags
- Classify an object using tags

You can create a Service at the same time you create a Deployment by using `--expose` in `kubectl`.



Labels can be attached to objects at creation time or later on. They can be modified at any time. Let's expose our application now using a Service and apply some labels.

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# Learn Kubernetes Basics

## Kubernetes Basics

This tutorial provides a walkthrough of the basics of the Kubernetes cluster orchestration system. Each module contains some background information on major Kubernetes features and concepts, and includes an interactive online tutorial. These interactive tutorials let you manage a simple cluster and its containerized applications for yourself.

Using the interactive tutorials, you can learn to:

- Deploy a containerized application on a cluster.
- Scale the deployment.
- Update the containerized application with a new software version.
- Debug the containerized application.

The tutorials use Katacoda to run a virtual terminal in your web browser that runs Minikube, a small-scale local deployment of Kubernetes that can run anywhere. There's no need to install any software or configure anything; each interactive tutorial runs directly out of your web browser itself.

## What can Kubernetes do for you?

With modern web services, users expect applications to be available 24/7, and developers expect to deploy new versions of those applications several times a day. Containerization helps package software to serve these goals, enabling applications to be released and updated in an easy and fast way without downtime. Kubernetes helps you make sure those containerized applications run where and when you want, and helps them find the resources and tools they need to work. Kubernetes is a production-ready, open source platform



designed with Google's accumulated experience in container orchestration, combined with best-of-breed ideas from the community.

## Kubernetes Basics Modules

[1. Create a Kubernetes cluster](#)

[2. Deploy an app](#)

[3. Explore your app](#)

[4. Expose your app publicly](#)

[5. Scale up your app](#)

[6. Update your app](#)

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## Interactive Tutorial - Creating a Cluster

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# Using Minikube to Create a Cluster

## Objectives

- Learn what a Kubernetes cluster is.
- Learn what Minikube is.
- Start a Kubernetes cluster using an online terminal.

## Kubernetes Clusters

**Kubernetes coordinates a highly available cluster of computers that are connected to work as a single unit.** The abstractions in Kubernetes allow you to deploy containerized applications to a cluster without tying them specifically to individual machines. To make use of this new model of deployment, applications need to be packaged in a way that decouples them from individual hosts: they need to be containerized. Containerized applications are more flexible and available than in past deployment models, where applications were installed directly onto specific machines as packages deeply integrated into the host. **Kubernetes automates the distribution and scheduling of application containers across a cluster in a more efficient way.** Kubernetes is an open-source platform and is production-ready.

A Kubernetes cluster consists of two types of resources:

- The **Master** coordinates the cluster
- **Nodes** are the workers that run applications

## Summary:

- Kubernetes cluster
- Minikube

*Kubernetes is a production-grade, open-source platform that orchestrates the placement (scheduling) and execution of application containers within and across computer clusters.*

## Cluster Diagram

**The Master is responsible for managing the cluster.** The master coordinates all activities in your cluster, such as scheduling applications, maintaining applications' desired state, scaling applications, and rolling out new updates.

**A node is a VM or a physical computer that serves as a worker machine in a Kubernetes cluster.** Each node has a Kubelet, which is an agent for managing the node and communicating with the Kubernetes master. The node should also have tools for handling container operations, such as Docker or rkt. A Kubernetes cluster that handles production traffic should have a minimum of three nodes.

*Masters manage the cluster and the nodes are used to host the running applications.*

When you deploy applications on Kubernetes, you tell the master to start the application containers. The master schedules the containers to run on the cluster's nodes. **The nodes communicate with the master using the Kubernetes API**, which the master exposes. End users can also use the Kubernetes API directly to interact with the cluster.

A Kubernetes cluster can be deployed on either physical or virtual machines. To get started with Kubernetes development, you can use Minikube. Minikube is a lightweight Kubernetes implementation that creates a VM on your local machine and deploys a simple cluster containing only one node. Minikube is available for Linux, macOS, and Windows

systems. The Minikube CLI provides basic bootstrapping operations for working with your cluster, including start, stop, status, and delete. For this tutorial, however, you'll use a provided online terminal with Minikube pre-installed.

Now that you know what Kubernetes is, let's go to the online tutorial and start our first cluster!

[Start Interactive Tutorial](#)

## Feedback

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# Using kubectl to Create a Deployment

## Objectives

- Learn about application Deployments.
- Deploy your first app on Kubernetes with kubectl.

## Kubernetes Deployments

Once you have a running Kubernetes cluster, you can deploy your containerized applications on top of it. To do so, you create a Kubernetes **Deployment** configuration. The Deployment instructs Kubernetes how to create and update instances of your application. Once you've created a Deployment, the Kubernetes master schedules mentioned application instances onto individual Nodes in the cluster.

Once the application instances are created, a Kubernetes Deployment Controller continuously monitors those instances. If the Node hosting an instance goes down or is deleted, the Deployment controller replaces the instance with an instance on another Node in the cluster. **This provides a self-healing mechanism to address machine failure or maintenance.**

In a pre-orchestration world, installation scripts would often be used to start applications, but they did not allow recovery from machine failure. By both creating your application

instances and keeping them running across Nodes, Kubernetes Deployments provide a fundamentally different approach to application management.

### Summary:

- Deployments
- Kubectl

*A Deployment is responsible for creating and updating instances of your application*

## Deploying your first app on Kubernetes

You can create and manage a Deployment by using the Kubernetes command line interface, **Kubectl**. Kubectl uses the Kubernetes API to interact with the cluster. In this module, you'll learn the most common Kubectl commands needed to create Deployments that run your applications on a Kubernetes cluster.

When you create a Deployment, you'll need to specify the container image for your application and the number of replicas that you want to run. You can change that information later by updating your Deployment; Modules [5](#) and [6](#) of the bootcamp discuss how you can scale and update your Deployments.

*Applications need to be packaged into one of the supported container formats in order to be deployed on Kubernetes*

For your first Deployment, you'll use a Node.js application packaged in a Docker container. (If you didn't already try creating a Node.js application and deploying it using a container, you can do that first by following the instructions from the [Hello Minikube tutorial](#)).

Now that you know what Deployments are, let's go to the online tutorial and deploy our first app!

[Start Interactive Tutorial](#) â€°

## Feedback

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## Interactive Tutorial - Deploying an App

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## Viewing Pods and Nodes

### Objectives

- Learn about Kubernetes Pods.
- Learn about Kubernetes Nodes.
- Troubleshoot deployed applications.

# Kubernetes Pods

When you created a Deployment in Module [2](#), Kubernetes created a **Pod** to host your application instance. A Pod is a Kubernetes abstraction that represents a group of one or more application containers (such as Docker or rkt), and some shared resources for those containers. Those resources include:

- Shared storage, as Volumes
- Networking, as a unique cluster IP address
- Information about how to run each container, such as the container image version or specific ports to use

A Pod models an application-specific "logical host" and can contain different application containers which are relatively tightly coupled. For example, a Pod might include both the container with your Node.js app as well as a different container that feeds the data to be published by the Node.js webserver. The containers in a Pod share an IP Address and port space, are always co-located and co-scheduled, and run in a shared context on the same Node.

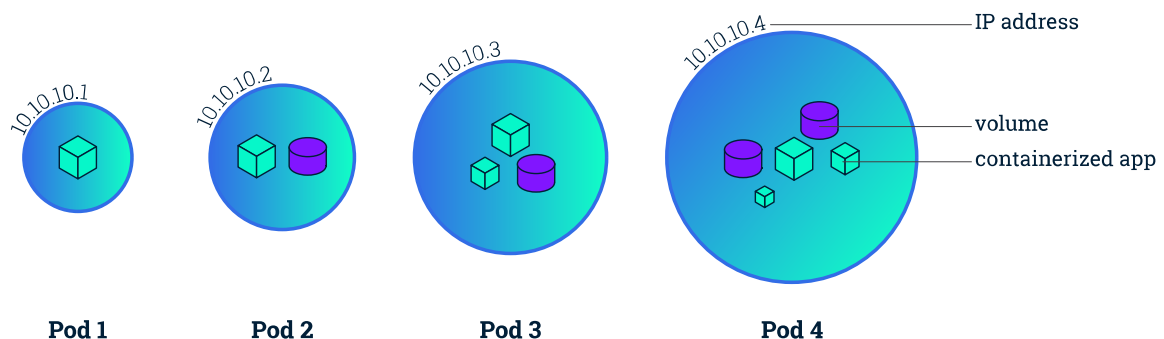
Pods are the atomic unit on the Kubernetes platform. When we create a Deployment on Kubernetes, that Deployment creates Pods with containers inside them (as opposed to creating containers directly). Each Pod is tied to the Node where it is scheduled, and remains there until termination (according to restart policy) or deletion. In case of a Node failure, identical Pods are scheduled on other available Nodes in the cluster.

## Summary:

- Pods
- Nodes
- Kubectl main commands

*A Pod is a group of one or more application containers (such as Docker or rkt) and includes shared storage (volumes), IP address and information about how to run them.*

## Pods overview



# Nodes

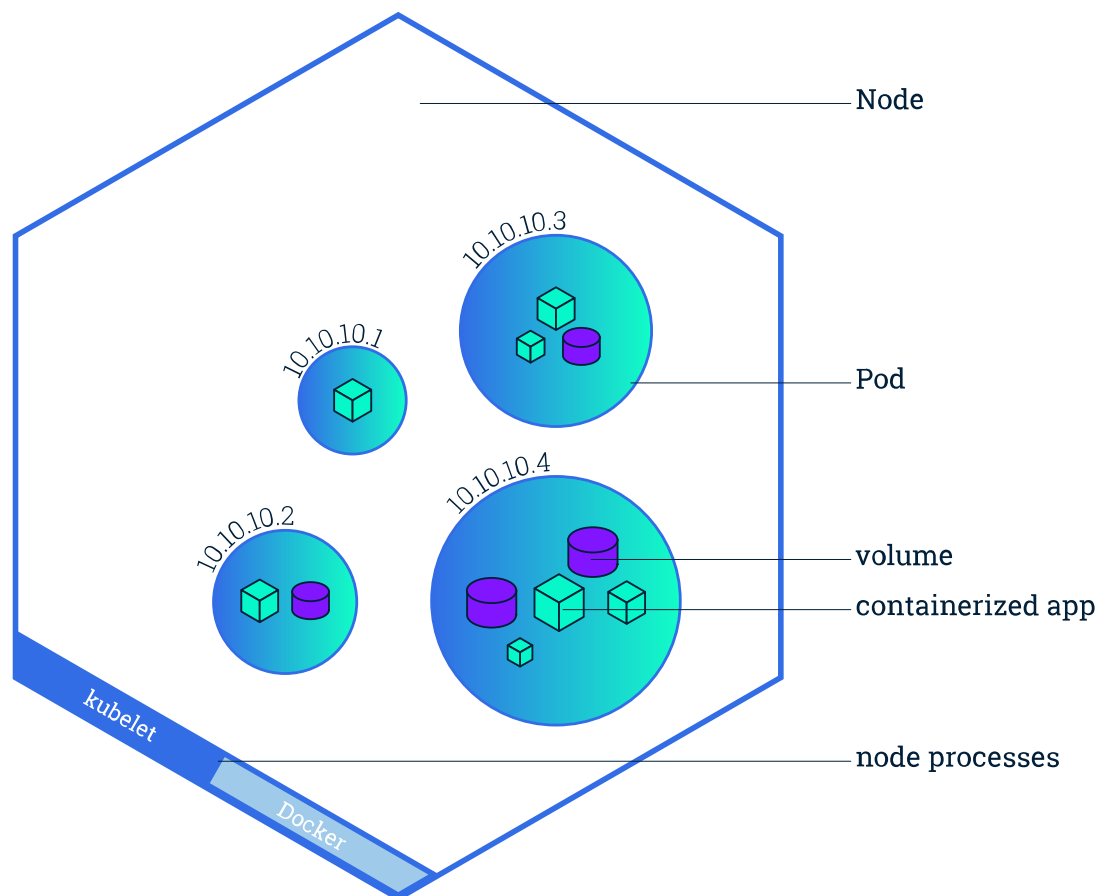
A Pod always runs on a **Node**. A Node is a worker machine in Kubernetes and may be either a virtual or a physical machine, depending on the cluster. Each Node is managed by the Master. A Node can have multiple pods, and the Kubernetes master automatically handles scheduling the pods across the Nodes in the cluster. The Master's automatic scheduling takes into account the available resources on each Node.

Every Kubernetes Node runs at least:

- Kubelet, a process responsible for communication between the Kubernetes Master and the Node; it manages the Pods and the containers running on a machine.
- A container runtime (like Docker, rkt) responsible for pulling the container image from a registry, unpacking the container, and running the application.

*Containers should only be scheduled together in a single Pod if they are tightly coupled and need to share resources such as disk.*

## Node overview





## Troubleshooting with kubectl

In Module 2, you used Kubectl command-line interface. You'll continue to use it in Module 3 to get information about deployed applications and their environments. The most common operations can be done with the following kubectl commands:

- **kubectl get** - list resources
- **kubectl describe** - show detailed information about a resource
- **kubectl logs** - print the logs from a container in a pod
- **kubectl exec** - execute a command on a container in a pod

You can use these commands to see when applications were deployed, what their current statuses are, where they are running and what their configurations are.

Now that we know more about our cluster components and the command line, let's explore our application.

*A node is a worker machine in Kubernetes and may be a VM or physical machine, depending on the cluster. Multiple Pods can run on one Node.*

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## Interactive Tutorial - Exploring Your App

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# Interactive Tutorial - Exposing Your App

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## Running Multiple Instances of Your App

### Objectives

- Scale an app using kubectl.

### Scaling an application

In the previous modules we created a [Deployment](#), and then exposed it publicly via a [Service](#). The Deployment created only one Pod for running our application. When traffic increases, we will need to scale the application to keep up with user demand.

**Scaling** is accomplished by changing the number of replicas in a Deployment

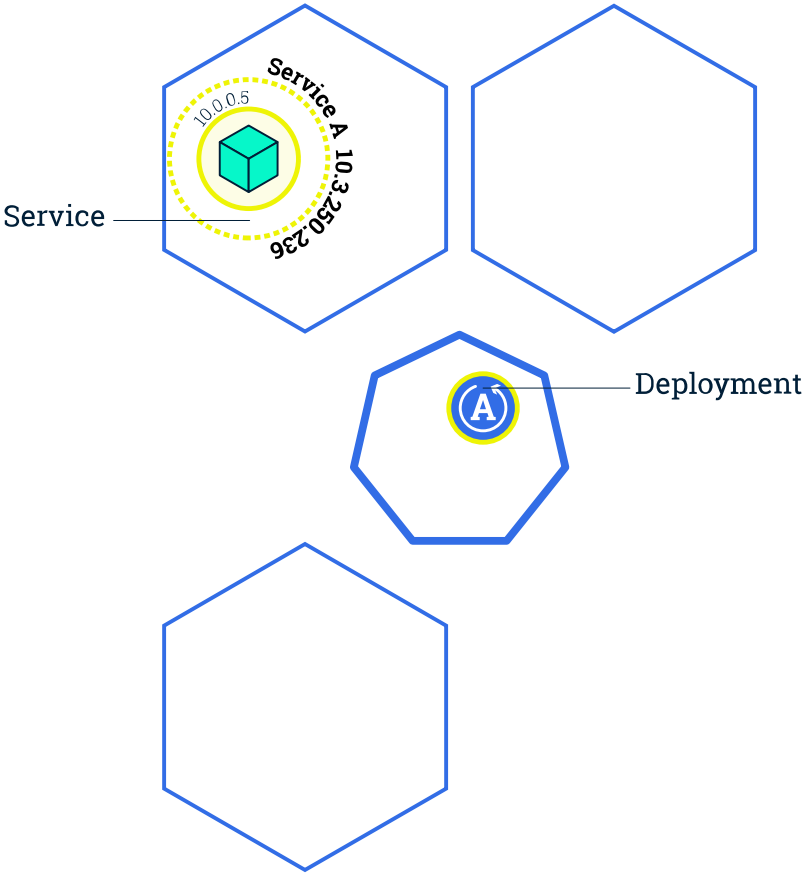
### Summary:

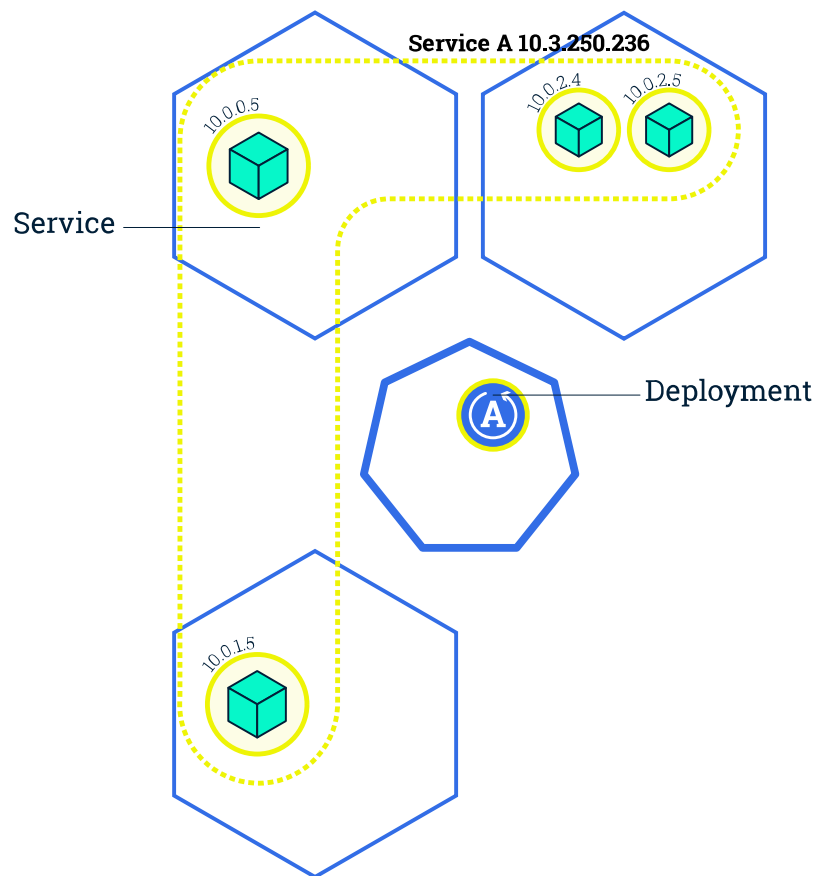
- Scaling a Deployment

*You can create from the start a Deployment with multiple instances using the --replicas parameter for the kubectl run command*

## Scaling overview

1.





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Scaling out a Deployment will ensure new Pods are created and scheduled to Nodes with available resources. Scaling will increase the number of Pods to the new desired state. Kubernetes also supports [autoscaling](#) of Pods, but it is outside of the scope of this tutorial. Scaling to zero is also possible, and it will terminate all Pods of the specified Deployment.

Running multiple instances of an application will require a way to distribute the traffic to all of them. Services have an integrated load-balancer that will distribute network traffic to all Pods of an exposed Deployment. Services will monitor continuously the running Pods using endpoints, to ensure the traffic is sent only to available Pods.

*Scaling is accomplished by changing the number of replicas in a Deployment.*

Once you have multiple instances of an Application running, you would be able to do Rolling updates without downtime. We'll cover that in the next module. Now, let's go to the online terminal and scale our application.

[Start Interactive Tutorial](#) â€°

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## Interactive Tutorial - Scaling Your App

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## Performing a Rolling Update

### Objectives

- Perform a rolling update using kubectl.

### Updating an application

Users expect applications to be available all the time and developers are expected to deploy new versions of them several times a day. In Kubernetes this is done with rolling updates.

**Rolling updates** allow Deployments' update to take place with zero downtime by incrementally updating Pods instances with new ones. The new Pods will be scheduled on Nodes with available resources.

In the previous module we scaled our application to run multiple instances. This is a requirement for performing updates without affecting application availability. By default, the maximum number of Pods that can be unavailable during the update and the maximum number of new Pods that can be created, is one. Both options can be configured to either numbers or percentages (of Pods). In Kubernetes, updates are versioned and any Deployment update can be reverted to previous (stable) version.

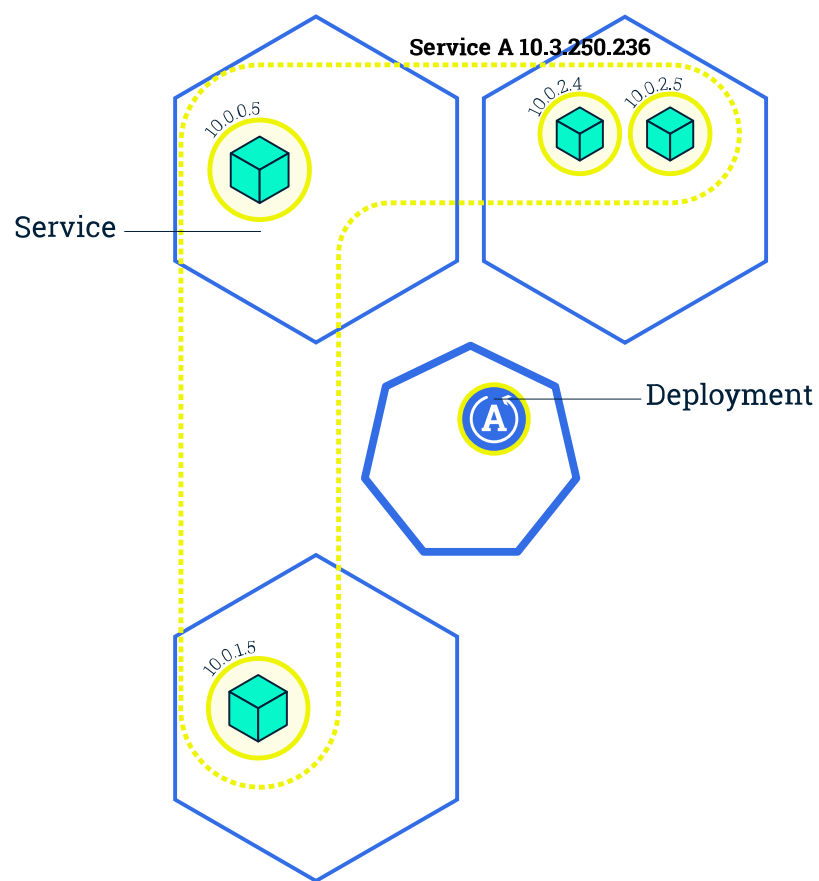
## Summary:

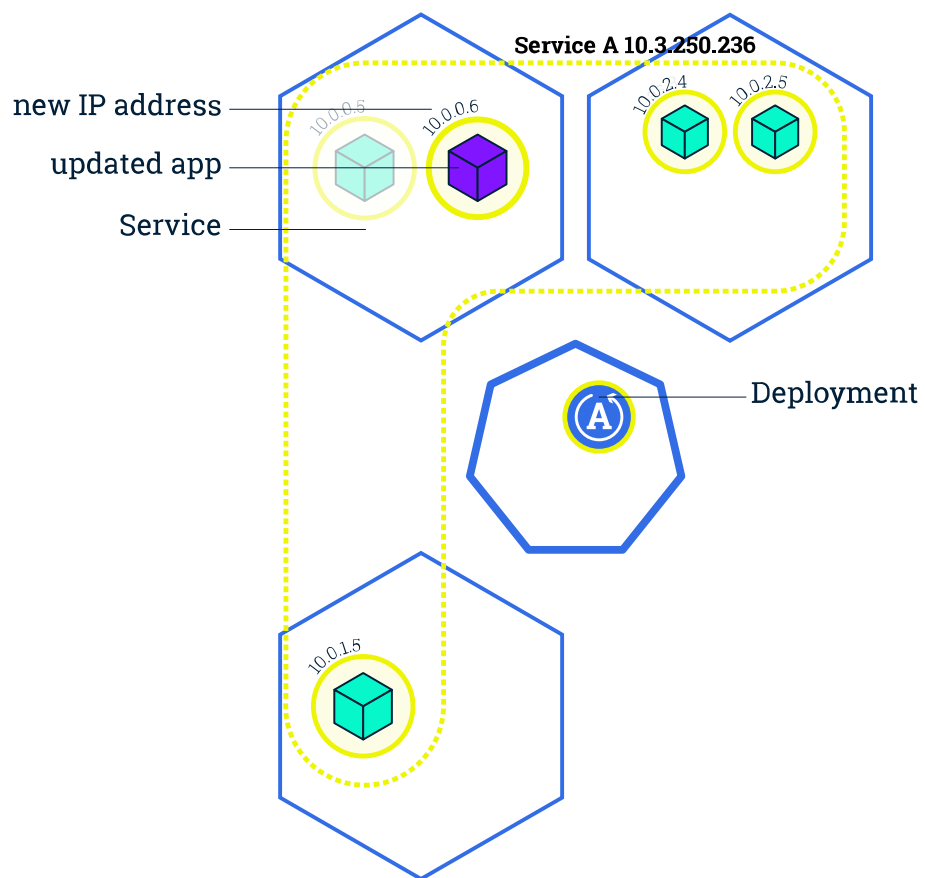
- Updating an app

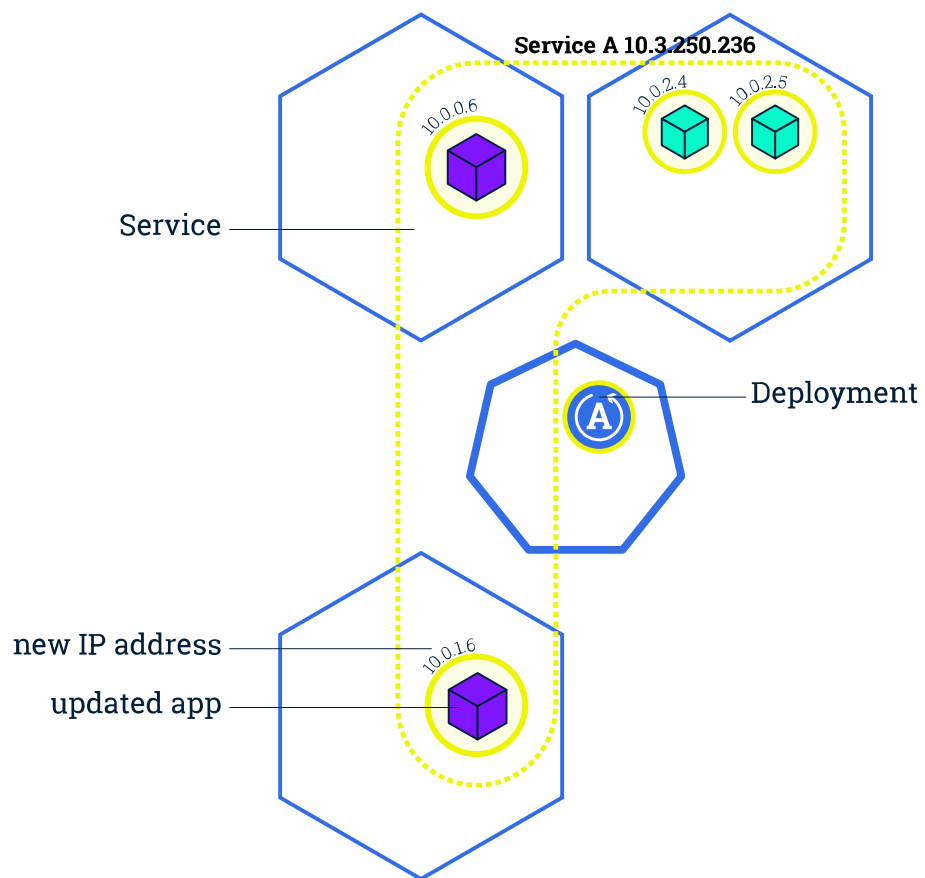
*Rolling updates allow Deployments' update to take place with zero downtime by incrementally updating Pods instances with new ones.*

## Rolling updates overview

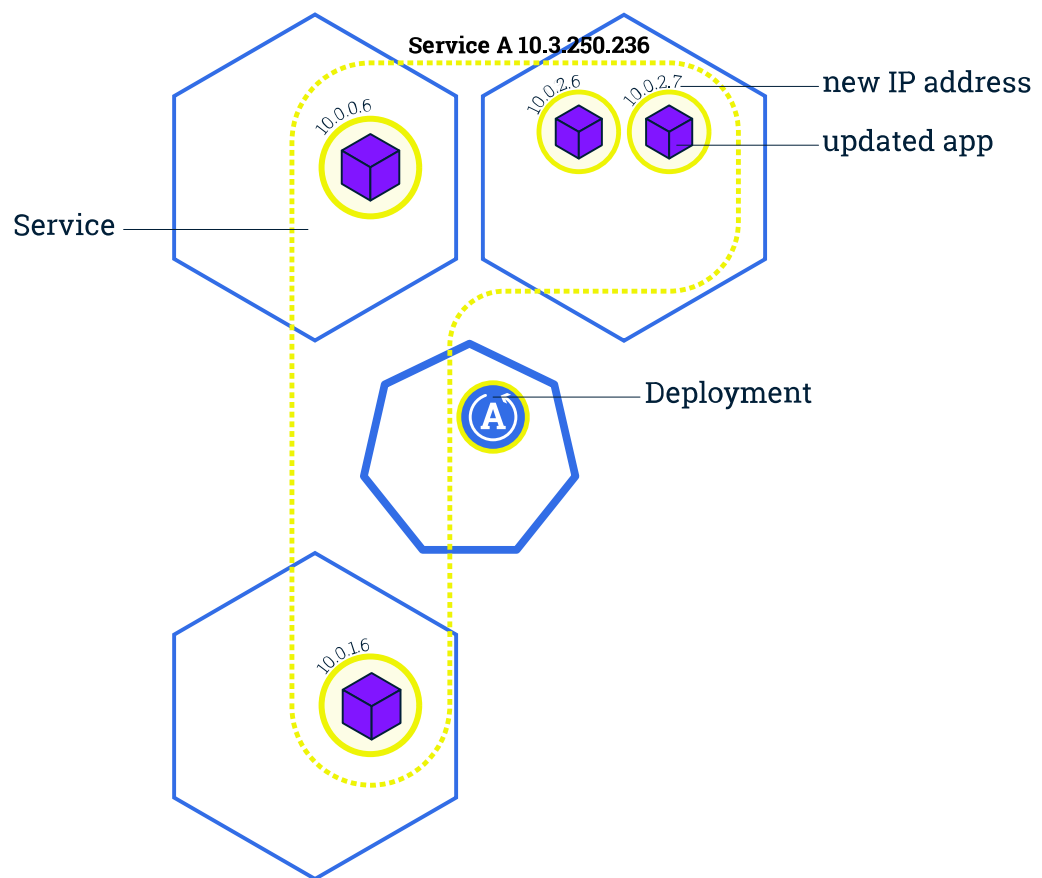
4.











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Similar to application Scaling, if a Deployment is exposed publicly, the Service will load-balance the traffic only to available Pods during the update. An available Pod is an instance that is available to the users of the application.

Rolling updates allow the following actions:

- Promote an application from one environment to another (via container image updates)
- Rollback to previous versions
- Continuous Integration and Continuous Delivery of applications with zero downtime

*If a Deployment is exposed publicly, the Service will load-balance the traffic only to available Pods during the update.*

In the following interactive tutorial, we'll update our application to a new version, and also perform a rollback.

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## Interactive Tutorial - Updating Your App

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## Overview of Kubernetes Online Training

Here are some of the sites that offer online training for Kubernetes:

- [AIOps Essentials \(Autoscaling Kubernetes with Prometheus Metrics\) with Hands-On Labs \(Linux Academy\)](#)
- [Amazon EKS Deep Dive with Hands-On Labs \(Linux Academy\)](#)
- [Cloud Native Certified Kubernetes Administrator \(CKA\) with Hands-On Labs & Practice Exams \(Linux Academy\)](#)
- [Certified Kubernetes Administrator Preparation Course with Practice Tests \(KodeKloud\)](#)
- [Certified Kubernetes Application Developer \(CKAD\) with Hands-On Labs & Practice Exams \(Linux Academy\)](#)
- [Certified Kubernetes Application Developer Preparation Course with Practice Tests \(KodeKloud\)](#)

- [Getting Started with Google Kubernetes Engine \(Coursera\)](#)
- [Getting Started with Kubernetes \(Pluralsight\)](#)
- [Getting Started with Kubernetes Clusters on OCI Oracle Kubernetes Engine \(OKE\) \(Learning Library\)](#)
- [Google Kubernetes Engine Deep Dive \(Linux Academy\)](#)
- [Helm Deep Dive with Hands-On Labs \(Linux Academy\)](#)
- [Hands-on Introduction to Kubernetes \(Instruqt\)](#)
- [IBM Cloud: Deploying Microservices with Kubernetes \(Coursera\)](#)
- [Introduction to Kubernetes \(edX\)](#)
- [Kubernetes Essentials with Hands-On Labs \(Linux Academy\)](#)
- [Kubernetes for the Absolute Beginners with Hands-on Labs \(KodeKloud\)](#)
- [Kubernetes Fundamentals \(LFS258\) \(The Linux Foundation\)](#)
- [Kubernetes Quick Start with Hands-On Labs \(Linux Academy\)](#)
- [Kubernetes the Hard Way with Hands-On Labs \(Linux Academy\)](#)
- [Kubernetes Security with Hands-On Labs \(Linux Academy\)](#)
- [Launch Your First OpenShift Operator with Hands-On Labs \(Linux Academy\)](#)
- [Learn Kubernetes by Doing - 100% Hands-On Experience \(Linux Academy\)](#)
- [Learn Kubernetes using Interactive Hands-on Scenarios \(Katacoda\)](#)
- [Microservice Applications in Kubernetes - 100% Hands-On Experience \(Linux Academy\)](#)
- [Monitoring Kubernetes With Prometheus with Hands-On Labs \(Linux Academy\)](#)
- [Service Mesh with Istio with Hands-On Labs \(Linux Academy\)](#)
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## Feedback

Was this page helpful?

Yes No

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# Configuring Redis using a ConfigMap

This page provides a real world example of how to configure Redis using a ConfigMap and builds upon the [Configure Containers Using a ConfigMap](#) task.

- [Objectives](#)
- [Before you begin](#)
- [Real World Example: Configuring Redis using a ConfigMap](#)
- [What's next](#)

## Objectives

- Create a `kustomization.yaml` file containing:
  - a ConfigMap generator
  - a Pod resource config using the ConfigMap
- Apply the directory by running `kubectl apply -k ./`
- Verify that the configuration was correctly applied.

## Before you begin

- You need to have a Kubernetes cluster, and the `kubectl` command-line tool must be configured to communicate with your cluster. If you do not already have a cluster, you can create one by using [Minikube](#), or you can use one of these Kubernetes playgrounds:
- [Katacoda](#)
- [Play with Kubernetes](#)

To check the version, enter `kubectl version`.

- The example shown on this page works with `kubectl` 1.14 and above.
- Understand [Configure Containers Using a ConfigMap](#).

## Real World Example: Configuring Redis using a ConfigMap

You can follow the steps below to configure a Redis cache using data stored in a ConfigMap.

First create a `kustomization.yaml` containing a ConfigMap from the `redis-config` file:

<a href="#">pods/config/redis-config</a>
<pre>maxmemory 2mb maxmemory-policy allkeys-lru</pre>

```
curl -OL https://k8s.io/examples/pods/config/redis-config

cat <<EOF >./kustomization.yaml
configMapGenerator:
- name: example-redis-config
  files:
  - redis-config
EOF
```

Add the pod resource config to the `kustomization.yaml`:

## [pods/config/redis-pod.yaml](#)

```
apiVersion: v1
kind: Pod
metadata:
  name: redis
spec:
  containers:
  - name: redis
    image: redis:5.0.4
    command:
      - redis-server
      - "/redis-master/redis.conf"
    env:
      - name: MASTER
        value: "true"
    ports:
      - containerPort: 6379
    resources:
      limits:
        cpu: "0.1"
    volumeMounts:
      - mountPath: /redis-master-data
        name: data
      - mountPath: /redis-master
        name: config
  volumes:
  - name: data
    emptyDir: {}
  - name: config
    configMap:
      name: example-redis-config
      items:
        - key: redis-config
          path: redis.conf
```

```
curl -OL https://raw.githubusercontent.com/kubernetes/website/master/content/en/examples/pods/config/redis-pod.yaml
```

```
cat <<EOF >>./kustomization.yaml
resources:
- redis-pod.yaml
EOF
```

Apply the kustomization directory to create both the ConfigMap and Pod objects:

```
kubectl apply -k .
```

Examine the created objects by

```
> kubectl get -k .
```

NAME	DATA	AGE
configmap/example-redis-config-dgh9dg555m	1	52s

NAME	READY	STATUS	RESTARTS	AGE
pod/redis	1/1	Running	0	52s

In the example, the config volume is mounted at `/redis-master`. It uses `path` to add the `redis-config` key to a file named `redis.conf`. The file path for the redis config, therefore, is `/redis-master/redis.conf`. This is where the image will look for the config file for the redis master.

Use `kubectl exec` to enter the pod and run the `redis-cli` tool to verify that the configuration was correctly applied:

```
kubectl exec -it redis redis-cli
127.0.0.1:6379> CONFIG GET maxmemory
1) "maxmemory"
2) "2097152"
127.0.0.1:6379> CONFIG GET maxmemory-policy
1) "maxmemory-policy"
2) "allkeys-lru"
```

Delete the created pod:

```
kubectl delete pod redis
```

## What's next

- Learn more about [ConfigMaps](#).

## Feedback

Was this page helpful?

Yes No

Thanks for the feedback. If you have a specific, answerable question about how to use Kubernetes, ask it on [Stack Overflow](#). Open an issue in the GitHub repo if you want to [report a problem](#) or [suggest an improvement](#).

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# Exposing an External IP Address to Access an Application in a Cluster

This page shows how to create a Kubernetes Service object that exposes an external IP address.

- [Objectives](#)
- [Before you begin](#)
- [Creating a service for an application running in five pods](#)
- [Cleaning up](#)
- [What's next](#)

## Objectives

- Run five instances of a Hello World application.
- Create a Service object that exposes an external IP address.
- Use the Service object to access the running application.

## Before you begin

- Install [kubectl](#).
- Use a cloud provider like Google Kubernetes Engine or Amazon Web Services to create a Kubernetes cluster. This tutorial creates an [external load balancer](#), which requires a cloud provider.
- Configure `kubectl` to communicate with your Kubernetes API server. For instructions, see the documentation for your cloud provider.

## Creating a service for an application running in five pods

1. Run a Hello World application in your cluster:



## [service/load-balancer-example.yaml](#)

```
apiVersion: apps/v1
kind: Deployment
metadata:
  labels:
    app.kubernetes.io/name: load-balancer-example
    name: hello-world
spec:
  replicas: 5
  selector:
    matchLabels:
      app.kubernetes.io/name: load-balancer-example
  template:
    metadata:
      labels:
        app.kubernetes.io/name: load-balancer-example
    spec:
      containers:
        - image: gcr.io/google-samples/node-hello:1.0
          name: hello-world
          ports:
            - containerPort: 8080
```

```
kubectl apply -f https://k8s.io/examples/service/load-balancer-example.yaml
```

The preceding command creates a [Deployment](#) object and an associated [ReplicaSet](#) object. The ReplicaSet has five [Pods](#), each of which runs the Hello World application.

1. Display information about the Deployment:

```
kubectl get deployments hello-world
kubectl describe deployments hello-world
```

2. Display information about your ReplicaSet objects:

```
kubectl get replicaset
kubectl describe replicaset
```

3. Create a Service object that exposes the deployment:

```
kubectl expose deployment hello-world --
type=LoadBalancer --name=my-service
```

4. Display information about the Service:

```
kubectl get services my-service
```

The output is similar to this:

NAME IP	TYPE PORT(S)	AGE AGE	CLUSTER-IP	EXTERNAL -
my-service	LoadBalancer	104.198.205.71	10.3.245.137	
	8080/TCP	54s		

Note: If the external IP address is shown as <pending>, wait for a minute and enter the same command again.

5. Display detailed information about the Service:

```
kubectl describe services my-service
```

The output is similar to this:

```
Name: my-service
Namespace: default
Labels: app.kubernetes.io/name=load-balancer-example
Annotations: <none>
Selector: app.kubernetes.io/name=load-balancer-example
Type: LoadBalancer
IP: 10.3.245.137
LoadBalancer Ingress: 104.198.205.71
Port: <unset> 8080/TCP
NodePort: <unset> 32377/TCP
Endpoints: 10.0.0.6:8080,10.0.1.6:8080,10.0.1.7:8080 + 2 more...
Session Affinity: None
Events: <none>
```

Make a note of the external IP address (LoadBalancer Ingress) exposed by your service. In this example, the external IP address is 104.198.205.71. Also note the value of Port and NodePort. In this example, the Port is 8080 and the NodePort is 32377.

6. In the preceding output, you can see that the service has several endpoints: 10.0.0.6:8080,10.0.1.6:8080,10.0.1.7:8080 + 2 more. These are internal addresses of the pods that are running the Hello World application. To verify these are pod addresses, enter this command:

```
kubectl get pods --output=wide
```

The output is similar to this:

NAME	...	IP	NODE
hello-world-2895499144-1jaz9	...	10.0.1.6	gke-cluster-1-default-pool-e0b8d269-1afc
hello-world-2895499144-2e5uh	...	10.0.1.8	gke-cluster-1-default-pool-e0b8d269-1afc
hello-world-2895499144-9m4h1	...	10.0.0.6	gke-cluster-1-default-pool-e0b8d269-5v7a
hello-world-2895499144-o4z13	...	10.0.1.7	gke-cluster-1-default-pool-e0b8d269-1afc

```
hello-world-2895499144-segjf ... 10.0.2.5 gke-  
cluster-1-default-pool-e0b8d269-cpuc
```

7. Use the external IP address (LoadBalancer Ingress) to access the Hello World application:

```
curl http://<external-ip>:<port>
```

where <external-ip> is the external IP address (LoadBalancer Ingress) of your Service, and <port> is the value of Port in your Service description. If you are using minikube, typing `minikube service my-service` will automatically open the Hello World application in a browser.

The response to a successful request is a hello message:

```
Hello Kubernetes!
```

## Cleaning up

To delete the Service, enter this command:

```
kubectl delete services my-service
```

To delete the Deployment, the ReplicaSet, and the Pods that are running the Hello World application, enter this command:

```
kubectl delete deployment hello-world
```

## What's next

Learn more about [connecting applications with services](#).

## Feedback

Was this page helpful?

Yes No

Thanks for the feedback. If you have a specific, answerable question about how to use Kubernetes, ask it on [Stack Overflow](#). Open an issue in the GitHub repo if you want to [report a problem](#) or [suggest an improvement](#).

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# Example: Deploying PHP Guestbook application with Redis

This tutorial shows you how to build and deploy a simple, multi-tier web application using Kubernetes and [Docker](#). This example consists of the following components:

- A single-instance [Redis](#) master to store guestbook entries
- Multiple [replicated Redis](#) instances to serve reads
- Multiple web frontend instances
- [Objectives](#)
- [Before you begin](#)
- [Start up the Redis Master](#)
- [Start up the Redis Slaves](#)
- [Set up and Expose the Guestbook Frontend](#)
- [Scale the Web Frontend](#)
- [Cleaning up](#)
- [What's next](#)

## Objectives

- Start up a Redis master.
- Start up Redis slaves.
- Start up the guestbook frontend.
- Expose and view the Frontend Service.
- Clean up.

## Before you begin

You need to have a Kubernetes cluster, and the `kubectl` command-line tool must be configured to communicate with your cluster. If you do not already have a cluster, you can create one by using [Minikube](#), or you can use one of these Kubernetes playgrounds:

- [Katacoda](#)
- [Play with Kubernetes](#)

To check the version, enter `kubectl version`.

## Start up the Redis Master

The guestbook application uses Redis to store its data. It writes its data to a Redis master instance and reads data from multiple Redis slave instances.

## Creating the Redis Master Deployment

The manifest file, included below, specifies a Deployment controller that runs a single replica Redis master Pod.

## [application/guestbook/redis-master-deployment.yaml](#)

```
apiVersion: apps/v1 # for versions before 1.9.0 use apps/
v1beta2
kind: Deployment
metadata:
  name: redis-master
  labels:
    app: redis
spec:
  selector:
    matchLabels:
      app: redis
      role: master
      tier: backend
  replicas: 1
  template:
    metadata:
      labels:
        app: redis
        role: master
        tier: backend
    spec:
      containers:
        - name: master
          image: k8s.gcr.io/redis:e2e # or just image: redis
          resources:
            requests:
              cpu: 100m
              memory: 100Mi
          ports:
            - containerPort: 6379
```

1. Launch a terminal window in the directory you downloaded the manifest files.
2. Apply the Redis Master Deployment from the `redis-master-deployment.yaml` file:

```
kubectl apply -f https://k8s.io/examples/application/
guestbook/redis-master-deployment.yaml
```

3. Query the list of Pods to verify that the Redis Master Pod is running:

```
kubectl get pods
```

The response should be similar to this:

NAME	READY	STATUS
RESTARTS    AGE		
redis-master-1068406935-3lswp	1/1	Running    0
28s		

4. Run the following command to view the logs from the Redis Master Pod:

```
kubectl logs -f POD-NAME
```

**Note:** Replace POD-NAME with the name of your Pod.

## Creating the Redis Master Service

The guestbook applications needs to communicate to the Redis master to write its data. You need to apply a [Service](#) to proxy the traffic to the Redis master Pod. A Service defines a policy to access the Pods.

[application/guestbook/redis-master-service.yaml](#)

```
apiVersion: v1
kind: Service
metadata:
  name: redis-master
  labels:
    app: redis
    role: master
    tier: backend
spec:
  ports:
  - port: 6379
    targetPort: 6379
  selector:
    app: redis
    role: master
    tier: backend
```

1. Apply the Redis Master Service from the following `redis-master-service.yaml` file:

```
kubectl apply -f https://k8s.io/examples/application/guestbook/redis-master-service.yaml
```

2. Query the list of Services to verify that the Redis Master Service is running:

```
kubectl get service
```

The response should be similar to this:

NAME	AGE	TYPE	CLUSTER-IP	EXTERNAL-IP	
kubernetes	1m	ClusterIP	10.0.0.1	<none>	4
redis-master	8s	ClusterIP	10.0.0.151	<none>	6

**Note:** This manifest file creates a Service named `redis-master` with a set of labels that match the labels previously defined, so the Service routes network traffic to the Redis master Pod.

## **Start up the Redis Slaves**

Although the Redis master is a single pod, you can make it highly available to meet traffic demands by adding replica Redis slaves.

### **Creating the Redis Slave Deployment**

Deployments scale based off of the configurations set in the manifest file. In this case, the Deployment object specifies two replicas.

If there are not any replicas running, this Deployment would start the two replicas on your container cluster. Conversely, if there are more than two replicas are running, it would scale down until two replicas are running.

## [application/guestbook/redis-slave-deployment.yaml](#)

```
apiVersion: apps/v1 # for versions before 1.9.0 use apps/
v1beta2
kind: Deployment
metadata:
  name: redis-slave
  labels:
    app: redis
spec:
  selector:
    matchLabels:
      app: redis
      role: slave
      tier: backend
  replicas: 2
  template:
    metadata:
      labels:
        app: redis
        role: slave
        tier: backend
    spec:
      containers:
        - name: slave
          image: gcr.io/google_samples/gb-redisslave:v3
          resources:
            requests:
              cpu: 100m
              memory: 100Mi
          env:
            - name: GET_HOSTS_FROM
              value: dns
              # Using `GET_HOSTS_FROM=dns` requires your
cluster to
              # provide a dns service. As of Kubernetes 1.3,
DNS is a built-in
              # service launched automatically. However, if the
cluster you are using
              # does not have a built-in DNS service, you can
instead
              # access an environment variable to find the
master
              # service's host. To do so, comment out the
'value: dns' line above, and
              # uncomment the line below:
              # value: env
            ports:
              - containerPort: 6379
```



1. Apply the Redis Slave Deployment from the `redis-slave-deployment.yaml` file:

```
kubectl apply -f https://k8s.io/examples/application/guestbook/redis-slave-deployment.yaml
```

2. Query the list of Pods to verify that the Redis Slave Pods are running:

```
kubectl get pods
```

The response should be similar to this:

NAME	STATUS	RESTARTS	AGE	READY
redis-master-1068406935-3lswp	Running	0	1m	1/1
redis-slave-2005841000-fpvqc	ContainerCreating	0	6s	0/1
redis-slave-2005841000-phfv9	ContainerCreating	0	6s	0/1

## Creating the Redis Slave Service

The guestbook application needs to communicate to Redis slaves to read data. To make the Redis slaves discoverable, you need to set up a Service. A Service provides transparent load balancing to a set of Pods.

[application/guestbook/redis-slave-service.yaml](https://k8s.io/examples/application/guestbook/redis-slave-service.yaml)

```
apiVersion: v1
kind: Service
metadata:
  name: redis-slave
  labels:
    app: redis
    role: slave
    tier: backend
spec:
  ports:
  - port: 6379
  selector:
    app: redis
    role: slave
    tier: backend
```

1. Apply the Redis Slave Service from the following `redis-slave-service.yaml` file:

```
kubectl apply -f https://k8s.io/examples/application/guestbook/redis-slave-service.yaml
```

2. Query the list of Services to verify that the Redis slave service is running:

```
kubectl get services
```

The response should be similar to this:

NAME	AGE	TYPE	CLUSTER-IP	EXTERNAL-IP
kubernetes	2m	ClusterIP	10.0.0.1	<none>
redis-master	1m	ClusterIP	10.0.0.151	<none>
redis-slave	6s	ClusterIP	10.0.0.223	<none>

## Set up and Expose the Guestbook Frontend

The guestbook application has a web frontend serving the HTTP requests written in PHP. It is configured to connect to the `redis-master` Service for write requests and the `redis-slave` service for Read requests.

## Creating the Guestbook Frontend Deployment

[application/guestbook/frontend-deployment.yaml](#)

```
apiVersion: apps/v1 # for versions before 1.9.0 use apps/
v1beta2
kind: Deployment
metadata:
  name: frontend
  labels:
    app: guestbook
spec:
  selector:
    matchLabels:
      app: guestbook
      tier: frontend
  replicas: 3
  template:
    metadata:
      labels:
        app: guestbook
        tier: frontend
    spec:
      containers:
        - name: php-redis
          image: gcr.io/google-samples/gb-frontend:v4
          resources:
            requests:
              cpu: 100m
              memory: 100Mi
          env:
            - name: GET_HOSTS_FROM
              value: dns
              # Using `GET_HOSTS_FROM=dns` requires your
cluster to
              # provide a dns service. As of Kubernetes 1.3,
DNS is a built-in
              # service launched automatically. However, if the
cluster you are using
              # does not have a built-in DNS service, you can
instead
              # access an environment variable to find the
master
              # service's host. To do so, comment out the
'value: dns' line above, and
              # uncomment the line below:
              # value: env
            ports:
              - containerPort: 80
```

1. Apply the frontend Deployment from the `frontend-deployment.yaml` file:

```
kubectl apply -f https://k8s.io/examples/application/guestbook/frontend-deployment.yaml
```

2. Query the list of Pods to verify that the three frontend replicas are running:

```
kubectl get pods -l app=guestbook -l tier=frontend
```

The response should be similar to this:

NAME	READY	STATUS
RESTARTS    AGE		
0            frontend-3823415956-dsvc5	1/1	Running
0            frontend-3823415956-k22zn	1/1	Running
0            frontend-3823415956-w9gbt	1/1	Running

## Creating the Frontend Service

The `redis-slave` and `redis-master` Services you applied are only accessible within the container cluster because the default type for a Service is [ClusterIP](#). `ClusterIP` provides a single IP address for the set of Pods the Service is pointing to. This IP address is accessible only within the cluster.

If you want guests to be able to access your guestbook, you must configure the frontend Service to be externally visible, so a client can request the Service from outside the container cluster. Minikube can only expose Services through `NodePort`.

**Note:** Some cloud providers, like Google Compute Engine or Google Kubernetes Engine, support external load balancers. If your cloud provider supports load balancers and you want to use it, simply delete or comment out `type: NodePort`, and uncomment `type: LoadBalancer`.

## [application/guestbook/frontend-service.yaml](#)

```
apiVersion: v1
kind: Service
metadata:
  name: frontend
  labels:
    app: guestbook
    tier: frontend
spec:
  # comment or delete the following line if you want to use
  # a LoadBalancer
  type: NodePort
  # if your cluster supports it, uncomment the following to
  # automatically create
  # an external load-balanced IP for the frontend service.
  # type: LoadBalancer
  ports:
  - port: 80
  selector:
    app: guestbook
    tier: frontend
```

1. Apply the frontend Service from the frontend-service.yaml file:

```
kubectl apply -f https://k8s.io/examples/application/
guestbook/frontend-service.yaml
```

2. Query the list of Services to verify that the frontend Service is running:

```
kubectl get services
```

The response should be similar to this:

NAME	TYPE	CLUSTER-IP	EXTERNAL-IP
PORT(S)	AGE		
frontend	NodePort	10.0.0.112	<none>
80:31323/TCP	6s		
kubernetes	ClusterIP	10.0.0.1	<none>
443/TCP	4m		
redis-master	ClusterIP	10.0.0.151	<none>
6379/TCP	2m		
redis-slave	ClusterIP	10.0.0.223	<none>
6379/TCP	1m		

## Viewing the Frontend Service via NodePort

If you deployed this application to Minikube or a local cluster, you need to find the IP address to view your Guestbook.

1. Run the following command to get the IP address for the frontend Service.

```
minikube service frontend --url
```

The response should be similar to this:

```
http://192.168.99.100:31323
```

2. Copy the IP address, and load the page in your browser to view your guestbook.

## Viewing the Frontend Service via LoadBalancer

If you deployed the `frontend-service.yaml` manifest with type: `LoadBalancer` you need to find the IP address to view your Guestbook.

1. Run the following command to get the IP address for the frontend Service.

```
kubectl get service frontend
```

The response should be similar to this:

NAME	TYPE	CLUSTER-IP	EXTERNAL -
IP	PORT(S)	AGE	
frontend	ClusterIP	10.51.242.136	
109.197.92.229	80:32372/TCP	1m	

2. Copy the external IP address, and load the page in your browser to view your guestbook.

## Scale the Web Frontend

Scaling up or down is easy because your servers are defined as a Service that uses a Deployment controller.

1. Run the following command to scale up the number of frontend Pods:

```
kubectl scale deployment frontend --replicas=5
```

2. Query the list of Pods to verify the number of frontend Pods running:

```
kubectl get pods
```

The response should look similar to this:

NAME	READY	STATUS
0 frontend-3823415956-70qj5	1/1	Running
0 frontend-3823415956-dsvc5	1/1	Running
0 frontend-3823415956-k22zn	1/1	Running
0 frontend-3823415956-w9gbt	1/1	Running
0 frontend-3823415956-x2pld	1/1	Running

0	5s	redis-master-1068406935-3lswp	1/1	Running
0	56m	redis-slave-2005841000-fpvqc	1/1	Running
0	55m	redis-slave-2005841000-phfv9	1/1	Running
0	55m			

- Run the following command to scale down the number of frontend Pods:

```
kubectl scale deployment frontend --replicas=2
```

- Query the list of Pods to verify the number of frontend Pods running:

```
kubectl get pods
```

The response should look similar to this:

NAME	READY	STATUS
RESTARTS AGE		
0 frontend-3823415956-k22zn	1/1	Running
0 frontend-3823415956-w9gbt	1/1	Running
0 redis-master-1068406935-3lswp	1/1	Running
0 redis-slave-2005841000-fpvqc	1/1	Running
0 redis-slave-2005841000-phfv9	1/1	Running
0		

## Cleaning up

Deleting the Deployments and Services also deletes any running Pods. Use labels to delete multiple resources with one command.

- Run the following commands to delete all Pods, Deployments, and Services.

```
kubectl delete deployment -l app=redis
kubectl delete service -l app=redis
kubectl delete deployment -l app=guestbook
kubectl delete service -l app=guestbook
```

The responses should be:

```
deployment.apps "redis-master" deleted
deployment.apps "redis-slave" deleted
service "redis-master" deleted
service "redis-slave" deleted
deployment.apps "frontend" deleted
service "frontend" deleted
```

- Query the list of Pods to verify that no Pods are running:

```
kubectl get pods
```

The response should be this:

```
No resources found.
```

## What's next

- Add [ELK logging and monitoring](#) to your Guestbook application
- Complete the [Kubernetes Basics](#) Interactive Tutorials
- Use Kubernetes to create a blog using [Persistent Volumes for MySQL and Wordpress](#)
- Read more about [connecting applications](#)
- Read more about [Managing Resources](#)

## Feedback

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Page last modified on April 30, 2019 at 3:38 PM PST by [Add a page expanding the PHP Guestbook with Redis example to include logs and metrics \(#13889\)](#) ([Page History](#))

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## Example: Add logging and metrics to the PHP / Redis Guestbook example

This tutorial builds upon the [PHP Guestbook with Redis](#) tutorial. Lightweight log, metric, and network data open source shippers, or *Beats*, from Elastic are deployed in the same Kubernetes cluster as the guestbook. The Beats collect, parse, and index the data into Elasticsearch so that you can view and analyze the resulting operational information in Kibana. This example consists of the following components:

- A running instance of the [PHP Guestbook with Redis tutorial](#)
- Elasticsearch and Kibana
- Filebeat
- Metricbeat
- Packetbeat
- [Objectives](#)
- [Before you begin](#)
- [Start up the PHP Guestbook with Redis](#)



- [Add a Cluster role binding](#)
- [Install kube-state-metrics](#)
- [Clone the Elastic examples GitHub repo](#)
- [Create a Kubernetes Secret](#)
- [Managed service](#)
- [Deploy the Beats](#)
- [View in Kibana](#)
- [Scale your deployments and see new pods being monitored](#)
- [View the changes in Kibana](#)
- [Cleaning up](#)
- [What's next](#)

## Objectives

- Start up the PHP Guestbook with Redis.
- Install kube-state-metrics.
- Create a Kubernetes secret.
- Deploy the Beats.
- View dashboards of your logs and metrics.

## Before you begin

You need to have a Kubernetes cluster, and the `kubectl` command-line tool must be configured to communicate with your cluster. If you do not already have a cluster, you can create one by using [Minikube](#), or you can use one of these Kubernetes playgrounds:

- [Katacoda](#)
- [Play with Kubernetes](#)

To check the version, enter `kubectl version`.

Additionally you need:

- A running deployment of the [PHP Guestbook with Redis](#) tutorial.
- A running Elasticsearch and Kibana deployment. You can use [Elasticsearch Service in Elastic Cloud](#), run the [download files](#) on your workstation or servers, or the [Elastic Helm Charts](#).

## Start up the PHP Guestbook with Redis

This tutorial builds on the [PHP Guestbook with Redis](#) tutorial. If you have the guestbook application running, then you can monitor that. If you do not have it running then follow the instructions to deploy the guestbook and do not perform the **Cleanup** steps. Come back to this page when you have the guestbook running.

## Add a Cluster role binding

Create a [cluster level role binding](#) so that you can deploy kube-state-metrics and the Beats at the cluster level (in kube-system).

```
kubectl create clusterrolebinding cluster-admin-binding \
  --clusterrole=cluster-admin --user=<your email associated
with the k8s provider account>
```

## Install kube-state-metrics

Kubernetes [kube-state-metrics](#) is a simple service that listens to the Kubernetes API server and generates metrics about the state of the objects. Metricbeat reports these metrics. Add kube-state-metrics to the Kubernetes cluster that the guestbook is running in.

### Check to see if kube-state-metrics is running

```
kubectl get pods --namespace=kube-system | grep kube-state
```

### Install kube-state-metrics if needed

```
git clone https://github.com/kubernetes/kube-state-
metrics.git kube-state-metrics
kubectl create -f kube-state-metrics/kubernetes
kubectl get pods --namespace=kube-system | grep kube-state
```

Verify that kube-state-metrics is running and ready

```
kubectl get pods -n kube-system -l k8s-app=kube-state-metrics
```

Output:

NAME	READY	STATUS
RESTARTS    AGE		
kube-state-metrics-89d656bf8-vdthm	2/2	Running
21s		0

## Clone the Elastic examples GitHub repo

```
git clone https://github.com/elastic/examples.git
```

The rest of the commands will reference files in the `examples/beats-k8s-send-anywhere` directory, so change dir there:

```
cd examples/beats-k8s-send-anywhere
```

## Create a Kubernetes Secret

A Kubernetes [SecretStores sensitive information, such as passwords, OAuth tokens, and ssh keys](#) is an object that contains a small amount of sensitive data such as a password, a token, or a key. Such information might otherwise be put in a Pod specification or in an image; putting it in a Secret object allows for more control over how it is used, and reduces the risk of accidental exposure.

**Note:** There are two sets of steps here, one for *self managed* Elasticsearch and Kibana (running on your servers or using the Elastic Helm Charts), and a

second separate set for the *managed service* Elasticsearch Service in Elastic Cloud. Only create the secret for the type of Elasticsearch and Kibana system that you will use for this tutorial.

- [Self Managed](#)
- [Managed service](#)

## Self managed

Switch to the **Managed service** tab if you are connecting to Elasticsearch Service in Elastic Cloud.

## Set the credentials

There are four files to edit to create a k8s secret when you are connecting to self managed Elasticsearch and Kibana (self managed is effectively anything other than the managed Elasticsearch Service in Elastic Cloud). The files are:

1. ELASTICSEARCH\_HOSTS
2. ELASTICSEARCH\_PASSWORD
3. ELASTICSEARCH\_USERNAME
4. KIBANA\_HOST

Set these with the information for your Elasticsearch cluster and your Kibana host. Here are some examples

### ELASTICSEARCH\_HOSTS

1. A nodeGroup from the Elastic Elasticsearch Helm Chart:

```
[ "http://elasticsearch-master.default.svc.cluster.local:9200" ]
```

2. A single Elasticsearch node running on a Mac where your Beats are running in Docker for Mac:

```
[ "http://host.docker.internal:9200" ]
```

3. Two Elasticsearch nodes running in VMs or on physical hardware:

```
[ "http://host1.example.com:9200", "http://host2.example.com:9200" ]
```

Edit ELASTICSEARCH\_HOSTS

```
vi ELASTICSEARCH_HOSTS
```

### ELASTICSEARCH\_PASSWORD

Just the password; no whitespace, quotes, or <>:

```
<yoursecretpassword>
```

Edit ELASTICSEARCH\_PASSWORD

```
vi ELASTICSEARCH_PASSWORD
```

## ELASTICSEARCH\_USERNAME

Just the username; no whitespace, quotes, or <>:

```
<your ingest username for Elasticsearch>
```

Edit ELASTICSEARCH\_USERNAME

```
vi ELASTICSEARCH_USERNAME
```

## KIBANA\_HOST

1. The Kibana instance from the Elastic Kibana Helm Chart. The subdomain `default` refers to the default namespace. If you have deployed the Helm Chart using a different namespace, then your subdomain will be different:

```
"kibana-kibana.default.svc.cluster.local:5601"
```

2. A Kibana instance running on a Mac where your Beats are running in Docker for Mac:

```
"host.docker.internal:5601"
```

3. Two Elasticsearch nodes running in VMs or on physical hardware:

```
"host1.example.com:5601"
```

Edit KIBANA\_HOST

```
vi KIBANA_HOST
```

## Create a Kubernetes secret

This command creates a secret in the Kubernetes system level namespace (kube-system) based on the files you just edited:

```
kubectl create secret generic dynamic-logging \
  --from-file=./ELASTICSEARCH_HOSTS \
  --from-file=./ELASTICSEARCH_PASSWORD \
  --from-file=./ELASTICSEARCH_USERNAME \
  --from-file=./KIBANA_HOST \
  --namespace=kube-system
```

## Managed service

This tab is for Elasticsearch Service in Elastic Cloud only, if you have already created a secret for a self managed Elasticsearch and Kibana deployment, then continue with [Deploy the Beats](#).

## Set the credentials

There are two files to edit to create a k8s secret when you are connecting to the managed Elasticsearch Service in Elastic Cloud. The files are:

1. ELASTIC\_CLOUD\_AUTH
2. ELASTIC\_CLOUD\_ID

Set these with the information provided to you from the Elasticsearch Service console when you created the deployment. Here are some examples:

### ELASTIC\_CLOUD\_ID

```
devk8s:ABC123def456ghi789jkl123mno456pqr789stu123vwx456yza789bcd012efg345hijj678klm901nop345zEwOTJjMTc5YWQ0YzQ50ThlN2U5MjAwYTg4NTIzZQ==
```

### ELASTIC\_CLOUD\_AUTH

Just the username, a colon (:), and the password, no whitespace or quotes:

```
elastic:VFxJJf9Tjwer90wnfTghsn8w
```

## Edit the required files:

```
vi ELASTIC_CLOUD_ID
vi ELASTIC_CLOUD_AUTH
```

## Create a Kubernetes secret

This command creates a secret in the Kubernetes system level namespace (kube-system) based on the files you just edited:

```
kubectl create secret generic dynamic-logging \
  --from-file=./ELASTIC_CLOUD_ID \
  --from-file=./ELASTIC_CLOUD_AUTH \
  --namespace=kube-system
```

## Deploy the Beats

Manifest files are provided for each Beat. These manifest files use the secret created earlier to configure the Beats to connect to your Elasticsearch and Kibana servers.

### About Filebeat

Filebeat will collect logs from the Kubernetes nodes and the containers running in each pod running on those nodes. Filebeat is deployed as a [DaemonSetEnsures a copy of a Pod is running across a set of nodes in a cluster](#). Filebeat can autodiscover applications running in your Kubernetes cluster. At startup Filebeat scans existing containers and launches the proper configurations for them, then it will watch for new start/stop events.

Here is the autodiscover configuration that enables Filebeat to locate and parse Redis logs from the Redis containers deployed with the guestbook application. This configuration is in the file `filebeat-kubernetes.yaml`:

```
- condition.contains:
  kubernetes.labels.app: redis
  config:
    - module: redis
      log:
        input:
          type: docker
          containers.ids:
            - ${data.kubernetes.container.id}
        slowlog:
          enabled: true
          var.hosts: ["${data.host}:${data.port}"]
```

This configures Filebeat to apply the Filebeat module `redis` when a container is detected with a label `app` containing the string `redis`. The `redis` module has the ability to collect the `log` stream from the container by using the `docker` input type (reading the file on the Kubernetes node associated with the `STDOUT` stream from this Redis container). Additionally, the module has the ability to collect Redis `slowlog` entries by connecting to the proper pod host and port, which is provided in the container metadata.

## Deploy Filebeat:

```
kubectl create -f filebeat-kubernetes.yaml
```

## Verify

```
kubectl get pods -n kube-system -l k8s-app=filebeat-dynamic
```

## About Metricbeat

Metricbeat autodiscover is configured in the same way as Filebeat. Here is the Metricbeat autodiscover configuration for the Redis containers. This configuration is in the file `metricbeat-kubernetes.yaml`:

```
- condition.equals:
  kubernetes.labels.tier: backend
  config:
    - module: redis
      metricsets: ["info", "keyspace"]
      period: 10s

      # Redis hosts
      hosts: ["${data.host}:${data.port}"]
```

This configures Metricbeat to apply the Metricbeat module `redis` when a container is detected with a label `tier` equal to the string `backend`. The `redis` module has the ability to collect the `info` and `keyspace` metrics from the container by connecting to the proper pod host and port, which is provided in the container metadata.

## Deploy Metricbeat

```
kubectl create -f metricbeat-kubernetes.yaml
```

### Verify

```
kubectl get pods -n kube-system -l k8s-app=metricbeat
```

## About Packetbeat

Packetbeat configuration is different than Filebeat and Metricbeat. Rather than specify patterns to match against container labels the configuration is based on the protocols and port numbers involved. Shown below is a subset of the port numbers.

**Note:** If you are running a service on a non-standard port add that port number to the appropriate type in `filebeat.yaml` and delete / create the Packetbeat DaemonSet.

```
packetbeat.interfaces.device: any
```

```
packetbeat.protocols:
```

- type: dns  
ports: [53]  
include\_authorities: true  
include\_additional: true
- type: http  
ports: [80, 8000, 8080, 9200]
- type: mysql  
ports: [3306]
- type: redis  
ports: [6379]

```
packetbeat.flows:
```

```
timeout: 30s  
period: 10s
```

## Deploy Packetbeat

```
kubectl create -f packetbeat-kubernetes.yaml
```

### Verify

```
kubectl get pods -n kube-system -l k8s-app=packetbeat-dynamic
```

## View in Kibana

Open Kibana in your browser and then open the **Dashboard** application. In the search bar type Kubernetes and click on the Metricbeat dashboard for Kubernetes. This dashboard reports on the state of your Nodes, deployments, etc.

Search for Packetbeat on the Dashboard page, and view the Packetbeat overview.

Similarly, view dashboards for Apache and Redis. You will see dashboards for logs and metrics for each. The Apache Metricbeat dashboard will be blank. Look at the Apache Filebeat dashboard and scroll to the bottom to view the Apache error logs. This will tell you why there are no metrics available for Apache.

To enable Metricbeat to retrieve the Apache metrics, enable server-status by adding a ConfigMap including a mod-status configuration file and re-deploy the guestbook.

## Scale your deployments and see new pods being monitored

List the existing deployments:

```
kubectl get deployments
```

The output:

NAME	READY	UP-TO-DATE	AVAILABLE	AGE
frontend	3/3	3	3	3h27m
redis-master	1/1	1	1	3h27m
redis-slave	2/2	2	2	3h27m

Scale the frontend down to two pods:

```
kubectl scale --replicas=2 deployment/frontend
```

The output:

```
deployment.extensions/frontend scaled
```

## View the changes in Kibana

See the screenshot, add the indicated filters and then add the columns to the view. You can see the ScalingReplicaSet entry that is marked, following from there to the top of the list of



The screenshot shows the Kibana interface with the following components:

- Search Bar:** Contains the query `metricset.module: "kubernetes" metricset.name: "event"`.
- Left Sidebar:**
  - Discover:** Selected view.
  - Visualize:** Option to create visualizations.
  - Dashboard:** Option to create dashboards.
  - Timeline:** Option to view event timelines.
  - Graph:** Option to create graphs.
  - Dev Tools:** Option to view developer tools.
  - Monitoring:** Option to view monitoring dashboards.
  - Management:** Option to manage the cluster.
- Main Area:**
  - Selected Fields:** `kubernetes.event.message`, `kubernetes.event.reason`.
  - Available Fields:** `@timestamp`, `_id`, `_index`, `_score`, `_type`, `beat.hostname`, `beat.name`, `beat.version`, `# kubernetes.event.count`, `kubernetes.event.involved...`, `kubernetes.event.involved...`, `kubernetes.event.involved...`.
  - Bar Chart:** Shows event counts over time. The x-axis is labeled `@timestamp per 30 seconds`. The y-axis is labeled `Count`.
  - Table:**

Time	kubernetes.event.message	kubernetes.event.reason
June 12th 2018, 20:20:06.209	Started container	Started
June 12th 2018, 20:20:06.061	Created container	Created
June 12th 2018, 20:20:06.001	Container image "gcr.io/google-samples/gb-frontend:v4" already present on machine	Pulled
June 12th 2018, 20:20:05.280	MountVolume.Setup succeeded for volume "default-token-ffr9w"	SuccessfulMountVolume
June 12th 2018, 20:20:05.245	MountVolume.Setup succeeded for volume "mod-status-config"	SuccessfulMountVolume
June 12th 2018, 20:20:05.239	MountVolume.Setup succeeded for volume "apache2-config"	SuccessfulMountVolume
June 12th 2018, 20:20:05.012	Successfully assigned frontend-789df695fb-jtwmq to 10.73.90.150	Scheduled
June 12th 2018, 20:20:05.008	Created pod: frontend-789df695fb-jtwmq	SuccessfulCreate
June 12th 2018, 20:20:05.002	Scaled up replica set frontend-789df695fb to 3	ScalingReplicaSet

Deleting the Deployments and Services also deletes any running Pods. Use labels to delete multiple resources with one command.

- ```
kubectl delete deployment -l app=redis
kubectl delete service -l app=redis
kubectl delete deployment -l app=guestbook
kubectl delete service -l app=guestbook
kubectl delete -f filebeat-kubernetes.yaml
kubectl delete -f metricbeat-kubernetes.yaml
kubectl delete -f packetbeat-kubernetes.yaml
kubectl delete secret dynamic-logging -n kube-system
```

- ```
kubectl get pods
```

No resources found.

- Learn about [tools for monitoring resources](#)
- Read more about [logging architecture](#)
- Read more about [application introspection and debugging](#)
- Read more about [troubleshoot applications](#)

## Yes No

Thanks for the feedback. If you have a specific, answerable question about how to use Kubernetes, ask it on [Stack Overflow](#). Open an issue in the GitHub repo if you want to [report a problem](#) or [suggest an improvement](#).

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Page last modified on June 06, 2019 at 10:44 AM PST by [Update guestbook-logs-metrics-with-elk.md \(#14755\)](#) ([Page History](#))

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# Example: Deploying WordPress and MySQL with Persistent Volumes

This tutorial shows you how to deploy a WordPress site and a MySQL database using Minikube. Both applications use PersistentVolumes and PersistentVolumeClaims to store data.

A [PersistentVolume](#) (PV) is a piece of storage in the cluster that has been manually provisioned by an administrator, or dynamically provisioned by Kubernetes using a [StorageClass](#). A [PersistentVolumeClaim](#) (PVC) is a request for storage by a user that can be fulfilled by a PV. PersistentVolumes and PersistentVolumeClaims are independent from Pod lifecycles and preserve data through restarting, rescheduling, and even deleting Pods.

**Warning:** This deployment is not suitable for production use cases, as it uses single instance WordPress and MySQL Pods. Consider using [WordPress Helm Chart](#) to deploy WordPress in production.

**Note:** The files provided in this tutorial are using GA Deployment APIs and are specific to kubernetes version 1.9 and later. If you wish to use this tutorial with an earlier version of Kubernetes, please update the API version appropriately, or reference earlier versions of this tutorial.

- [Objectives](#)
- [Before you begin](#)
- [Create PersistentVolumeClaims and PersistentVolumes](#)
- [Create a kustomization.yaml](#)
- [Add resource configs for MySQL and WordPress](#)
- [Apply and Verify](#)
- [Cleaning up](#)
- [What's next](#)

## Objectives

- Create PersistentVolumeClaims and PersistentVolumes
- Create a `kustomization.yaml` with
  - a Secret generator
  - MySQL resource configs
  - WordPress resource configs

- Apply the customization directory by `kubectl apply -k ./`
- Clean up

## Before you begin

You need to have a Kubernetes cluster, and the `kubectl` command-line tool must be configured to communicate with your cluster. If you do not already have a cluster, you can create one by using [Minikube](#), or you can use one of these Kubernetes playgrounds:

- [Katacoda](#)
- [Play with Kubernetes](#)

To check the version, enter `kubectl version`.

The example shown on this page works with `kubectl` 1.14 and above.

Download the following configuration files:

1. [mysql-deployment.yaml](#)
2. [wordpress-deployment.yaml](#)

## Create PersistentVolumeClaims and PersistentVolumes

MySQL and Wordpress each require a PersistentVolume to store data. Their PersistentVolumeClaims will be created at the deployment step.

Many cluster environments have a default StorageClass installed. When a StorageClass is not specified in the PersistentVolumeClaim, the cluster's default StorageClass is used instead.

When a PersistentVolumeClaim is created, a PersistentVolume is dynamically provisioned based on the StorageClass configuration.

**Warning:** In local clusters, the default StorageClass uses the `hostPath` provisioner. `hostPath` volumes are only suitable for development and testing. With `hostPath` volumes, your data lives in `/tmp` on the node the Pod is scheduled onto and does not move between nodes. If a Pod dies and gets scheduled to another node in the cluster, or the node is rebooted, the data is lost.

**Note:** If you are bringing up a cluster that needs to use the `hostPath` provisioner, the `--enable-hostpath-provisioner` flag must be set in the `controller-manager` component.

**Note:** If you have a Kubernetes cluster running on Google Kubernetes Engine, please follow [this guide](#).

# Create a kustomization.yaml

## Add a Secret generator

A [Secret](#) is an object that stores a piece of sensitive data like a password or key. Since 1.14, `kubectl` supports the management of Kubernetes objects using a kustomization file. You can create a Secret by generators in `kustomization.yaml`.

Add a Secret generator in `kustomization.yaml` from the following command. You will need to replace `YOUR_PASSWORD` with the password you want to use.

```
cat <<EOF > ./kustomization.yaml
secretGenerator:
- name: mysql-pass
  literals:
  - password=YOUR_PASSWORD
EOF
```

## Add resource configs for MySQL and WordPress

The following manifest describes a single-instance MySQL Deployment. The MySQL container mounts the PersistentVolume at `/var/lib/mysql`. The `MYSQL_ROOT_PASSWORD` environment variable sets the database password from the Secret.

```

apiVersion: v1
kind: Service
metadata:
  name: wordpress-mysql
  labels:
    app: wordpress
spec:
  ports:
    - port: 3306
  selector:
    app: wordpress
    tier: mysql
  clusterIP: None
---
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: mysql-pv-claim
  labels:
    app: wordpress
spec:
  accessModes:
    - ReadWriteOnce
  resources:
    requests:
      storage: 20Gi
---
apiVersion: apps/v1 # for versions before 1.9.0 use apps/
v1beta2
kind: Deployment
metadata:
  name: wordpress-mysql
  labels:
    app: wordpress
spec:
  selector:
    matchLabels:
      app: wordpress
      tier: mysql
  strategy:
    type: Recreate
  template:
    metadata:
      labels:
        app: wordpress
        tier: mysql
    spec:
      containers:
        - image: mysql:5.6
          name: mysql
          env:
            - name: MYSQL_ROOT_PASSWORD
              valueFrom:
                secretKeyRef:
                  name: mysql-pass
                  key: password
      ports:

```

The following manifest describes a single-instance WordPress Deployment. The WordPress container mounts the PersistentVolume at `/var/www/html` for website data files. The `WORDPRESS_DB_HOST` environment variable sets the name of the MySQL Service defined above, and WordPress will access the database by Service. The `WORDPRESS_DB_PASSWORD` environment variable sets the database password from the Secret `kustomize` generated.

```

apiVersion: v1
kind: Service
metadata:
  name: wordpress
  labels:
    app: wordpress
spec:
  ports:
    - port: 80
  selector:
    app: wordpress
    tier: frontend
  type: LoadBalancer
---
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: wp-pv-claim
  labels:
    app: wordpress
spec:
  accessModes:
    - ReadWriteOnce
  resources:
    requests:
      storage: 20Gi
---
apiVersion: apps/v1 # for versions before 1.9.0 use apps/
v1beta2
kind: Deployment
metadata:
  name: wordpress
  labels:
    app: wordpress
spec:
  selector:
    matchLabels:
      app: wordpress
      tier: frontend
  strategy:
    type: Recreate
  template:
    metadata:
      labels:
        app: wordpress
        tier: frontend
    spec:
      containers:
        - image: wordpress:4.8-apache
          name: wordpress
          env:
            - name: WORDPRESS_DB_HOST
              value: wordpress-mysql
            - name: WORDPRESS_DB_PASSWORD
              valueFrom:
                secretKeyRef:
                  name: mysql-pass

```

1. Download the MySQL deployment configuration file.

```
curl -LO https://k8s.io/examples/application/wordpress/
mysql-deployment.yaml
```

2. Download the WordPress configuration file.

```
curl -LO https://k8s.io/examples/application/wordpress/
wordpress-deployment.yaml
```

3. Add them to `kustomization.yaml` file.

```
cat <<EOF >>./kustomization.yaml
resources:
- mysql-deployment.yaml
- wordpress-deployment.yaml
EOF
```

## Apply and Verify

The `kustomization.yaml` contains all the resources for deploying a WordPress site and a MySQL database. You can apply the directory by

```
kubectl apply -k ./
```

Now you can verify that all objects exist.

1. Verify that the Secret exists by running the following command:

```
kubectl get secrets
```

The response should be like this:

NAME	DATA	AGE
mysql-pass-c57bb4t7mf		
Opaque	1	9s

2. Verify that a PersistentVolume got dynamically provisioned.

```
kubectl get pvc
```

**Note:** It can take up to a few minutes for the PVs to be provisioned and bound.

The response should be like this:

NAME	STATUS	CAPACITY
mysql-pv-claim	Bound	pvc-8cbd7b2e-4044-11e9-b2bb-42010a800002
standard	20Gi	77s
wp-pv-claim	Bound	pvc-8cd0df54-4044-11e9-



b2bb-42010a800002	20Gi	RWO
standard	77s	

3. Verify that the Pod is running by running the following command:

```
kubectl get pods
```

**Note:** It can take up to a few minutes for the Pod's Status to be RUNNING.

The response should be like this:

NAME	READY	STATUS
RESTARTS AGE		
wordpress-mysql-1894417608-x5dzt0	1/1	Running
40s		

4. Verify that the Service is running by running the following command:

```
kubectl get services wordpress
```

The response should be like this:

NAME	TYPE	CLUSTER-IP	EXTERNAL-IP
PORT(S)	AGE		
wordpress	ClusterIP	10.0.0.89	<pending>
80:32406/TCP	4m		

**Note:** Minikube can only expose Services through NodePort. The EXTERNAL-IP is always pending.

5. Run the following command to get the IP Address for the WordPress Service:

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

The response should be like this:

```
http://1.2.3.4:32406
```

6. Copy the IP address, and load the page in your browser to view your site.

You should see the WordPress set up page similar to the following screenshot.



English (United States)

العربية المغربية

العربية

Azərbaycan dili

گۆنئی آذربایجان

Български

বাংলা

Bosanski

Català

Cebuano

Cymraeg

Dansk

Deutsch (Schweiz)

Deutsch (Sie)

Continue

**Warning:** Do not leave your WordPress installation on this page. If another user finds it, they can set up a website on your instance and use it to serve malicious content.

Either install WordPress by creating a username and password or delete your instance.

## Cleaning up

1. Run the following command to delete your Secret, Deployments, Services and PersistentVolumeClaims:

```
kubectl delete -k ./
```

## What's next

- Learn more about [Introspection and Debugging](#)
- Learn more about [Jobs](#)
- Learn more about [Port Forwarding](#)
- Learn how to [Get a Shell to a Container](#)

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## StatefulSet Basics

This tutorial provides an introduction to managing applications with [StatefulSets](#). It demonstrates how to create, delete, scale, and update the Pods of StatefulSets.

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# Objectives

StatefulSets are intended to be used with stateful applications and distributed systems. However, the administration of stateful applications and distributed systems on Kubernetes is a broad, complex topic. In order to demonstrate the basic features of a StatefulSet, and not to conflate the former topic with the latter, you will deploy a simple web application using a StatefulSet.

After this tutorial, you will be familiar with the following.

- How to create a StatefulSet
- How a StatefulSet manages its Pods
- How to delete a StatefulSet
- How to scale a StatefulSet
- How to update a StatefulSet's Pods

## Before you begin

Before you begin this tutorial, you should familiarize yourself with the following Kubernetes concepts.

- [Pods](#)
- [Cluster DNS](#)
- [Headless Services](#)
- [PersistentVolumes](#)
- [PersistentVolume Provisioning](#)
- [StatefulSets](#)
- [kubect CLI](#)

This tutorial assumes that your cluster is configured to dynamically provision PersistentVolumes. If your cluster is not configured to do so, you will have to manually provision two 1 GiB volumes prior to starting this tutorial.

## Creating a StatefulSet

Begin by creating a StatefulSet using the example below. It is similar to the example presented in the [StatefulSets](#) concept. It creates a [Headless Service](#), `nginx`, to publish the IP addresses of Pods in the StatefulSet, `web`.

## [application/web/web.yaml](#)

```
apiVersion: v1
kind: Service
metadata:
  name: nginx
  labels:
    app: nginx
spec:
  ports:
    - port: 80
      name: web
  clusterIP: None
  selector:
    app: nginx
---
apiVersion: apps/v1
kind: StatefulSet
metadata:
  name: web
spec:
  serviceName: "nginx"
  replicas: 2
  selector:
    matchLabels:
      app: nginx
  template:
    metadata:
      labels:
        app: nginx
    spec:
      containers:
        - name: nginx
          image: k8s.gcr.io/nginx-slim:0.8
          ports:
            - containerPort: 80
              name: web
          volumeMounts:
            - name: www
              mountPath: /usr/share/nginx/html
  volumeClaimTemplates:
    - metadata:
        name: www
      spec:
        accessModes: [ "ReadWriteOnce" ]
        resources:
          requests:
            storage: 1Gi
```

Download the example above, and save it to a file named `web.yaml`

You will need to use two terminal windows. In the first terminal, use [kubectl get](#) to watch the creation of the StatefulSet's Pods.

```
kubectl get pods -w -l app=nginx
```

In the second terminal, use [kubectl apply](#) to create the Headless Service and StatefulSet defined in `web.yaml`.

```
kubectl apply -f web.yaml
service/nginx created
statefulset.apps/web created
```

The command above creates two Pods, each running an [NGINX](#) webserver. Get the `nginx` Service and the `web` StatefulSet to verify that they were created successfully.

```
kubectl get service nginx
NAME      TYPE          CLUSTER-IP    EXTERNAL-IP    PORT(S)
AGE
nginx     ClusterIP     None          <none>         80/TCP
12s

kubectl get statefulset web
NAME      DESIRED    CURRENT    AGE
web       2          1          20s
```

## Ordered Pod Creation

For a StatefulSet with  $N$  replicas, when Pods are being deployed, they are created sequentially, in order from  $\{0..N-1\}$ . Examine the output of the `kubectl get` command in the first terminal. Eventually, the output will look like the example below.

```
kubectl get pods -w -l app=nginx
NAME      READY    STATUS             RESTARTS    AGE
web-0     0/1      Pending            0           0s
web-0     0/1      Pending            0           0s
web-0     0/1      ContainerCreating  0           0s
web-0     1/1      Running            0           19s
web-1     0/1      Pending            0           0s
web-1     0/1      Pending            0           0s
web-1     0/1      ContainerCreating  0           0s
web-1     1/1      Running            0           18s
```

Notice that the `web-1` Pod is not launched until the `web-0` Pod is [Running and Ready](#).

## Pods in a StatefulSet

Pods in a StatefulSet have a unique ordinal index and a stable network identity.

### Examining the Pod's Ordinal Index

Get the StatefulSet's Pods.

```
kubectl get pods -l app=nginx
```

NAME	READY	STATUS	RESTARTS	AGE
web-0	1/1	Running	0	1m
web-1	1/1	Running	0	1m

As mentioned in the [StatefulSets](#) concept, the Pods in a StatefulSet have a sticky, unique identity. This identity is based on a unique ordinal index that is assigned to each Pod by the StatefulSet controller. The Pods' names take the form `<statefulset name>-<ordinal index>`. Since the web StatefulSet has two replicas, it creates two Pods, `web-0` and `web-1`.

## Using Stable Network Identities

Each Pod has a stable hostname based on its ordinal index. Use [kubectl exec](#) to execute the `hostname` command in each Pod.

```
for i in 0 1; do kubectl exec web-$i -- sh -c 'hostname'; done
```

```
web-0
web-1
```

Use [kubectl run](#) to execute a container that provides the `nslookup` command from the `dnsutils` package. Using `nslookup` on the Pods' hostnames, you can examine their in-cluster DNS addresses.

```
kubectl run -i --tty --image busybox:1.28 dns-test --
restart=Never --rm
nslookup web-0.nginx
Server:      10.0.0.10
Address 1: 10.0.0.10 kube-dns.kube-system.svc.cluster.local

Name:        web-0.nginx
Address 1: 10.244.1.6

nslookup web-1.nginx
Server:      10.0.0.10
Address 1: 10.0.0.10 kube-dns.kube-system.svc.cluster.local

Name:        web-1.nginx
Address 1: 10.244.2.6
```

The CNAME of the headless service points to SRV records (one for each Pod that is Running and Ready). The SRV records point to A record entries that contain the Pods' IP addresses.

In one terminal, watch the StatefulSet's Pods.

```
kubectl get pod -w -l app=nginx
```

In a second terminal, use [kubectl delete](#) to delete all the Pods in the StatefulSet.

```
kubectl delete pod -l app=nginx
```

```
pod "web-0" deleted
pod "web-1" deleted
```

Wait for the StatefulSet to restart them, and for both Pods to transition to Running and Ready.

```
kubectl get pod -w -l app=nginx
```

NAME	READY	STATUS	RESTARTS	AGE
web-0	0/1	ContainerCreating	0	0s
NAME	READY	STATUS	RESTARTS	AGE
web-0	1/1	Running	0	2s
web-1	0/1	Pending	0	0s
web-1	0/1	Pending	0	0s
web-1	0/1	ContainerCreating	0	0s
web-1	1/1	Running	0	34s

Use `kubectl exec` and `kubectl run` to view the Pods hostnames and in-cluster DNS entries.

```
for i in 0 1; do kubectl exec web-$i -- sh -c 'hostname'; done
web-0
web-1

kubectl run -i --tty --image busybox:1.28 dns-test --
restart=Never --rm /bin/sh
nslookup web-0.nginx
Server:      10.0.0.10
Address 1: 10.0.0.10 kube-dns.kube-system.svc.cluster.local

Name:        web-0.nginx
Address 1: 10.244.1.7

nslookup web-1.nginx
Server:      10.0.0.10
Address 1: 10.0.0.10 kube-dns.kube-system.svc.cluster.local

Name:        web-1.nginx
Address 1: 10.244.2.8
```

The Pods' ordinals, hostnames, SRV records, and A record names have not changed, but the IP addresses associated with the Pods may have changed. In the cluster used for this tutorial, they have. This is why it is important not to configure other applications to connect to Pods in a StatefulSet by IP address.

If you need to find and connect to the active members of a StatefulSet, you should query the CNAME of the Headless Service (`nginx.default.svc.cluster.local`). The SRV records associated with the CNAME will contain only the Pods in the StatefulSet that are Running and Ready.

If your application already implements connection logic that tests for liveness and readiness, you can use the SRV records of the Pods (`web-0.nginx.default.svc.cluster.local`, `web-1.nginx.default.svc.cluster.local`), as they are stable, and your application will be able to discover the Pods' addresses when they transition to Running and Ready.



## Writing to Stable Storage

Get the PersistentVolumeClaims for web-0 and web-1.

```
kubectl get pvc -l app=nginx
```

NAME	STATUS	VOLUME	CAPACITY
www-web-0	Bound	pvc-15c268c7-b507-11e6-932f-42010a800002	1Gi
www-web-1	Bound	pvc-15c79307-b507-11e6-932f-42010a800002	1Gi

The StatefulSet controller created two PersistentVolumeClaims that are bound to two [PersistentVolumes](#). As the cluster used in this tutorial is configured to dynamically provision PersistentVolumes, the PersistentVolumes were created and bound automatically.

The NGINX webserver, by default, will serve an index file at `/usr/share/nginx/html/index.html`. The `volumeMounts` field in the StatefulSets spec ensures that the `/usr/share/nginx/html` directory is backed by a PersistentVolume.

Write the Pods' hostnames to their `index.html` files and verify that the NGINX webserver serve the hostnames.

```
for i in 0 1; do kubectl exec web-$i -- sh -c 'echo $(hostname) > /usr/share/nginx/html/index.html'; done
```

```
for i in 0 1; do kubectl exec -it web-$i -- curl localhost; done
```

```
web-0
```

```
web-1
```

### Note:

If you instead see 403 Forbidden responses for the above curl command, you will need to fix the permissions of the directory mounted by the `volumeMounts` (due to a [bug when using hostPath volumes](#)) with:

```
for i in 0 1; do kubectl exec web-$i -- chmod 755 /usr/share/nginx/html; done
```

before retrying the curl command above.

In one terminal, watch the StatefulSet's Pods.

```
kubectl get pod -w -l app=nginx
```

In a second terminal, delete all of the StatefulSet's Pods.

```
kubectl delete pod -l app=nginx
```

```
pod "web-0" deleted
```

```
pod "web-1" deleted
```

Examine the output of the `kubectl get` command in the first terminal, and wait for all of the Pods to transition to Running and Ready.

```
kubectl get pod -w -l app=nginx
```

NAME	READY	STATUS	RESTARTS	AGE
web-0	0/1	ContainerCreating	0	0s
NAME	READY	STATUS	RESTARTS	AGE
web-0	1/1	Running	0	2s
web-1	0/1	Pending	0	0s
web-1	0/1	Pending	0	0s
web-1	0/1	ContainerCreating	0	0s
web-1	1/1	Running	0	34s

Verify the web servers continue to serve their hostnames.

```
for i in 0 1; do kubectl exec -it web-$i -- curl localhost;
done
web-0
web-1
```

Even though `web-0` and `web-1` were rescheduled, they continue to serve their hostnames because the PersistentVolumes associated with their PersistentVolumeClaims are remounted to their `volumeMounts`. No matter what node `web-0` and `web-1` are scheduled on, their PersistentVolumes will be mounted to the appropriate mount points.

## Scaling a StatefulSet

Scaling a StatefulSet refers to increasing or decreasing the number of replicas. This is accomplished by updating the `replicas` field. You can use either [kubectl scale](#) or [kubectl patch](#) to scale a StatefulSet.

### Scaling Up

In one terminal window, watch the Pods in the StatefulSet.

```
kubectl get pods -w -l app=nginx
```

In another terminal window, use `kubectl scale` to scale the number of replicas to 5.

```
kubectl scale sts web --replicas=5
statefulset.apps/web scaled
```

Examine the output of the `kubectl get` command in the first terminal, and wait for the three additional Pods to transition to Running and Ready.

```
kubectl get pods -w -l app=nginx
```

web-0	1/1	Running	0	2h
web-1	1/1	Running	0	2h
NAME	READY	STATUS	RESTARTS	AGE
web-2	0/1	Pending	0	0s
web-2	0/1	Pending	0	0s
web-2	0/1	ContainerCreating	0	0s

web-2	1/1	Running	0	19s	
web-3	0/1	Pending	0	0s	
web-3	0/1	Pending	0	0s	
web-3	0/1	ContainerCreating	0	0s	
web-3	1/1	Running	0	18s	
web-4	0/1	Pending	0	0s	
web-4	0/1	Pending	0	0s	
web-4	0/1	ContainerCreating	0	0s	
web-4	1/1	Running	0	19s	

The StatefulSet controller scaled the number of replicas. As with [StatefulSet creation](#), the StatefulSet controller created each Pod sequentially with respect to its ordinal index, and it waited for each Pod's predecessor to be Running and Ready before launching the subsequent Pod.

## Scaling Down

In one terminal, watch the StatefulSet's Pods.

```
kubectl get pods -w -l app=nginx
```

In another terminal, use `kubectl patch` to scale the StatefulSet back down to three replicas.

```
kubectl patch sts web -p '{"spec":{"replicas":3}}'
statefulset.apps/web patched
```

Wait for web-4 and web-3 to transition to Terminating.

```
kubectl get pods -w -l app=nginx
```

NAME	READY	STATUS	RESTARTS	AGE
web-0	1/1	Running	0	3h
web-1	1/1	Running	0	3h
web-2	1/1	Running	0	55s
web-3	1/1	Running	0	36s
web-4	0/1	ContainerCreating	0	18s

NAME	READY	STATUS	RESTARTS	AGE
web-4	1/1	Running	0	19s
web-4	1/1	Terminating	0	24s
web-4	1/1	Terminating	0	24s
web-3	1/1	Terminating	0	42s
web-3	1/1	Terminating	0	42s

## Ordered Pod Termination

The controller deleted one Pod at a time, in reverse order with respect to its ordinal index, and it waited for each to be completely shutdown before deleting the next.

Get the StatefulSet's PersistentVolumeClaims.

```
kubectl get pvc -l app=nginx
```

NAME	STATUS	
VOLUME		CAPACITY
ACCESSMODES	AGE	

www-web-0	Bound	pvc-15c268c7-b507-11e6-932f-42010a800002	1Gi	RWO	13h
www-web-1	Bound	pvc-15c79307-b507-11e6-932f-42010a800002	1Gi	RWO	13h
www-web-2	Bound	pvc-e1125b27-b508-11e6-932f-42010a800002	1Gi	RWO	13h
www-web-3	Bound	pvc-e1176df6-b508-11e6-932f-42010a800002	1Gi	RWO	13h
www-web-4	Bound	pvc-e11bb5f8-b508-11e6-932f-42010a800002	1Gi	RWO	13h

There are still five PersistentVolumeClaims and five PersistentVolumes. When exploring a Pod's [stable storage](#), we saw that the PersistentVolumes mounted to the Pods of a StatefulSet are not deleted when the StatefulSet's Pods are deleted. This is still true when Pod deletion is caused by scaling the StatefulSet down.

## Updating StatefulSets

In Kubernetes 1.7 and later, the StatefulSet controller supports automated updates. The strategy used is determined by the `spec.updateStrategy` field of the StatefulSet API Object. This feature can be used to upgrade the container images, resource requests and/or limits, labels, and annotations of the Pods in a StatefulSet. There are two valid update strategies, `RollingUpdate` and `OnDelete`.

`RollingUpdate` update strategy is the default for StatefulSets.

### Rolling Update

The `RollingUpdate` update strategy will update all Pods in a StatefulSet, in reverse ordinal order, while respecting the StatefulSet guarantees.

Patch the web StatefulSet to apply the `RollingUpdate` update strategy.

```
kubectl patch statefulset web -p '{"spec":{"updateStrategy":{"type":"RollingUpdate"}}}'
statefulset.apps/web patched
```

In one terminal window, patch the web StatefulSet to change the container image again.

```
kubectl patch statefulset web --type='json' -p='[{"op": "replace", "path": "/spec/template/spec/containers/0/image", "value": "gcr.io/google_containers/nginx-slim:0.8"}]'
statefulset.apps/web patched
```

In another terminal, watch the Pods in the StatefulSet.

```
kubectl get po -l app=nginx -w
```

NAME	READY	STATUS	RESTARTS	AGE
web-0	1/1	Running	0	7m
web-1	1/1	Running	0	7m
web-2	1/1	Running	0	8m
web-2	1/1	Terminating	0	8m
web-2	1/1	Terminating	0	8m
web-2	0/1	Terminating	0	8m

web-2	0/1	Terminating	0	8m	
web-2	0/1	Terminating	0	8m	
web-2	0/1	Terminating	0	8m	
web-2	0/1	Pending	0	0s	
web-2	0/1	Pending	0	0s	
web-2	0/1	ContainerCreating	0		0s
web-2	1/1	Running	0	19s	
web-1	1/1	Terminating	0	8m	
web-1	0/1	Terminating	0	8m	
web-1	0/1	Terminating	0	8m	
web-1	0/1	Terminating	0	8m	
web-1	0/1	Pending	0	0s	
web-1	0/1	Pending	0	0s	
web-1	0/1	ContainerCreating	0		0s
web-1	1/1	Running	0	6s	
web-0	1/1	Terminating	0	7m	
web-0	1/1	Terminating	0	7m	
web-0	0/1	Terminating	0	7m	
web-0	0/1	Terminating	0	7m	
web-0	0/1	Terminating	0	7m	
web-0	0/1	Terminating	0	7m	
web-0	0/1	Pending	0	0s	
web-0	0/1	Pending	0	0s	
web-0	0/1	ContainerCreating	0		0s
web-0	1/1	Running	0	10s	

The Pods in the StatefulSet are updated in reverse ordinal order. The StatefulSet controller terminates each Pod, and waits for it to transition to Running and Ready prior to updating the next Pod. Note that, even though the StatefulSet controller will not proceed to update the next Pod until its ordinal successor is Running and Ready, it will restore any Pod that fails during the update to its current version. Pods that have already received the update will be restored to the updated version, and Pods that have not yet received the update will be restored to the previous version. In this way, the controller attempts to continue to keep the application healthy and the update consistent in the presence of intermittent failures.

Get the Pods to view their container images.

```
for p in 0 1 2; do kubectl get po web-$p --template '{{range $i, $c := .spec.containers}}{{{$c.image}}{{end}}'}; echo; done
k8s.gcr.io/nginx-slim:0.8
k8s.gcr.io/nginx-slim:0.8
k8s.gcr.io/nginx-slim:0.8
```

All the Pods in the StatefulSet are now running the previous container image.

**Tip** You can also use `kubectl rollout status sts/<name>` to view the status of a rolling update.

## Staging an Update

You can stage an update to a StatefulSet by using the `partition` parameter of the `RollingUpdate` update strategy. A staged update will keep all of the Pods in the StatefulSet at the current version while allowing mutations to the StatefulSet's `.spec.template`.

Patch the web StatefulSet to add a partition to the updateStrategy field.

```
kubectl patch statefulset web -p '{"spec":{"updateStrategy":{"type":"RollingUpdate","rollingUpdate":{"partition":3}}}}'
statefulset.apps/web patched
```

Patch the StatefulSet again to change the container's image.

```
kubectl patch statefulset web --type='json' -p='[{"op": "replace", "path": "/spec/template/spec/containers/0/image", "value": "k8s.gcr.io/nginx-slim:0.7"}]'
statefulset.apps/web patched
```

Delete a Pod in the StatefulSet.

```
kubectl delete po web-2
pod "web-2" deleted
```

Wait for the Pod to be Running and Ready.

```
kubectl get po -l app=nginx -w
```

NAME	READY	STATUS	RESTARTS	AGE
web-0	1/1	Running	0	4m
web-1	1/1	Running	0	4m
web-2	0/1	ContainerCreating	0	11s
web-2	1/1	Running	0	18s

Get the Pod's container.

```
kubectl get po web-2 --template '{{range $i, $c := .spec.containers}}{{ $c.image }}{{end}}'
k8s.gcr.io/nginx-slim:0.8
```

Notice that, even though the update strategy is RollingUpdate the StatefulSet controller restored the Pod with its original container. This is because the ordinal of the Pod is less than the partition specified by the updateStrategy.

## Rolling Out a Canary

You can roll out a canary to test a modification by decrementing the partition you specified [above](#).

Patch the StatefulSet to decrement the partition.

```
kubectl patch statefulset web -p '{"spec":{"updateStrategy":{"type":"RollingUpdate","rollingUpdate":{"partition":2}}}}'
statefulset.apps/web patched
```

Wait for web-2 to be Running and Ready.

```
kubectl get po -l app=nginx -w
```

NAME	READY	STATUS	RESTARTS	AGE
web-0	1/1	Running	0	4m
web-1	1/1	Running	0	4m

web-2	0/1	ContainerCreating	0	11s
web-2	1/1	Running	0	18s

Get the Pod's container.

```
kubectl get po web-2 --template '{{range $i,
$c := .spec.containers}}{{ $c.image}}{{end}}'
k8s.gcr.io/nginx-slim:0.7
```

When you changed the `partition`, the StatefulSet controller automatically updated the `web-2` Pod because the Pod's ordinal was greater than or equal to the `partition`.

Delete the `web-1` Pod.

```
kubectl delete po web-1
pod "web-1" deleted
```

Wait for the `web-1` Pod to be Running and Ready.

```
kubectl get po -l app=nginx -w
```

NAME	READY	STATUS	RESTARTS	AGE
web-0	1/1	Running	0	6m
web-1	0/1	Terminating	0	6m
web-2	1/1	Running	0	2m
web-1	0/1	Terminating	0	6m
web-1	0/1	Terminating	0	6m
web-1	0/1	Terminating	0	6m
web-1	0/1	Pending	0	0s
web-1	0/1	Pending	0	0s
web-1	0/1	ContainerCreating	0	0s
web-1	1/1	Running	0	18s

Get the `web-1` Pods container.

```
kubectl get po web-1 --template '{{range $i,
$c := .spec.containers}}{{ $c.image}}{{end}}'
k8s.gcr.io/nginx-slim:0.8
```

`web-1` was restored to its original configuration because the Pod's ordinal was less than the partition. When a partition is specified, all Pods with an ordinal that is greater than or equal to the partition will be updated when the StatefulSet's `.spec.template` is updated. If a Pod that has an ordinal less than the partition is deleted or otherwise terminated, it will be restored to its original configuration.

## Phased Roll Outs

You can perform a phased roll out (e.g. a linear, geometric, or exponential roll out) using a partitioned rolling update in a similar manner to how you rolled out a [canary](#). To perform a phased roll out, set the `partition` to the ordinal at which you want the controller to pause the update.

The partition is currently set to 2. Set the partition to 0.

```
kubectl patch statefulset web -p '{"spec":{"updateStrategy":{"type":"RollingUpdate","rollingUpdate":{"partition":0}}}}'
statefulset.apps/web patched
```

Wait for all of the Pods in the StatefulSet to become Running and Ready.

```
kubectl get po -l app=nginx -w
```

NAME	READY	STATUS	RESTARTS	AGE
web-0	1/1	Running	0	3m
web-1	0/1	ContainerCreating	0	11s
web-2	1/1	Running	0	2m
web-1	1/1	Running	0	18s
web-0	1/1	Terminating	0	3m
web-0	1/1	Terminating	0	3m
web-0	0/1	Terminating	0	3m
web-0	0/1	Terminating	0	3m
web-0	0/1	Terminating	0	3m
web-0	0/1	Terminating	0	3m
web-0	0/1	Pending	0	0s
web-0	0/1	Pending	0	0s
web-0	0/1	ContainerCreating	0	0s
web-0	1/1	Running	0	3s

Get the Pod's containers.

```
for p in 0 1 2; do kubectl get po web-$p --template '{{range $i, $c := .spec.containers}}{{ $c.image }}{{end}}'; echo; done
k8s.gcr.io/nginx-slim:0.7
k8s.gcr.io/nginx-slim:0.7
k8s.gcr.io/nginx-slim:0.7
```

By moving the partition to 0, you allowed the StatefulSet controller to continue the update process.

## On Delete

The OnDelete update strategy implements the legacy (1.6 and prior) behavior. When you select this update strategy, the StatefulSet controller will not automatically update Pods when a modification is made to the StatefulSet's `.spec.template` field. This strategy can be selected by setting the `.spec.template.updateStrategy.type` to `OnDelete`.

## Deleting StatefulSets

StatefulSet supports both Non-Cascading and Cascading deletion. In a Non-Cascading Delete, the StatefulSet's Pods are not deleted when the StatefulSet is deleted. In a Cascading Delete, both the StatefulSet and its Pods are deleted.

### Non-Cascading Delete

In one terminal window, watch the Pods in the StatefulSet.



```
kubectl get pods -w -l app=nginx
```

Use [kubectl delete](#) to delete the StatefulSet. Make sure to supply the `--cascade=false` parameter to the command. This parameter tells Kubernetes to only delete the StatefulSet, and to not delete any of its Pods.

```
kubectl delete statefulset web --cascade=false
statefulset.apps "web" deleted
```

Get the Pods to examine their status.

```
kubectl get pods -l app=nginx
```

NAME	READY	STATUS	RESTARTS	AGE
web-0	1/1	Running	0	6m
web-1	1/1	Running	0	7m
web-2	1/1	Running	0	5m

Even though web has been deleted, all of the Pods are still Running and Ready. Delete web-0.

```
kubectl delete pod web-0
pod "web-0" deleted
```

Get the StatefulSet's Pods.

```
kubectl get pods -l app=nginx
```

NAME	READY	STATUS	RESTARTS	AGE
web-1	1/1	Running	0	10m
web-2	1/1	Running	0	7m

As the web StatefulSet has been deleted, web-0 has not been relaunched.

In one terminal, watch the StatefulSet's Pods.

```
kubectl get pods -w -l app=nginx
```

In a second terminal, recreate the StatefulSet. Note that, unless you deleted the nginx Service ( which you should not have ), you will see an error indicating that the Service already exists.

```
kubectl apply -f web.yaml
statefulset.apps/web created
service/nginx unchanged
```

Ignore the error. It only indicates that an attempt was made to create the nginx Headless Service even though that Service already exists.

Examine the output of the `kubectl get` command running in the first terminal.

```
kubectl get pods -w -l app=nginx
```

NAME	READY	STATUS	RESTARTS	AGE
web-1	1/1	Running	0	16m
web-2	1/1	Running	0	2m

NAME	READY	STATUS	RESTARTS	AGE
web-0	0/1	Pending	0	0s

web-0	0/1	Pending	0	0s	
web-0	0/1	ContainerCreating	0		0s
web-0	1/1	Running	0	18s	
web-2	1/1	Terminating	0		3m
web-2	0/1	Terminating	0		3m
web-2	0/1	Terminating	0		3m
web-2	0/1	Terminating	0		3m

When the web StatefulSet was recreated, it first relaunched web-0. Since web-1 was already Running and Ready, when web-0 transitioned to Running and Ready, it simply adopted this Pod. Since you recreated the StatefulSet with replicas equal to 2, once web-0 had been recreated, and once web-1 had been determined to already be Running and Ready, web-2 was terminated.

Let's take another look at the contents of the index.html file served by the Pods' web servers.

```
for i in 0 1; do kubectl exec -it web-$i -- curl localhost; done
web-0
web-1
```

Even though you deleted both the StatefulSet and the web-0 Pod, it still serves the hostname originally entered into its index.html file. This is because the StatefulSet never deletes the PersistentVolumes associated with a Pod. When you recreated the StatefulSet and it relaunched web-0, its original PersistentVolume was remounted.

## Cascading Delete

In one terminal window, watch the Pods in the StatefulSet.

```
kubectl get pods -w -l app=nginx
```

In another terminal, delete the StatefulSet again. This time, omit the --cascade=false parameter.

```
kubectl delete statefulset web
statefulset.apps "web" deleted
```

Examine the output of the kubectl get command running in the first terminal, and wait for all of the Pods to transition to Terminating.

```
kubectl get pods -w -l app=nginx
```

NAME	READY	STATUS	RESTARTS	AGE
web-0	1/1	Running	0	11m
web-1	1/1	Running	0	27m
NAME	READY	STATUS	RESTARTS	AGE
web-0	1/1	Terminating	0	12m
web-1	1/1	Terminating	0	29m
web-0	0/1	Terminating	0	12m
web-0	0/1	Terminating	0	12m
web-0	0/1	Terminating	0	12m
web-1	0/1	Terminating	0	29m

web-1	0/1	Terminating	0	29m
web-1	0/1	Terminating	0	29m

As you saw in the [Scaling Down](#) section, the Pods are terminated one at a time, with respect to the reverse order of their ordinal indices. Before terminating a Pod, the StatefulSet controller waits for the Pod's successor to be completely terminated.

Note that, while a cascading delete will delete the StatefulSet and its Pods, it will not delete the Headless Service associated with the StatefulSet. You must delete the `nginx` Service manually.

```
kubectl delete service nginx
service "nginx" deleted
```

Recreate the StatefulSet and Headless Service one more time.

```
kubectl apply -f web.yaml
service/nginx created
statefulset.apps/web created
```

When all of the StatefulSet's Pods transition to Running and Ready, retrieve the contents of their `index.html` files.

```
for i in 0 1; do kubectl exec -it web-$i -- curl localhost; done
web-0
web-1
```

Even though you completely deleted the StatefulSet, and all of its Pods, the Pods are recreated with their PersistentVolumes mounted, and `web-0` and `web-1` will still serve their hostnames.

Finally delete the `web` StatefulSet and the `nginx` service.

```
kubectl delete service nginx
service "nginx" deleted

kubectl delete statefulset web
statefulset "web" deleted
```

## Pod Management Policy

For some distributed systems, the StatefulSet ordering guarantees are unnecessary and/or undesirable. These systems require only uniqueness and identity. To address this, in Kubernetes 1.7, we introduced `.spec.podManagementPolicy` to the StatefulSet API Object.

### OrderedReady Pod Management

OrderedReady pod management is the default for StatefulSets. It tells the StatefulSet controller to respect the ordering guarantees demonstrated above.

## **Parallel Pod Management**

Parallel pod management tells the StatefulSet controller to launch or terminate all Pods in parallel, and not to wait for Pods to become Running and Ready or completely terminated prior to launching or terminating another Pod.

## [application/web/web-parallel.yaml](#)

```
apiVersion: v1
kind: Service
metadata:
  name: nginx
  labels:
    app: nginx
spec:
  ports:
    - port: 80
      name: web
  clusterIP: None
  selector:
    app: nginx
---
apiVersion: apps/v1
kind: StatefulSet
metadata:
  name: web
spec:
  serviceName: "nginx"
  podManagementPolicy: "Parallel"
  replicas: 2
  selector:
    matchLabels:
      app: nginx
  template:
    metadata:
      labels:
        app: nginx
    spec:
      containers:
        - name: nginx
          image: k8s.gcr.io/nginx-slim:0.8
          ports:
            - containerPort: 80
              name: web
          volumeMounts:
            - name: www
              mountPath: /usr/share/nginx/html
  volumeClaimTemplates:
    - metadata:
        name: www
      spec:
        accessModes: [ "ReadWriteOnce" ]
        resources:
          requests:
            storage: 1Gi
```

Download the example above, and save it to a file named `web-parallel.yaml`

This manifest is identical to the one you downloaded above except that the `.spec.podManagementPolicy` of the `web StatefulSet` is set to `Parallel`.

In one terminal, watch the Pods in the `StatefulSet`.

```
kubectl get po -l app=nginx -w
```

In another terminal, create the `StatefulSet` and `Service` in the manifest.

```
kubectl apply -f web-parallel.yaml
service/nginx created
statefulset.apps/web created
```

Examine the output of the `kubectl get` command that you executed in the first terminal.

```
kubectl get po -l app=nginx -w
NAME      READY   STATUS             RESTARTS   AGE
web-0     0/1     Pending            0           0s
web-0     0/1     Pending            0           0s
web-1     0/1     Pending            0           0s
web-1     0/1     Pending            0           0s
web-0     0/1     ContainerCreating  0           0s
web-1     0/1     ContainerCreating  0           0s
web-0     1/1     Running            0          10s
web-1     1/1     Running            0          10s
```

The `StatefulSet` controller launched both `web-0` and `web-1` at the same time.

Keep the second terminal open, and, in another terminal window scale the `StatefulSet`.

```
kubectl scale statefulset/web --replicas=4
statefulset.apps/web scaled
```

Examine the output of the terminal where the `kubectl get` command is running.

```
web-3     0/1     Pending            0           0s
web-3     0/1     Pending            0           0s
web-3     0/1     Pending            0           7s
web-3     0/1     ContainerCreating  0           7s
web-2     1/1     Running            0          10s
web-3     1/1     Running            0          26s
```

The `StatefulSet` controller launched two new Pods, and it did not wait for the first to become `Running` and `Ready` prior to launching the second.

Keep this terminal open, and in another terminal delete the `web StatefulSet`.

```
kubectl delete sts web
```

Again, examine the output of the `kubectl get` command running in the other terminal.

```
web-3     1/1     Terminating      0           9m
web-2     1/1     Terminating      0           9m
web-3     1/1     Terminating      0           9m
```

web-2	1/1	Terminating	0	9m
web-1	1/1	Terminating	0	44m
web-0	1/1	Terminating	0	44m
web-0	0/1	Terminating	0	44m
web-3	0/1	Terminating	0	9m
web-2	0/1	Terminating	0	9m
web-1	0/1	Terminating	0	44m
web-0	0/1	Terminating	0	44m
web-2	0/1	Terminating	0	9m
web-2	0/1	Terminating	0	9m
web-2	0/1	Terminating	0	9m
web-1	0/1	Terminating	0	44m
web-1	0/1	Terminating	0	44m
web-1	0/1	Terminating	0	44m
web-0	0/1	Terminating	0	44m
web-0	0/1	Terminating	0	44m
web-0	0/1	Terminating	0	44m
web-3	0/1	Terminating	0	9m
web-3	0/1	Terminating	0	9m
web-3	0/1	Terminating	0	9m

The StatefulSet controller deletes all Pods concurrently, it does not wait for a Pod's ordinal successor to terminate prior to deleting that Pod.

Close the terminal where the `kubectl get` command is running and delete the `nginx` Service.

```
kubectl delete svc nginx
```

## Cleaning up

You will need to delete the persistent storage media for the PersistentVolumes used in this tutorial. Follow the necessary steps, based on your environment, storage configuration, and provisioning method, to ensure that all storage is reclaimed.

## Feedback

Was this page helpful?

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Page last modified on July 24, 2019 at 3:28 AM PST by [replace kubectl error message with the related output \(#15510\)](#) ([Page History](#))

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# Example: Deploying Cassandra with Stateful Sets

This tutorial shows you how to develop a native cloud [Cassandra](#) deployment on Kubernetes. In this example, a custom Cassandra *SeedProvider* enables Cassandra to discover new Cassandra nodes as they join the cluster.

*StatefulSets* make it easier to deploy stateful applications within a clustered environment. For more information on the features used in this tutorial, see the [StatefulSet](#) documentation.

## Cassandra on Docker

The *Pods* in this tutorial use the [gcr.io/google-samples/cassandra:v13](#) image from Google's [container registry](#). The Docker image above is based on [debian-base](#) and includes OpenJDK 8.

This image includes a standard Cassandra installation from the Apache Debian repo. By using environment variables you can change values that are inserted into `cassandra.yaml`.

ENV VAR	DEFAULT VALUE
CASSANDRA_CLUSTER_NAME	'Test Cluster'
CASSANDRA_NUM_TOKENS	32
CASSANDRA_RPC_ADDRESS	0.0.0.0

- [Objectives](#)
- [Before you begin](#)
- [Creating a Cassandra Headless Service](#)
- [Using a StatefulSet to Create a Cassandra Ring](#)
- [Validating The Cassandra StatefulSet](#)
- [Modifying the Cassandra StatefulSet](#)
- [Cleaning up](#)
- [What's next](#)

## Objectives

- Create and validate a Cassandra headless [Service](#).
- Use a [StatefulSet](#) to create a Cassandra ring.
- Validate the [StatefulSet](#).
- Modify the [StatefulSet](#).
- Delete the [StatefulSet](#) and its [Pods](#).

## Before you begin

To complete this tutorial, you should already have a basic familiarity with [Pods](#), [Services](#), and [StatefulSets](#). In addition, you should:

- [Install and Configure](#) the *kubectl* command-line tool



- Download [cassandra-service.yaml](#) and [cassandra-statefulset.yaml](#)
- Have a supported Kubernetes cluster running

**Note:** Please read the [setup](#) if you do not already have a cluster.

## Additional Minikube Setup Instructions

### Caution:

[Minikube](#) defaults to 1024MB of memory and 1 CPU. Running Minikube with the default resource configuration results in insufficient resource errors during this tutorial. To avoid these errors, start Minikube with the following settings:

```
minikube start --memory 5120 --cpus=4
```

## Creating a Cassandra Headless Service

A Kubernetes [Service](#) describes a set of [Pods](#) that perform the same task.

The following Service is used for DNS lookups between Cassandra Pods and clients within the Kubernetes cluster.

[application/cassandra/cassandra-service.yaml](#)

```
apiVersion: v1
kind: Service
metadata:
  labels:
    app: cassandra
  name: cassandra
spec:
  clusterIP: None
  ports:
  - port: 9042
  selector:
    app: cassandra
```

1. Launch a terminal window in the directory you downloaded the manifest files.
2. Create a Service to track all Cassandra StatefulSet nodes from the `cassandra-service.yaml` file:

```
kubectl apply -f https://k8s.io/examples/application/cassandra/cassandra-service.yaml
```

## Validating (optional)

Get the Cassandra Service.

```
kubectl get svc cassandra
```

The response is

NAME	TYPE	CLUSTER-IP	EXTERNAL-IP
PORT(S)	AGE		
cassandra	ClusterIP	None	<none>
TCP 9042	45s		

Service creation failed if anything else is returned. Read [Debug Services](#) for common issues.

## Using a StatefulSet to Create a Cassandra Ring

The StatefulSet manifest, included below, creates a Cassandra ring that consists of three Pods.

**Note:** This example uses the default provisioner for Minikube. Please update the following StatefulSet for the cloud you are working with.

```

apiVersion: apps/v1
kind: StatefulSet
metadata:
  name: cassandra
  labels:
    app: cassandra
spec:
  serviceName: cassandra
  replicas: 3
  selector:
    matchLabels:
      app: cassandra
  template:
    metadata:
      labels:
        app: cassandra
    spec:
      terminationGracePeriodSeconds: 1800
      containers:
        - name: cassandra
          image: gcr.io/google-samples/cassandra:v13
          imagePullPolicy: Always
          ports:
            - containerPort: 7000
              name: intra-node
            - containerPort: 7001
              name: tls-intra-node
            - containerPort: 7199
              name: jmx
            - containerPort: 9042
              name: cql
          resources:
            limits:
              cpu: "500m"
              memory: 1Gi
            requests:
              cpu: "500m"
              memory: 1Gi
          securityContext:
            capabilities:
              add:
                - IPC_LOCK
          lifecycle:
            preStop:
              exec:
                command:
                  - /bin/sh
                  - -c
                  - nodetool drain
          env:
            - name: MAX_HEAP_SIZE
              value: 512M
            - name: HEAP_NEWSIZE
              value: 100M
            - name: CASSANDRA_SEEDS
              value: "cassandra-0.cassandra.default.svc.cluste
r.local"

```

1. Update the StatefulSet if necessary.
2. Create the Cassandra StatefulSet from the `cassandra-statefulset.yaml` file:

```
kubectl apply -f https://k8s.io/examples/application/cassandra/cassandra-statefulset.yaml
```

## Validating The Cassandra StatefulSet

1. Get the Cassandra StatefulSet:

```
kubectl get statefulset cassandra
```

The response should be:

NAME	DESIRED	CURRENT	AGE
cassandra	3	0	13s

The StatefulSet resource deploys Pods sequentially.

2. Get the Pods to see the ordered creation status:

```
kubectl get pods -l="app=cassandra"
```

The response should be:

NAME	READY	STATUS	RESTARTS	AGE
cassandra-0	1/1	Running	0	1m
cassandra-1	0/1	ContainerCreating	0	8s

It can take several minutes for all three Pods to deploy. Once they are deployed, the same command returns:

NAME	READY	STATUS	RESTARTS	AGE
cassandra-0	1/1	Running	0	10m
cassandra-1	1/1	Running	0	9m
cassandra-2	1/1	Running	0	8m

3. Run the Cassandra [nodetool](#) to display the status of the ring.

```
kubectl exec -it cassandra-0 -- nodetool status
```

The response should look something like this:

```
Datcenter: DC1-K8Demo
=====
Status=Up/Down
|/ State=Normal/Leaving/Joining/Moving
-- Address      Load          Tokens         Owns            Rack
(effective)  Host ID
UN  172.17.0.5    83.57 KiB     32
74.0%                e2dd09e6-d9d3-477e-96c5-45094c08db0f
Rack1-K8Demo
```

```
UN 172.17.0.4 101.04 KiB 32
58.8% f89d6835-3a42-4419-92b3-0e62cae1479c
Rack1-K8Demo
UN 172.17.0.6 84.74 KiB 32
67.1% a6a1e8c2-3dc5-4417-b1a0-26507af2aaad
Rack1-K8Demo
```

## Modifying the Cassandra StatefulSet

Use `kubectl edit` to modify the size of a Cassandra StatefulSet.

1. Run the following command:

```
kubectl edit statefulset cassandra
```

This command opens an editor in your terminal. The line you need to change is the `replicas` field. The following sample is an excerpt of the `StatefulSet` file:

```
# Please edit the object below. Lines beginning with a
'#' will be ignored,
# and an empty file will abort the edit. If an error
occurs while saving this file will be
# reopened with the relevant failures.
#
apiVersion: apps/v1 # for versions before 1.9.0 use apps/
v1beta2
kind: StatefulSet
metadata:
  creationTimestamp: 2016-08-13T18:40:58Z
  generation: 1
  labels:
    app: cassandra
    name: cassandra
    namespace: default
    resourceVersion: "323"
    uid: 7a219483-6185-11e6-a910-42010a8a0fc0
spec:
  replicas: 3
```

2. Change the number of replicas to 4, and then save the manifest.

The `StatefulSet` now contains 4 Pods.

3. Get the Cassandra StatefulSet to verify:

```
kubectl get statefulset cassandra
```

The response should be

NAME	DESIRED	CURRENT	AGE
cassandra	4	4	36m

## Cleaning up

Deleting or scaling a StatefulSet down does not delete the volumes associated with the StatefulSet. This setting is for your safety because your data is more valuable than automatically purging all related StatefulSet resources.

**Warning:** Depending on the storage class and reclaim policy, deleting the *PersistentVolumeClaims* may cause the associated volumes to also be deleted. Never assume you'll be able to access data if its volume claims are deleted.

1. Run the following commands (chained together into a single command) to delete everything in the Cassandra StatefulSet:

```
grace=$(kubectl get po cassandra-0 -o=jsonpath='{.spec.terminationGracePeriodSeconds}') \
&& kubectl delete statefulset -l app=cassandra \
&& echo "Sleeping $grace" \
&& sleep $grace \
&& kubectl delete pvc -l app=cassandra
```

2. Run the following command to delete the Cassandra Service.

```
kubectl delete service -l app=cassandra
```

## What's next

- Learn how to [Scale a StatefulSet](#).
- Learn more about the [KubernetesSeedProvider](#)
- See more custom [Seed Provider Configurations](#)

## Feedback

Was this page helpful?

Yes No

Thanks for the feedback. If you have a specific, answerable question about how to use Kubernetes, ask it on [Stack Overflow](#). Open an issue in the GitHub repo if you want to [report a problem](#) or [suggest an improvement](#).

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# Running ZooKeeper, A Distributed System Coordinator

This tutorial demonstrates running [Apache Zookeeper](#) on Kubernetes using [StatefulSets](#), [PodDisruptionBudgets](#), and [PodAntiAffinity](#).

- [Objectives](#)
- [Before you begin](#)
- [Creating a ZooKeeper Ensemble](#)
- [Ensuring Consistent Configuration](#)
- [Managing the ZooKeeper Process](#)
- [Tolerating Node Failure](#)
- [Surviving Maintenance](#)
- [Cleaning up](#)

## Objectives

After this tutorial, you will know the following.

- How to deploy a ZooKeeper ensemble using StatefulSet.
- How to consistently configure the ensemble using ConfigMaps.
- How to spread the deployment of ZooKeeper servers in the ensemble.
- How to use PodDisruptionBudgets to ensure service availability during planned maintenance.

## Before you begin

Before starting this tutorial, you should be familiar with the following Kubernetes concepts.

- [Pods](#)
- [Cluster DNS](#)
- [Headless Services](#)
- [PersistentVolumes](#)
- [PersistentVolume Provisioning](#)
- [StatefulSets](#)
- [PodDisruptionBudgets](#)
- [PodAntiAffinity](#)
- [kubect CLI](#)

You will require a cluster with at least four nodes, and each node requires at least 2 CPUs and 4 GiB of memory. In this tutorial you will cordon and drain the cluster's nodes. **This means that the cluster will terminate and evict all Pods on its nodes, and the nodes will temporarily become unschedulable.** You should use a dedicated cluster for this tutorial, or you should ensure that the disruption you cause will not interfere with other tenants.

This tutorial assumes that you have configured your cluster to dynamically provision PersistentVolumes. If your cluster is not configured to do so, you will have to manually provision three 20 GiB volumes before starting this tutorial.

## ZooKeeper Basics

[Apache ZooKeeper](#) is a distributed, open-source coordination service for distributed applications. ZooKeeper allows you to read, write, and observe updates to data. Data are organized in a file system like hierarchy and replicated to all ZooKeeper servers in the ensemble (a set of ZooKeeper servers). All operations on data are atomic and sequentially consistent. ZooKeeper ensures this by using the [Zab](#) consensus protocol to replicate a state machine across all servers in the ensemble.

The ensemble uses the Zab protocol to elect a leader, and the ensemble cannot write data until that election is complete. Once complete, the ensemble uses Zab to ensure that it replicates all writes to a quorum before it acknowledges and makes them visible to clients. Without respect to weighted quorums, a quorum is a majority component of the ensemble containing the current leader. For instance, if the ensemble has three servers, a component that contains the leader and one other server constitutes a quorum. If the ensemble can not achieve a quorum, the ensemble cannot write data.

ZooKeeper servers keep their entire state machine in memory, and write every mutation to a durable WAL (Write Ahead Log) on storage media. When a server crashes, it can recover its previous state by replaying the WAL. To prevent the WAL from growing without bound, ZooKeeper servers will periodically snapshot them in memory state to storage media. These snapshots can be loaded directly into memory, and all WAL entries that preceded the snapshot may be discarded.

## Creating a ZooKeeper Ensemble

The manifest below contains a [Headless Service](#), a [Service](#), a [PodDisruptionBudget](#), and a [StatefulSet](#).



```
apiVersion: v1
kind: Service
metadata:
  name: zk-hs
  labels:
    app: zk
spec:
  ports:
    - port: 2888
      name: server
    - port: 3888
      name: leader-election
  clusterIP: None
  selector:
    app: zk
---
apiVersion: v1
kind: Service
metadata:
  name: zk-cs
  labels:
    app: zk
spec:
  ports:
    - port: 2181
      name: client
  selector:
    app: zk
---
apiVersion: policy/v1beta1
kind: PodDisruptionBudget
metadata:
  name: zk-pdb
spec:
  selector:
    matchLabels:
      app: zk
  maxUnavailable: 1
---
apiVersion: apps/v1
kind: StatefulSet
metadata:
  name: zk
spec:
  selector:
    matchLabels:
      app: zk
  serviceName: zk-hs
  replicas: 3
  updateStrategy:
    type: RollingUpdate
  podManagementPolicy: OrderedReady
  template:
    metadata:
      labels:
        app: zk
    spec:
```

Open a terminal, and use the [kubectl apply](#) command to create the manifest.

```
kubectl apply -f https://k8s.io/examples/application/zookeeper/zookeeper.yaml
```

This creates the zk-hs Headless Service, the zk-cs Service, the zk-pdb PodDisruptionBudget, and the zk StatefulSet.

```
service/zk-hs created
service/zk-cs created
poddisruptionbudget.policy/zk-pdb created
statefulset.apps/zk created
```

Use [kubectl get](#) to watch the StatefulSet controller create the StatefulSet's Pods.

```
kubectl get pods -w -l app=zk
```

Once the zk-2 Pod is Running and Ready, use CTRL -C to terminate kubectl.

NAME	READY	STATUS	RESTARTS	AGE	
zk-0	0/1	Pending	0	0s	
zk-0	0/1	Pending	0	0s	
zk-0	0/1	ContainerCreating	0	0s	0s
zk-0	0/1	Running	0	19s	
zk-0	1/1	Running	0	40s	
zk-1	0/1	Pending	0	0s	
zk-1	0/1	Pending	0	0s	
zk-1	0/1	ContainerCreating	0	0s	0s
zk-1	0/1	Running	0	18s	
zk-1	1/1	Running	0	40s	
zk-2	0/1	Pending	0	0s	
zk-2	0/1	Pending	0	0s	
zk-2	0/1	ContainerCreating	0	0s	0s
zk-2	0/1	Running	0	19s	
zk-2	1/1	Running	0	40s	

The StatefulSet controller creates three Pods, and each Pod has a container with a [ZooKeeper](#) server.

## Facilitating Leader Election

Because there is no terminating algorithm for electing a leader in an anonymous network, Zab requires explicit membership configuration to perform leader election. Each server in the ensemble needs to have a unique identifier, all servers need to know the global set of identifiers, and each identifier needs to be associated with a network address.

Use [kubectl exec](#) to get the hostnames of the Pods in the zk StatefulSet.

```
for i in 0 1 2; do kubectl exec zk-$i -- hostname; done
```

The StatefulSet controller provides each Pod with a unique hostname based on its ordinal index. The hostnames take the form of <statefulset name>-<ordinal index>. Because the replicas field of the zk StatefulSet is set to 3, the Set's controller creates three Pods with their hostnames set to zk-0, zk-1, and zk-2.

```
zk-0
zk-1
zk-2
```

The servers in a ZooKeeper ensemble use natural numbers as unique identifiers, and store each server's identifier in a file called `myid` in the server's data directory.

To examine the contents of the `myid` file for each server use the following command.

```
for i in 0 1 2; do echo "myid zk-$i"; kubectl exec zk-$i --
cat /var/lib/zookeeper/data/myid; done
```

Because the identifiers are natural numbers and the ordinal indices are non-negative integers, you can generate an identifier by adding 1 to the ordinal.

```
myid zk-0
1
myid zk-1
2
myid zk-2
3
```

To get the Fully Qualified Domain Name (FQDN) of each Pod in the `zk` StatefulSet use the following command.

```
for i in 0 1 2; do kubectl exec zk-$i -- hostname -f; done
```

The `zk-hs` Service creates a domain for all of the Pods, `zk-hs.default.svc.cluster.local`.

```
zk-0.zk-hs.default.svc.cluster.local
zk-1.zk-hs.default.svc.cluster.local
zk-2.zk-hs.default.svc.cluster.local
```

The A records in [Kubernetes DNS](#) resolve the FQDNs to the Pods' IP addresses. If Kubernetes reschedules the Pods, it will update the A records with the Pods' new IP addresses, but the A records names will not change.

ZooKeeper stores its application configuration in a file named `zoo.cfg`. Use `kubectl exec` to view the contents of the `zoo.cfg` file in the `zk-0` Pod.

```
kubectl exec zk-0 -- cat /opt/zookeeper/conf/zoo.cfg
```

In the `server.1`, `server.2`, and `server.3` properties at the bottom of the file, the 1, 2, and 3 correspond to the identifiers in the ZooKeeper servers' `myid` files. They are set to the FQDNs for the Pods in the `zk` StatefulSet.

```
clientPort=2181
dataDir=/var/lib/zookeeper/data
dataLogDir=/var/lib/zookeeper/log
tickTime=2000
initLimit=10
syncLimit=2000
maxClientCnxns=60
```

```

minSessionTimeout= 4000
maxSessionTimeout= 40000
autopurge.snapRetainCount=3
autopurge.purgeInterval=0
server.1=zk-0.zk-hs.default.svc.cluster.local:2888:3888
server.2=zk-1.zk-hs.default.svc.cluster.local:2888:3888
server.3=zk-2.zk-hs.default.svc.cluster.local:2888:3888

```

## Achieving Consensus

Consensus protocols require that the identifiers of each participant be unique. No two participants in the Zab protocol should claim the same unique identifier. This is necessary to allow the processes in the system to agree on which processes have committed which data. If two Pods are launched with the same ordinal, two ZooKeeper servers would both identify themselves as the same server.

```
kubectl get pods -w -l app=zk
```

NAME	READY	STATUS	RESTARTS	AGE	
zk-0	0/1	Pending	0	0s	
zk-0	0/1	Pending	0	0s	
zk-0	0/1	ContainerCreating	0	0s	0s
zk-0	0/1	Running	0	19s	
zk-0	1/1	Running	0	40s	
zk-1	0/1	Pending	0	0s	
zk-1	0/1	Pending	0	0s	
zk-1	0/1	ContainerCreating	0	0s	0s
zk-1	0/1	Running	0	18s	
zk-1	1/1	Running	0	40s	
zk-2	0/1	Pending	0	0s	
zk-2	0/1	Pending	0	0s	
zk-2	0/1	ContainerCreating	0	0s	0s
zk-2	0/1	Running	0	19s	
zk-2	1/1	Running	0	40s	

The A records for each Pod are entered when the Pod becomes Ready. Therefore, the FQDNs of the ZooKeeper servers will resolve to a single endpoint, and that endpoint will be the unique ZooKeeper server claiming the identity configured in its `myid` file.

```

zk-0.zk-hs.default.svc.cluster.local
zk-1.zk-hs.default.svc.cluster.local
zk-2.zk-hs.default.svc.cluster.local

```

This ensures that the `servers` properties in the ZooKeepers' `zoo.cfg` files represents a correctly configured ensemble.

```

server.1=zk-0.zk-hs.default.svc.cluster.local:2888:3888
server.2=zk-1.zk-hs.default.svc.cluster.local:2888:3888
server.3=zk-2.zk-hs.default.svc.cluster.local:2888:3888

```

When the servers use the Zab protocol to attempt to commit a value, they will either achieve consensus and commit the value (if leader election has succeeded and at least two of the Pods are Running and Ready), or they will fail to do so (if either of the conditions

are not met). No state will arise where one server acknowledges a write on behalf of another.

## Sanity Testing the Ensemble

The most basic sanity test is to write data to one ZooKeeper server and to read the data from another.

The command below executes the `zkCli.sh` script to write `world` to the path `/hello` on the `zk-0` Pod in the ensemble.

```
kubectl exec zk-0 zkCli.sh create /hello world
```

```
WATCHER::
```

```
WatchedEvent state:SyncConnected type:None path:null  
Created /hello
```

To get the data from the `zk-1` Pod use the following command.

```
kubectl exec zk-1 zkCli.sh get /hello
```

The data that you created on `zk-0` is available on all the servers in the ensemble.

```
WATCHER::
```

```
WatchedEvent state:SyncConnected type:None path:null  
world  
cZxid = 0x100000002  
ctime = Thu Dec 08 15:13:30 UTC 2016  
mZxid = 0x100000002  
mtime = Thu Dec 08 15:13:30 UTC 2016  
pZxid = 0x100000002  
cversion = 0  
dataVersion = 0  
aclVersion = 0  
ephemeralOwner = 0x0  
dataLength = 5  
numChildren = 0
```

## Providing Durable Storage

As mentioned in the [ZooKeeper Basics](#) section, ZooKeeper commits all entries to a durable WAL, and periodically writes snapshots in memory state, to storage media. Using WALs to provide durability is a common technique for applications that use consensus protocols to achieve a replicated state machine.

Use the [kubectl delete](#) command to delete the `zk` StatefulSet.

```
kubectl delete statefulset zk  
statefulset.apps "zk" deleted
```

Watch the termination of the Pods in the StatefulSet.

```
kubectl get pods -w -l app=zk
```

When zk-0 is fully terminated, use CTRL-C to terminate kubectl.

zk-2	1/1	Terminating	0	9m
zk-0	1/1	Terminating	0	11m
zk-1	1/1	Terminating	0	10m
zk-2	0/1	Terminating	0	9m
zk-2	0/1	Terminating	0	9m
zk-2	0/1	Terminating	0	9m
zk-1	0/1	Terminating	0	10m
zk-1	0/1	Terminating	0	10m
zk-1	0/1	Terminating	0	10m
zk-0	0/1	Terminating	0	11m
zk-0	0/1	Terminating	0	11m
zk-0	0/1	Terminating	0	11m

Reapply the manifest in zookeeper.yaml.

```
kubectl apply -f https://k8s.io/examples/application/zookeeper/zookeeper.yaml
```

This creates the zk StatefulSet object, but the other API objects in the manifest are not modified because they already exist.

Watch the StatefulSet controller recreate the StatefulSet's Pods.

```
kubectl get pods -w -l app=zk
```

Once the zk-2 Pod is Running and Ready, use CTRL-C to terminate kubectl.

NAME	READY	STATUS	RESTARTS	AGE	
zk-0	0/1	Pending	0	0s	
zk-0	0/1	Pending	0	0s	
zk-0	0/1	ContainerCreating	0	0s	0s
zk-0	0/1	Running	0	19s	
zk-0	1/1	Running	0	40s	
zk-1	0/1	Pending	0	0s	
zk-1	0/1	Pending	0	0s	
zk-1	0/1	ContainerCreating	0	0s	0s
zk-1	0/1	Running	0	18s	
zk-1	1/1	Running	0	40s	
zk-2	0/1	Pending	0	0s	
zk-2	0/1	Pending	0	0s	
zk-2	0/1	ContainerCreating	0	0s	0s
zk-2	0/1	Running	0	19s	
zk-2	1/1	Running	0	40s	

Use the command below to get the value you entered during the [sanity test](#), from the zk-2 Pod.

```
kubectl exec zk-2 zkCli.sh get /hello
```

Even though you terminated and recreated all of the Pods in the zk StatefulSet, the ensemble still serves the original value.

```
WATCHER::
```

```
WatchedEvent state:SyncConnected type:None path:null
world
cZxid = 0x100000002
ctime = Thu Dec 08 15:13:30 UTC 2016
mZxid = 0x100000002
mtime = Thu Dec 08 15:13:30 UTC 2016
pZxid = 0x100000002
cversion = 0
dataVersion = 0
aclVersion = 0
ephemeralOwner = 0x0
dataLength = 5
numChildren = 0
```

The `volumeClaimTemplates` field of the zk StatefulSet's `spec` specifies a `PersistentVolume` provisioned for each Pod.

```
volumeClaimTemplates:
- metadata:
  name: datadir
  annotations:
    volume.alpha.kubernetes.io/storage-class: anything
  spec:
    accessModes: [ "ReadWriteOnce" ]
    resources:
      requests:
        storage: 20Gi
```

The StatefulSet controller generates a `PersistentVolumeClaim` for each Pod in the StatefulSet.

Use the following command to get the StatefulSet's `PersistentVolumeClaims`.

```
kubectl get pvc -l app=zk
```

When the StatefulSet recreated its Pods, it remounts the Pods' `PersistentVolumes`.

NAME	STATUS			
VOLUME			CAPACITY	
ACCESSMODES	AGE			
datadir-zk-0	Bound	pvc-bed742cd-bcb1-11e6-994f-42010a800002	20Gi	RWO 1h
datadir-zk-1	Bound	pvc-bedd27d2-bcb1-11e6-994f-42010a800002	20Gi	RWO 1h
datadir-zk-2	Bound	pvc-bee0817e-bcb1-11e6-994f-42010a800002	20Gi	RWO 1h

The `volumeMounts` section of the StatefulSet's container template mounts the `PersistentVolumes` in the ZooKeeper servers' data directories.

```
volumeMounts:
  - name: datadir
    mountPath: /var/lib/zookeeper
```

When a Pod in the zk StatefulSet is (re)scheduled, it will always have the same PersistentVolume mounted to the ZooKeeper server's data directory. Even when the Pods are rescheduled, all the writes made to the ZooKeeper servers' WALs, and all their snapshots, remain durable.

## Ensuring Consistent Configuration

As noted in the [Facilitating Leader Election](#) and [Achieving Consensus](#) sections, the servers in a ZooKeeper ensemble require consistent configuration to elect a leader and form a quorum. They also require consistent configuration of the Zab protocol in order for the protocol to work correctly over a network. In our example we achieve consistent configuration by embedding the configuration directly into the manifest.

Get the zk StatefulSet.

```
kubectl get sts zk -o yaml
â€¦
command:
  - sh
  - -c
  - "start-zookeeper \
    --servers=3 \
    --data_dir=/var/lib/zookeeper/data \
    --data_log_dir=/var/lib/zookeeper/data/log \
    --conf_dir=/opt/zookeeper/conf \
    --client_port=2181 \
    --election_port=3888 \
    --server_port=2888 \
    --tick_time=2000 \
    --init_limit=10 \
    --sync_limit=5 \
    --heap=512M \
    --max_client_cnxns=60 \
    --snap_retain_count=3 \
    --purge_interval=12 \
    --max_session_timeout=40000 \
    --min_session_timeout=4000 \
    --log_level=INFO"
â€¦
```

The command used to start the ZooKeeper servers passed the configuration as command line parameter. You can also use environment variables to pass configuration to the ensemble.



## Configuring Logging

One of the files generated by the `zkGenConfig.sh` script controls ZooKeeper's logging. ZooKeeper uses [Log4j](#), and, by default, it uses a time and size based rolling file appender for its logging configuration.

Use the command below to get the logging configuration from one of Pods in the `zk StatefulSet`.

```
kubectl exec zk-0 cat /usr/etc/zookeeper/log4j.properties
```

The logging configuration below will cause the ZooKeeper process to write all of its logs to the standard output file stream.

```
zookeeper.root.logger=CONSOLE
zookeeper.console.threshold=INFO
log4j.rootLogger=${zookeeper.root.logger}
log4j.appender.CONSOLE=org.apache.log4j.ConsoleAppender
log4j.appender.CONSOLE.Threshold=${zookeeper.console.threshold}
log4j.appender.CONSOLE.layout=org.apache.log4j.PatternLayout
log4j.appender.CONSOLE.layout.ConversionPattern=%d{ISO8601}
[myid:%X{myid}] - %-5p [%t:%C{1}:@%L] - %m%n
```

This is the simplest possible way to safely log inside the container. Because the applications write logs to standard out, Kubernetes will handle log rotation for you. Kubernetes also implements a sane retention policy that ensures application logs written to standard out and standard error do not exhaust local storage media.

Use [kubectl logs](#) to retrieve the last 20 log lines from one of the Pods.

```
kubectl logs zk-0 --tail 20
```

You can view application logs written to standard out or standard error using `kubectl logs` and from the Kubernetes Dashboard.

```
2016-12-06 19:34:16,236 [myid:1] - INFO [NIOServerCxn.Factory:0.0.0.0/0.0.0.0:2181:NIOServerCnxn@827] - Processing ruok command from /127.0.0.1:52740
2016-12-06 19:34:16,237 [myid:1] - INFO [Thread-1136:NIOServerCnxn@1008] - Closed socket connection for client /127.0.0.1:52740 (no session established for client)
2016-12-06 19:34:26,155 [myid:1] - INFO [NIOServerCxn.Factory:0.0.0.0/0.0.0.0:2181:NIOServerCnxnFactory@192] - Accepted socket connection from /127.0.0.1:52749
2016-12-06 19:34:26,155 [myid:1] - INFO [NIOServerCxn.Factory:0.0.0.0/0.0.0.0:2181:NIOServerCnxn@827] - Processing ruok command from /127.0.0.1:52749
2016-12-06 19:34:26,156 [myid:1] - INFO [Thread-1137:NIOServerCnxn@1008] - Closed socket connection for client /127.0.0.1:52749 (no session established for client)
2016-12-06 19:34:26,222 [myid:1] - INFO [NIOServerCxn.Factory:0.0.0.0/0.0.0.0:2181:NIOServerCnxnFactory@192] - Accepted
```

```

socket connection from /127.0.0.1:52750
2016-12-06 19:34:26,222 [myid:1] - INFO [NIOServerCxn.Factor
y:0.0.0.0/0.0.0.0:2181:NIOServerCxn@827] - Processing ruok c
ommand from /127.0.0.1:52750
2016-12-06 19:34:26,226 [myid:1] - INFO [Thread-1138:NIOServ
erCxn@1008] - Closed socket connection for client /
127.0.0.1:52750 (no session established for client)
2016-12-06 19:34:36,151 [myid:1] - INFO [NIOServerCxn.Factor
y:0.0.0.0/0.0.0.0:2181:NIOServerCxnFactory@192] - Accepted
socket connection from /127.0.0.1:52760
2016-12-06 19:34:36,152 [myid:1] - INFO [NIOServerCxn.Factor
y:0.0.0.0/0.0.0.0:2181:NIOServerCxn@827] - Processing ruok c
ommand from /127.0.0.1:52760
2016-12-06 19:34:36,152 [myid:1] - INFO [Thread-1139:NIOServ
erCxn@1008] - Closed socket connection for client /
127.0.0.1:52760 (no session established for client)
2016-12-06 19:34:36,230 [myid:1] - INFO [NIOServerCxn.Factor
y:0.0.0.0/0.0.0.0:2181:NIOServerCxnFactory@192] - Accepted
socket connection from /127.0.0.1:52761
2016-12-06 19:34:36,231 [myid:1] - INFO [NIOServerCxn.Factor
y:0.0.0.0/0.0.0.0:2181:NIOServerCxn@827] - Processing ruok c
ommand from /127.0.0.1:52761
2016-12-06 19:34:36,231 [myid:1] - INFO [Thread-1140:NIOServ
erCxn@1008] - Closed socket connection for client /
127.0.0.1:52761 (no session established for client)
2016-12-06 19:34:46,149 [myid:1] - INFO [NIOServerCxn.Factor
y:0.0.0.0/0.0.0.0:2181:NIOServerCxnFactory@192] - Accepted
socket connection from /127.0.0.1:52767
2016-12-06 19:34:46,149 [myid:1] - INFO [NIOServerCxn.Factor
y:0.0.0.0/0.0.0.0:2181:NIOServerCxn@827] - Processing ruok c
ommand from /127.0.0.1:52767
2016-12-06 19:34:46,149 [myid:1] - INFO [Thread-1141:NIOServ
erCxn@1008] - Closed socket connection for client /
127.0.0.1:52767 (no session established for client)
2016-12-06 19:34:46,230 [myid:1] - INFO [NIOServerCxn.Factor
y:0.0.0.0/0.0.0.0:2181:NIOServerCxnFactory@192] - Accepted
socket connection from /127.0.0.1:52768
2016-12-06 19:34:46,230 [myid:1] - INFO [NIOServerCxn.Factor
y:0.0.0.0/0.0.0.0:2181:NIOServerCxn@827] - Processing ruok c
ommand from /127.0.0.1:52768
2016-12-06 19:34:46,230 [myid:1] - INFO [Thread-1142:NIOServ
erCxn@1008] - Closed socket connection for client /
127.0.0.1:52768 (no session established for client)

```

Kubernetes supports more powerful, but more complex, logging integrations with [Stackdriver](#) and [Elasticsearch and Kibana](#). For cluster level log shipping and aggregation, consider deploying a [sidecar](#) container to rotate and ship your logs.

## Configuring a Non-Privileged User

The best practices to allow an application to run as a privileged user inside of a container are a matter of debate. If your organization requires that applications run as a non-privileged user you can use a [SecurityContext](#) to control the user that the entry point runs as.

The zk StatefulSet's Pod template contains a SecurityContext.

```
securityContext:
  runAsUser: 1000
  fsGroup: 1000
```

In the Pods' containers, UID 1000 corresponds to the zookeeper user and GID 1000 corresponds to the zookeeper group.

Get the ZooKeeper process information from the zk-0 Pod.

```
kubectl exec zk-0 -- ps -elf
```

As the runAsUser field of the securityContext object is set to 1000, instead of running as root, the ZooKeeper process runs as the zookeeper user.

```
F S UID          PID PPID  C PRI  NI ADDR SZ WCHAN  STIME
TTY          TIME CMD
4 S zookeep+      1    0  0  80   0 - 1127 -      20:
46 ?           00:00:00 sh -c zkGenConfig.sh && zkServer.sh
start-foreground
0 S zookeep+     27    1  0  80   0 - 1155556 -      20:
46 ?           00:00:19 /usr/lib/jvm/java-8-openjdk-amd64/bin/
java -Dzookeeper.log.dir=/var/log/zookeeper -
Dzookeeper.root.logger=INFO,CONSOLE -cp /usr/bin/./build/
classes:/usr/bin/./build/lib/*.jar:/usr/bin/./share/
zookeeper/zookeeper-3.4.9.jar:/usr/bin/./share/zookeeper/
slf4j-log4j12-1.6.1.jar:/usr/bin/./share/zookeeper/slf4j-
api-1.6.1.jar:/usr/bin/./share/zookeeper/
netty-3.10.5.Final.jar:/usr/bin/./share/zookeeper/
log4j-1.2.16.jar:/usr/bin/./share/zookeeper/
jline-0.9.94.jar:/usr/bin/./src/java/lib/*.jar:/usr/bin/./
etc/zookeeper: -Xmx2G -Xms2G -Dcom.sun.management.jmxremote -
Dcom.sun.management.jmxremote.local.only=false
org.apache.zookeeper.server.quorum.QuorumPeerMain /usr/
bin/./etc/zookeeper/zoo.cfg
```

By default, when the Pod's PersistentVolumes is mounted to the ZooKeeper server's data directory, it is only accessible by the root user. This configuration prevents the ZooKeeper process from writing to its WAL and storing its snapshots.

Use the command below to get the file permissions of the ZooKeeper data directory on the zk-0 Pod.

```
kubectl exec -ti zk-0 -- ls -ld /var/lib/zookeeper/data
```

Because the fsGroup field of the securityContext object is set to 1000, the ownership of the Pods' PersistentVolumes is set to the zookeeper group, and the ZooKeeper process is able to read and write its data.

```
drwxr-sr-x 3 zookeeper zookeeper 4096 Dec  5 20:45 /var/lib/
zookeeper/data
```

# Managing the ZooKeeper Process

The [ZooKeeper documentation](#) mentions that "You will want to have a supervisory process that manages each of your ZooKeeper server processes (JVM)." Utilizing a watchdog (supervisory process) to restart failed processes in a distributed system is a common pattern. When deploying an application in Kubernetes, rather than using an external utility as a supervisory process, you should use Kubernetes as the watchdog for your application.

## Updating the Ensemble

The zk StatefulSet is configured to use the RollingUpdate update strategy.

You can use `kubectl patch` to update the number of cpus allocated to the servers.

```
kubectl patch sts zk --type='json' -p='[{"op": "replace",  
"path": "/spec/template/spec/containers/0/resources/requests/  
cpu", "value":"0.3"}]'
```

```
statefulset.apps/zk patched
```

Use `kubectl rollout status` to watch the status of the update.

```
kubectl rollout status sts/zk  
  
waiting for statefulset rolling update to complete 0 pods at  
revision zk-5db4499664...  
Waiting for 1 pods to be ready...  
Waiting for 1 pods to be ready...  
waiting for statefulset rolling update to complete 1 pods at  
revision zk-5db4499664...  
Waiting for 1 pods to be ready...  
Waiting for 1 pods to be ready...  
waiting for statefulset rolling update to complete 2 pods at  
revision zk-5db4499664...  
Waiting for 1 pods to be ready...  
Waiting for 1 pods to be ready...  
statefulset rolling update complete 3 pods at revision  
zk-5db4499664...
```

This terminates the Pods, one at a time, in reverse ordinal order, and recreates them with the new configuration. This ensures that quorum is maintained during a rolling update.

Use the `kubectl rollout history` command to view a history of previous configurations.

```
kubectl rollout history sts/zk
```

```
statefulsets "zk"  
REVISION  
1  
2
```

Use the `kubectl rollout undo` command to roll back the modification.

```
kubectl rollout undo sts/zk  
statefulset.apps/zk rolled back
```

## Handling Process Failure

[Restart Policies](#) control how Kubernetes handles process failures for the entry point of the container in a Pod. For Pods in a `StatefulSet`, the only appropriate `RestartPolicy` is `Always`, and this is the default value. For stateful applications you should **never** override the default policy.

Use the following command to examine the process tree for the ZooKeeper server running in the `zk-0` Pod.

```
kubectl exec zk-0 -- ps -ef
```

The command used as the container's entry point has PID 1, and the ZooKeeper process, a child of the entry point, has PID 27.

UID	PID	PPID	C	STIME	TTY	TIME	CMD
zookeeper+	1	0	0	15:03	?	00:00:00	sh -c
zkGenConfig.sh	&&	zkServer.sh					start-foreground
zookeeper+	27	1	0	15:03	?	00:00:03	/usr/lib/jvm/ java-8-openjdk-amd64/bin/java -Dzookeeper.log.dir=/var/log/ zookeeper -Dzookeeper.root.logger=INFO,CONSOLE -cp /usr/ bin/./build/classes:/usr/bin/./build/lib/*.jar:/usr/bin/./ share/zookeeper/zookeeper-3.4.9.jar:/usr/bin/./share/ zookeeper/slf4j-log4j12-1.6.1.jar:/usr/bin/./share/ zookeeper/slf4j-api-1.6.1.jar:/usr/bin/./share/zookeeper/ netty-3.10.5.Final.jar:/usr/bin/./share/zookeeper/ log4j-1.2.16.jar:/usr/bin/./share/zookeeper/ jline-0.9.94.jar:/usr/bin/./src/java/lib/*.jar:/usr/bin/./ etc/zookeeper: -Xmx2G -Xms2G -Dcom.sun.management.jmxremote - Dcom.sun.management.jmxremote.local.only=false org.apache.zookeeper.server.quorum.QuorumPeerMain /usr/ bin/./etc/zookeeper/zoo.cfg

In another terminal watch the Pods in the `zk StatefulSet` with the following command.

```
kubectl get pod -w -l app=zk
```

In another terminal, terminate the ZooKeeper process in Pod `zk-0` with the following command.

```
kubectl exec zk-0 -- pkill java
```

The termination of the ZooKeeper process caused its parent process to terminate. Because the `RestartPolicy` of the container is `Always`, it restarted the parent process.

NAME	READY	STATUS	RESTARTS	AGE
zk-0	1/1	Running	0	21m
zk-1	1/1	Running	0	20m
zk-2	1/1	Running	0	19m

NAME	READY	STATUS	RESTARTS	AGE
zk-0	0/1	Error	0	29m
zk-0	0/1	Running	1	29m
zk-0	1/1	Running	1	29m

If your application uses a script (such as `zkServer.sh`) to launch the process that implements the application's business logic, the script must terminate with the child process. This ensures that Kubernetes will restart the application's container when the process implementing the application's business logic fails.

## Testing for Liveness

Configuring your application to restart failed processes is not enough to keep a distributed system healthy. There are scenarios where a system's processes can be both alive and unresponsive, or otherwise unhealthy. You should use liveness probes to notify Kubernetes that your application's processes are unhealthy and it should restart them.

The Pod template for the `zk StatefulSet` specifies a liveness probe. ``

```
livenessProbe:
  exec:
    command:
      - sh
      - -c
      - "zookeeper-ready 2181"
    initialDelaySeconds: 15
    timeoutSeconds: 5
```

The probe calls a bash script that uses the ZooKeeper `ruok` four letter word to test the server's health.

```
OK=$(echo ruok | nc 127.0.0.1 $1)
if [ "$OK" == "imok" ]; then
  exit 0
else
  exit 1
fi
```

In one terminal window, use the following command to watch the Pods in the `zk StatefulSet`.

```
kubectl get pod -w -l app=zk
```

In another window, using the following command to delete the `zkOk.sh` script from the file system of Pod `zk-0`.

```
kubectl exec zk-0 -- rm /usr/bin/zookeeper-ready
```

When the liveness probe for the ZooKeeper process fails, Kubernetes will automatically restart the process for you, ensuring that unhealthy processes in the ensemble are restarted.

```
kubectl get pod -w -l app=zk
```

NAME	READY	STATUS	RESTARTS	AGE
zk-0	1/1	Running	0	1h

zk-1	1/1	Running	0	1h
zk-2	1/1	Running	0	1h
NAME	READY	STATUS	RESTARTS	AGE
zk-0	0/1	Running	0	1h
zk-0	0/1	Running	1	1h
zk-0	1/1	Running	1	1h

## Testing for Readiness

Readiness is not the same as liveness. If a process is alive, it is scheduled and healthy. If a process is ready, it is able to process input. Liveness is a necessary, but not sufficient, condition for readiness. There are cases, particularly during initialization and termination, when a process can be alive but not ready.

If you specify a readiness probe, Kubernetes will ensure that your application's processes will not receive network traffic until their readiness checks pass.

For a ZooKeeper server, liveness implies readiness. Therefore, the readiness probe from the `zookeeper.yaml` manifest is identical to the liveness probe.

```
readinessProbe:
  exec:
    command:
      - sh
      - -c
      - "zookeeper-ready 2181"
  initialDelaySeconds: 15
  timeoutSeconds: 5
```

Even though the liveness and readiness probes are identical, it is important to specify both. This ensures that only healthy servers in the ZooKeeper ensemble receive network traffic.

## Tolerating Node Failure

ZooKeeper needs a quorum of servers to successfully commit mutations to data. For a three server ensemble, two servers must be healthy for writes to succeed. In quorum based systems, members are deployed across failure domains to ensure availability. To avoid an outage, due to the loss of an individual machine, best practices preclude co-locating multiple instances of the application on the same machine.

By default, Kubernetes may co-locate Pods in a `StatefulSet` on the same node. For the three server ensemble you created, if two servers are on the same node, and that node fails, the clients of your ZooKeeper service will experience an outage until at least one of the Pods can be rescheduled.

You should always provision additional capacity to allow the processes of critical systems to be rescheduled in the event of node failures. If you do so, then the outage will only last until the Kubernetes scheduler reschedules one of the ZooKeeper servers. However, if you want your service to tolerate node failures with no downtime, you should set `podAntiAffinity`.

Use the command below to get the nodes for Pods in the `zk StatefulSet`.



```
for i in 0 1 2; do kubectl get pod zk-$i --template {{.spec.nodeName}}; echo ""; done
```

All of the Pods in the zk StatefulSet are deployed on different nodes.

```
kubernetes-node-cxpk
kubernetes-node-a5aq
kubernetes-node-2g2d
```

This is because the Pods in the zk StatefulSet have a PodAntiAffinity specified.

```
affinity:
  podAntiAffinity:
    requiredDuringSchedulingIgnoredDuringExecution:
      - labelSelector:
          matchExpressions:
            - key: "app"
              operator: In
              values:
                - zk
        topologyKey: "kubernetes.io/hostname"
```

The `requiredDuringSchedulingIgnoredDuringExecution` field tells the Kubernetes Scheduler that it should never co-locate two Pods which have `app` label as `zk` in the domain defined by the `topologyKey`. The `topologyKey kubernetes.io/hostname` indicates that the domain is an individual node. Using different rules, labels, and selectors, you can extend this technique to spread your ensemble across physical, network, and power failure domains.

## Surviving Maintenance

**In this section you will cordon and drain nodes. If you are using this tutorial on a shared cluster, be sure that this will not adversely affect other tenants.**

The previous section showed you how to spread your Pods across nodes to survive unplanned node failures, but you also need to plan for temporary node failures that occur due to planned maintenance.

Use this command to get the nodes in your cluster.

```
kubectl get nodes
```

Use [kubectl cordon](#) to cordon all but four of the nodes in your cluster.

```
kubectl cordon <node-name>
```

Use this command to get the zk-pdb PodDisruptionBudget.

```
kubectl get pdb zk-pdb
```

The `max-unavailable` field indicates to Kubernetes that at most one Pod from zk StatefulSet can be unavailable at any time.



NAME	MIN-AVAILABLE	MAX-UNAVAILABLE	ALLOWED-DISRUPTIONS
zk-pdb	N/A	1	1

In one terminal, use this command to watch the Pods in the zk StatefulSet.

```
kubectl get pods -w -l app=zk
```

In another terminal, use this command to get the nodes that the Pods are currently scheduled on.

```
for i in 0 1 2; do kubectl get pod zk-$i --template {{.spec.nodeName}}; echo ""; done
```

```
kubernetes-node-pb41
kubernetes-node-ixsl
kubernetes-node-i4c4
```

Use [kubectl drain](#) to cordon and drain the node on which the zk-0 Pod is scheduled.

```
kubectl drain $(kubectl get pod zk-0 --template {{.spec.nodeName}}) --ignore-daemonsets --force --delete-local-data
node "kubernetes-node-pb41" cordoned
```

```
WARNING: Deleting pods not managed by ReplicationController, ReplicaSet, Job, or DaemonSet: fluentd-cloud-logging-
kubernetes-node-pb41, kube-proxy-kubernetes-node-pb41;
Ignoring DaemonSet-managed pods: node-problem-detector-v0.1-
o5elz
pod "zk-0" deleted
node "kubernetes-node-pb41" drained
```

As there are four nodes in your cluster, `kubectl drain`, succeeds and the zk-0 is rescheduled to another node.

NAME	READY	STATUS	RESTARTS	AGE
zk-0	1/1	Running	2	1h
zk-1	1/1	Running	0	1h
zk-2	1/1	Running	0	1h
NAME	READY	STATUS	RESTARTS	AGE
zk-0	1/1	Terminating	2	2h
zk-0	0/1	Terminating	2	2h
zk-0	0/1	Terminating	2	2h
zk-0	0/1	Terminating	2	2h
zk-0	0/1	Pending	0	0s
zk-0	0/1	Pending	0	0s
zk-0	0/1	ContainerCreating	0	0s
zk-0	0/1	Running	0	51s
zk-0	1/1	Running	0	1m

Keep watching the StatefulSet's Pods in the first terminal and drain the node on which zk-1 is scheduled.

```
kubectl drain $(kubectl get pod zk-1 --template {{.spec.nodeName}}) --ignore-daemonsets --force --delete-local-data "kubernetes-node-ixsl" cordoned
```

```
WARNING: Deleting pods not managed by ReplicationController, ReplicaSet, Job, or DaemonSet: fluentd-cloud-logging-kubernetes-node-ixsl, kube-proxy-kubernetes-node-ixsl; Ignoring DaemonSet-managed pods: node-problem-detector-v0.1-voc74  
pod "zk-1" deleted  
node "kubernetes-node-ixsl" drained
```

The zk-1 Pod cannot be scheduled because the zk StatefulSet contains a PodAntiAffinity rule preventing co-location of the Pods, and as only two nodes are schedulable, the Pod will remain in a Pending state.

```
kubectl get pods -w -l app=zk
```

NAME	READY	STATUS	RESTARTS	AGE
zk-0	1/1	Running	2	1h
zk-1	1/1	Running	0	1h
zk-2	1/1	Running	0	1h

NAME	READY	STATUS	RESTARTS	AGE
zk-0	1/1	Terminating	2	2h
zk-0	0/1	Terminating	2	2h
zk-0	0/1	Terminating	2	2h
zk-0	0/1	Terminating	2	2h
zk-0	0/1	Pending	0	0s
zk-0	0/1	Pending	0	0s
zk-0	0/1	ContainerCreating	0	0s
zk-0	0/1	Running	0	51s
zk-0	1/1	Running	0	1m
zk-1	1/1	Terminating	0	2h
zk-1	0/1	Terminating	0	2h
zk-1	0/1	Terminating	0	2h
zk-1	0/1	Terminating	0	2h
zk-1	0/1	Pending	0	0s
zk-1	0/1	Pending	0	0s

Continue to watch the Pods of the stateful set, and drain the node on which zk-2 is scheduled.

```
kubectl drain $(kubectl get pod zk-2 --template {{.spec.nodeName}}) --ignore-daemonsets --force --delete-local-data node "kubernetes-node-i4c4" cordoned
```

```
WARNING: Deleting pods not managed by ReplicationController, ReplicaSet, Job, or DaemonSet: fluentd-cloud-logging-kubernetes-node-i4c4, kube-proxy-kubernetes-node-i4c4; Ignoring DaemonSet-managed pods: node-problem-detector-v0.1-dyrog  
WARNING: Ignoring DaemonSet-managed pods: node-problem-detector-v0.1-dyrog; Deleting pods not managed by
```

ReplicationController, ReplicaSet, Job, or DaemonSet:  
fluentd-cloud-logging-kubernetes-node-i4c4, kube-proxy-  
kubernetes-node-i4c4  
There are pending pods when an error occurred: Cannot evict  
pod as it would violate the pod's disruption budget.  
pod/zk-2

Use CTRL-C to terminate to kubectl.

You cannot drain the third node because evicting zk-2 would violate zk-budget.  
However, the node will remain cordoned.

Use zkCli.sh to retrieve the value you entered during the sanity test from zk-0.

```
kubectl exec zk-0 zkCli.sh get /hello
```

The service is still available because its PodDisruptionBudget is respected.

```
WatchedEvent state:SyncConnected type:None path:null
world
cZxid = 0x200000002
ctime = Wed Dec 07 00:08:59 UTC 2016
mZxid = 0x200000002
mtime = Wed Dec 07 00:08:59 UTC 2016
pZxid = 0x200000002
cversion = 0
dataVersion = 0
aclVersion = 0
ephemeralOwner = 0x0
dataLength = 5
numChildren = 0
```

Use [kubectl uncordon](#) to uncordon the first node.

```
kubectl uncordon kubernetes-node-pb41
```

```
node "kubernetes-node-pb41" uncordoned
```

zk-1 is rescheduled on this node. Wait until zk-1 is Running and Ready.

```
kubectl get pods -w -l app=zk
```

NAME	READY	STATUS	RESTARTS	AGE
zk-0	1/1	Running	2	1h
zk-1	1/1	Running	0	1h
zk-2	1/1	Running	0	1h

NAME	READY	STATUS	RESTARTS	AGE
zk-0	1/1	Terminating	2	2h
zk-0	0/1	Terminating	2	2h
zk-0	0/1	Terminating	2	2h
zk-0	0/1	Terminating	2	2h
zk-0	0/1	Pending	0	0s
zk-0	0/1	Pending	0	0s
zk-0	0/1	ContainerCreating	0	0s
zk-0	0/1	Running	0	51s

zk-0	1/1	Running	0	1m	
zk-1	1/1	Terminating	0	2h	
zk-1	0/1	Terminating	0	2h	
zk-1	0/1	Terminating	0	2h	
zk-1	0/1	Terminating	0	2h	
zk-1	0/1	Pending	0	0s	
zk-1	0/1	Pending	0	0s	
zk-1	0/1	Pending	0	12m	
zk-1	0/1	ContainerCreating	0	12m	
zk-1	0/1	Running	0	13m	
zk-1	1/1	Running	0	13m	

Attempt to drain the node on which zk-2 is scheduled.

```
kubectl drain $(kubectl get pod zk-2 --template {{.spec.nodeName}}) --ignore-daemonsets --force --delete-local-data
```

The output:

```
node "kubernetes-node-i4c4" already cordoned
WARNING: Deleting pods not managed by ReplicationController,
ReplicaSet, Job, or DaemonSet: fluentd-cloud-logging-
kubernetes-node-i4c4, kube-proxy-kubernetes-node-i4c4;
Ignoring DaemonSet-managed pods: node-problem-detector-v0.1-
dyrog
pod "heapster-v1.2.0-2604621511-wh1r" deleted
pod "zk-2" deleted
node "kubernetes-node-i4c4" drained
```

This time `kubectl drain` succeeds.

Uncordon the second node to allow zk-2 to be rescheduled.

```
kubectl uncordon kubernetes-node-ixsl
```

```
node "kubernetes-node-ixsl" uncordoned
```

You can use `kubectl drain` in conjunction with `PodDisruptionBudgets` to ensure that your services remain available during maintenance. If drain is used to cordon nodes and evict pods prior to taking the node offline for maintenance, services that express a disruption budget will have that budget respected. You should always allocate additional capacity for critical services so that their Pods can be immediately rescheduled.

## Cleaning up

- Use `kubectl uncordon` to uncordon all the nodes in your cluster.
- You will need to delete the persistent storage media for the `PersistentVolumes` used in this tutorial. Follow the necessary steps, based on your environment, storage configuration, and provisioning method, to ensure that all storage is reclaimed.

## Feedback

Was this page helpful?

Yes No

Thanks for the feedback. If you have a specific, answerable question about how to use Kubernetes, ask it on [Stack Overflow](#). Open an issue in the GitHub repo if you want to [report a problem](#) or [suggest an improvement](#).

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Page last modified on June 18, 2019 at 10:49 PM PST by [Outdated terminology: "kubernetes-minion-group" \(#14859\)](#) ([Page History](#))

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# AppArmor

**FEATURE STATE:** Kubernetes v1.4 [beta](#)

This feature is currently in a *beta* state, meaning:

- The version names contain beta (e.g. v2beta3).
- Code is well tested. Enabling the feature is considered safe. Enabled by default.
- Support for the overall feature will not be dropped, though details may change.
- The schema and/or semantics of objects may change in incompatible ways in a subsequent beta or stable release. When this happens, we will provide instructions for migrating to the next version. This may require deleting, editing, and re-creating API objects. The editing process may require some thought. This may require downtime for applications that rely on the feature.
- Recommended for only non-business-critical uses because of potential for incompatible changes in subsequent releases. If you have multiple clusters that can be upgraded independently, you may be able to relax this restriction.
- **Please do try our beta features and give feedback on them! After they exit beta, it may not be practical for us to make more changes.**

AppArmor is a Linux kernel security module that supplements the standard Linux user and group based permissions to confine programs to a limited set of resources. AppArmor can be configured for any application to reduce its potential attack surface and provide greater in-depth defense. It is configured through profiles tuned to whitelist the access needed by a specific program or container, such as Linux capabilities, network access, file permissions, etc. Each profile can be run in either *enforcing* mode, which blocks access to disallowed resources, or *complain* mode, which only reports violations.

AppArmor can help you to run a more secure deployment by restricting what containers are allowed to do, and/or provide better auditing through system logs. However, it is important to keep in mind that AppArmor is not a silver bullet and can only do so much to protect against exploits in your application code. It is important to provide good, restrictive profiles, and harden your applications and cluster from other angles as well.

- [Objectives](#)
- [Before you begin](#)
- [Securing a Pod](#)
- [Example](#)
- [Administration](#)
- [Authoring Profiles](#)
- [API Reference](#)

- [What's next](#)

## Objectives

- See an example of how to load a profile on a node
- Learn how to enforce the profile on a Pod
- Learn how to check that the profile is loaded
- See what happens when a profile is violated
- See what happens when a profile cannot be loaded

## Before you begin

Make sure:

1. Kubernetes version is at least v1.4 - Kubernetes support for AppArmor was added in v1.4. Kubernetes components older than v1.4 are not aware of the new AppArmor annotations, and will **silently ignore** any AppArmor settings that are provided. To ensure that your Pods are receiving the expected protections, it is important to verify the Kubelet version of your nodes:

```
kubectl get nodes -o=jsonpath='{range .items[*]}
{@.metadata.name}: {@.status.nodeInfo.kubeletVersion}\n{end}'
```

```
gke-test-default-pool-239f5d02-gyn2: v1.4.0
gke-test-default-pool-239f5d02-x1kf: v1.4.0
gke-test-default-pool-239f5d02-xwux: v1.4.0
```

1. AppArmor kernel module is enabled - For the Linux kernel to enforce an AppArmor profile, the AppArmor kernel module must be installed and enabled. Several distributions enable the module by default, such as Ubuntu and SUSE, and many others provide optional support. To check whether the module is enabled, check the `/sys/module/apparmor/parameters/enabled` file:

```
cat /sys/module/apparmor/parameters/enabled
Y
```

If the Kubelet contains AppArmor support ( $\geq$  v1.4), it will refuse to run a Pod with AppArmor options if the kernel module is not enabled.

**Note:** Ubuntu carries many AppArmor patches that have not been merged into the upstream Linux kernel, including patches that add additional hooks and features. Kubernetes has only been tested with the upstream version, and does not promise support for other features.

1. Container runtime is Docker - Currently the only Kubernetes-supported container runtime that also supports AppArmor is Docker. As more runtimes add AppArmor support, the options will be expanded. You can verify that your nodes are running docker with:

```
kubectl get nodes -o=jsonpath='{range .items[*]}
{@.metadata.name}:
{@.status.nodeInfo.containerRuntimeVersion}\n{end}'
```

```
gke-test-default-pool-239f5d02-gyn2: docker://1.11.2
gke-test-default-pool-239f5d02-x1kf: docker://1.11.2
gke-test-default-pool-239f5d02-xwux: docker://1.11.2
```

If the Kubelet contains AppArmor support ( $\geq v1.4$ ), it will refuse to run a Pod with AppArmor options if the runtime is not Docker.

1. Profile is loaded - AppArmor is applied to a Pod by specifying an AppArmor profile that each container should be run with. If any of the specified profiles is not already loaded in the kernel, the Kubelet ( $\geq v1.4$ ) will reject the Pod. You can view which profiles are loaded on a node by checking the `/sys/kernel/security/apparmor/profiles` file. For example:

```
ssh gke-test-default-pool-239f5d02-gyn2 "sudo cat /sys/
kernel/security/apparmor/profiles | sort"
```

```
apparmor-test-deny-write (enforce)
apparmor-test-audit-write (enforce)
docker-default (enforce)
k8s-nginx (enforce)
```

For more details on loading profiles on nodes, see [Setting up nodes with profiles](#).

As long as the Kubelet version includes AppArmor support ( $\geq v1.4$ ), the Kubelet will reject a Pod with AppArmor options if any of the prerequisites are not met. You can also verify AppArmor support on nodes by checking the node ready condition message (though this is likely to be removed in a later release):

```
kubectl get nodes -o=jsonpath='${range .items[*]}
{@.metadata.name}: {.status.conditions[?
(@.reason=="KubeletReady")].message}\n{end}'
```

```
gke-test-default-pool-239f5d02-gyn2: kubelet is posting
ready status. AppArmor enabled
gke-test-default-pool-239f5d02-x1kf: kubelet is posting
ready status. AppArmor enabled
gke-test-default-pool-239f5d02-xwux: kubelet is posting
ready status. AppArmor enabled
```

## Securing a Pod

**Note:** AppArmor is currently in beta, so options are specified as annotations. Once support graduates to general availability, the annotations will be replaced with first-class fields (more details in [Upgrade path to GA](#)).

AppArmor profiles are specified *per-container*. To specify the AppArmor profile to run a Pod container with, add an annotation to the Pod's metadata:

```
container.apparmor.security.beta.kubernetes.io/
<container_name>: <profile_ref>
```

Where `<container_name>` is the name of the container to apply the profile to, and `<profile_ref>` specifies the profile to apply. The `profile_ref` can be one of:

- `runtime/default` to apply the runtime's default profile
- `localhost/<profile_name>` to apply the profile loaded on the host with the name `<profile_name>`
- `unconfined` to indicate that no profiles will be loaded

See the [API Reference](#) for the full details on the annotation and profile name formats.

Kubernetes AppArmor enforcement works by first checking that all the prerequisites have been met, and then forwarding the profile selection to the container runtime for enforcement. If the prerequisites have not been met, the Pod will be rejected, and will not run.

To verify that the profile was applied, you can look for the AppArmor security option listed in the container created event:

```
kubectl get events | grep Created
```

```
22s          22s          1          hello-apparmor
Pod          spec.containers{hello}    Normal    Created
{kubelet e2e-test-stclair-node-pool-31nt}    Created
container with docker id 269a53b202d3; Security:
[seccomp=unconfined apparmor=k8s-apparmor-example-deny-write]
```

You can also verify directly that the container's root process is running with the correct profile by checking its proc attr:

```
kubectl exec <pod_name> cat /proc/1/attr/current
```

```
k8s-apparmor-example-deny-write (enforce)
```

## Example

*This example assumes you have already set up a cluster with AppArmor support.*

First, we need to load the profile we want to use onto our nodes. The profile we'll use simply denies all file writes:



## [deny-write.profile docs/tutorials/clusters](#)

```
#include <tunables/global>

profile k8s-apparmor-example-deny-write
flags=(attach_disconnected) {
    #include <abstractions/base>

    file,

    # Deny all file writes.
    deny /** w,
}
```

Since we don't know where the Pod will be scheduled, we'll need to load the profile on all our nodes. For this example we'll just use SSH to install the profiles, but other approaches are discussed in [Setting up nodes with profiles](#).

```
NODES=(
    # The SSH-accessible domain names of your nodes
    gke-test-default-pool-239f5d02-gyn2.us-central1-a.my-k8s
    gke-test-default-pool-239f5d02-x1kf.us-central1-a.my-k8s
    gke-test-default-pool-239f5d02-xwux.us-central1-a.my-k8s)
for NODE in ${NODES[*]}; do ssh $NODE 'sudo apparmor_parser -
q <<EOF
#include <tunables/global>

profile k8s-apparmor-example-deny-write
flags=(attach_disconnected) {
    #include <abstractions/base>

    file,

    # Deny all file writes.
    deny /** w,
}
EOF '
done
```

Next, we'll run a simple "Hello AppArmor" pod with the deny-write profile:

## [pods/security/hello-apparmor.yaml](#)

```
apiVersion: v1
kind: Pod
metadata:
  name: hello-apparmor
  annotations:
    # Tell Kubernetes to apply the AppArmor profile "k8s-
    apparmor-example-deny-write".
    # Note that this is ignored if the Kubernetes node is
    not running version 1.4 or greater.
    container.apparmor.security.beta.kubernetes.io/hello: localhost/k8s-apparmor-example-deny-write
spec:
  containers:
  - name: hello
    image: busybox
    command: [ "sh", "-c", "echo 'Hello AppArmor!' && sleep
1h" ]
```

```
kubectl create -f ./hello-apparmor.yaml
```

If we look at the pod events, we can see that the Pod container was created with the AppArmor profile "k8s-apparmor-example-deny-write":

```
kubectl get events | grep hello-apparmor
```

```
14s          14s          1          hello-apparmor
Pod          Normal          Scheduled
{default-scheduler }          Successfully
assigned hello-apparmor to gke-test-default-pool-239f5d02-
gyn2
14s          14s          1          hello-apparmor    Pod
spec.containers{hello}    Normal          Pulling          {kubelet gke-
test-default-pool-239f5d02-gyn2}    pulling image "busybox"
13s          13s          1          hello-apparmor    Pod
spec.containers{hello}    Normal          Pulled           {kubelet gke-
test-default-pool-239f5d02-gyn2}    Successfully pulled image
"busybox"
13s          13s          1          hello-apparmor    Pod
spec.containers{hello}    Normal          Created          {kubelet gke-
test-default-pool-239f5d02-gyn2}    Created container with
docker id 06b6cd1c0989; Security:[seccomp=unconfined
apparmor=k8s-apparmor-example-deny-write]
13s          13s          1          hello-apparmor    Pod
spec.containers{hello}    Normal          Started          {kubelet gke-
test-default-pool-239f5d02-gyn2}    Started container with
docker id 06b6cd1c0989
```

We can verify that the container is actually running with that profile by checking its proc attr:

```
kubectl exec hello-apparmor cat /proc/1/attr/current
```

```
k8s-apparmor-example-deny-write (enforce)
```

Finally, we can see what happens if we try to violate the profile by writing to a file:

```
kubectl exec hello-apparmor touch /tmp/test
```

```
touch: /tmp/test: Permission denied
error: error executing remote command: command terminated
with non-zero exit code: Error executing in Docker
Container: 1
```

To wrap up, let's look at what happens if we try to specify a profile that hasn't been loaded:

```
kubectl create -f /dev/stdin <<EOF
```

```
apiVersion: v1
kind: Pod
metadata:
  name: hello-apparmor-2
  annotations:
    container.apparmor.security.beta.kubernetes.io/hello: localhost/k8s-apparmor-example-allow-write
spec:
  containers:
  - name: hello
    image: busybox
    command: [ "sh", "-c", "echo 'Hello AppArmor!' && sleep
1h" ]
EOF
pod/hello-apparmor-2 created
```

```
kubectl describe pod hello-apparmor-2
```

```
Name:          hello-apparmor-2
Namespace:     default
Node:          gke-test-default-pool-239f5d02-x1kf/
Start Time:    Tue, 30 Aug 2016 17:58:56 -0700
Labels:        <none>
Annotations:   container.apparmor.security.beta.kubernetes.io/
hello=localhost/k8s-apparmor-example-allow-write
Status:        Pending
Reason:        AppArmor
Message:       Pod Cannot enforce AppArmor: profile "k8s-
apparmor-example-allow-write" is not loaded
IP:            <none>
Controllers:   <none>
Containers:
  hello:
    Container ID:
    Image:        busybox
    Image ID:
```

```

Port:
Command:
  sh
  -C
  echo 'Hello AppArmor!' && sleep 1h
State:      Waiting
Reason:     Blocked
Ready:      False
Restart Count: 0
Environment: <none>
Mounts:
  /var/run/secrets/kubernetes.io/serviceaccount from
default-token-dnz7v (ro)
Conditions:
  Type      Status
  Initialized True
  Ready      False
  PodScheduled True
Volumes:
  default-token-dnz7v:
    Type:      Secret (a volume populated by a Secret)
    SecretName: default-token-dnz7v
    Optional:   false
QoS Class:    BestEffort
Node-Selectors: <none>
Tolerations:  <none>
Events:
  FirstSeen    LastSeen    Count   SubobjectPath   Type
From
Reason        Message
-----
-----
23s          23s          1      {default-
scheduler }      Normal
Scheduled      Successfully assigned hello-apparmor-2 to e2e-
test-stclair-node-pool-t1f5
23s          23s          1      {kubelet e2e-test-
stclair-node-pool-t1f5}      Warning
AppArmor      Cannot enforce AppArmor: profile "k8s-apparmor-
example-allow-write" is not loaded

```

Note the pod status is Failed, with a helpful error message: Pod Cannot enforce AppArmor: profile "k8s-apparmor-example-allow-write" is not loaded. An event was also recorded with the same message.

# Administration

## Setting up nodes with profiles

Kubernetes does not currently provide any native mechanisms for loading AppArmor profiles onto nodes. There are lots of ways to setup the profiles though, such as:

- Through a [DaemonSet](#) that runs a Pod on each node to ensure the correct profiles are loaded. An example implementation can be found [here](#).
- At node initialization time, using your node initialization scripts (e.g. Salt, Ansible, etc.) or image.
- By copying the profiles to each node and loading them through SSH, as demonstrated in the [Example](#).

The scheduler is not aware of which profiles are loaded onto which node, so the full set of profiles must be loaded onto every node. An alternative approach is to add a node label for each profile (or class of profiles) on the node, and use a [node selector](#) to ensure the Pod is run on a node with the required profile.

## Restricting profiles with the PodSecurityPolicy

If the PodSecurityPolicy extension is enabled, cluster-wide AppArmor restrictions can be applied. To enable the PodSecurityPolicy, the following flag must be set on the `apiserver`:

```
--enable-admission-plugins=PodSecurityPolicy[,others...]
```

The AppArmor options can be specified as annotations on the PodSecurityPolicy:

```
apparmor.security.beta.kubernetes.io/defaultProfileName: <profile_ref>  
apparmor.security.beta.kubernetes.io/allowedProfileNames:  
<profile_ref>[,others...]
```

The default profile name option specifies the profile to apply to containers by default when none is specified. The allowed profile names option specifies a list of profiles that Pod containers are allowed to be run with. If both options are provided, the default must be allowed. The profiles are specified in the same format as on containers. See the [API Reference](#) for the full specification.

## Disabling AppArmor

If you do not want AppArmor to be available on your cluster, it can be disabled by a command-line flag:

```
--feature-gates=AppArmor=false
```

When disabled, any Pod that includes an AppArmor profile will fail validation with a "Forbidden" error. Note that by default docker always enables the "docker-default" profile on non-privileged pods (if the AppArmor kernel module is enabled), and will continue to do so even if the feature-gate is disabled. The option to disable AppArmor will be removed when AppArmor graduates to general availability (GA).

## Upgrading to Kubernetes v1.4 with AppArmor

No action is required with respect to AppArmor to upgrade your cluster to v1.4. However, if any existing pods had an AppArmor annotation, they will not go through validation (or PodSecurityPolicy admission). If permissive profiles are loaded on the nodes, a malicious user could pre-apply a permissive profile to escalate the pod privileges above the docker-default. If this is a concern, it is recommended to scrub the cluster of any pods containing an annotation with `apparmor.security.beta.kubernetes.io`.

## Upgrade path to General Availability

When AppArmor is ready to be graduated to general availability (GA), the options currently specified through annotations will be converted to fields. Supporting all the upgrade and downgrade paths through the transition is very nuanced, and will be explained in detail when the transition occurs. We will commit to supporting both fields and annotations for at least 2 releases, and will explicitly reject the annotations for at least 2 releases after that.

## Authoring Profiles

Getting AppArmor profiles specified correctly can be a tricky business. Fortunately there are some tools to help with that:

- `aa-genprof` and `aa-logprof` generate profile rules by monitoring an application's activity and logs, and admitting the actions it takes. Further instructions are provided by the [AppArmor documentation](#).
- `bane` is an AppArmor profile generator for Docker that uses a simplified profile language.

It is recommended to run your application through Docker on a development workstation to generate the profiles, but there is nothing preventing running the tools on the Kubernetes node where your Pod is running.

To debug problems with AppArmor, you can check the system logs to see what, specifically, was denied. AppArmor logs verbose messages to `dmesg`, and errors can usually be found in the system logs or through `journalctl`. More information is provided in [AppArmor failures](#).

## API Reference

### Pod Annotation

Specifying the profile a container will run with:

- **key:** `container.apparmor.security.beta.kubernetes.io/<container_name>` Where `<container_name>` matches the name of a container in the Pod. A separate profile can be specified for each container in the Pod.
- **value:** a profile reference, described below

## Profile Reference

- `runtime/default`: Refers to the default runtime profile.
  - Equivalent to not specifying a profile (without a PodSecurityPolicy default), except it still requires AppArmor to be enabled.
  - For Docker, this resolves to the [docker-default](#) profile for non-privileged containers, and unconfined (no profile) for privileged containers.
- `localhost/<profile_name>`: Refers to a profile loaded on the node (localhost) by name.
  - The possible profile names are detailed in the [core policy reference](#).
- `unconfined`: This effectively disables AppArmor on the container.

Any other profile reference format is invalid.

## PodSecurityPolicy Annotations

Specifying the default profile to apply to containers when none is provided:

- **key**: `apparmor.security.beta.kubernetes.io/defaultProfileName`
- **value**: a profile reference, described above

Specifying the list of profiles Pod containers is allowed to specify:

- **key**: `apparmor.security.beta.kubernetes.io/allowedProfileNames`
- **value**: a comma-separated list of profile references (described above)
  - Although an escaped comma is a legal character in a profile name, it cannot be explicitly allowed here.

## What's next

Additional resources:

- [Quick guide to the AppArmor profile language](#)
- [AppArmor core policy reference](#)

## Feedback

Was this page helpful?

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Thanks for the feedback. If you have a specific, answerable question about how to use Kubernetes, ask it on [Stack Overflow](#). Open an issue in the GitHub repo if you want to [report a problem](#) or [suggest an improvement](#).

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# Using Source IP

Applications running in a Kubernetes cluster find and communicate with each other, and the outside world, through the Service abstraction. This document explains what happens to the source IP of packets sent to different types of Services, and how you can toggle this behavior according to your needs.

- [Objectives](#)
- [Before you begin](#)
- [Terminology](#)
- [Prerequisites](#)
- [Source IP for Services with Type=ClusterIP](#)
- [Source IP for Services with Type=NodePort](#)
- [Source IP for Services with Type=LoadBalancer](#)
- [Cleaning up](#)
- [What's next](#)

## Objectives

- Expose a simple application through various types of Services
- Understand how each Service type handles source IP NAT
- Understand the tradeoffs involved in preserving source IP

## Before you begin

You need to have a Kubernetes cluster, and the `kubectl` command-line tool must be configured to communicate with your cluster. If you do not already have a cluster, you can create one by using [Minikube](#), or you can use one of these Kubernetes playgrounds:

- [Katacoda](#)
- [Play with Kubernetes](#)

To check the version, enter `kubectl version`.

## Terminology

This document makes use of the following terms:

- [NAT](#): network address translation
- [Source NAT](#): replacing the source IP on a packet, usually with a node's IP
- [Destination NAT](#): replacing the destination IP on a packet, usually with a pod IP
- [VIP](#): a virtual IP, such as the one assigned to every Kubernetes Service
- [Kube-proxy](#): a network daemon that orchestrates Service VIP management on every node



## Prerequisites

You must have a working Kubernetes 1.5 cluster to run the examples in this document. The examples use a small nginx webserver that echoes back the source IP of requests it receives through an HTTP header. You can create it as follows:

```
kubectl run source-ip-app --image=k8s.gcr.io/echoserver:1.4
```

The output is:

```
deployment.apps/source-ip-app created
```

## Source IP for Services with Type=ClusterIP

Packets sent to ClusterIP from within the cluster are never source NAT'd if you're running kube-proxy in [iptables mode](#), which is the default since Kubernetes 1.2. Kube-proxy exposes its mode through a proxyMode endpoint:

```
kubectl get nodes
```

The output is similar to this:

NAME		STATUS	ROLES	AGE
VERSION				
kubernetes-node-6jst	Ready	<none>	2h	v1.13.0
kubernetes-node-cx31	Ready	<none>	2h	v1.13.0
kubernetes-node-jj1t	Ready	<none>	2h	v1.13.0

Get the proxy mode on one of the node

```
kubernetes-node-6jst $ curl localhost:10249/proxyMode
```

The output is:

```
iptables
```

You can test source IP preservation by creating a Service over the source IP app:

```
kubectl expose deployment source-ip-app --name=clusterip --port=80 --target-port=8080
```

The output is:

```
service/clusterip exposed
```

```
kubectl get svc clusterip
```

The output is similar to:

NAME	TYPE	CLUSTER-IP	EXTERNAL-IP
PORT(S)	AGE		
clusterip	ClusterIP	10.0.170.92	<none>
TCP	51s		80/

And hitting the ClusterIP from a pod in the same cluster:

```
kubectl run busybox -it --image=busybox --restart=Never --rm
```

The output is similar to this:

Waiting for pod default/busybox to be running, status is Pending, pod ready: false  
If you don't see a command prompt, try pressing enter.

```
# ip addr
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
    inet 127.0.0.1/8 scope host lo
        valid_lft forever preferred_lft forever
    inet6 ::1/128 scope host
        valid_lft forever preferred_lft forever
3: eth0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1460 qdisc noqueue
    link/ether 0a:58:0a:f4:03:08 brd ff:ff:ff:ff:ff:ff
    inet 10.244.3.8/24 scope global eth0
        valid_lft forever preferred_lft forever
    inet6 fe80::188a:84ff:feb0:26a5/64 scope link
        valid_lft forever preferred_lft forever

# wget -qO - 10.0.170.92
CLIENT VALUES:
client_address=10.244.3.8
command=GET
...
```

The `client_address` is always the client pod's IP address, whether the client pod and server pod are in the same node or in different nodes.

## Source IP for Services with Type=NodePort

As of Kubernetes 1.5, packets sent to Services with [Type=NodePort](#) are source NAT'd by default. You can test this by creating a NodePort Service:

```
kubectl expose deployment source-ip-app --name=nodeport --port=80 --target-port=8080 --type=NodePort
```

The output is:

```
service/nodeport exposed
```

```
NODEPORT=$(kubectl get -o jsonpath="{.spec.ports[0].nodePort}" services nodeport)
NODES=$(kubectl get nodes -o jsonpath='{ $$.items[*].status.addresses[?(@.type=="ExternalIP")].address }')
```

If you're running on a cloudprovider, you may need to open up a firewall-rule for the node `s:nodeport` reported above. Now you can try reaching the Service from outside the cluster through the node port allocated above.

```
for node in $NODES; do curl -s $node:$NODEPORT | grep -i  
client_address; done
```

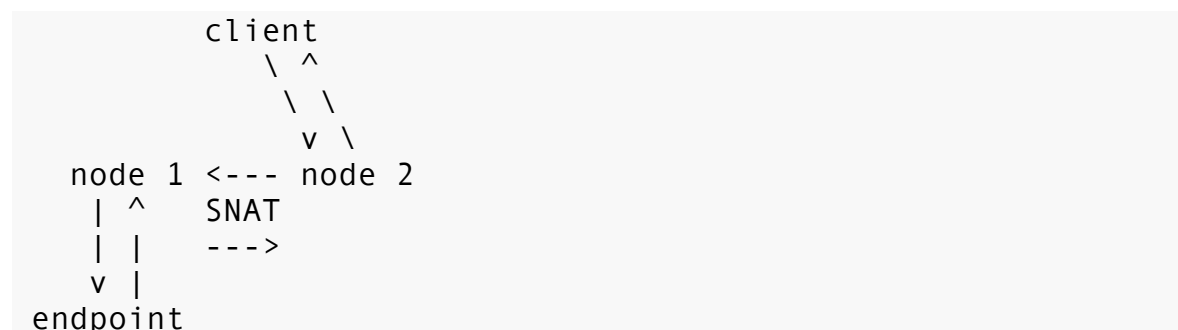
The output is similar to:

```
client_address=10.180.1.1  
client_address=10.240.0.5  
client_address=10.240.0.3
```

Note that these are not the correct client IPs, they're cluster internal IPs. This is what happens:

- Client sends packet to `node2:nodePort`
- `node2` replaces the source IP address (SNAT) in the packet with its own IP address
- `node2` replaces the destination IP on the packet with the pod IP
- packet is routed to node 1, and then to the endpoint
- the pod's reply is routed back to `node2`
- the pod's reply is sent back to the client

Visually:



To avoid this, Kubernetes has a feature to preserve the client source IP ([check here for feature availability](#)). Setting `service.spec.externalTrafficPolicy` to the value `Local` will only proxy requests to local endpoints, never forwarding traffic to other nodes and thereby preserving the original source IP address. If there are no local endpoints, packets sent to the node are dropped, so you can rely on the correct source-ip in any packet processing rules you might apply a packet that make it through to the endpoint.

Set the `service.spec.externalTrafficPolicy` field as follows:

```
kubectl patch svc nodeport -p '{"spec":  
{"externalTrafficPolicy":"Local"}}'
```

The output is:

```
service/nodeport patched
```

Now, re-run the test:

```
for node in $NODES; do curl --connect-timeout 1 -s $node:
$NODEPORT | grep -i client_address; done
```

The output is:

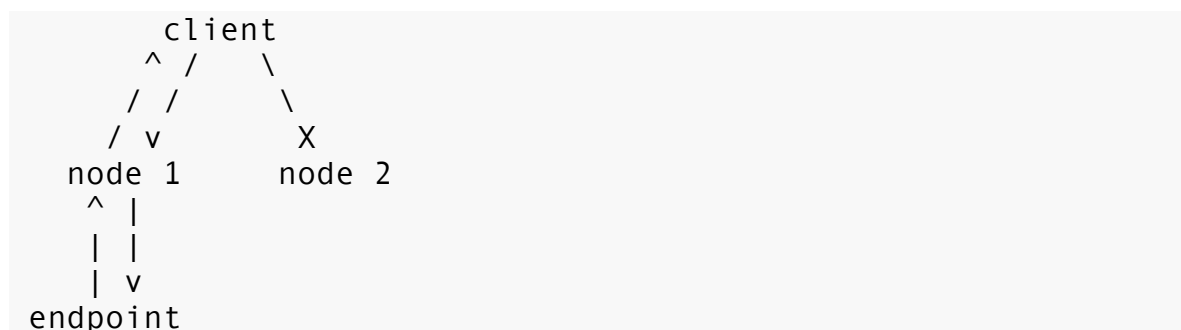
```
client_address=104.132.1.79
```

Note that you only got one reply, with the *right* client IP, from the one node on which the endpoint pod is running.

This is what happens:

- client sends packet to node2:nodePort, which doesn't have any endpoints
- packet is dropped
- client sends packet to node1:nodePort, which *does* have endpoints
- node1 routes packet to endpoint with the correct source IP

Visually:



## Source IP for Services with Type=LoadBalancer

As of Kubernetes 1.5, packets sent to Services with [Type=LoadBalancer](#) are source NAT'd by default, because all schedulable Kubernetes nodes in the Ready state are eligible for loadbalanced traffic. So if packets arrive at a node without an endpoint, the system proxies it to a node *with* an endpoint, replacing the source IP on the packet with the IP of the node (as described in the previous section).

You can test this by exposing the source-ip-app through a loadbalancer

```
kubectl expose deployment source-ip-app --name=loadbalancer
--port=80 --target-port=8080 --type=LoadBalancer
```

The output is:

```
service/loadbalancer exposed
```

Print IPs of the Service:

```
kubectl get svc loadbalancer
```

The output is similar to this:

NAME IP	TYPE PORT(S)	AGE	CLUSTER-IP	EXTERNAL -
------------	-----------------	-----	------------	------------

```
loadbalancer LoadBalancer 10.0.65.118
104.198.149.140 80/TCP 5m
```

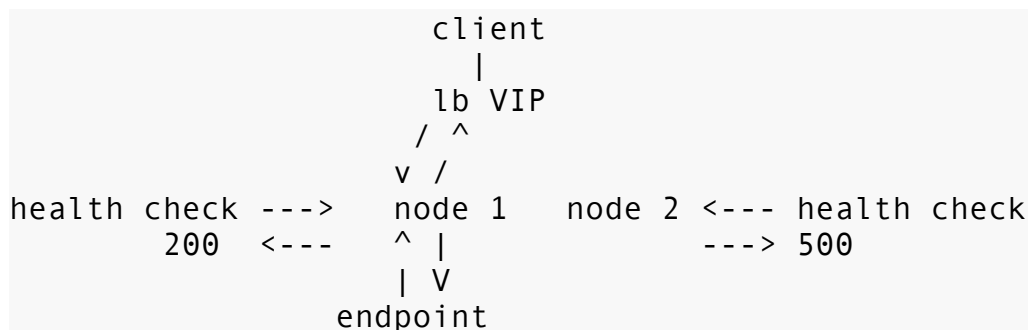
```
curl 104.198.149.140
```

The output is similar to this:

```
CLIENT VALUES:
client_address=10.240.0.5
...
```

However, if you're running on Google Kubernetes Engine/GCE, setting the same `service.spec.externalTrafficPolicy` field to `Local` forces nodes *without* Service endpoints to remove themselves from the list of nodes eligible for loadbalanced traffic by deliberately failing health checks.

Visually:



You can test this by setting the annotation:

```
kubectl patch svc loadbalancer -p '{"spec":
{"externalTrafficPolicy":"Local"}}'
```

You should immediately see the `service.spec.healthCheckNodePort` field allocated by Kubernetes:

```
kubectl get svc loadbalancer -o yaml | grep -i
healthCheckNodePort
```

The output is similar to this:

```
healthCheckNodePort: 32122
```

The `service.spec.healthCheckNodePort` field points to a port on every node serving the health check at `/healthz`. You can test this:

```
kubectl get pod -o wide -l run=source-ip-app
```

The output is similar to this:

NAME	READY	STATUS
RESTARTS	AGE	IP
		NODE
source-ip-app-826191075-qehz4	1/1	Running
0	20h	10.180.1.136
		kubernetes-node-6jst

Curl the `/healthz` endpoint on different nodes.

```
kubernetes-node-6jst $ curl localhost:32122/healthz
```

The output is similar to this:

```
1 Service Endpoints found
```

```
kubernetes-node-jj1t $ curl localhost:32122/healthz
```

The output is similar to this:

```
No Service Endpoints Found
```

A service controller running on the master is responsible for allocating the cloud loadbalancer, and when it does so, it also allocates HTTP health checks pointing to this port/path on each node. Wait about 10 seconds for the 2 nodes without endpoints to fail health checks, then curl the lb ip:

```
curl 104.198.149.140
```

The output is similar to this:

```
CLIENT VALUES:  
client_address=104.132.1.79  
...
```

## Cross platform support

As of Kubernetes 1.5, support for source IP preservation through Services with Type=LoadBalancer is only implemented in a subset of cloudproviders (GCP and Azure). The cloudprovider you're running on might fulfill the request for a loadbalancer in a few different ways:

1. With a proxy that terminates the client connection and opens a new connection to your nodes/endpoints. In such cases the source IP will always be that of the cloud LB, not that of the client.
2. With a packet forwarder, such that requests from the client sent to the loadbalancer VIP end up at the node with the source IP of the client, not an intermediate proxy.

Loadbalancers in the first category must use an agreed upon protocol between the loadbalancer and backend to communicate the true client IP such as the HTTP [X-FORWARDED-FOR](#) header, or the [proxy protocol](#). Loadbalancers in the second category can leverage the feature described above by simply creating an HTTP health check pointing at the port stored in the `service.spec.healthCheckNodePort` field on the Service.

## Cleaning up

Delete the Services:

```
kubectl delete svc -l run=source-ip-app
```

Delete the Deployment, ReplicaSet and Pod:

```
kubectl delete deployment source-ip-app
```

## What's next

- Learn more about [connecting applications via services](#)
- Learn more about [loadbalancing](#)

## Feedback

Was this page helpful?

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