

Desmistificando Microsserviços e DevOps: Projetando Arquiteturas Efetivamente Escaláveis

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[IF1004] - Seminários em SI 3
<https://github.com/vinicius3w/if1004-DevOps>

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Resources

- There is no textbook required. However, the following are some books that may be recommended:
 - [Introduction to Kubernetes - LinuxFoundationX - LFS158x](#)
 - [Kubernetes Ingress: NodePort, Load Balancers, and Ingress Controllers](#)
 - [Deploying Java Applications with Docker and Kubernetes](#)
 - [Deploying Java Applications with Kubernetes and an API Gateway](#)
 - [Kubernetes Documentation](#)



kubernetes

Introduction to Kubernetes

Overview

- Do you need guidelines on how to start transforming your organization with Kubernetes and cloud native patterns?
- Would you like to simplify software container orchestration and find a way to grow your use of Kubernetes without adding infrastructure complexity?
- In this lecture, we'll discuss some of Kubernetes' basic concepts and talk about the architecture of the system, the problems it solves, and the model that it uses to handle containerized deployments and scaling.
- This lecture offers an introduction to Kubernetes and includes technical instructions on how to deploy a stand-alone and multi-tier application

Topics

- The origin, architecture, primary components, and building blocks of Kubernetes
- How to set up and access a Kubernetes cluster using Minikube
- Ways to run applications on the deployed Kubernetes environment and access the deployed applications
- Usefulness of Kubernetes communities and how you can participate

Prerequisites

- Basic knowledge of container technologies, like Docker or rkt is required

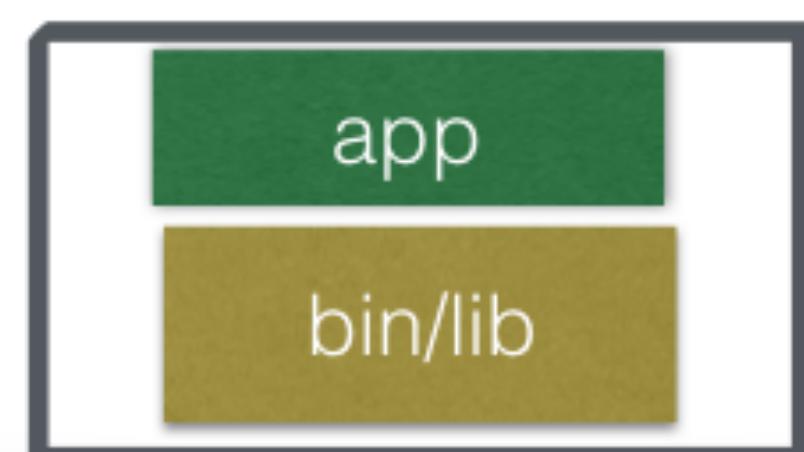
Introduction

Warm up

- With container images, we confine the application code, its runtime, and all of its dependencies in a pre-defined format
- And, with container runtimes like runC, containerd, or rkt we can use those pre-packaged images, to create one or more containers
- All of these runtimes are good at running containers on a single host
- But, in practice, we would like to have a fault-tolerant and scalable solution, which can be achieved by creating a single controller/management unit, after connecting multiple nodes together
- This controller/management unit is generally referred to as a Container Orchestrator.

Warm up

- Containers are an application-centric way to deliver high-performing, scalable applications on the infrastructure of your choice
- With a container image, we bundle the application along with its runtime and dependencies
- We use that image to create an isolated executable environment, also known as container
- We can deploy containers from a given image on the platform of our choice, such as desktops, VMs, Cloud, etc.



Desktop

Dev VM

QA Env.

Public Cloud

Private Cloud

Customer Site

What Is Container Orchestration?

- In Development and Quality Assurance (QA) environments, we can get away with running containers on a single host to develop and test applications
- However, when we go to production, we do not have the same liberty, as we need to ensure that our applications:
 - Are fault-tolerant
 - Can scale, and do this on-demand
 - Use resources optimally
 - Can discover other applications automatically, and communicate with each other
 - Are accessible from the external world
 - Can update/rollback without any downtime.

What Is Container Orchestration?

- Container Orchestrators are the tools which group hosts together to form a cluster, and help us fulfill the requirements mentioned earlier

Container Orchestrators

- **Docker Swarm:** is a Container Orchestrator provided by Docker, Inc.
It is part of Docker Engine
- **Kubernetes:** was started by Google, but now, it is a part of the Cloud Native Computing Foundation project
- **Mesos Marathon:** is one of the frameworks to run containers at scale on Apache Mesos
- **Amazon EC2 Container Service (ECS):** is a hosted service provided by AWS to run Docker containers at scale on its infrastructure
- **Hashicorp Nomad:** is the Container Orchestrator provided by HashiCorp

Why Use Container Orchestrators?

- Bring multiple hosts together and make them part of a cluster
- Schedule containers to run on different hosts
- Help containers running on one host reach out to containers running on other hosts in the cluster
- Bind containers and storage
- Bind containers of similar type to a higher-level construct, like services, so we don't have to deal with individual containers
- Keep resource usage in-check, and optimize it when necessary
- Allow secure access to applications running inside containers

Where to Deploy Container Orchestrators?

- Most Container Orchestrators can be deployed on the infrastructure of our choice
- We can deploy them on bare-metal, VMs, on-premise, or on a cloud of our choice
 - For example, Kubernetes can be deployed on our laptop/workstation, inside a company's datacenter, on AWS, on OpenStack, etc
 - There are even one-click installers available to setup Kubernetes on the Cloud, like Google Container Engine on Google Cloud, or Azure Container Service on Microsoft Azure
 - Similar solutions are available for other Container Orchestrators, as well.
- There are companies who offer managed Container Orchestration as a Service

Kubernetes



What Is Kubernetes?

- "Kubernetes is an open-source system for automating deployment, scaling, and management of containerized applications."
- **K8s** comes from the Greek word κυβερνήτης:, which means helmsman or ship pilot.
 - With this analogy in mind, we can think of **k8s** as the manager for shipping containers.

What Is Kubernetes?

- K8s is highly inspired by the [Google Borg system](#), which we will explore in this lecture
 - It is an open source project written in the Go language, and licensed under the Apache License Version 2.0.
- k8s was started by Google and, with its v1.0 release in July 2015, Google donated it to the Cloud Native Computing Foundation (CNCF)
 - We will discuss more about CNCF a little later.
 - Generally, k8s has new releases every three months.

From Borg to Kubernetes

- "Google's Borg system is a cluster manager that runs hundreds of thousands of jobs, from many thousands of different applications, across a number of clusters each with up to tens of thousands of machines."
- For more than a decade, Borg was Google's secret to run containerized workloads in production
- Whatever services we use from Google, like Gmail, Drive, etc., they are all serviced using Borg.
- Some of the features/objects of k8s that can be traced back to Borg, or to lessons learnt from it, are:
 - API Servers
 - Pods
 - IP-per-Pod
 - Services
 - Labels

Kubernetes Features I

- **Automatic binpacking:** automatically schedules the containers based on resource usage and constraints, without sacrificing the availability
- **Self-healing:** automatically replaces and reschedules the containers from failed nodes. It also kills and restarts the containers which do not respond to health checks, based on existing rules/policy
- **Horizontal scaling:** can automatically scale applications based on resource usage like CPU and memory. In some cases, it also supports dynamic scaling based on customer metrics
- **Service discovery and Load balancing:** groups sets of containers and refers to them via a DNS name. This DNS name is also called a k8s **service**. K8s can discover these services automatically, and load-balance requests between containers of a given service.

Kubernetes Features II

- **Automated rollouts and rollbacks:** can roll out and roll back new versions/configurations of an application, without introducing any downtime
- **Secrets and configuration management:** can manage secrets and configuration details for an application without re-building the respective images. With secrets, we can share confidential information to our application without exposing it to the stack configuration, like on GitHub
- **Storage orchestration:** with k8s and its plugins, we can automatically mount local, external, and storage solutions to the containers in a seamless manner, based on Software Defined Storage (SDS)
- **Batch execution:** besides long running jobs, k8s also supports batch execution

Why Use Kubernetes?

- K8s is very portable and extensible and can be deployed on the environment of our choice, be it VMs, bare-metal, or public/private/hybrid/multi-cloud setups
- Also has a very modular and pluggable architecture
- We can write custom APIs or plugins to extend its functionalities
- K8s has a very thriving community across the world
 - It has more than 1350 contributors, who, over time, have done over 47,000 commits
 - There are meet-up groups in different cities which meet regularly to discuss about k8s and its ecosystem
 - There are Special Interest Groups (SIGs), which focus on special interests, such as scaling, bare-metal, networking, etc

Kubernetes Users

- With just a few years since its debut, many companies are running workloads using k8s
 - Box
 - eBay
 - Pearson
 - SAP
 - Wikimedia
 - IF1007
 - And many more

Cloud Native Computing Foundation (CNCF)

- The Cloud Native Computing Foundation (CNCF) is one of the projects hosted by The Linux Foundation
- CNCF aims to accelerate the adoption of containers, microservices, and cloud-native applications
- CNCF provides resources to each of the projects, but, at the same time, each project continues to operate independently under its pre-existing governance structure and with its existing maintainers

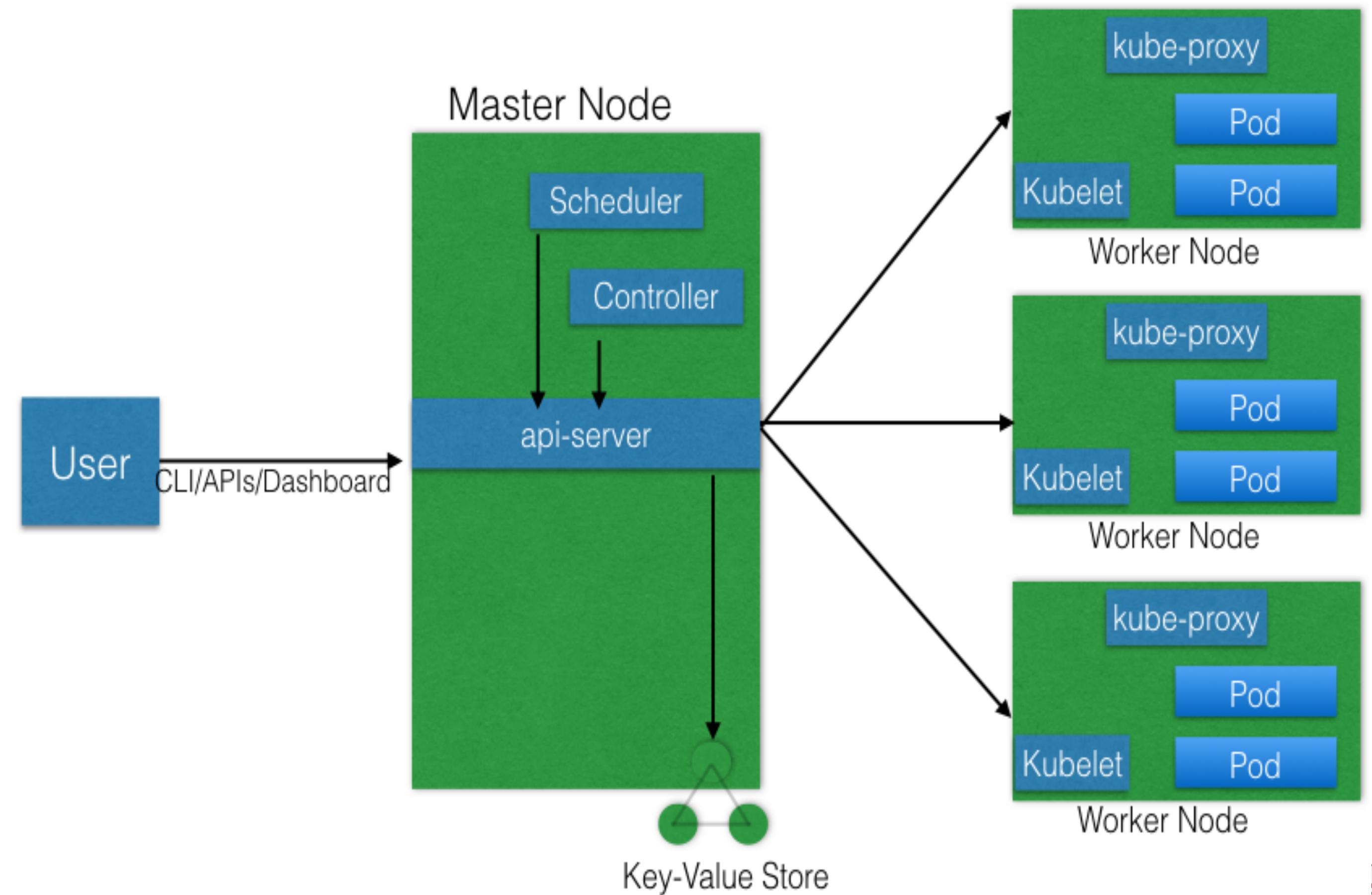
CNCF and Kubernetes

- For k8s, the Cloud Native Computing Foundation:
 - Provides a neutral home for the k8s trademark and enforces proper usage
 - Provides license scanning of core and vendored code
 - Offers legal guidance on patent and copyright issues
 - Creates open source curriculum, training, and certification
 - Manages a software conformance working group
 - Actively markets k8s
 - Hosts and funds developer marketing activities like K8Sport
 - Supports ad hoc activities, like offering a neutral k8s AMI in the AWS Marketplace
 - Funds conferences and meetup events.

Kubernetes architecture overview

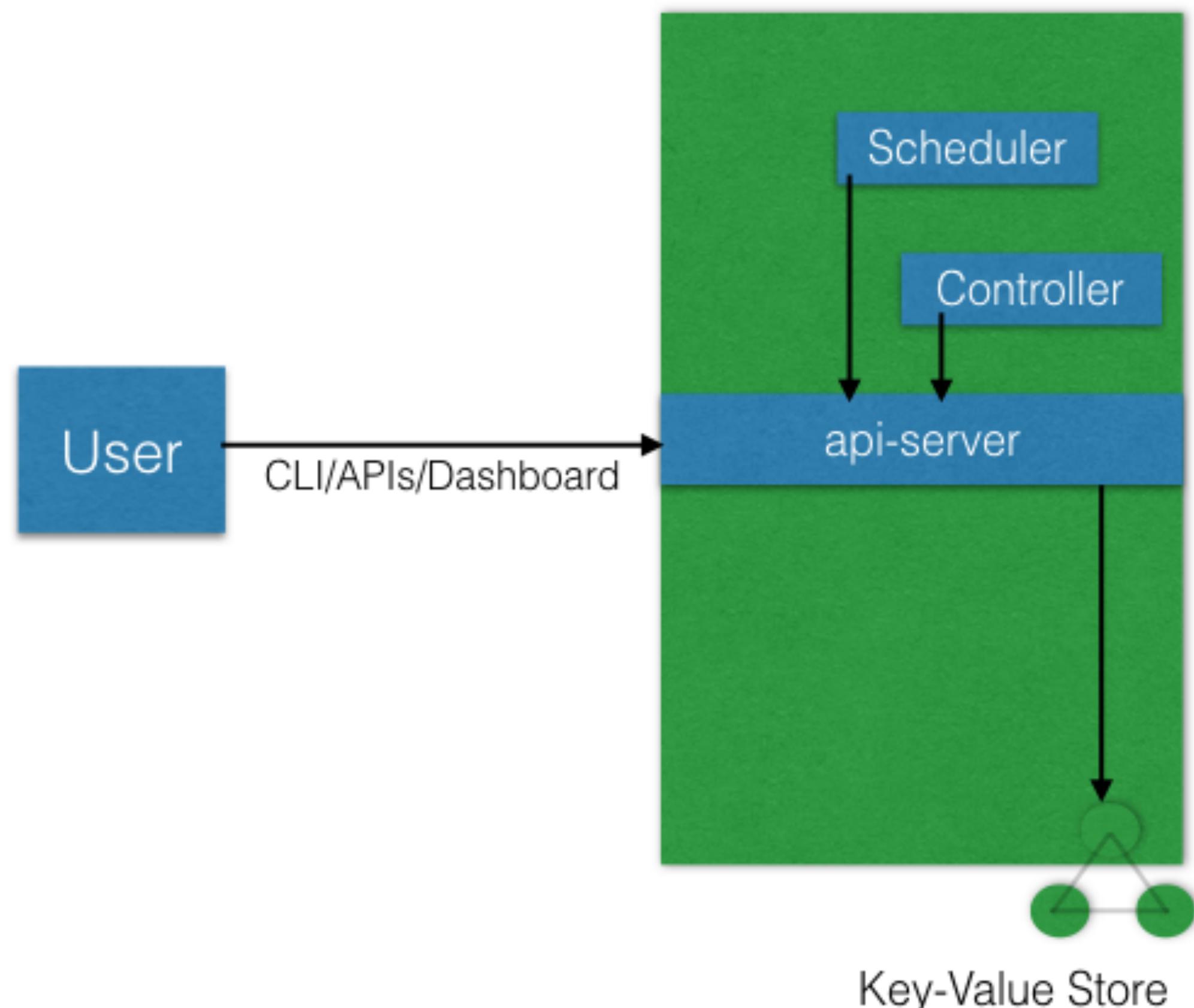
Kubernetes Architecture

- At a very high level, k8s has the following main components:
 - One or more Master Nodes
 - One or more Worker Nodes
 - Distributed key-value store, like etcd



Master Node

- Responsible for managing the k8s cluster, and it is the entry point for all administrative tasks
- We can communicate to the Master Node via the CLI, the GUI (Dashboard), or via APIs
- If we have more than one Master Node, they would be in a HA (High Availability) mode
- To manage the cluster state, k8s uses etcd, and all Master Nodes connect to it



Master Node Components I

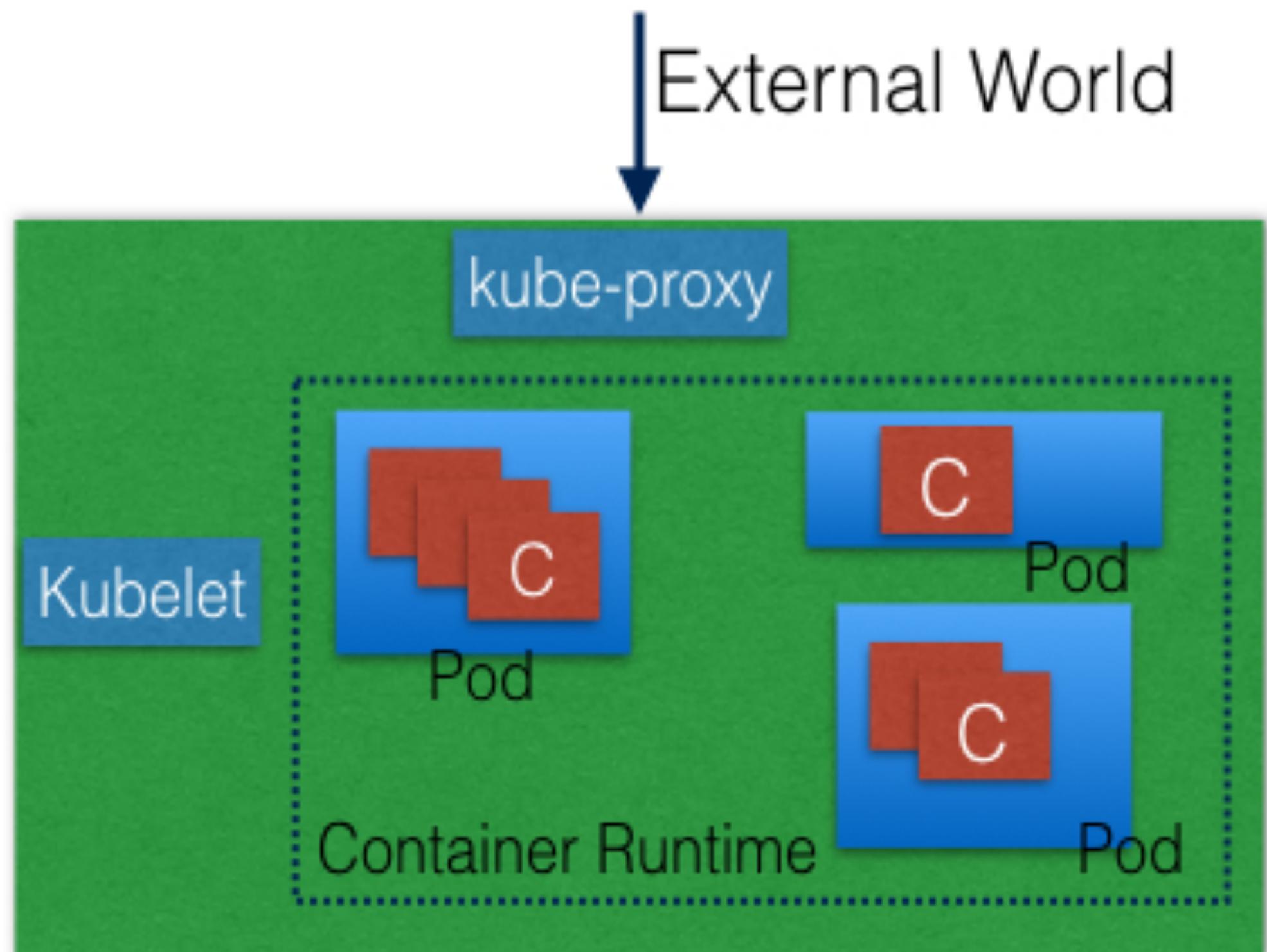
- **API Server**
 - All the administrative tasks are performed via the API Server within the Master Node
 - A user/operator sends REST commands to the API Server, which then validates and processes the requests
 - After executing the requests, the resulting state of the cluster is stored in the distributed key-value store.
- **Scheduler**
 - As the name suggests, the Scheduler schedules the work to different Worker Nodes
 - The Scheduler has the resource usage information for each Worker Node. It also knows about the constraints that users/operators may have set, such as scheduling work on a node that has the label `disk==ssd` set
 - Before scheduling the work, the Scheduler also takes into account the quality of the service requirements, data locality, affinity, anti-affinity, etc
 - The Scheduler schedules the work in terms of Pods and Services

Master Node Components II

- **Controller Manager**
 - Manages different non-terminating control loops, which regulate the state of the k8s cluster
 - Each one of these control loops knows about the desired state of the objects it manages, and watches their current state through the API Server
 - In a control loop, if the current state of the objects it manages does not meet the desired state, then the control loop takes corrective steps to make sure that the current state is the same as the desired state
- **etcd**
 - As discussed earlier, etcd is a distributed key-value store which is used to store the cluster state
 - It can be part of the k8s Master, or, it can be configured externally, in which case, Master Nodes would connect to it

Worker Node

- A Worker Node is a machine (VM, physical server, etc.) which runs the applications using Pods and is controlled by the Master Node
- Pods are scheduled on the Worker Nodes, which have the necessary tools to run and connect them
- A Pod is the scheduling unit in k8s
- It is a logical collection of one or more containers which are always scheduled together
- Also, to access the applications from the external world, we connect to Worker Nodes and not to the Master Node/s



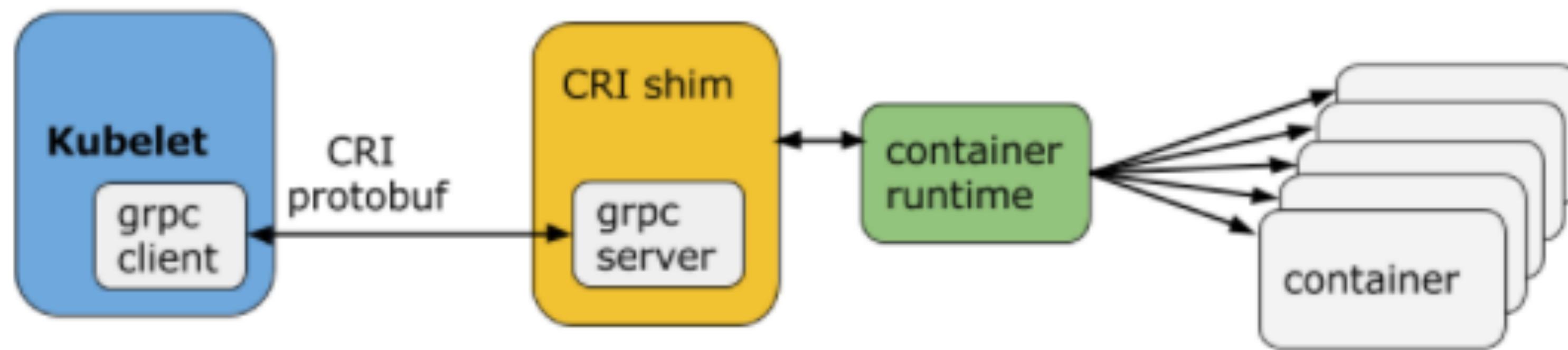
Worker Node Components I

- **Container Runtime**

- To run containers, we need a Container Runtime on the Worker Node
- By default, k8s is configured to run containers with Docker. It can also run containers using the rkt Container Runtime.

- **kubelet**

- Is an agent which runs on each Worker Node and communicates with the Master Node
- It receives the Pod definition via various means (primarily, through the API Server), and runs the containers associated with the Pod
- It also makes sure the containers which are part of the Pods are healthy at all times.
- The kubelet connects with the Container Runtimes to run containers

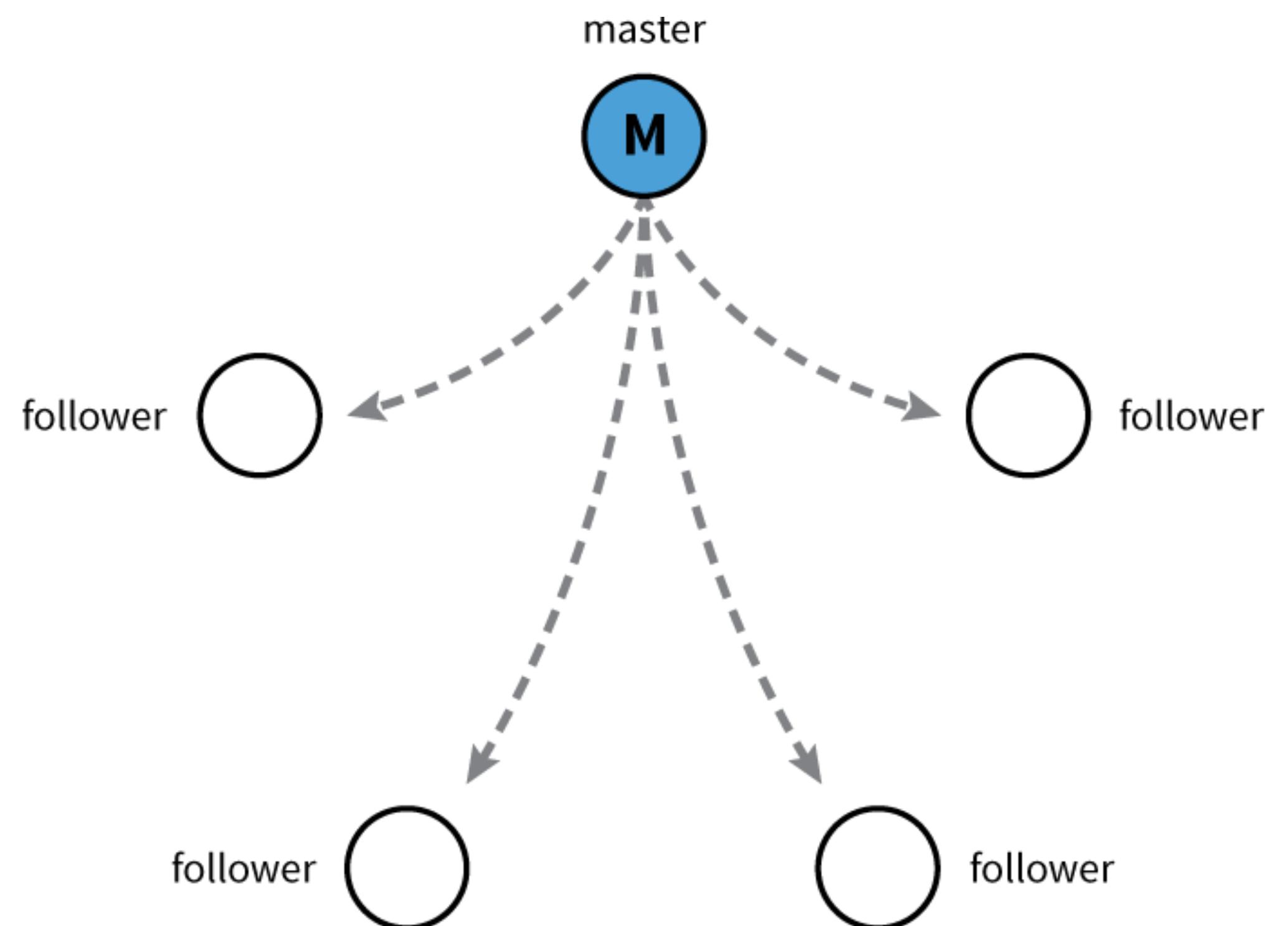


Worker Node Components II

- **kube-proxy**
 - Instead of connecting directly to Pods to access the applications, we use a logical construct called a Service as a connection endpoint
 - A Service groups related Pods, which it load balances when accessed
 - **kube-proxy** is the network proxy which runs on each Worker Node and listens to the API Server for each Service endpoint creation/deletion
 - For each Service endpoint, **kube-proxy** sets up the routes so that it can reach to it

State Management with etcd

- **etcd** is a distributed key-value store based on the Raft Consensus Algorithm
- Raft allows a collection of machines to work as a coherent group that can survive the failures of some of its members
- At any given time, one of the nodes in the group will be the Master, and the rest of them will be the Followers
- Any node can be treated as a Master

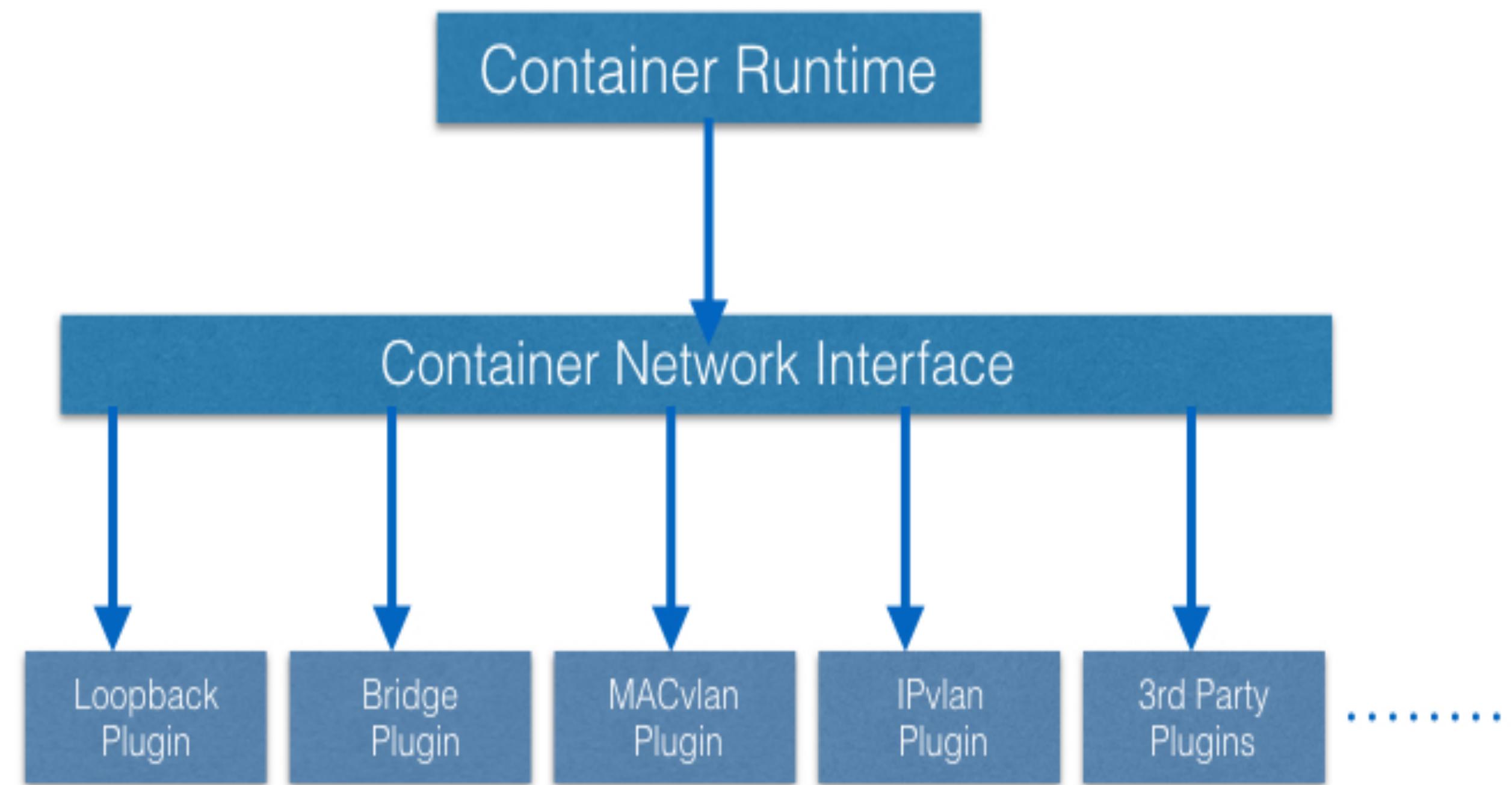


Network Setup Challenges

- To have a fully functional k8s cluster, we need to make sure of the following:
 - A unique IP is assigned to each Pod
 - Containers in a Pod can communicate to each other
 - The Pod is able to communicate with other Pods in the cluster
 - If configured, the application deployed inside a Pod is accessible from the external world
- All of the above are networking challenges which must be addressed before deploying the k8s cluster

Assigning a Unique IP Address to Each Pod

- In k8s, each Pod gets a unique IP address
- For container networking, there are two primary specifications:
 - Container Network Model (CNM), proposed by Docker
 - Container Network Interface (CNI), proposed by CoreOS.
- k8s uses CNI to assign the IP address to each Pod.



Container-to-Container Communication Inside a Pod

- With the help of the underlying Host OS, all of the Container Runtimes generally create an isolated network entity for each container that it starts
- On Linux, that entity is referred to as a Network Namespace
- These Network Namespaces can be shared across containers, or with the Host Operating System
- Inside a Pod, containers share the Network Namespaces, so that they can reach to each other via localhost

Pod-to-Pod Communication Across Nodes

- In a clustered environment, the Pods can be scheduled on any node
- We need to make sure that the Pods can communicate across the nodes, and all the nodes should be able to reach any Pod
- K8s also puts a condition that there shouldn't be any Network Address Translation (NAT) while doing the Pod-to-Pod communication across Hosts. We can achieve this via:
 - Routable Pods and nodes, using the underlying physical infrastructure, like Google Container Engine
 - Using Software Defined Networking, like Flannel, Weave, Calico, etc.
- For more details, you can take a look at the available k8s documentation

Communication Between the External World and Pods

- By exposing our services to the external world with kube-proxy, we can access our applications from outside the cluster
- We will have a complete section dedicated to this, so we will dive into this later

Installing Kubernetes

Kubernetes Configuration

- **All-in-One Single-Node Installation**
 - With All-in-One, all the Master and Worker components are installed on a single node
 - This is very useful for learning, development, and testing
 - This type should not be used in production
 - **Minikube** is one such example, and we are going to explore it in future sections
- **Single-Node etcd, Single-Master, and Multi-Worker Installation**
 - In this setup, we will have a single Master Node, which will also run a single-node **etcd** instance
 - Multiple Worker Nodes are connected to the Master Node

Kubernetes Configuration

- **Single-Node etcd, Multi-Master, and Multi-Worker Installation**
 - In this setup, we will have multiple Master Nodes, which will work in HA mode, but we will have a single-node etcd instance
 - Multiple Worker Nodes are connected to the Master Nodes
- **Multi-Node etcd, Multi-Master, and Multi-Worker Installation**
 - In this mode, **etcd** is configured in a clustered mode, outside the k8s cluster, and the Nodes connect to it
 - The Master Nodes are all configured in an HA mode, connecting to multiple Worker Nodes
 - This is the most advanced and recommended production setup

Infrastructure for Kubernetes Installation

- Once we decide on the installation type, we also need to make some infrastructure-related decisions, such as:
 - Should we set up k8s on bare-metal, public cloud, or private cloud?
 - Which underlying system should we use? Should we choose RHEL, CoreOS, CentOS, or something else?
 - Which networking solution should we use? And so on.
- The k8s documentation has details in regards to choosing the right solution

localhost Installation

- There are a few localhost installation options available to deploy single- or multi-node k8s clusters on our workstation/laptop:
 - Minikube
 - Ubuntu on LXD.
- Minikube is the preferred and recommended way to create an all-in-one k8s setup
- We will be using it extensively in this lecture

On-Premise Installation

- **On-Premise VMs**
 - k8s can be installed on VMs created via Vagrant, VMware vSphere, KVM, etc
 - There are different tools available to automate the installation, like Ansible or kubeadm
- **On-Premise Bare Metal**
 - K8s can be installed on on-premise Bare Metal, on top of different Operating Systems, like RHEL, CoreOS, CentOS, Fedora, Ubuntu, etc
 - Most of the tools used to install VMs can be used with Bare Metal as well

Cloud Installation

- **Hosted Solutions**

- With Hosted Solutions, any given software is completely managed by the provider
- The user will just need to pay hosting and management charges
- Some examples of vendors providing Hosted Solutions for k8s are listed below:
 - Google Container Engine (GKE)
 - Azure Container Service
 - OpenShift Dedicated
 - Platform9
 - IBM Bluemix Container Service

Cloud Installation

- **Turnkey Cloud Solutions**
 - With Turnkey Cloud Solutions, we can deploy a solution or software with just a few commands
 - For k8s, we have some Turnkey Cloud Solutions, with which k8s can be installed with just a few commands on an underlying IaaS platform, such as:
 - Google Compute Engine Amazon
 - AWS
 - Microsoft Azure
 - Tectonic by CoreOS

Cloud Installation

- Bare Metal
 - K8s can be installed on Bare Metal provided by different cloud providers

Kubernetes Installation Tools/Resources

- **kubeadm**
 - is a first-class citizen on the k8s ecosystem
 - It is a secure and recommended way to bootstrap the k8s cluster
 - It has a set of building blocks to setup the cluster, but it is easily extendable to add more functionality
 - Please note that **kubeadm** does not support the provisioning of machines.
- **Kubespray**
 - With Kubespray (formerly known as Kargo), we can install Highly Available k8s clusters on AWS, GCE, Azure, OpenStack, or Bare Metal
 - Kubespray is based on Ansible, and is available on most Linux distributions. It is a Kubernetes Incubator project.
- **Kops**
 - With Kops, we can create, destroy, upgrade, and maintain production-grade, highly-available k8s clusters from the command line. It can provision the machines as well
 - Currently, AWS is officially supported. Support for GCE and VMware vSphere are in alpha stage, and other platforms are planned for the future.

Setting Up a Single-Node Kubernetes Cluster with Minikube



Requirements for Running Minikube

- Minikube runs as a VM. Therefore, we need to make sure that we have the supported hardware and the hypervisor to create VMs
- kubectl: is a binary to access any k8s cluster
- On macOS: xhyve driver, VirtualBox or VMware Fusion hypervisors
- On Linux: VirtualBox or KVM hypervisors
- On Windows: VirtualBox or Hyper-V hypervisors
- VT-x/AMD-v virtualization must be enabled in BIOS
- Internet connection on first run

Installing Minikube on Linux

Installing Minikube on macOS

Installing Minikube on Windows

Accessing Minikube

Accessing Minikube

- **Command Line Interface (CLI)**
 - kubectl is the CLI tool to manage the k8s cluster resources and applications
- **Graphical User Interface (GUI)**
 - K8s dashboard provides the GUI to interact with its resources and containerized applications.
- **APIs**
 - As we know, k8s has the API Server, and operators/users connect to it from the external world to interact with the cluster
 - Using both CLI and GUI, we can connect to the API Server on the Master Node to perform different operations
 - We can directly connect to the API Server using its API endpoints and send commands to it, as long as we can access the Master Node and have the right credentials

kubectl

- Is generally installed before installing minikube, but we can also install it later
- There are different methods that can be used to install kubectl, which are mentioned in the k8s Documentation.
- Next, we will look at the steps to install kubectl on Linux, macOS, and Windows systems.

Installing kubectl on Linux

- Download the latest stable **kubectl** binary
 - `$ curl -LO https://storage.googleapis.com/kubernetes-release/release/$(curl -s https://storage.googleapis.com/kubernetes-release/release/stable.txt)/bin/linux/amd64/kubectl`
- Make the **kubectl** binary executable
 - `$ chmod +x ./kubectl`
- Move the **kubectl** binary to the **PATH**
 - `$ sudo mv ./kubectl /usr/local/bin/kubectl`

Installing kubectl on macOS

- To manually install **kubectl** on macOS, follow the instructions below:
 - Download the latest stable **kubectl** binary
 - `$ curl -LO https://storage.googleapis.com/kubernetes-release/release/$(curl -s https://storage.googleapis.com/kubernetes-release/release/stable.txt)/bin/darwin/amd64/kubectl`
 - Make the **kubectl** binary executable
 - `$ chmod +x ./kubectl`
 - Move the **kubectl** binary to the **PATH**
 - `$ sudo mv ./kubectl /usr/local/bin/kubectl`
- To install **kubectl** on macOS using the Homebrew package manager, do:
 - `$ brew install kubectl`

Installing kubectl on Windows

- To install **kubectl** on Windows, follow the steps below:
 - Get the latest **kubectl** release from here
 - Depending on the latest release, download the **kubectl** binary. In the example below, we are downloading the v1.6.3 release
 - `$ curl -LO https://storage.googleapis.com/kubernetesrelease/release/v1.6.3/bin/windows/amd64/kubectl.exe`
 - Once downloaded, move the kubectl binary to the PATH

kubectl Configuration File

- To connect to the k8s cluster, **kubectl** needs the Master Node endpoint and the credentials to connect to it
- While starting minikube, the startup process creates, by default, a configuration file, **config**, inside the **.kube** directory, which resides in user's home directory
- That configuration file has all the connection details
- By default, the **kubectl** binary accesses this file to find the Master Node's connection endpoint, along with the credentials

```
$ kubectl config view  
apiVersion: v1  
clusters:  
  - cluster:  
      certificate-authority: /Users/nkhare/.minikube/ca.crt  
      server: https://192.168.99.100:8443  
      name: minikube  
contexts:  
  - context:  
      cluster: minikube  
      user: minikube  
      name: minikube  
currentContext: minikube  
kind: Config  
preferences: {}  
users:  
  - name: minikube  
    user:  
      clientcertificate: /Users/nkhare/.minikube/apiserver.crt  
      clientkey: /Users/nkhare/.minikube/apiserver.key
```

kubectl Configuration File

- Once **kubectl** is installed, we can get information about the minikube cluster with the **kubectl cluster-info** command:

```
$ kubectl cluster-info
```

```
Kubernetes master is running at https://  
192.168.99.100:8443
```

To further debug and diagnose cluster problems,
use 'kubectl cluster-info dump'.

- You can find more details about the kubectl command line options [here](#)

Using the 'minikube dashboard' Command

- As mentioned earlier, the k8s Dashboard provides the user interface for the k8s cluster
- To access the Dashboard of Minikube, we can use minikube dashboard, which would open a new tab on our web browser, displaying the k8s dashboard:
 - `$ minikube dashboard`

← → C ⓘ 192.168.99.100:30000#!/workload?namespace=default

☰ kubernetes Workloads + CREATE

Admin Namespaces Nodes Persistent Volumes Storage Classes

Namespace default

Workloads Deployments Replica Sets Replication Controllers Daemon Sets

There is nothing to display here

You can [deploy a containerized app](#), select other namespace or [take the Dashboard Tour](#) to learn more.

There is nothing to display here

You can [deploy a containerized app](#), select other namespace or [take the Dashboard Tour](#) to learn more.

Using the 'kubectl proxy' Command

- Using the `kubectl proxy` command, `kubectl` would authenticate with the API Server on the Master Node and would make the dashboard available on `http://localhost:8001/ui`

```
$ kubectl proxy
```

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

- After running the above command, we can access the dashboard at `http://127.0.0.1:8001/ui`

Admin

Namespaces

Nodes

Persistent Volumes

Storage Classes

Namespace

default

Workloads

Deployments

Replica Sets

Replication Controllers

Daemon Sets

Stateful Sets

Jobs

Pods

Services and discovery

Services

Ingresses

Storage

There is nothing to display here



You can [deploy a containerized app](#), select other namespace or [take the Dashboard Tour](#) to learn more.

APIs - with 'kubectl proxy'

- When kubectl proxy is configured, we can send requests to localhost on the proxy port
- With the above curl request, we requested all the API endpoints from the API Server.

```
$ curl http://localhost:8001/  
{  
  "paths": [  
    "/api",  
    "/api/v1",  
    "/apis",  
    "/apis/apps",  
    .....  
    .....  
    "/logs",  
    "/metrics",  
    "/swaggerapi/",  
    "/ui/",  
    "/version"  
  ]  
}%
```

APIs - without 'kubectl proxy'

- Without `kubectl proxy` configured, we can get the **Bearer Token** using `kubectl`, and then send it with the API request
- A **Bearer Token** is an **access token** which is generated by the authentication server (the API server on the Master Node) and given back to the client
- Using that token, the client can connect back to the k8s API server without providing further authentication details, and then, access resources

APIs - without 'kubectl proxy'

- Get the token
 - ```
$ TOKEN=$(kubectl describe secret $
(kubectl get secrets | grep default |
cut -f1 -d ' ') | grep E '^token' | cut
-f2 -d':' | tr -d '\t')
```
- Get the API Server endpoint
  - ```
$ APISERVER=$(kubectl config view | grep  
https | cut -f 2- -d ":" | tr -d " ")
```

Access the API Server using the curl command

```
$ curl $APISERVER header "Authorization: Bearer $TOKEN"  
insecure  
{  
  "paths": [  
    "/api",  
    "/api/v1",  
    "/apis",  
    "/apis/apps",  
    .....  
    .....  
    "/logs",  
    "/metrics",  
    "/swaggerapi/",  
    "/ui/",  
    "/version"  
  ]  
}%
```

Kubernetes Building Blocks

Kubernetes Object Model

- K8s has a very rich object model, with which it represents different persistent entities in the k8s cluster. Those entities describe:
 - What containerized applications we are running and on which node
 - Application resource consumption
 - Different policies attached to applications, like restart/upgrade policies, fault tolerance, etc.
- With each object, we declare our intent or desired state using the spec field
- The k8s system manages the status field for objects, in which it records the actual state of the object
- At any given point in time, the k8s Control Plane tries to match the object's actual state to the object's desired state
- Examples: Pods, Deployments, ReplicaSets, etc.

Kubernetes Object Model

- To create an object, we need to provide the `spec` field to the k8s API Server
- The `spec` field describes the desired state, along with some basic information, like the name
- The API request to create the object must have the `spec` field, as well as other details, in a JSON format
- Most often, we provide an object's definition in a `.yaml` file, which is converted by `kubectl` in a JSON payload and sent to the API Server

```
apiVersion: apps/v1beta1
kind: Deployment
metadata:
  name: nginx-deployment
spec:
  replicas: 3
  template:
    metadata:
      labels:
        app: nginx
    spec:
      containers:
        - name: nginx
          image: nginx:1.7.9
      ports:
        - containerPort: 80
```

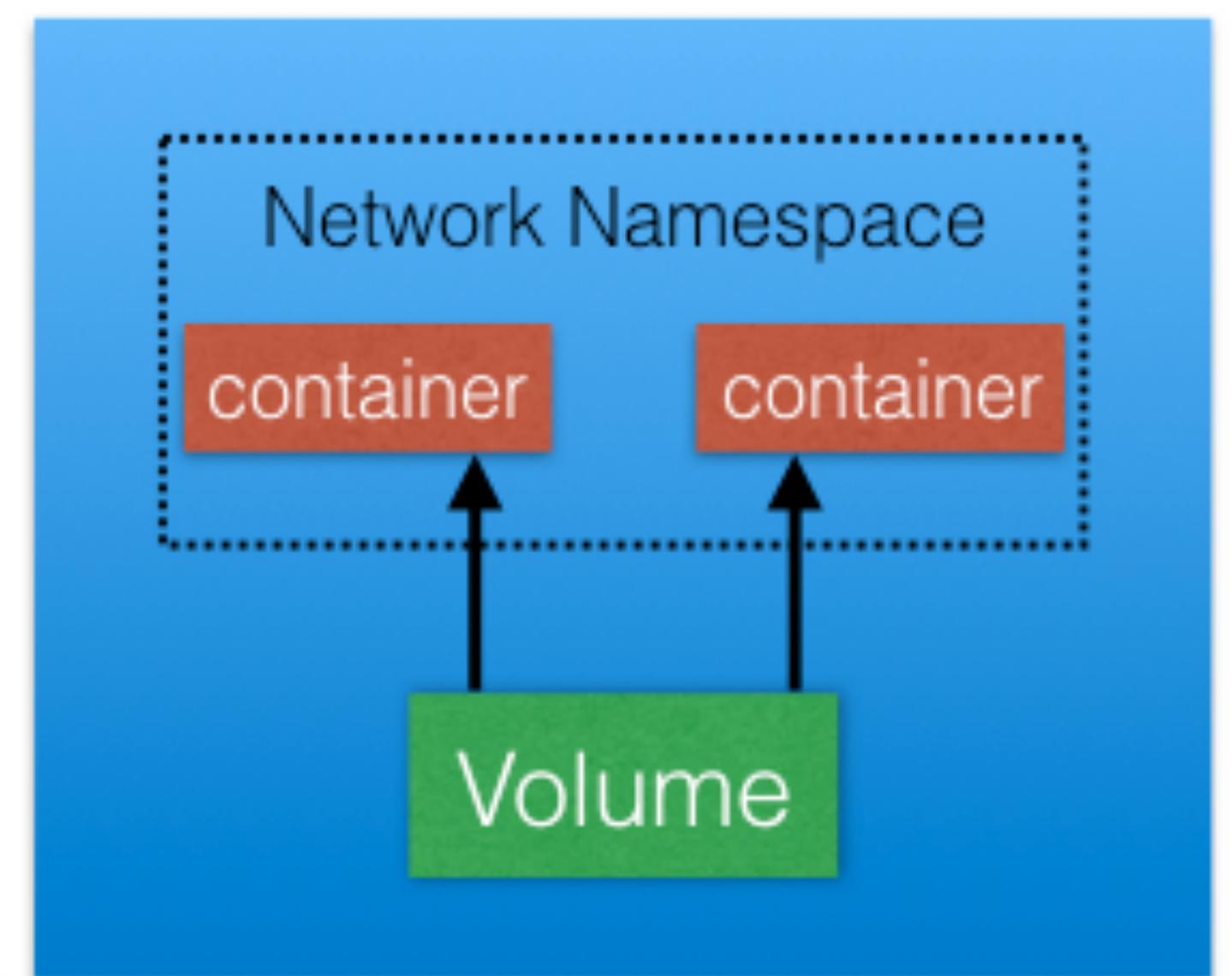
Kubernetes Object Model

- With the `apiVersion` field in the example above, we mention the API endpoint on the API Server which we want to connect to
- With the `kind` field, we mention the object type - in our case, we have `Deployment`
- With the `metadata` field, we attach the basic information to objects, like the name
- You may have noticed that in above we have two `spec` fields (`spec` and `spec.template.spec`)
 - With `spec`, we define the desired state of the deployment
 - In `spec.template.spec`, we define the desired state of the Pod - here, our Pod would be created using `nginx:1.7.9`

```
apiVersion: apps/v1beta1
kind: Deployment
metadata:
  name: nginx-deployment
spec:
  replicas: 3
  template:
    metadata:
      labels:
        app: nginx
    spec:
      containers:
        - name: nginx
          image: nginx:1.7.9
      ports:
        - containerPort: 80
```

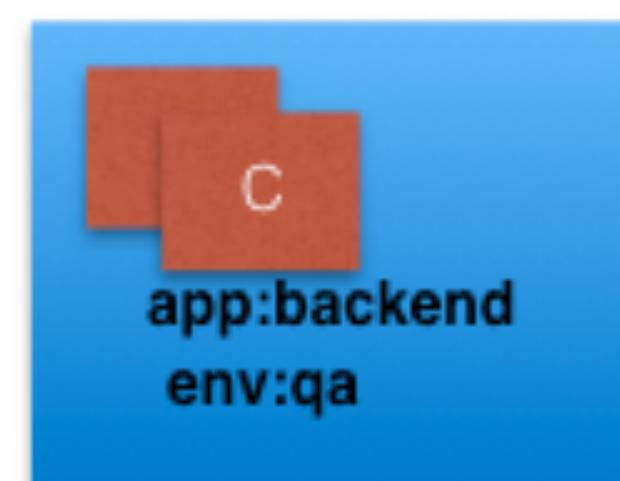
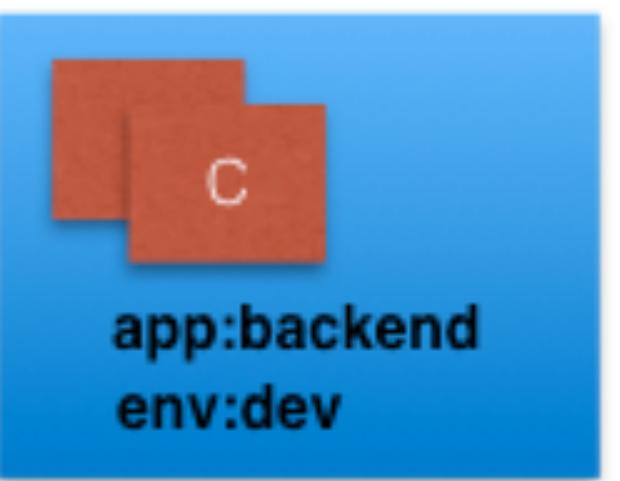
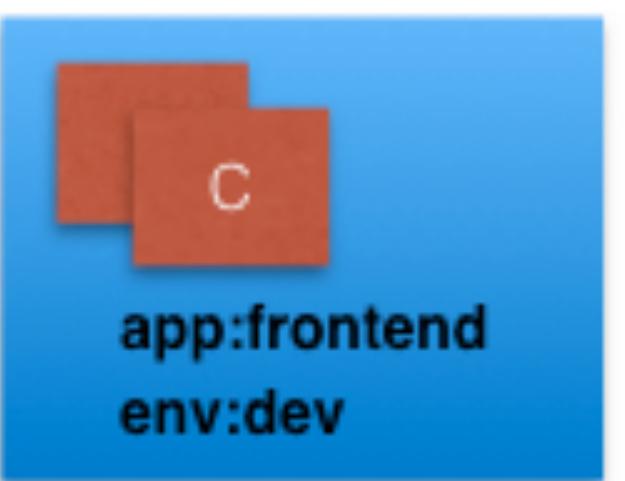
Pods

- A [Pod](#) is the smallest and simplest k8s object
- It is the unit of deployment in k8s, which represents a single instance of the application
- A Pod is a logical collection of one or more containers, which:
 - Are scheduled together on the same host
 - Share the same network namespace
 - Mount the same external storage (Volumes)
- Pods are ephemeral in nature, and they do not have the capability to self-heal by themselves



Labels

- Labels are key-value pairs that can be attached to any k8s objects (e.g. Pods)
- Labels are used to organize and select a subset of objects, based on the requirements in place
- Many objects can have the same label(s)
- Labels do not provide uniqueness to objects



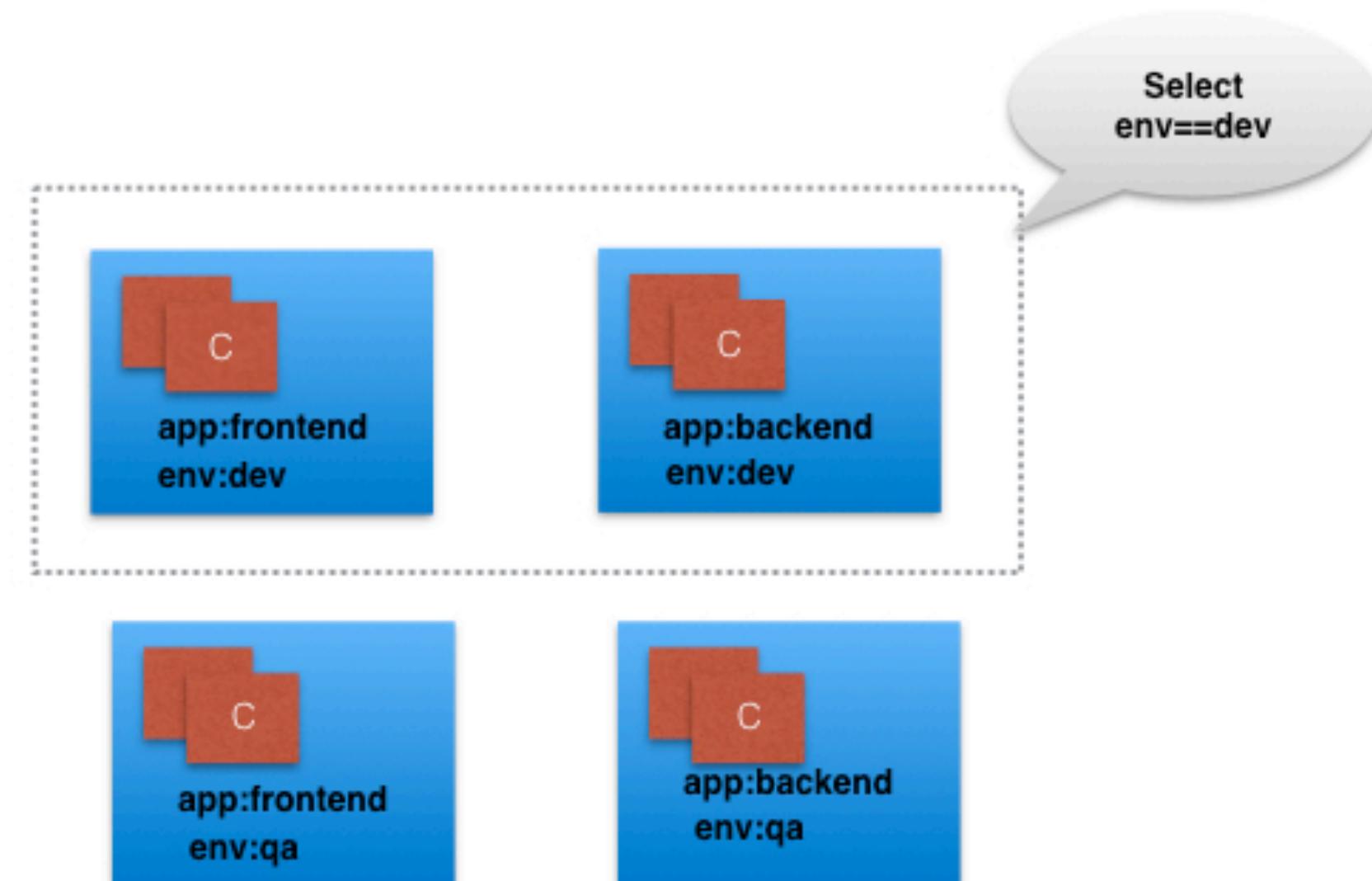
Label Selectors

- **Equality-Based Selectors**

- Allow filtering of objects based on label keys and values
- With this type of Selectors, we can use the `=`, `==`, or `!=` operators
- For example, with `env==dev` we are selecting the objects where the `env` label is set to `dev`

- **Set-Based Selectors**

- Allow filtering of objects based on a set of values
- With this type of Selectors, we can use the `in`, `notin`, and `exist` operators
- For example, with `env in (dev,qa)`, we are selecting objects where the `env` label is set to `dev` or `qa`



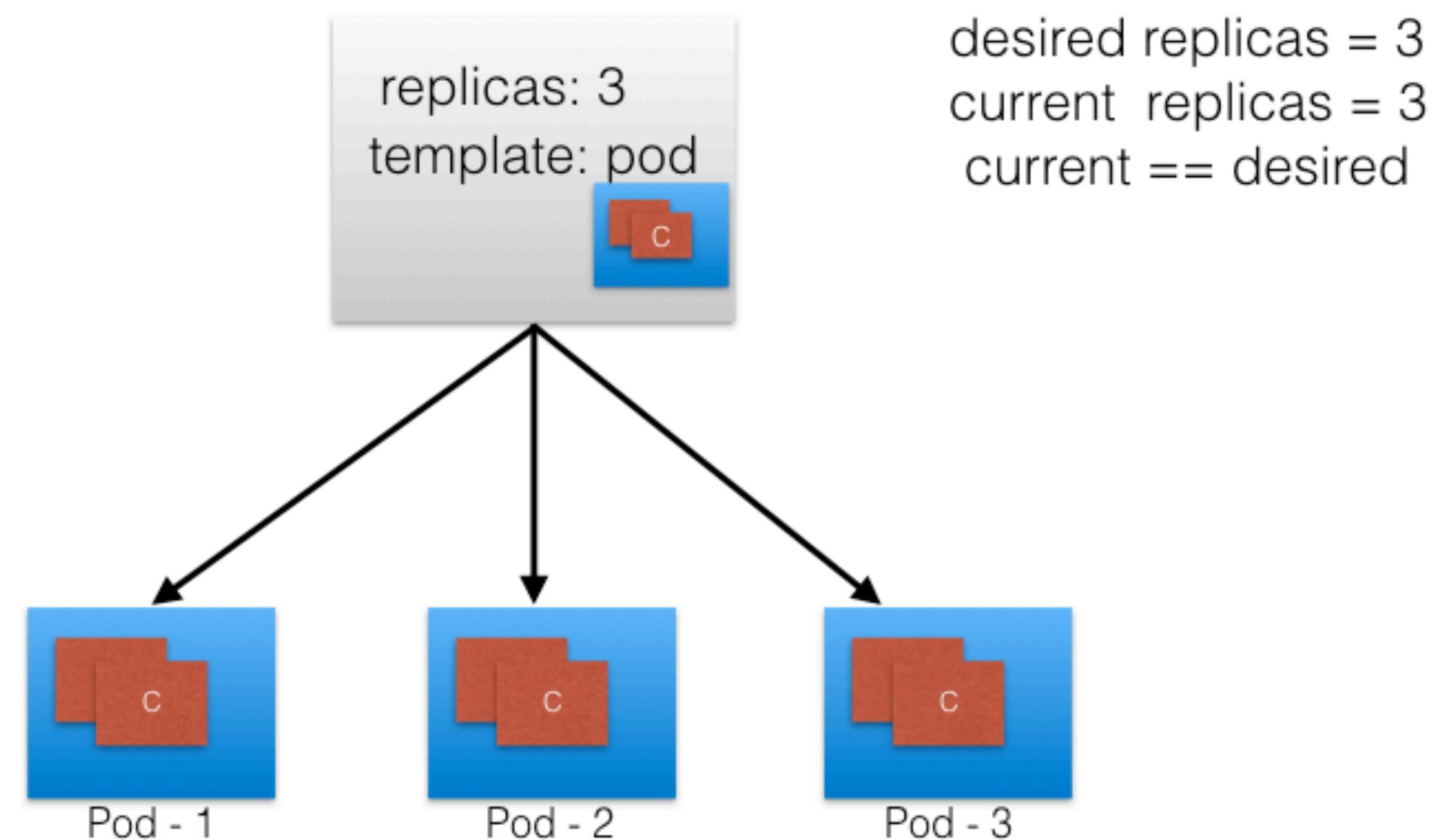
Replication Controllers

- A [**ReplicationController**](#) (`rc`) is a controller that is part of the Master Node's Controller Manager
- It makes sure the specified number of replicas for a Pod is running at any given point in time
- If there are more Pods than the desired count, the **ReplicationController** would kill the extra Pods, and, if there are less Pods, then the **ReplicationController** would create more Pods to match the desired count
- Generally, we don't deploy a Pod independently, as it would not be able to re-start itself, if something goes wrong
- We always use controllers like **ReplicationController** to create and manage Pods

ReplicaSets I

- A [ReplicaSet \(rs\)](#) is the next-generation ReplicationController
- ReplicaSets support both equality- and set-based Selectors, whereas ReplicationControllers only support equality-based Selectors
- Next, you can see a graphical representation of a ReplicaSet, where we have set the replica count to 3 for a Pod
- Now, let's suppose that one Pod dies, and our current state is not matching the desired state anymore

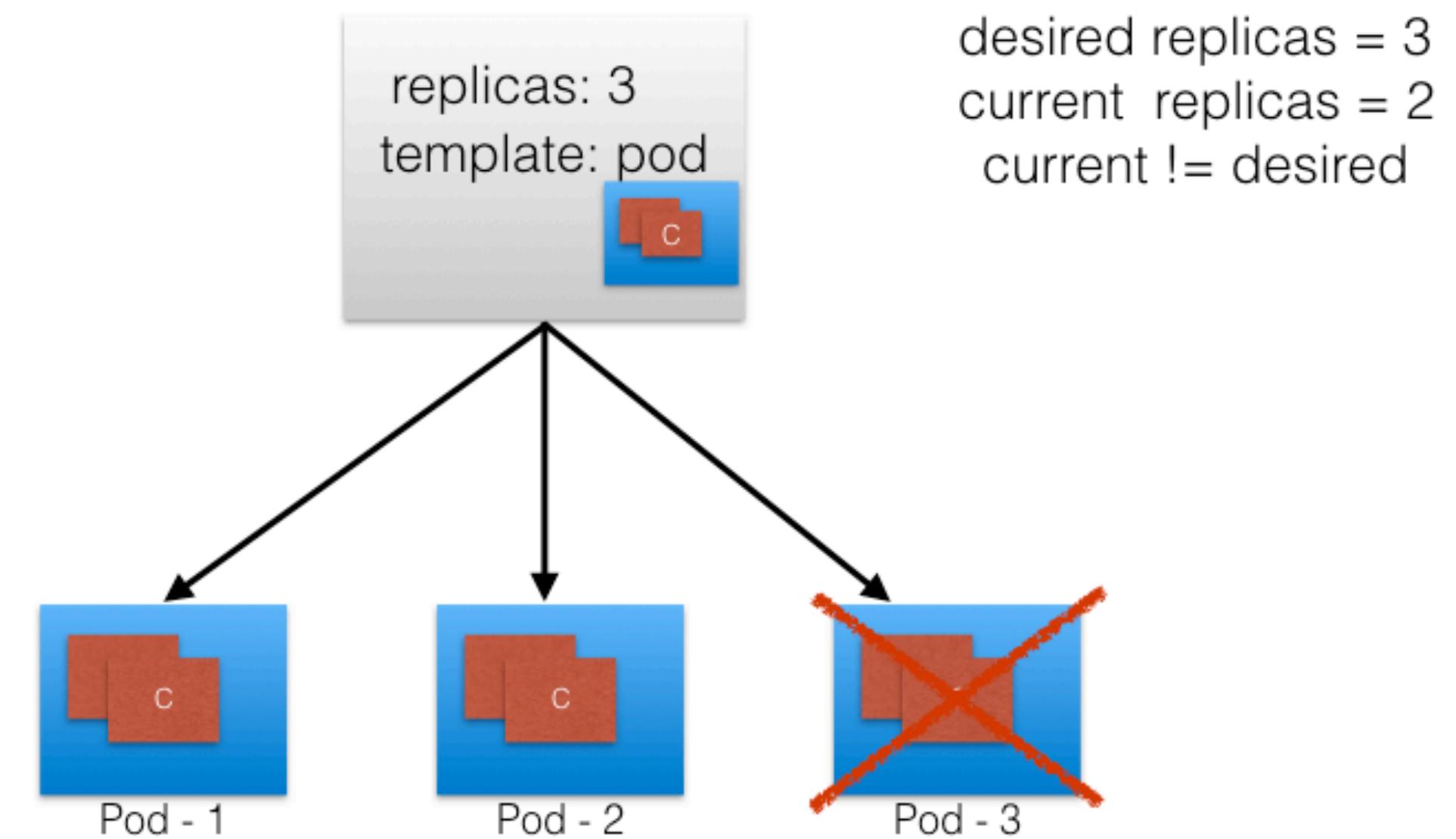
Replica Set



ReplicaSets I

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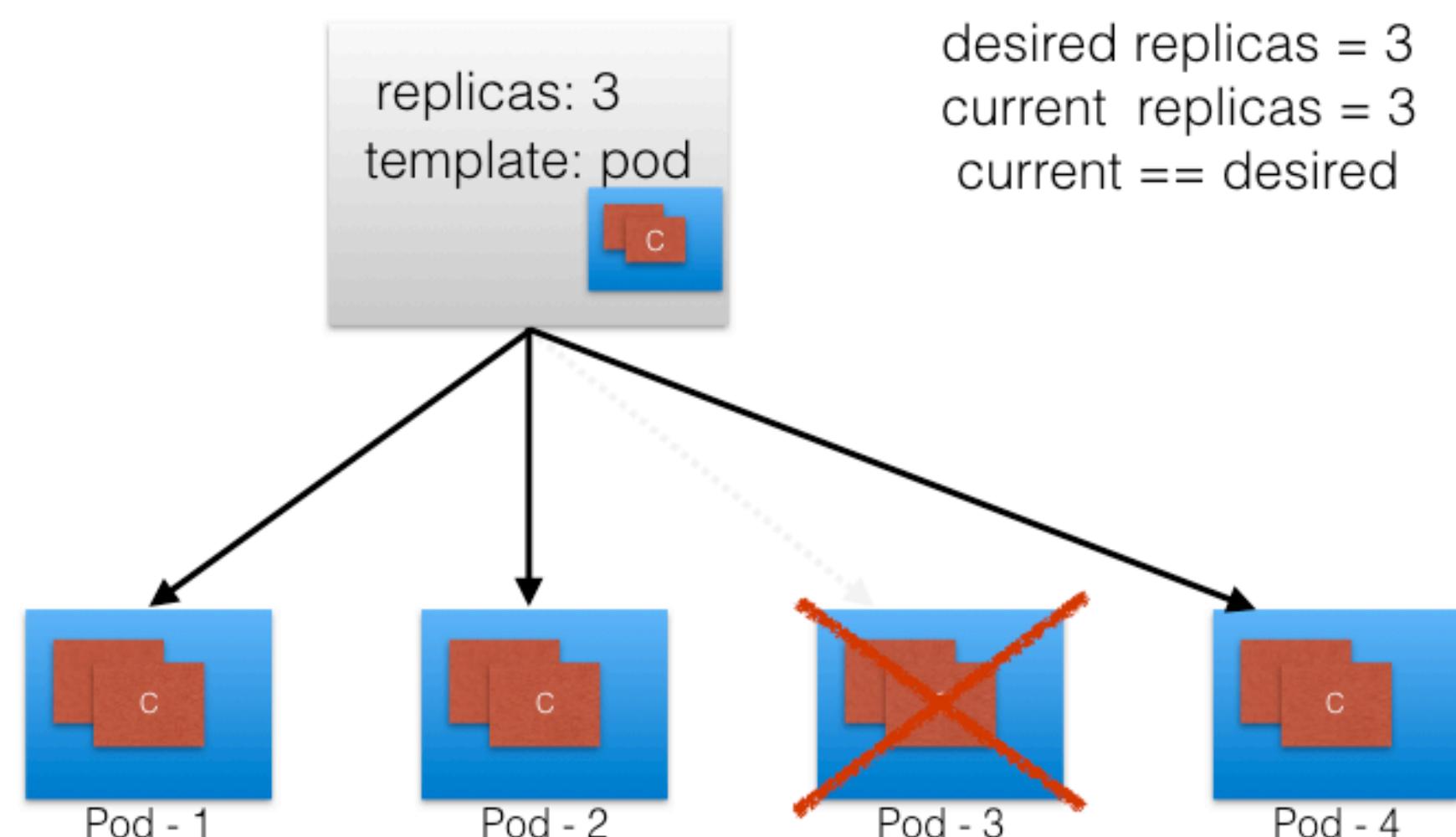
Replica Set



ReplicaSets II

- The ReplicaSet will detect that the current state is no longer matching the desired state
- So, in our given scenario, the ReplicaSet will create one more Pod, thus ensuring that the current state matches the desired state
- ReplicaSets can be used independently, but they are mostly used by Deployments to orchestrate the Pod creation, deletion, and updates
- A Deployment automatically creates the ReplicaSets, and we do not have to worry about managing them.

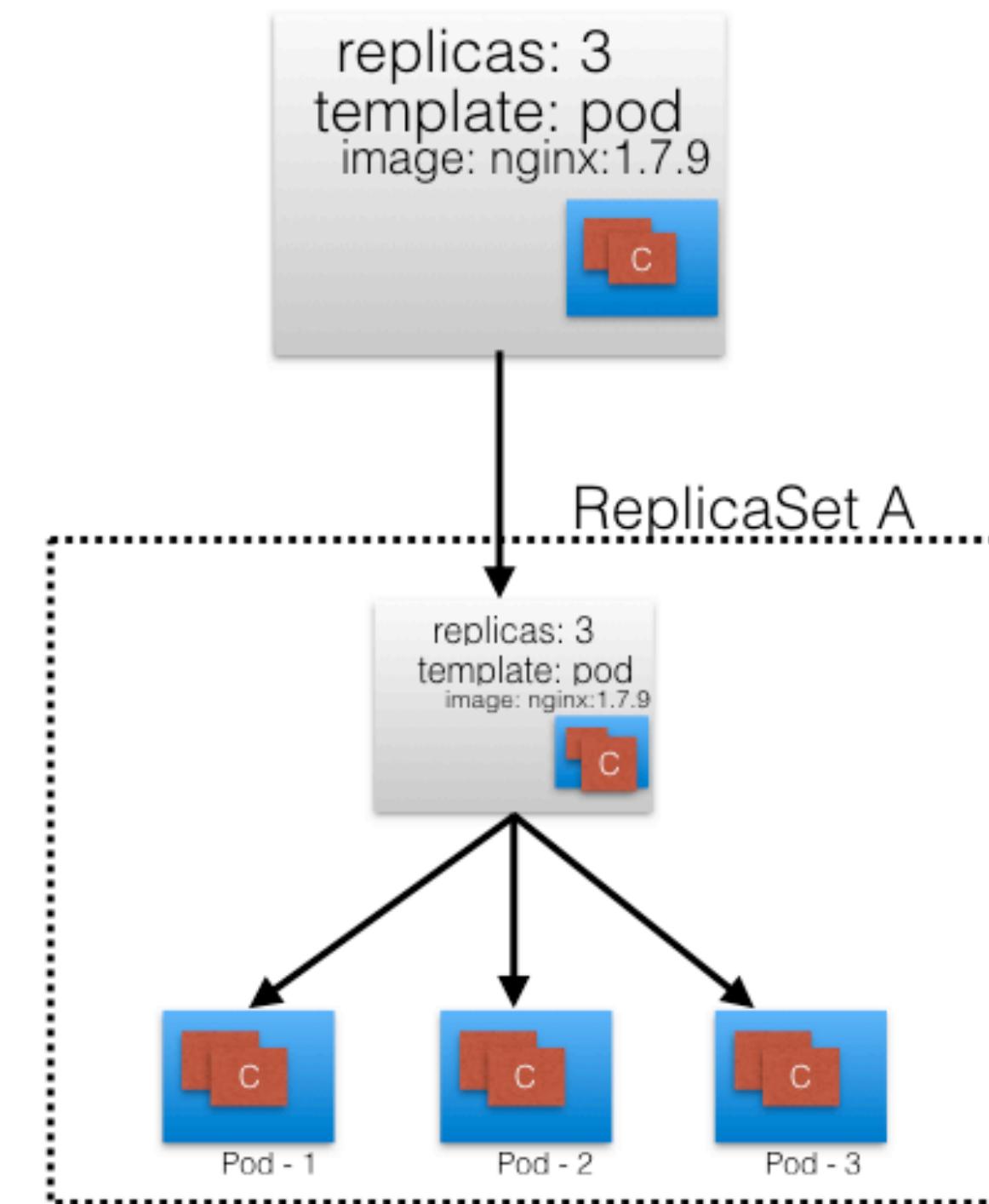
Replica Set



Deployments

- [Deployment](#) objects provide declarative updates to Pods and ReplicaSets
- The DeploymentController is part of the Master Node's Controller Manager, and it makes sure that the current state always matches the desired state
- In the following example, we have a **Deployment** which creates a [ReplicaSet A](#)
 - [ReplicaSet A](#) then creates **3 Pods**
 - In each Pod, one of the containers uses the [nginx:1.7.9](#) image

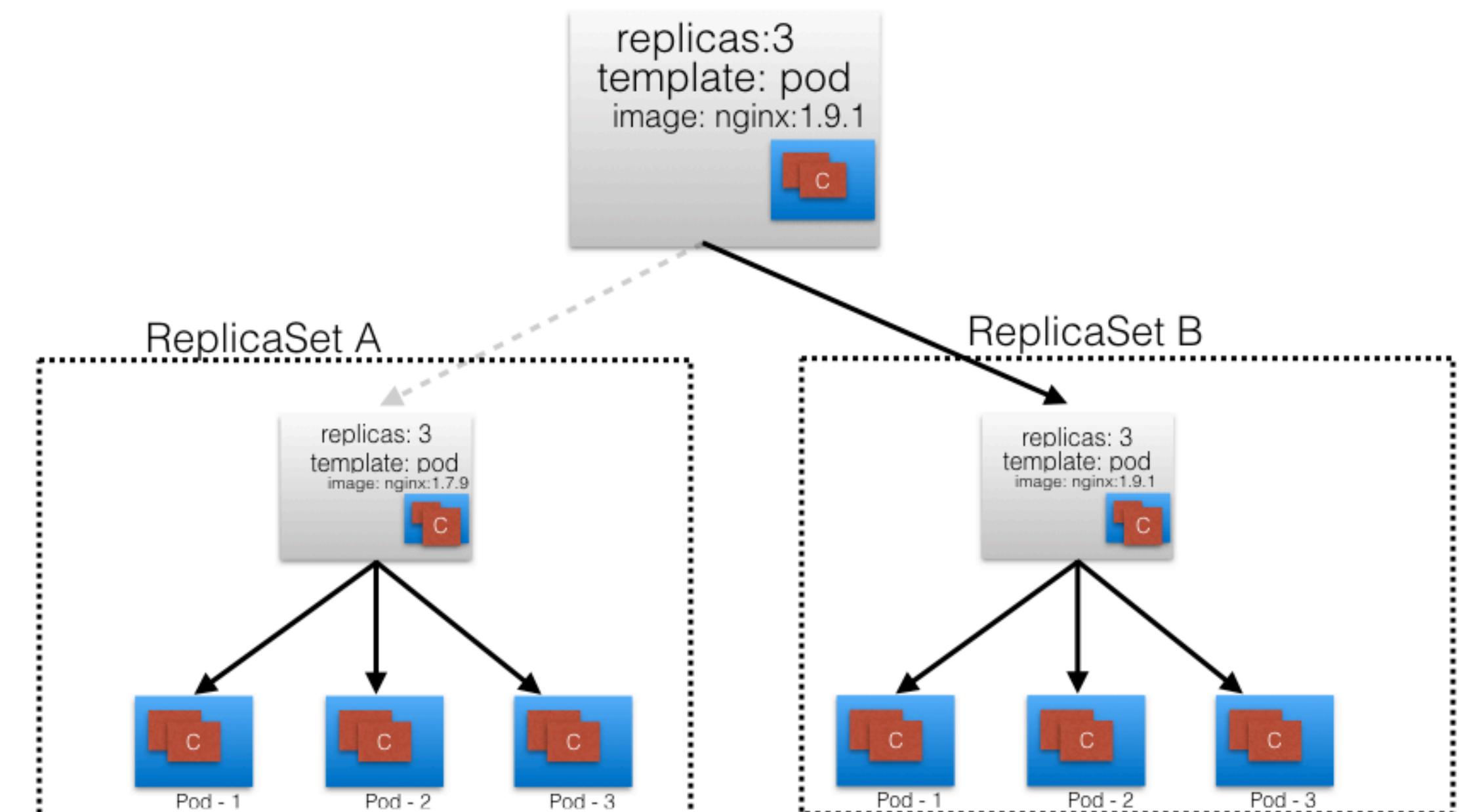
Deployment



Deployments

- Now, in the Deployment, we change the Pod's template and we update the image for the `nginx` container from `nginx:1.7.9` to `nginx:1.9.1`
- As have modified the Pod's template, a new `ReplicaSet B` gets created
- This process is referred to as a **Deployment rollout**
 - A rollout is only triggered when we update the Pod's template for a deployment
 - Operations like **scaling the deployment** do not trigger the deployment

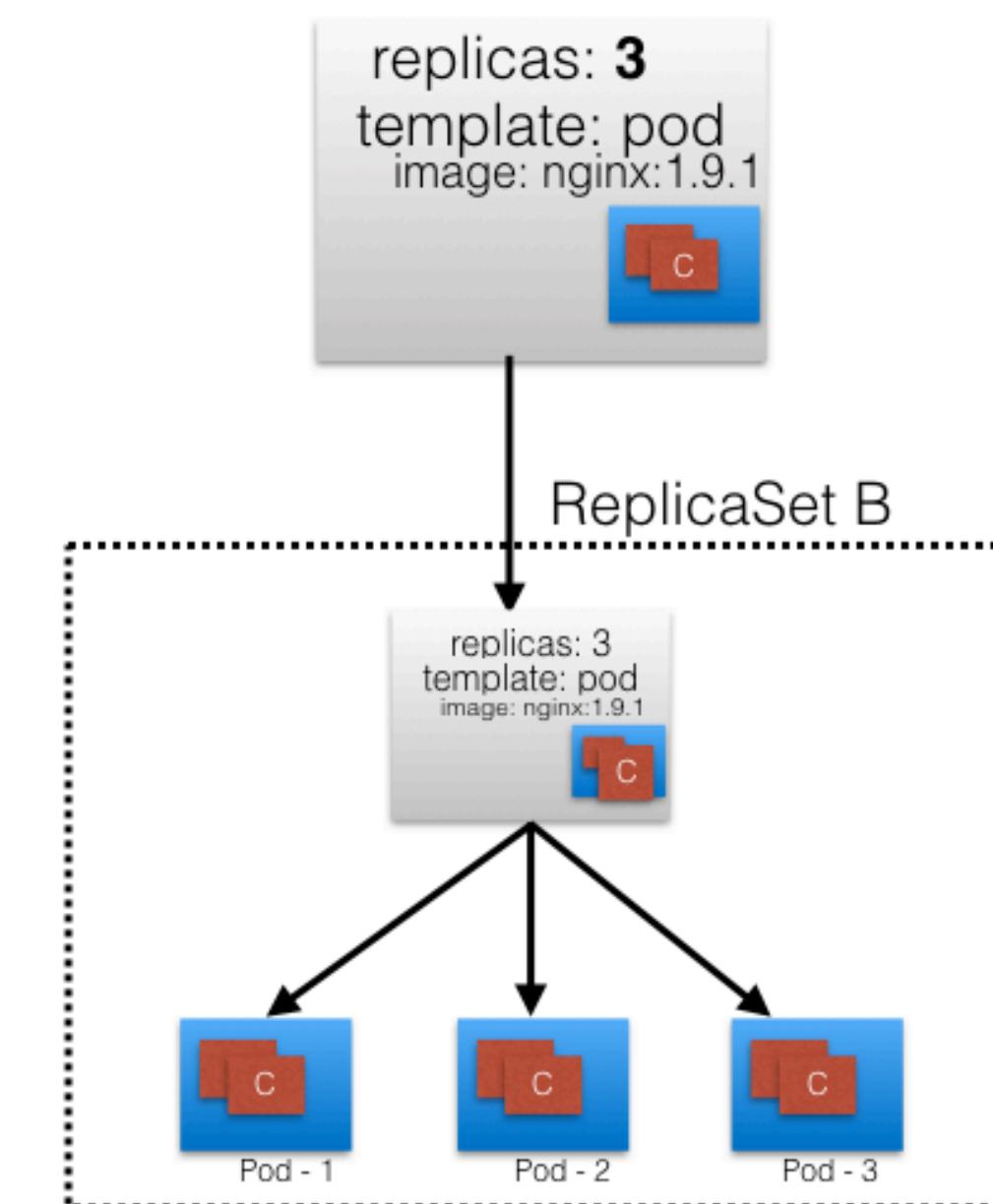
Deployment - Update



Deployments

- Once **ReplicaSet B** is ready, the Deployment starts pointing to it
- On top of ReplicaSets, Deployments provide features like Deployment recording, with which, if something goes wrong, we can rollback to a previously known state

Deployment



Namespaces

- If we have numerous users whom we would like to organize into teams/projects, we can partition the k8s cluster into sub-clusters using [Namespaces](#)
- The names of the resources/objects created inside a Namespace are unique, but not across Namespaces
- To list all the Namespaces, we can run the following command:

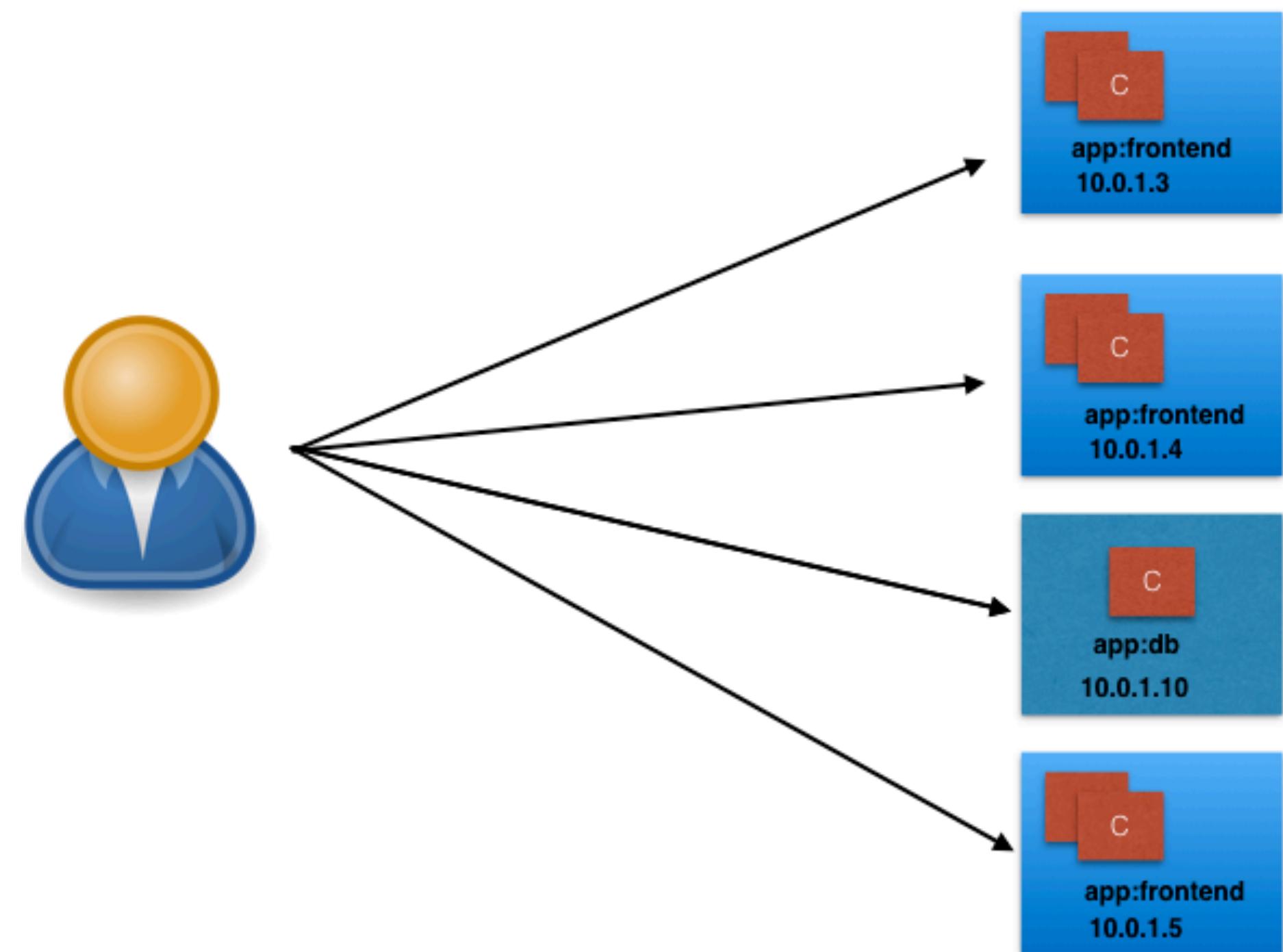
```
$ kubectl get namespaces
```

NAME	STATUS	AGE
default	Active	11h
kube-public	Active	11h
kube-system	Active	11h

Services

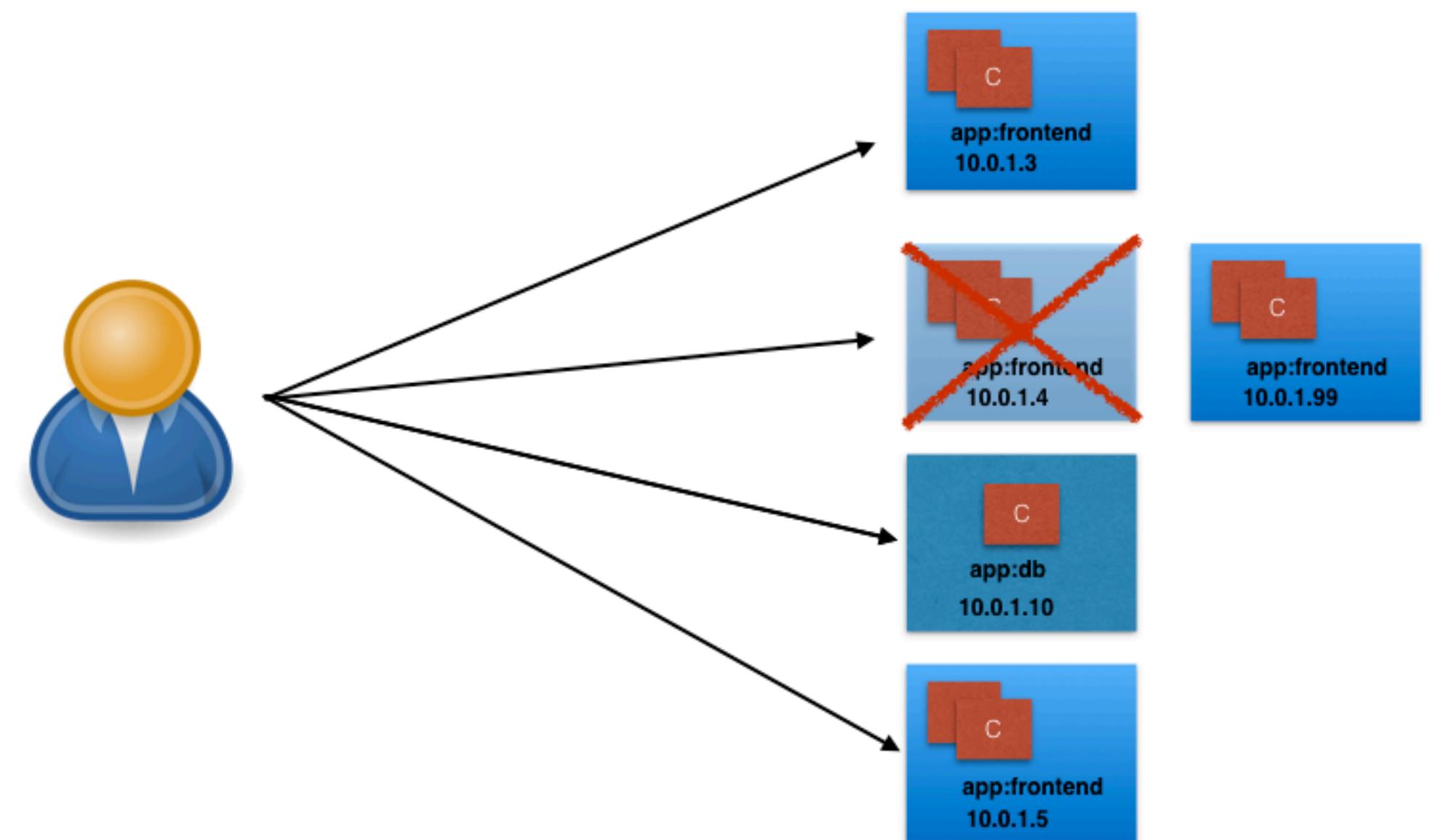
Connecting Users to Pods

- To access the application, a user/client needs to connect to the Pods
- As Pods are ephemeral in nature, resources like IP addresses allocated to it cannot be static
- Pods could die abruptly or be rescheduled based on existing requirements
- Unexpectedly, the Pod to which the user/client is connected dies, and a new Pod is created by the controller



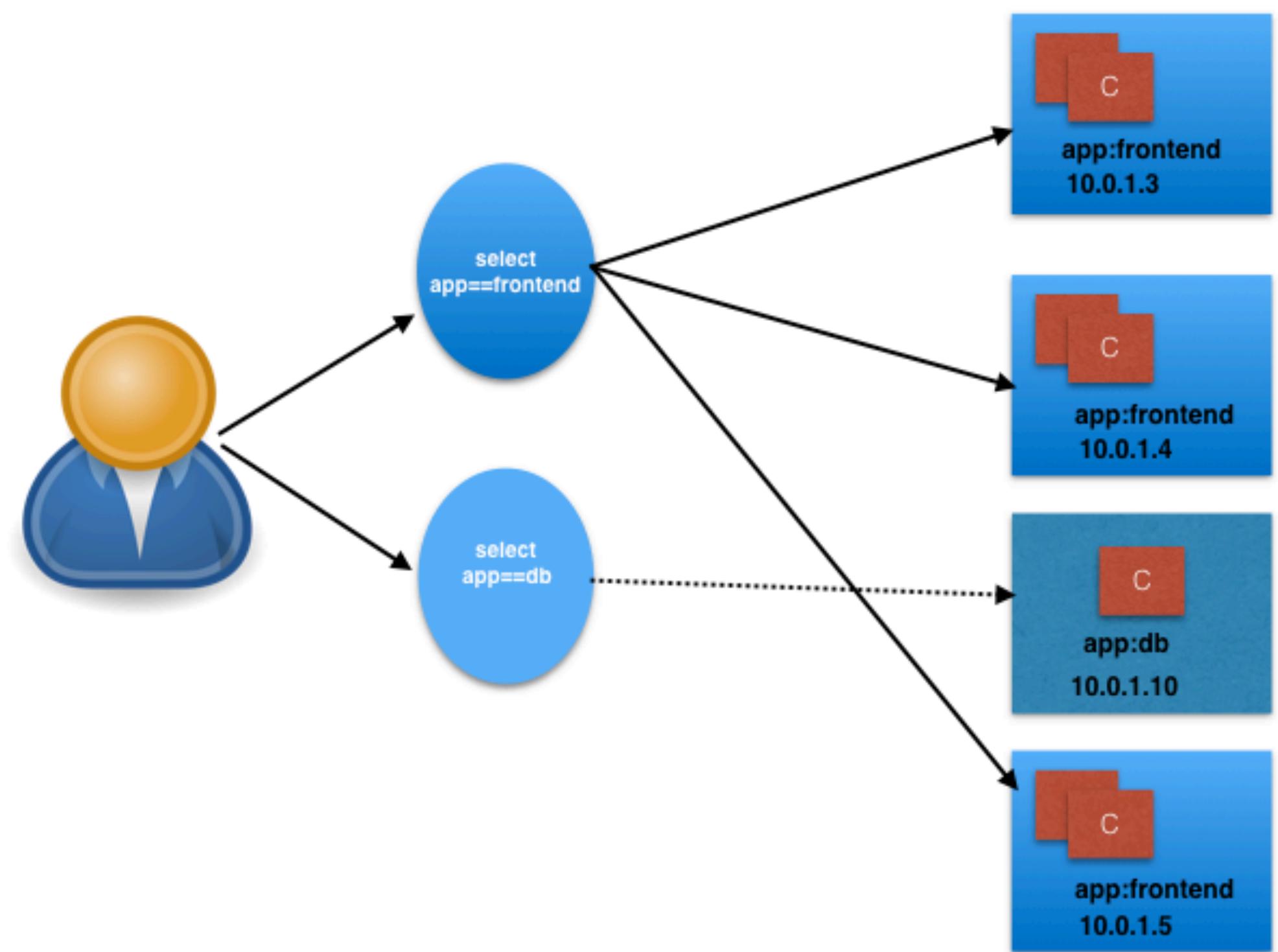
Connecting Users to Pods

- The new Pod will have a new IP address, which will not be known automatically to the user/client of the earlier Pod
- To overcome this situation, k8s provides a higher-level abstraction called Service, which logically groups Pods and a policy to access them
- This grouping is achieved via Labels and Selectors, which we talked about in the previous chapter.



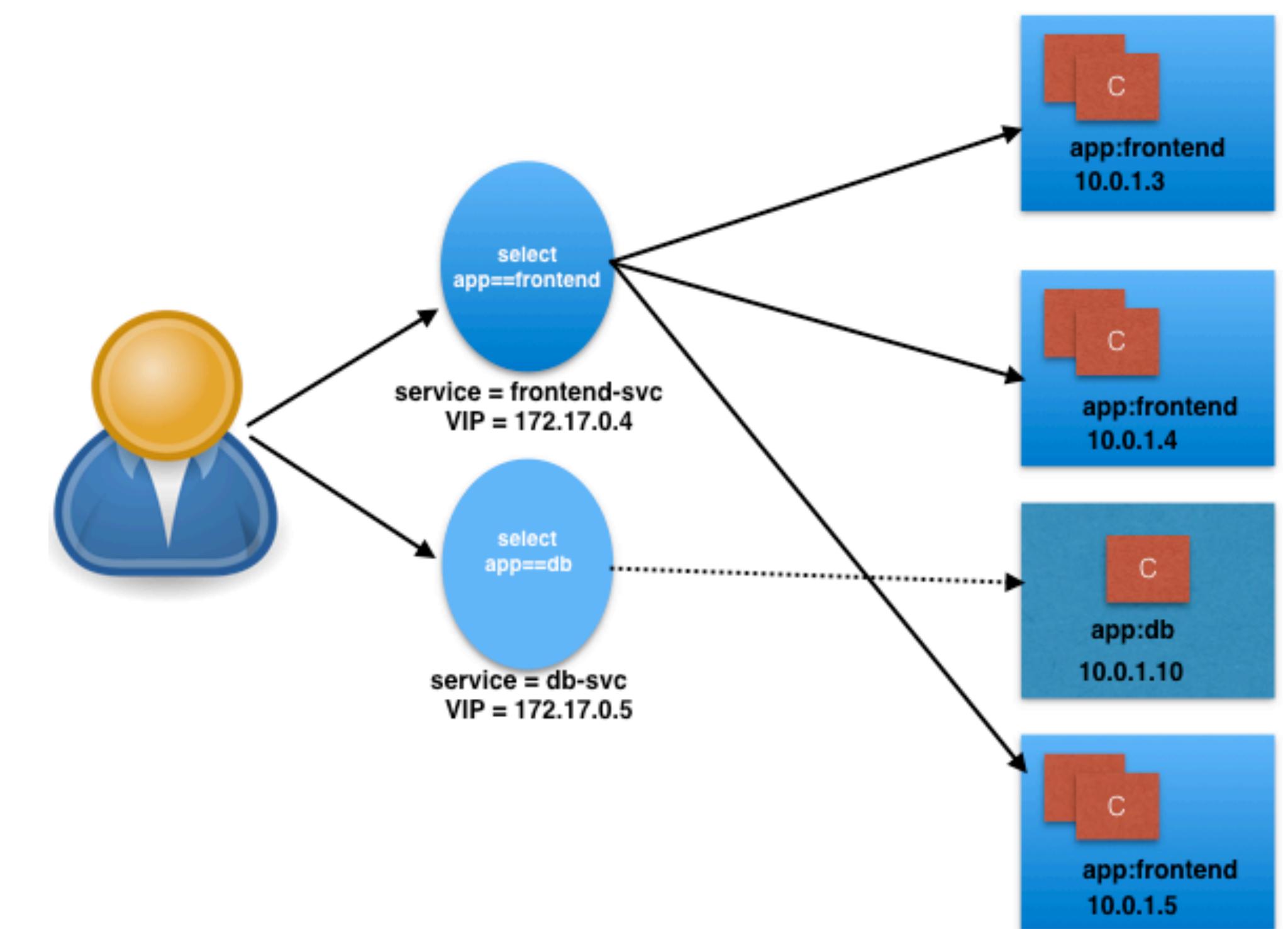
Services

- Here we have used the app keyword as a Label, and frontend and db as values for different Pods
- Using Selectors (`app==frontend` and `app==db`), we can group them into two logical groups: one with 3 Pods, and one with just one Pod



Services

- We can assign a name to the logical grouping, referred to as a **service name**
- In our example, we have created two Services, **frontend-svc** and **db-svc**, and they have the **app==frontend** and the **app==db** Selectors, respectively



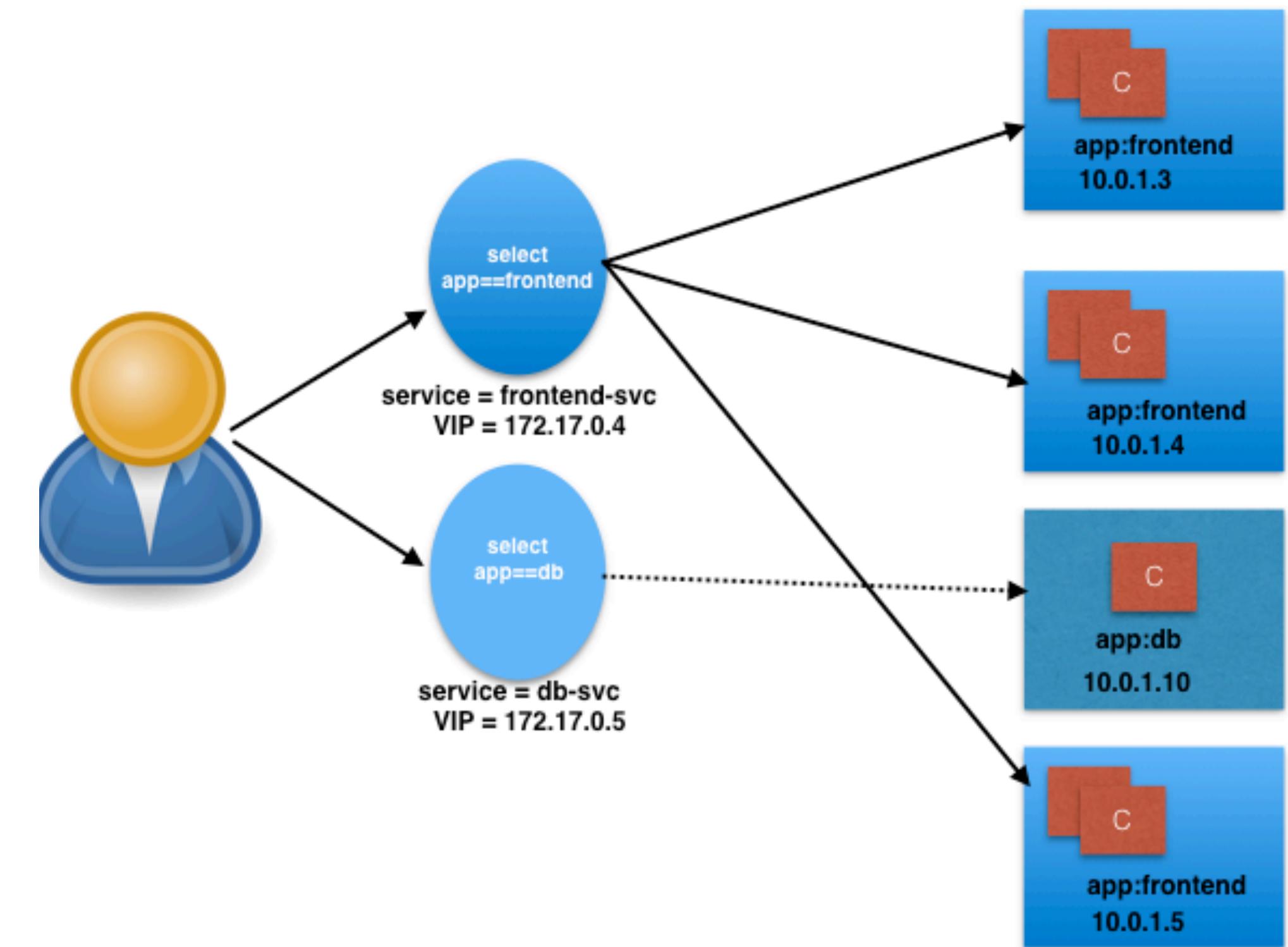
Service Object Example

- We are creating a `frontend-svc` Service by selecting all the Pods that have the Label `app` set to the `frontend`
- By default, each Service also gets an IP address, which is routable only inside the cluster
- In our case, we have `172.17.0.4` and `172.17.0.5` IP addresses for our `frontend-svc` and `db-svc` Services, respectively
- The IP address attached to each Service is also known as the ClusterIP for that Service

```
kind: Service
apiVersion: v1
metadata:
  name: frontend-svc
spec:
  selector:
    app: frontend
  ports:
    - protocol: TCP
      port: 80
      targetPort: 5000
```

Service Object Example

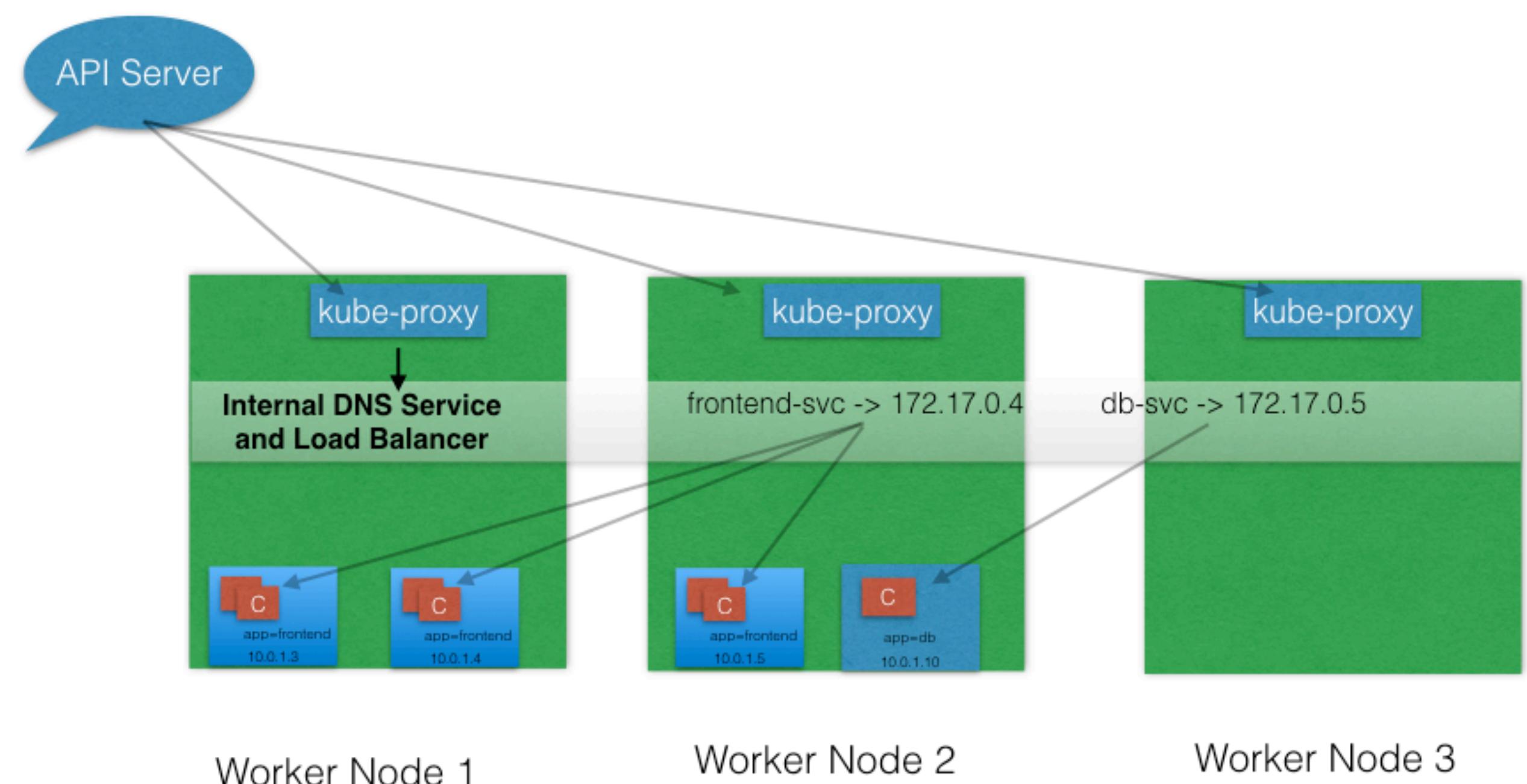
- The user/client now connects to a Service via the IP address, which forwards the traffic to one of the Pods attached to it
- A Service does the load balancing while selecting the Pods for forwarding the data/traffic
- While forwarding the traffic from the Service, we can select the target port on the Pod
- A tuple of Pods, IP addresses, along with the targetPort is referred to as a Service Endpoint



kube-proxy

- All of the Worker Nodes run a daemon called [**kube-proxy**](#), which watches the API Server on the Master Node for the addition and removal of Services and endpoints
- For each new Service, on each node, **kube-proxy** configures the IPTables rules to capture the traffic for its ClusterIP and forwards it to one of the endpoints
- When the Service is removed, **kube-proxy** removes the IPTables rules on all nodes as well

Service



Service Discovery

- **Environment Variables**

- As soon as the Pod starts on any Worker Node, the `kubelet` daemon running on that node adds a set of environment variables in the Pod for all active Services
- For example, if we have an active Service called `redis-master`, which exposes port 6379, and its ClusterIP is 172.17.0.6, then, on a newly created Pod:

```
REDIS_MASTER_SERVICE_HOST=172.17.0.6
REDIS_MASTER_SERVICE_PORT=6379
REDIS_MASTER_PORT=tcp://172.17.0.6:6379
REDIS_MASTER_PORT_6379_TCP=tcp://172.17.0.6:6379
REDIS_MASTER_PORT_6379_TCP_PROTO=tcp
REDIS_MASTER_PORT_6379_TCP_PORT=6379
REDIS_MASTER_PORT_6379_TCP_ADDR=172.17.0.6
```

- With this solution, we need to be careful while ordering our Services, as the Pods will not have the environment variables set for Services which are created after the Pods are created

Service Discovery

- DNS
 - K8s has an [add-on for DNS](#), which creates a DNS record for each Service and its format is like `my-svc.my-namespace.svc.cluster.local`
 - Services within the same namespace can reach to other services with just their name
 - For example, if we add a Service `redis-master` in the `my-ns` Namespace, then all the Pods in the same Namespace can reach to the `redis` Service just by using its name, `redis-master`
 - Pods from other Namespaces can reach the Service by adding the respective Namespace as a suffix, like `redis-master.my-ns`

Service Type

- While defining a Service, we can also choose its access scope. We can decide whether the Service:
 - Is only accessible within the cluster
 - Is accessible from within the cluster and the external world
 - Maps to an external entity which resides outside the cluster.
- Access scope is decided by `ServiceType`, which can be mentioned when creating the Service

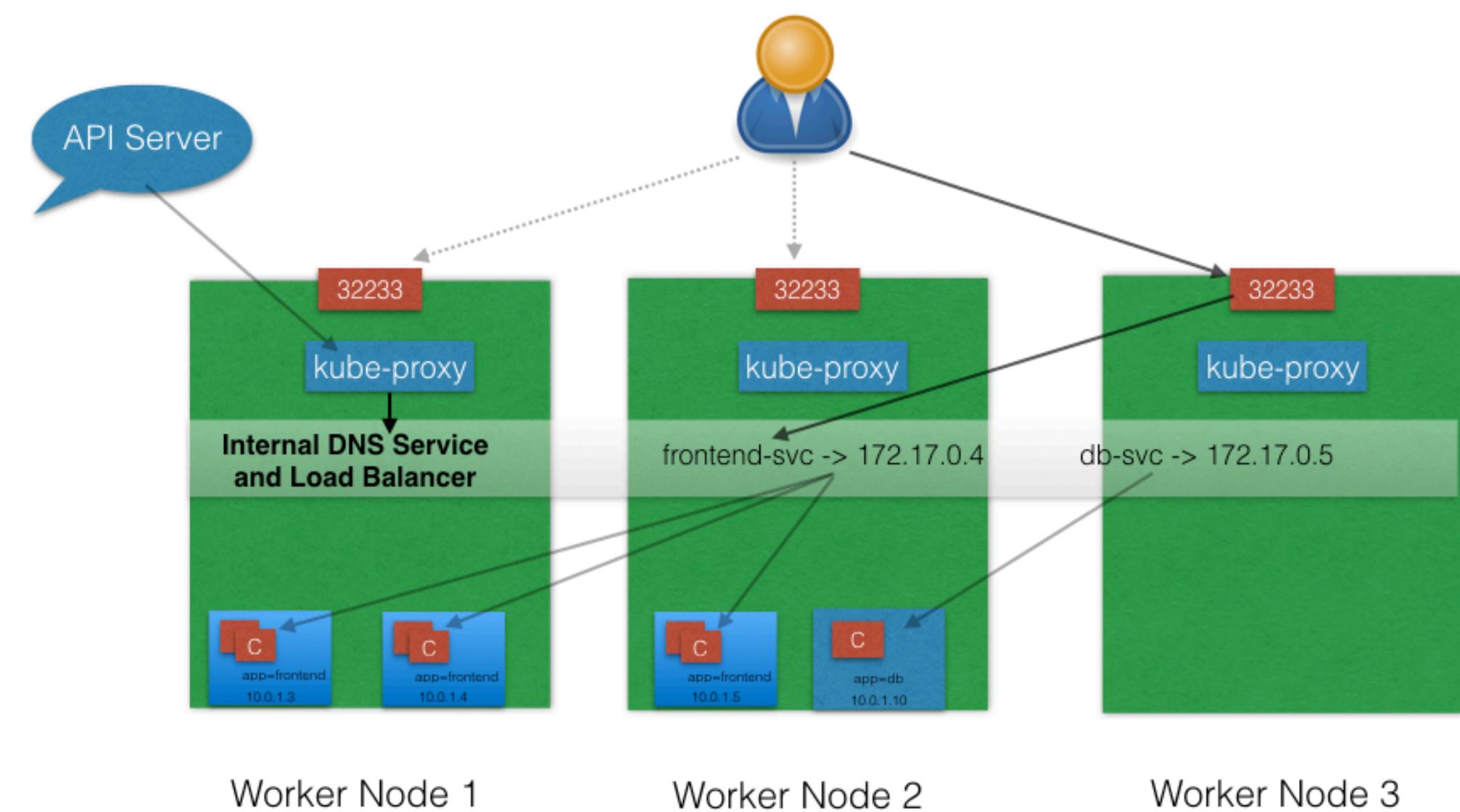
ServiceType - ClusterIP and NodePort

- **ClusterIP** is the default *ServiceType*
 - A Service gets its Virtual IP address using the ClusterIP
 - That IP address is used for communicating with the Service and is accessible only within the cluster.
- With the **NodePort** *ServiceType*, in addition to creating a ClusterIP, a port from the range **30000–32767** is mapped to the respective service, from all the Worker Nodes
 - For example, if the mapped NodePort is **32233** for the service **frontend-svc**, then, if we connect to any Worker Node on port **32233**, the node would redirect all the traffic to the assigned ClusterIP - **172.17.0.4**

Service NodePort

- The **NodePort ServiceType** is useful when we want to make our services accessible from the external world
- The end-user connects to the Worker Nodes on the specified port, which forwards the traffic to the applications running inside the cluster
- To access the application from the external world, administrators can configure a reverse proxy outside the k8s cluster and map the specific endpoint to the respective port on the Worker Nodes

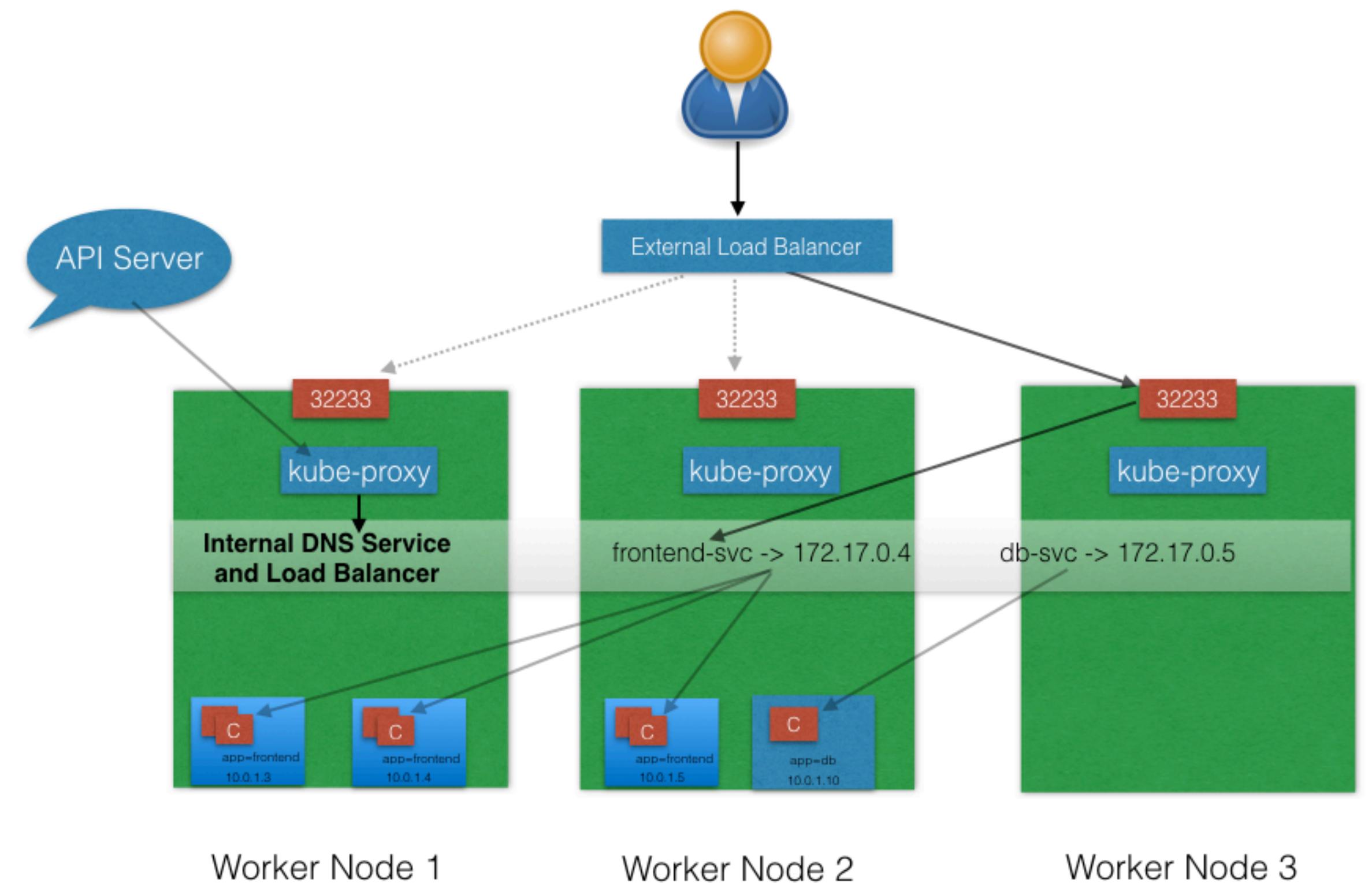
Service - NodePort



ServiceType - LoadBalancer

- NodePort and ClusterIP Services are automatically created, and the external load balancer will route to them
- The Services are exposed at a static port on each Worker Node
- The Service is exposed externally using the underlying Cloud provider's load balancer feature

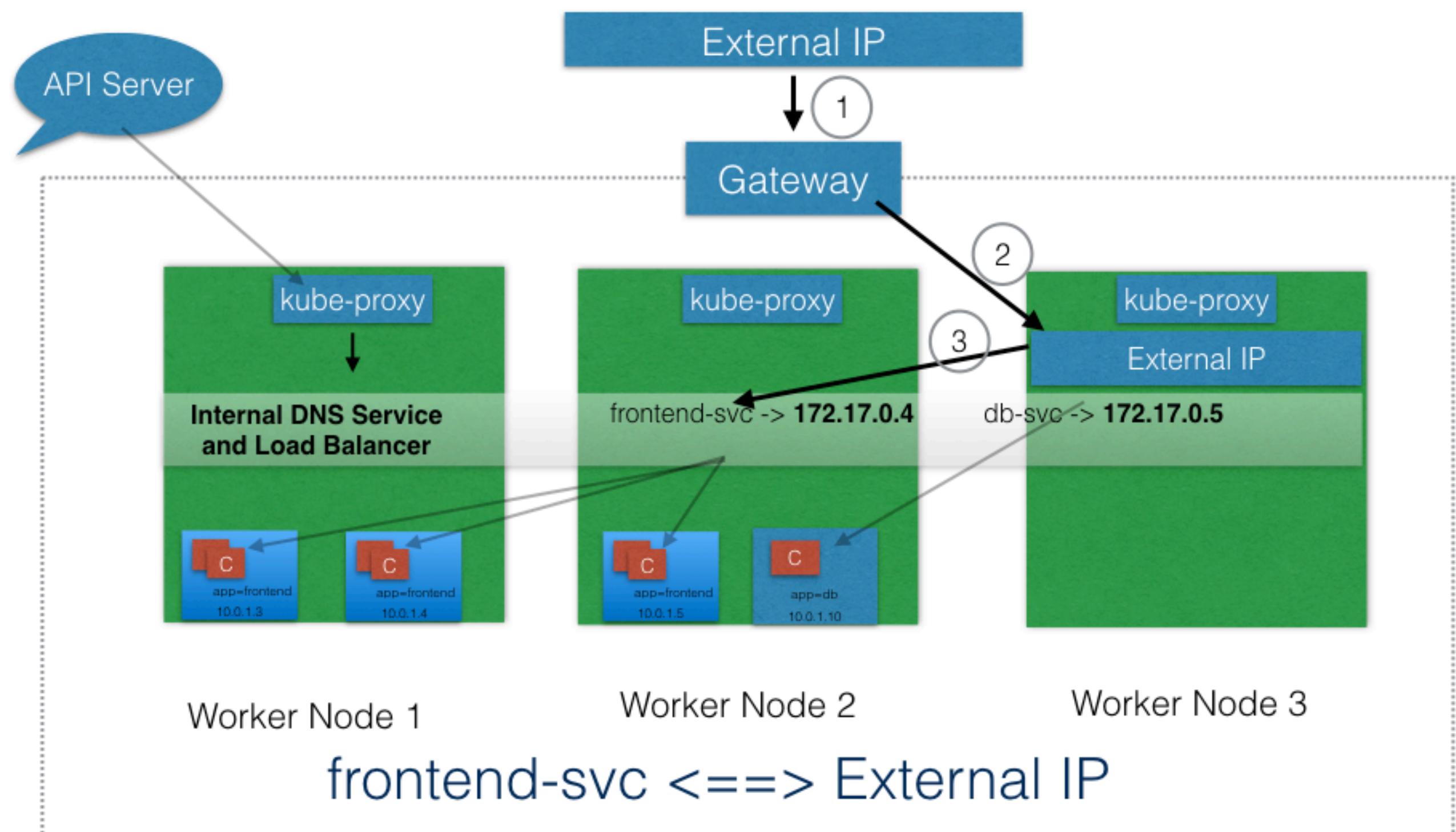
Service - LoadBalancer



ServiceType - ExternalIP

- A Service can be mapped to an ExternalIP address if it can route to one or more of the Worker Nodes
- Traffic that is ingressed into the cluster with the ExternalIP (as destination IP) on the Service port, gets routed to one of the the Service endpoints

Service - ExternalIP



ServiceType - ExternalName

- **ExternalName** is a special *ServiceType*, that has no Selectors and does not define any endpoints
- When accessed within the cluster, it returns a **CNAME** record of an externally configured service
- The primary use case of this *ServiceType* is to make externally configured services like **my-database.example.com** available inside the cluster, using just the name, like **my-database**, to other services inside the same Namespace

Deploying a Stand-Alone Application

Deploying an Application Using the Minikube GUI I

- **Make sure that minikube is running**

```
$ minikube status  
minikubeVM: Running  
localkube: Running
```

- **Start the minikube Dashboard**

- \$ minikube dashboard
 - Running this command will open up a browser with the Kubernetes GUI, which we can use to manage containerized applications

Admin

Namespaces

Nodes

Persistent Volumes

Storage Classes

Namespace

default ▾

Workloads

Deployments

Replica Sets

Replication Controllers

Daemon Sets

Stateful Sets

Jobs

Pods

Services and discovery

Services

Ingresses

Storage

There is nothing to display here

You can [deploy a containerized app](#), select other namespace or [take the Dashboard Tour](#) to learn more.

Deploying an Application Using the Minikube GUI II

The screenshot shows the Kubernetes Dashboard interface for deploying a containerized application. The main panel is titled "Deploy a Containerized App". It includes the following fields:

- Specify app details below** (radio button selected)
- Upload a YAML or JSON file** (radio button unselected)
- App name ***: webserver (9 / 24 characters)
- Container image ***: nginx:alpine
- Number of pods ***: 3
- Service ***: None

On the left sidebar, under the "Cluster" section, the "Namespaces" section is expanded, showing "default" selected. Other sections like "Nodes", "Persistent Volumes", "Roles", and "Storage Classes" are also listed. Under "Workloads", "Deployments" is selected, while "Daemon Sets", "Jobs", "Pods", "Replica Sets", "Replication Controllers", and "Stateful Sets" are also listed. At the bottom of the main panel, there are "SHOW ADVANCED OPTIONS", "DEPLOY", and "CANCEL" buttons.

Deploying an Application Using the Minikube GUI II

- We can either provide the application details here, or we can upload a YAML file with our Deployment details. As shown, we are providing the following application details:
 - The application name is `webserver`
 - The Docker image to use is `nginx:alpine`, where `alpine` is the image tag
 - The replica count, or the number of Pods, is 3
 - No Service, as we will be creating it later

Deploying an Application Using the Minikube GUI II

- If we click on *SHOW ADVANCED OPTIONS*, we can specify options such as Labels, Environment Variables, etc
 - By default, the Label is set to the application name
 - In our example, an `app:webserver` Label is set to different objects created by this Deployment.
- By clicking on the *DEPLOY* button, we can trigger the deployment.
 - As expected, the Deployment `webserver` will create a ReplicaSet (`webserver-1529352408`), which will eventually create three Pods (`webserver-1529352408-xxxx`)

Admin

Namespaces

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default

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Replica Sets

Replication Controllers

Daemon Sets

Stateful Sets

Jobs

Pods

Services and discovery

Services

Ingresses

Deployments

Name	Labels	Pods	Age	Images	⋮
webserver	app: webserver version: alpine	3 / 3	-	nginx:alpine	⋮

Replica Sets

Name	Labels	Pods	Age	Images	⋮
webserver-3101375161	app: webserver pod-template-hash: 3101375161 version: alpine	3 / 3	-	nginx:alpine	⋮

Pods

Name	Status	Restarts	Age	⋮
webserver-3101375161-jzk57	Running	0	-	⋮
webserver-3101375161-vxw2g	Running	0	-	⋮
webserver-3101375161-w1flz	Running	0	-	⋮

Check out Deployments, ReplicaSets, and Pods from the CLI

- List the Deployment in the given Namespace:

```
$ kubectl get deployments
```

NAME	DESIRED	CURRENT	UP-TO-DATE	AVAILABLE	AGE
webserver	3	3	3	3	3m

- List the ReplicaSets in the given Namespace:

```
$ kubectl get replicaset
```

NAME	DESIRED	CURRENT	READY	AGE
webserver-3101375161	3	3	3	4m

- List the Pods in the given Namespace:

```
$ kubectl get pods
```

NAME	READY	STATUS	RESTARTS	AGE
webserver-3101375161-jzk57	1/1	Running	0	4m
webserver-3101375161-vxw2g	1/1	Running	0	4m
webserver-31013755161-w1flz	1/1	Running	0	4m

Exploring Labels and Selectors I

- Earlier, we have seen that Labels and Selectors play an important role in grouping a subset of objects on which we can perform operations
- Next, we will take a closer look at them

Look at a Pod's details

- As you were able to see, with kubectl's describe subcommand we can get all the details about a Pod

```
$ kubectl describe pod webserver-3101375161-jzk57
Name:           webserver-3101375161-jzk57
Namespace:      default
Node:           minikube/192.168.99.100
Start Time:     Mon, 29 May 2017 12:58:34 +0530
Labels:         app=webserver
                pod-template-hash=3101375161
                version=alpine
Annotations:   kubernetes.io/created-
                by={"kind":"SerializedReference","apiVersion":"v1","reference":-
                {"kind":"ReplicaSet","namespace":"default","name":"webserver-
                3101375161","uid":"6c85e06b-4440-11e7-9c3b-080027a4605..."}
Status:         Running
IP:            172.17.0.4
.....
```

List the Pods, along with their attached Labels

\$ kubectl get pods -L app,label2					
NAME	READY	STATUS	RESTARTS	AGE	APP
LABEL2					
webserver-3101375161-jzk57	1/1	Running	0	12m	webserver
<none>					
webserver-3101375161-vxw2g	1/1	Running	0	12m	webserver
<none>					
webserver-3101375161-wiflz	1/1	Running	0	12m	webserver
<none>					

- All of the Pods are listed, as each Pod has the Label app, whose value is set to webserver
- We can see that from the APP column
- As none of the Pods has the label2 Label, the value <none> is listed under the LABEL2 column

Select the Pods with a given Label

```
$ kubectl get pods -l app=webserver
```

NAME	READY	STATUS	RESTARTS	AGE
webserver-3101375161-jzk57	1/1	Running	0	16m
webserver-3101375161-vxw2g	1/1	Running	0	16m
webserver-3101375161-wlflz	1/1	Running	0	16m

Delete the Deployment we created earlier

- We can delete any object using the kubectl delete command

```
$ kubectl delete deployments webserver  
deployment "webserver" deleted
```

- Deleting a Deployment also deletes the ReplicaSets and the Pods we created:

```
$ kubectl get replicaset  
No resources found.
```

```
$ kubectl get pods  
No resources found.
```

Create a YAML file with Deployment details

```
apiVersion: extensions/v1beta1
kind: Deployment
metadata:
  name: webserver
spec:
  replicas: 3
  template:
    metadata:
      labels:
        app: webserver
    spec:
      containers:
        - name: webserver
          image: nginx:alpine
          ports:
            - containerPort: 80
```

Create a YAML file with Deployment details

- Using **kubectl**, we will create the Deployment from the YAML file, with the **-f** option to the **kubectl create** command we can pass a YAML file as an object's specification

```
$ kubectl create -f webserver.yaml  
deployment "webserver" created
```

- This will also create a ReplicaSet and Pods, as defined.

```
$ kubectl get replicsets
```

NAME	DESIRED	CURRENT	READY	AGE
webserver-1529352408	3	3	3	3s

```
$ kubectl get pods
```

NAME	READY	STATUS	RESTARTS	AGE
webserver-1529352408-5xln6	1/1	Running	0	6s
webserver-1529352408-9st86	1/1	Running	0	6s
webserver-1529352408-tlz4m	1/1	Running	0	6s

Create a Service and Expose It to the External World with NodePort I

- In the previous section, we took a look at different *ServiceTypes*, with which we can define the access method for a given Service
- For a given Service, with the NodePort *ServiceType*, k8s opens up a static port on all the Worker Nodes
- If we connect to that port from any node, we are forwarded to the respective Service
- Next, let us use the NodePort *ServiceType* and create a Service

Create a Service and Expose It to the External World with NodePort I

```
apiVersion: v1
kind: Service
metadata:
  name: web-service
  labels:
    run: web-service
spec:
  type: NodePort
  ports:
  - port: 80
    protocol: TCP
  selector:
    app: webserver
```

```
$ kubectl create -f webserver-svc.yaml
service "web-service" created
```

List the Services

```
$ kubectl get service
```

NAME	CLUSTER	EXTERNAL-IP	PORT(S)	AGE
kubernetes	10.0.0.1	<none>	443/TCP	23d
web-service	10.0.0.133	<nodes>	80:32636/TCP	15s

- Our web-service is now created and its ClusterIP is [10.0.0.133](#)
- In the PORT(S) section we can see a mapping of [80:32636](#), which means that we have reserved a static port [32636](#) on the node
- If we connect to the node on that port, our requests will be forwarded to the ClusterIP on port [80](#)
- It is not necessary to create the Deployment first, and the Service after. They can be created in any order. A Service will connect Pods based on the Selector

Create a Service and Expose It to the External World with NodePort II

```
$ kubectl describe svc web-service
```

Name: web-service
Namespace: default
Labels: run=web-service
Annotations:
Selector: app=webserver
Type: NodePort
IP: 10.0.0.133
Port: <unset> 80/TCP
NodePort: <unset> 32636/TCP
Endpoints: 172.17.0.4:80,172.17.0.5:80,172.17.0.6:80
Session Affinity: None
Events: <none>

web-service uses app=webserver as a Selector, through which it selected our three Pods, which are listed as endpoints. So, whenever we send a request to our Service, it will be served by one of the Pods listed in the Endpoints section

Accessing the Application Using the Exposed NodePort

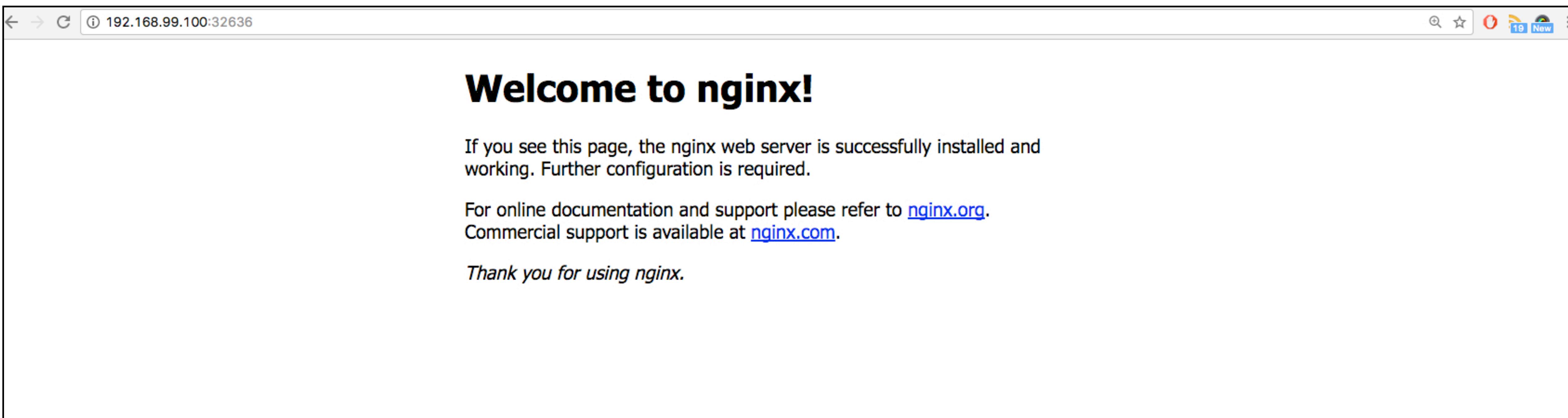
- Our application is running inside the minikube VM
- To access the application from our workstation, let's first get the IP address of the minikube VM

```
$ minikube ip
```

```
192.168.99.100
```

- Now, open the browser and access the application on 192.168.99.100 at port 32636

Accessing the Application Using the Exposed NodePort



- We can see the *Nginx* welcome page, through which we can access a **webserver** running inside one of the Pods created
- Our requests can be served by any one of the three endpoints selected via our Service

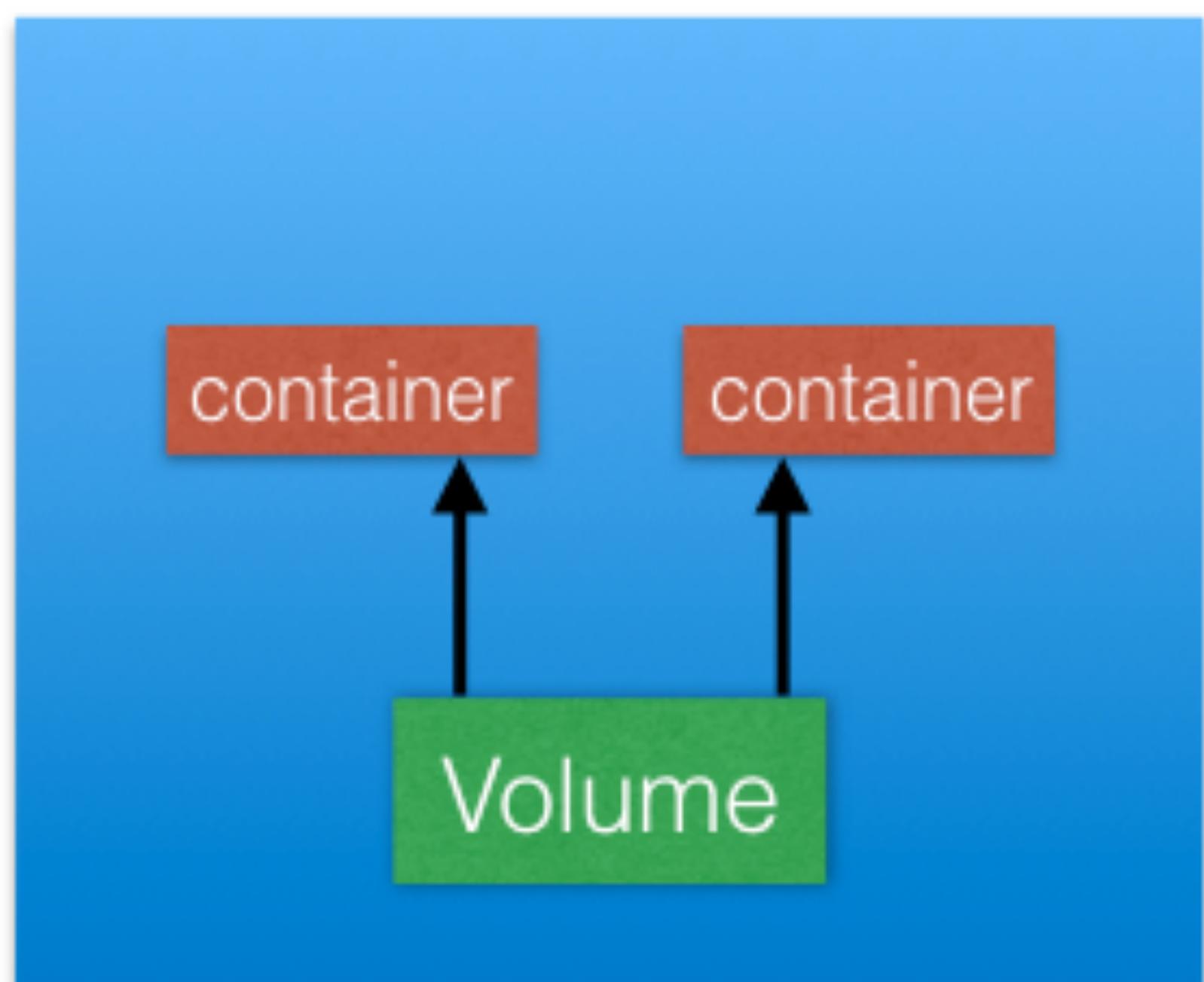
Kubernetes Volume Management

Volumes

- All data stored inside a container is deleted if the container crashes
 - However, `kubelet` will restart it with a clean state, which means that it will not have any of the old data.
- To overcome this problem, k8s uses [Volumes](#)
 - A Volume is essentially a directory backed by a storage medium
 - The storage medium and its content are determined by the Volume Type

Volumes

- In k8s, a Volume is attached to a Pod and shared among the containers of that Pod
- The Volume has the same life span as the Pod, and it outlives the containers of the Pod - this allows data to be preserved across container restarts



Pod

Volume Types

- **emptyDir**
 - An [empty](#) Volume is created for the Pod as soon as it is scheduled on the Worker Node. The Volume's life is tightly coupled with the Pod. If the Pod dies, the content of [emptyDir](#) is deleted forever
- **hostPath**
 - With the [hostPath](#) Volume Type, we can share a directory from the host to the Pod. If the Pod dies, the content of the Volume is still available on the host
- **gcePersistentDisk**
 - With the [gcePersistentDisk](#) Volume Type, we can mount a [Google Compute Engine \(GCE\) persistent disk](#) into a Pod
- **awsElasticBlockStore**
 - With the [awsElasticBlockStore](#) Volume Type, we can mount an [AWS EBS Volume](#) into a Pod

Volume Types

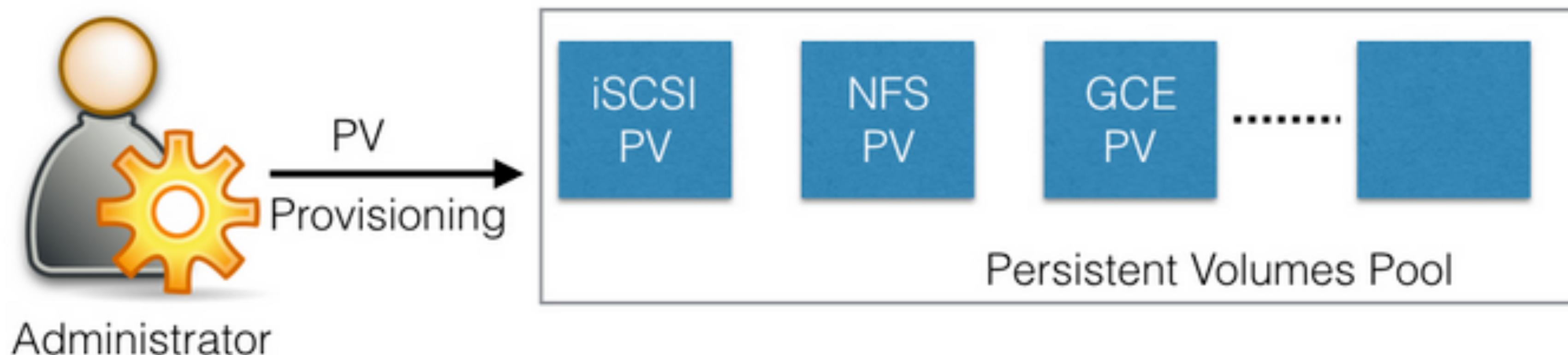
- **nfs**
 - With [nfs](#), we can mount an NFS share into a Pod.
- **iscsi**
 - With [iscsi](#), we can mount an iSCSI share into a Pod.
- **secret**
 - With the [secret](#) Volume Type, we can pass sensitive information, such as passwords, to Pods. We will take a look at an example in a later chapter.
- **persistentVolumeClaim**
 - We can attach a [Persistent Volume](#) to a Pod using a persistentVolumeClaim

Persistent Volumes

- In a typical IT environment, storage is managed by the storage/system administrators
 - The end user will just get instructions to use the storage, but does not have to worry about the underlying storage management
- In the containerized world, we would like to follow similar rules, but it becomes challenging, given the many Volume Types we have seen earlier
 - K8s resolves this problem with the Persistent Volume subsystem, which provides APIs for users and administrators to manage and consume storage

Persistent Volumes

- To manage the Volume, it uses the PersistentVolume (PV) API resource type, and to consume it, it uses the PersistentVolumeClaim (PVC) API resource type
- A Persistent Volume is a network attached storage in the cluster, which is provisioned by the administrator



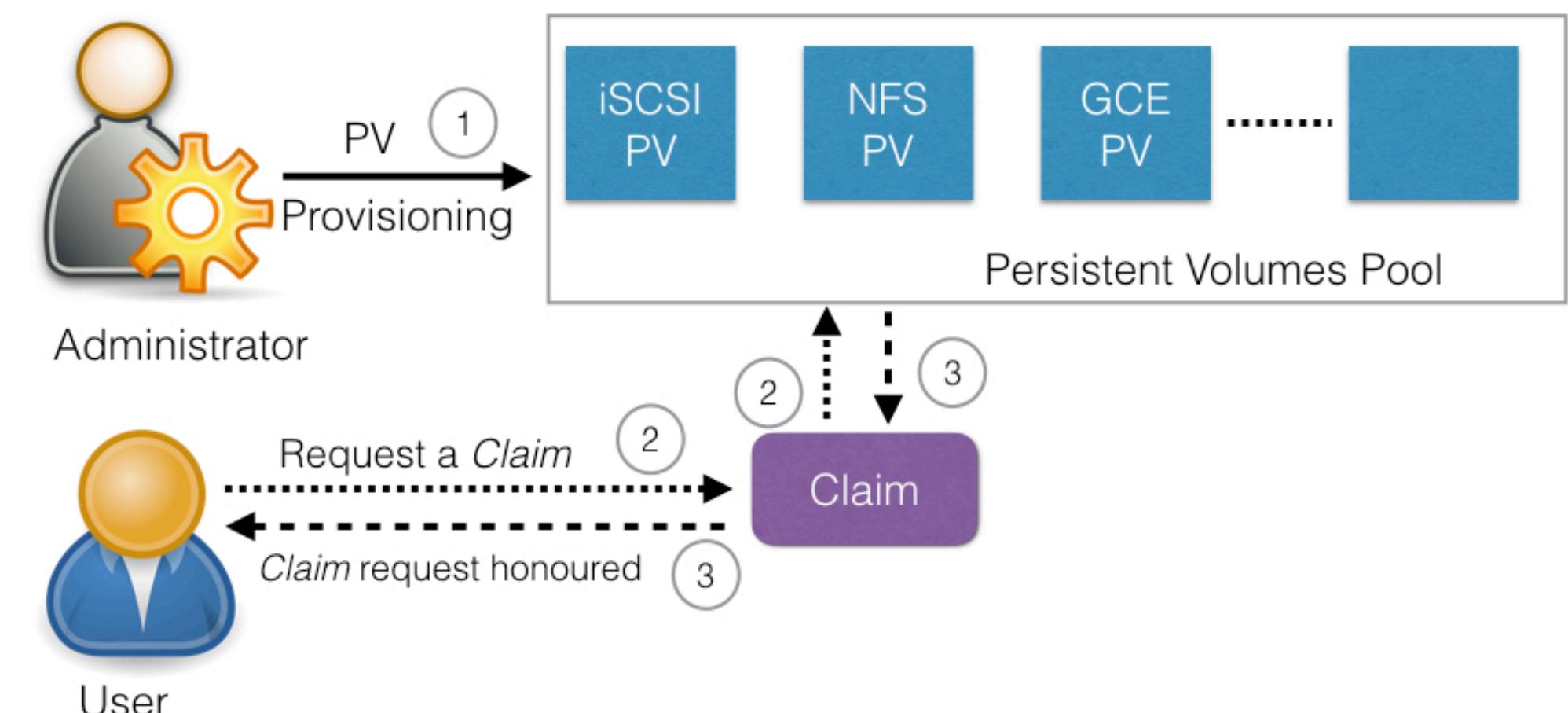
Persistent Volumes

- Persistent Volumes can be provisioned statically by the administrator, or dynamically, based on the StorageClass resource
 - A StorageClass contains pre-defined provisioners and parameters to create a Persistent Volume
- Some of the Volume Types that support managing storage using Persistent Volumes are:
 - GCEPersistentDisk
 - AWSElasticBlockStore
 - AzureFile
 - NFS
 - iSCSI
 - CephFS
 - Cinder

Persistent Volume Claims

- A PersistentVolumeClaim (PVC) is a request for storage by a user
- Users request for Persistent Volume resources based on size, access modes, etc
- Once a suitable Persistent Volume is found, it is bound to a Persistent Volume Claim

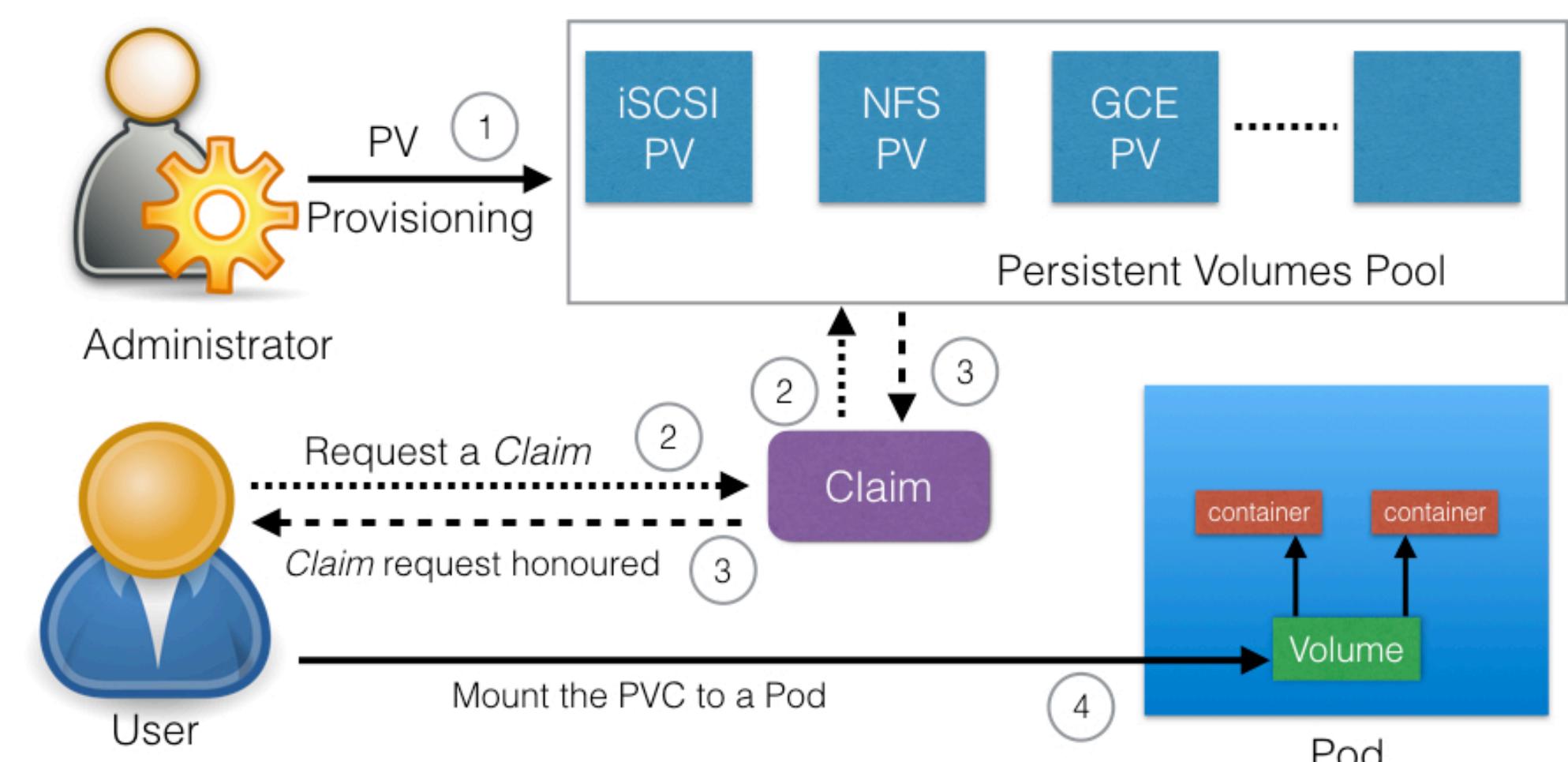
Persistent Volumes Claim (PVC)



Persistent Volume Claims

- After a successful bind, the `PersistentVolumeClaim` resource can be used in a Pod
- Once a user finishes its work, the attached Persistent Volumes can be released
- The underlying Persistent Volumes can then be reclaimed and recycled for future usage.

Persistent Volumes Claim (PVC)



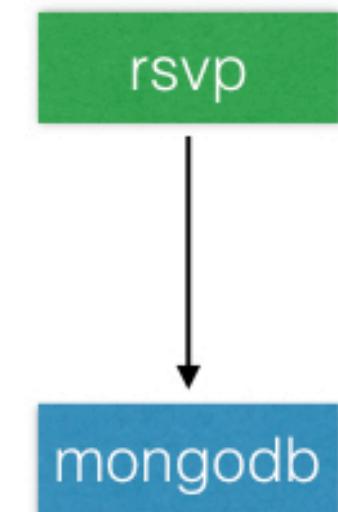
Deploying a Multi-Tier Application

RSVP Application

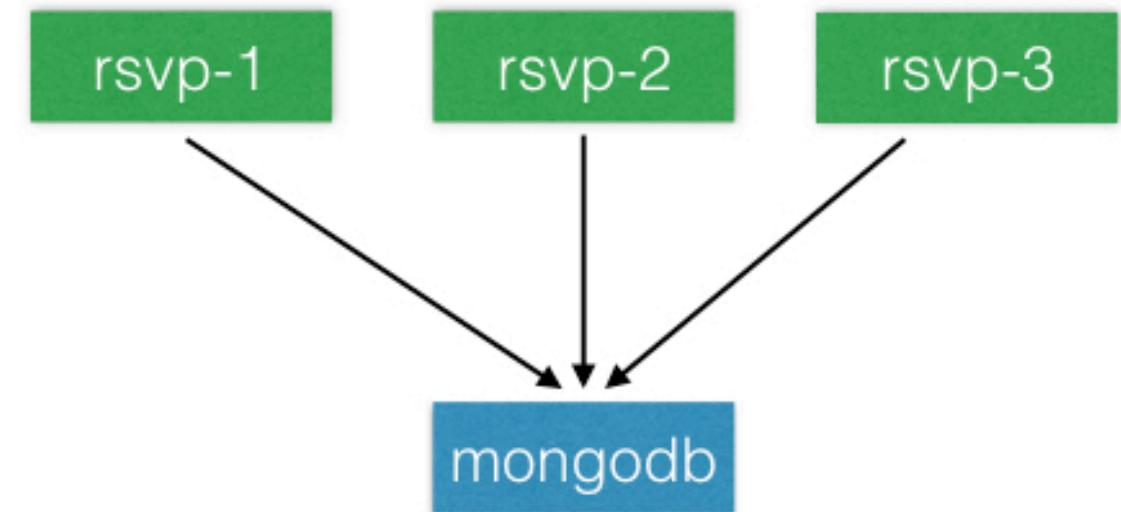
- We will be using a sample RSVP application
- Using this application, users can register for an event by providing their username and email id
- Once a user registers, his/her name and email appears in a table
- The application consists of a backend database and a frontend
 - For the backend, we will be using a MongoDB database, and for the frontend, we have a Python Flask-based application

RSVP Application

A frontend connected to a backend



Multiple frontends connected to a backend



RSVP Application

- The application's code: <https://github.com/vinicius3w/rsvpapp>
- In the frontend code (`rsvp.py`), we will look for the `MONGODB_HOST` environment variable for the database endpoint, and, if it is set, we will connect to it on port `27017`

```
MONGODB_HOST=os.environ.get('MONGODB_HOST', 'localhost')  
client = MongoClient(MONGODB_HOST, 27017)
```

- After deploying the application with one backend and one frontend, we will scale the frontend to explore the scaling feature of k8s
- Next, we will deploy the MongoDB database - for this, we will need to create a Deployment and a Service for MongoDB

Create the Deployment for MongoDB

```
apiVersion: extensions/v1beta1
kind: Deployment
metadata:
  name: rsvp-db
spec:
  replicas: 1
  template:
    metadata:
      labels:
        appdb: rsvpdb
    spec:
      containers:
        - name: rsvpd-db
          image: mongo:3.3
          env:
            - name: MONGODB_DATABASE
              value: rsvpdata
      ports:
        - containerPort: 27017
```

```
$ kubectl create -f rsvp-db.yaml
deployment "rsvp-db" created
```

Create the Service for MongoDB

```
apiVersion: v1
kind: Service
metadata:
  name: mongodb
  labels:
    app: rsvpdbc
spec:
  ports:
  - port: 27017
    protocol: TCP
  selector:
    appdb: rsvpdbc
```

```
$ kubectl create -f rsvp-db-service.yaml
service "mongodb" created
```

As we did not specify any ServiceType, mongodb will have the default ClusterIP ServiceType. This means that the mongodb Service will not be accessible from the external world.

Check Out the Available Deployments and Services

```
$ kubectl get deployments
```

NAME	DESIRED	CURRENT	UP-TO-DATE	AVAILABLE	AGE
rsvp-db	1	1	1	1	10m
webserver	3	3	3	3	1d

```
$ kubectl get services
```

NAME	CLUSTER-IP	EXTERNAL-IP	PORT(S)	AGE
kubernetes	10.0.0.1	<none>	443/TCP	24d
mongodb	10.0.0.32	<none>	27017/TCP	8m
web-service	10.0.0.133	<nodes>	80/32636/TCP	1d

Deploy the Python Flask-Based Frontend

- The frontend is created using a [Python Flask-based microframework](#)
- Its source code is available [here](#)
 - We have created a Docker image called [teamcloudyuga/rsvpapp](#), in which we have imported the application's source code
 - The application's code is executed when a container created from that image runs
 - The Dockerfile to create the [teamcloudyuga/rsvpapp](#) image is available [here](#)

Create the Deployment for the 'rsvp' Frontend

```
apiVersion: extensions/v1beta1
kind: Deployment
metadata:
  name: rsvp
spec:
  replicas: 1
  template:
    metadata:
      labels:
        app: rsvp
    spec:
      containers:
        - name: rsvp-app
          image: teamcloudyuga/rsvpapp
          env:
            - name: MONGODB_HOST
              value: mongodb
          ports:
            - containerPort: 5000
              name: web-port
```

```
$ kubectl create -f rsvp-web.yaml
deployment "rsvp" created
```

Create the Deployment for the 'rsvp' Frontend

- While creating the Deployment for the frontend, we are passing the name of the MongoDB Service, `mongodb`, as an environment variable, which is expected by our frontend
- Notice that in the `ports` section we mentioned the `containerPort 5000`, and given it the `web-port` name
- We will be using the referenced `web-port` name while creating the Service for the `rsvp` application
- This is useful, as we can change the underlying `containerPort` without making any changes to our Service.

Create the Service for the 'rsvp' Frontend

```
apiVersion: v1
kind: Service
metadata:
  name: rsvp
  labels:
    apps: rsvp
spec:
  type: NodePort
  ports:
  - port: 80
    targetPort: web-port
    protocol: TCP
  selector:
    app: rsvp
```

```
$ kubectl create -f rsvp-web-service.yaml
service "rsvp" created
```

Check Out the Available Deployments and Services

```
$ kubectl get deployments
```

NAME	DESIRED	CURRENT	UP-TO-DATE	AVAILABLE	AGE
rsvp	1	1	1	1	40m
rsvp-db	1	1	1	1	1h
webserver	3	3	3	3	1d

```
$ kubectl get services
```

NAME	CLUSTER-IP	EXTERNAL-IP	PORT(S)	AGE
kubernetes	10.0.0.1	<none>	443/TCP	25d
mongodb	10.0.0.32	<none>	27017/TCP	1h
rsvp	10.0.0.225	<nodes>	80:31314/TCP	7m
web-service	10.0.0.133	<nodes>	80:32636/TCP	1d

Access the RSVP Application from the Workstation

- While deploying the frontend's Service, we have used NodePort as the *ServiceType*, which has configured [port 31314](#) on the minikube VM to access the application
 - Please note that on your setup, the configured [port](#) for [NodePort](#) may be different than ours
 - For this section, please use that respective port wherever we use [port 31314](#). Let's now get minikube's IP address:

```
$ minikube ip  
192.168.99.100
```

- and open a browser to access the application at <http://192.168.99.100:31314>

CloudYuga Garage RSVP!

Serving from Host: rsvp-3654889312-bpckk

Name:

Email:

Submit

RSVP Count : 2

Name	Email
Neependra Khare	neependra@cloudyuga.guru
test	test@test.com

CloudYuga Technology Pvt. Ltd.

Scale the Frontend

- Currently, we have one replica running for the frontend. To scale it to 4 replicas, we can use the following command:

```
$ kubectl scale --replicas=4 -f /tmp/rsvp-web.yaml  
deployment "rsvp" scaled
```

- We can verify if it scaled correctly by looking at the Deployments:

```
$ kubectl get deployments
```

NAME	DESIRED	CURRENT	UP-TO-DATE	AVAILABLE	AGE
rsvp	4	4	4	4	1h
rsvp-db	1	1	1	1	1h
webserver	3	3	3	3	1d

Scale the Frontend

- If we go to the browser and refresh the frontend, the `hostname` printed after the `Serving from Host` text keeps changing: `rsvp-3654889312-b51fn`, `rsvp-3654889312-s7738`, and so on
- This is because the `hostname` is coming from the underlying Pod and, when we refresh the page, we hit different endpoints from our Service

ConfigMaps and Secrets

ConfigMaps

- [ConfigMaps](#) allow us to decouple the configuration details from the container image
- Using ConfigMaps, we can pass configuration details as key-value pairs, which can be later consumed by Pods, or any other system components, such as controllers
- We can create ConfigMaps in two ways:
 - From literal values
 - From files

Create a ConfigMap from Literal Values and Get Its Details

- A ConfigMap can be created with the `kubectl create` command, and we can get the values using the `kubectl get` command.
- Create the ConfigMap

```
$ kubectl create configmap my-config --  
from-literal=key1=value1 --from-  
literal=key2=value2
```

```
configmap "my-config" created
```

Create a ConfigMap from Literal Values and Get Its Details

```
$ kubectl get configmaps my-config -o yaml
apiVersion: v1
data:
  key1: value1
  key2: value2
kind: ConfigMap
metadata:
  creationTimestamp: 2017-05-31T07:21:55Z
  name: my-config
  namespace: default
  resourceVersion: "241345"
  selfLink: /api/v1/namespaces/default/configmaps/my-config
  uid: d35f0a3d-45d1-11e7-9e62-080027a46057
```

Create a ConfigMap from a Configuration File

- First, we need to create a configuration file. We can have a configuration file with the content like:

```
apiVersion: v1
kind: ConfigMap
metadata:
  name: customer1
data:
  TEXT1: Customer1_Company
  TEXT2: Welcomes You
  COMPANY: Customer1 Company Technology Pct. Ltd.
```

- in which we mentioned the `kind`, `metadata`, and `data` fields, which are targeted to connect with the `v1` endpoint of the API Server.

Create a ConfigMap from a Configuration File

- If we name the file with the configuration above as `customer1-configmap.yaml`, we can then create the ConfigMap with the following command:

```
$ kubectl create -f customer1-  
configmap.yaml  
configmap "customer1" created
```

Use ConfigMap Inside Pods

- We can get the values of the given key as **environment variables** inside a Pod
- In the following example, while creating the Deployment, we are assigning values for environment variables from the `customer1` ConfigMap
- We will get the `TEXT1` environment variable set to `Customer1_Company`, `TEXT2` environment variable set to `Welcomes You`, and so on

```
....  
  containers:  
    - name: rsvp-app  
      image: teamcloudyuga/rsvpapp  
      env:  
        - name: MONGODB_HOST  
          value: mongodb  
        - name: TEXT1  
          valueFrom:  
            configMapKeyRef:  
              name: customer1  
              key: TEXT1  
        - name: TEXT2  
          valueFrom:  
            configMapKeyRef:  
              name: customer1  
              key: TEXT2  
        - name: COMPANY  
          valueFrom:  
            configMapKeyRef:  
              name: customer1  
              key: COMPANY
```

....

Use ConfigMap Inside Pods

- We can mount a ConfigMap as a Volume inside a Pod
- For each key, we will see a file in the mount path and the content of that file become the respective key's value
- For more details, please study the [K8s Documentation](#)

Secrets

- Let's assume that we have a *Wordpress blog* application, in which our `wordpress` frontend connects to the `MySQL` database backend using a password
- While creating the Deployment for `wordpress`, we can put down the `MySQL` password in the Deployment's YAML file, but the password would not be protected
- The password would be available to anyone who has access to the configuration file
- In situations such as the one we just mentioned, the `Secret` object can help

Secrets

- With Secret, we can share sensitive information like passwords, tokens, or keys in the form of key-value pairs, similar to ConfigMaps; thus, we can control how the information in a Secret is used, reducing the risk for accidental exposures
- In Deployments or other system components, the Secret object is referenced, without exposing its content
- It is important to keep in mind that the Secret data is stored as plain text inside `etcd`
- Administrators must limit the access to the API Server and `etcd`

Create the Secret with the 'kubectl create secret' Command

- To create a Secret, we can use the `kubectl create secret` command:

```
$ kubectl create secret generic my-password  
--from-literal=password=mysqlpassword
```

- The above command would create a secret called `my-password`, which has the value of the `password` key set to `mysqlpassword`

'get' and 'describe' the Secret

- Analyzing the `get` and `describe` examples, we can see that they do not reveal the content of the Secret
- The type is listed as `Opaque`

```
$ kubectl get secret my-password  
NAME          TYPE        DATA  AGE  
my-password   Opaque      1     8m
```

```
$ kubectl describe secret my-password  
Name:         my-password  
Namespace:    default  
Labels:       <none>  
Annotations:  <none>
```

Type Opaque

Data

====

password.txt: 13 bytes

Create a Secret Manually

- With Secrets, each object data must be encoded using base64. If we want to have a configuration file for our Secret, we must first get the base64 encoding for our password

```
$ echo mysqlpassword | base64  
bxLzcWxwYXNzd29yZAo=
```

- and then use it in the configuration file:

```
apiVersion: v1  
kind: Secret  
metadata:  
  name: my-password  
  type: Opaque  
data:  
  password: bxLzcWxwYXNzd29yZAo=
```

ATENTION!!!

- Please note that base64 encoding does not do any encryption, and anyone can easily decode it:

```
$ echo "bXlzcWxwYXNzd29yZAo=" |  
base64 --decode
```

- Therefore, make sure you **do not commit** a Secret's configuration file in the source code

Use Secrets Inside Pods

- Using Secrets as Environment Variables
 - As shown in the following example, we can reference a Secret and assign the value of its key as an environment variable (WORDPRESS_DB_PASSWORD)

```
.....  
spec:  
  containers:  
    - image: wordpress:4.7.3-apache  
      name: wordpress  
    env:  
      - name: WORDPRESS_DB_HOST  
        value: wordpress-mysql  
      - name: WORDPRESS_DB_PASSWORD  
        valueFrom:  
          secretKeyRef:  
            name: my-password  
            key: password
```

.....

Use Secrets Inside Pods

- Using Secrets as Files from a Pod
 - We can also mount a Secret as a Volume inside a Pod
 - A file would be created for each key mentioned in the Secret, whose content would be the respective value
 - For more details, you can study the [k8s Documentation](#)

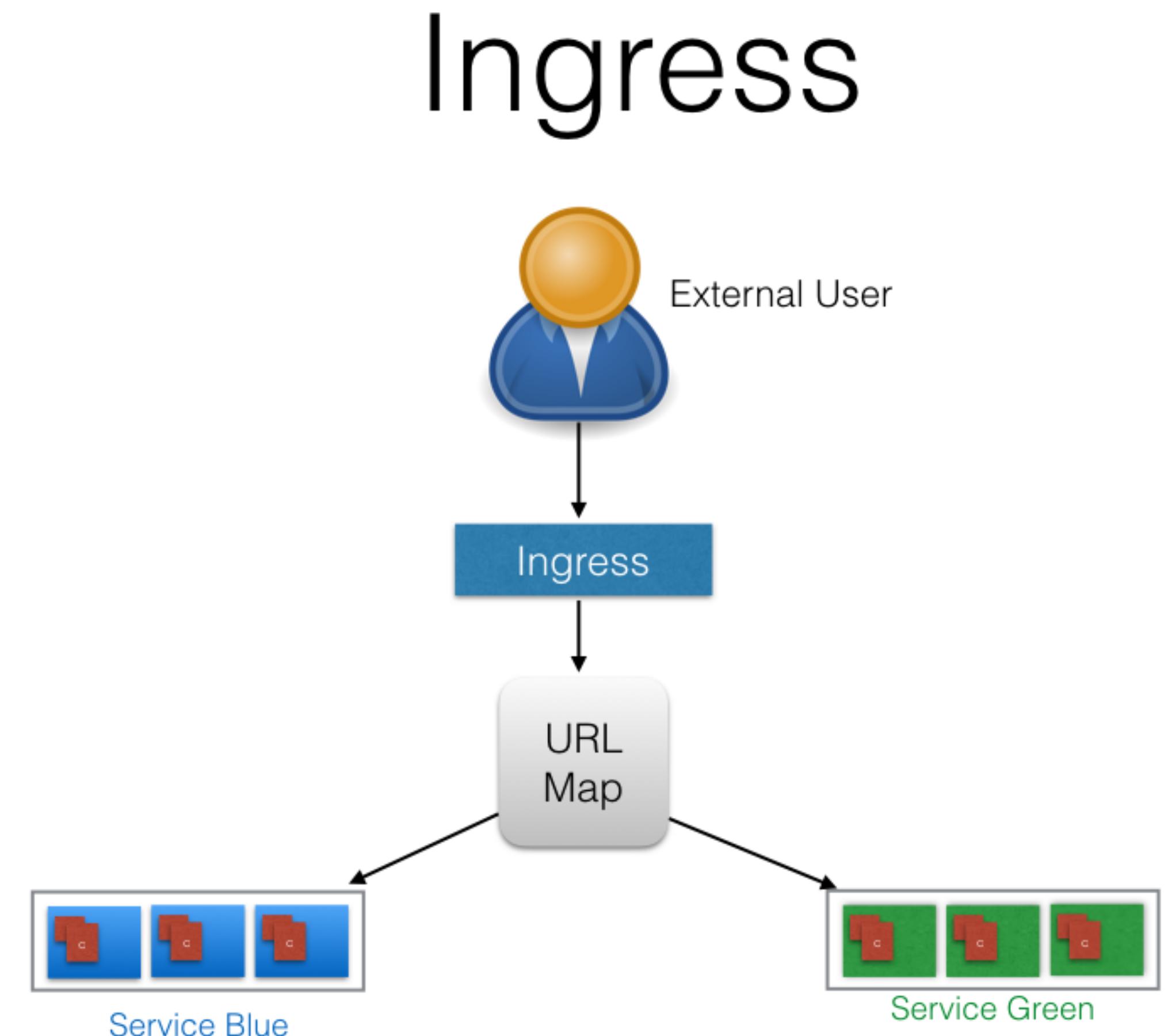
Ingress

Ingress

- With Services, routing rules are attached to a given Service
- They exist for as long as the Service exists
 - If we can somehow decouple the routing rules from the application, we can then update our application without worrying about its external access
- This can be done using the Ingress resource
- According to kubernetes.io,
 - "*An Ingress is a collection of rules that allow inbound connections to reach the cluster Services.*"

Ingress

- To allow the inbound connection to reach the cluster Services, Ingress configures a Layer 7 HTTP load balancer for Services and provides the following:
 - TLS (Transport Layer Security)
 - Name-based virtual hosting
 - Path-based routing
 - Custom rules



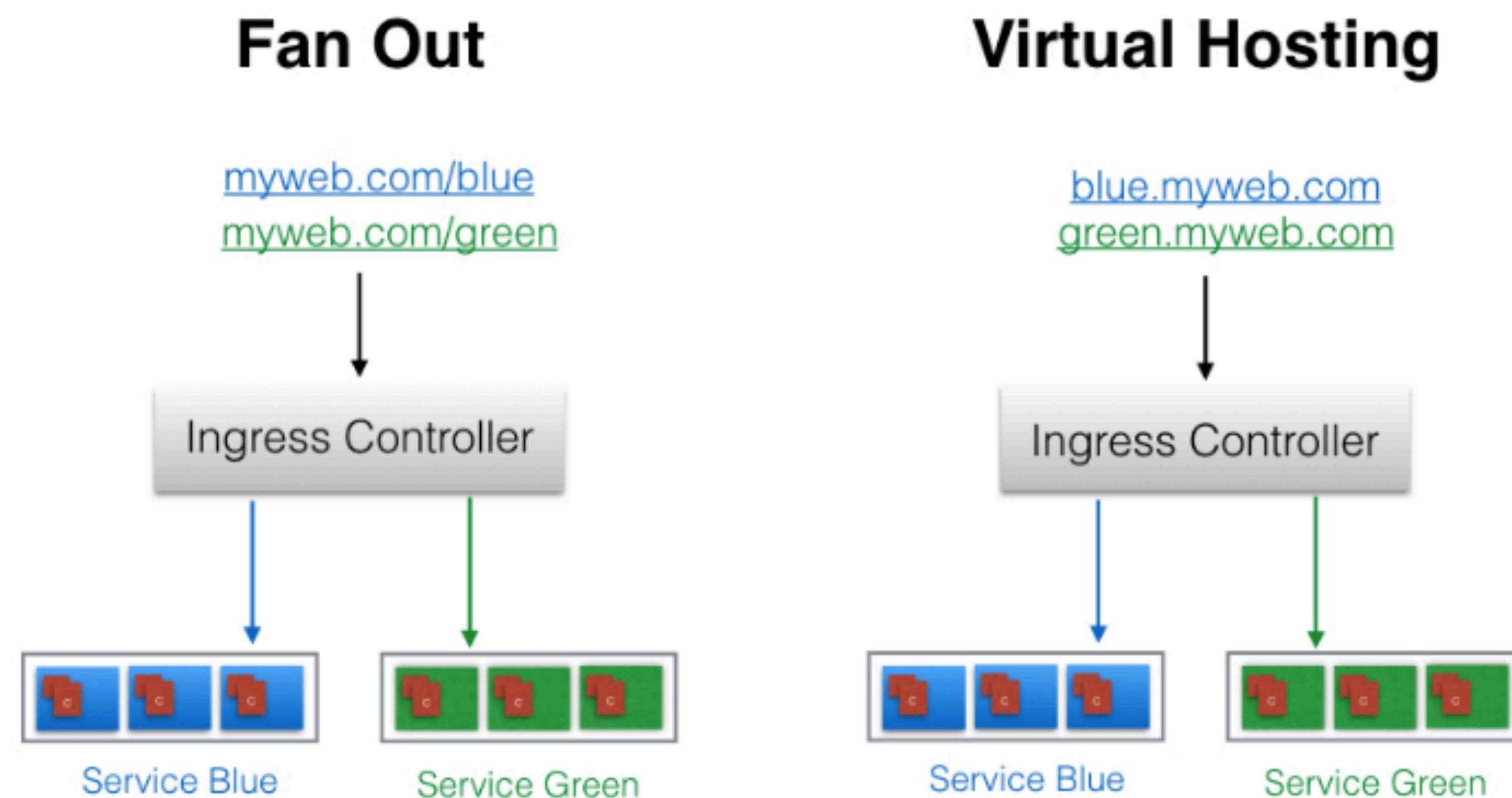
Ingress II

- With Ingress, users don't connect directly to a Service
 - Users reach the Ingress endpoint, and, from there, the request is forwarded to the respective Service
 - users requests to both `blue.myweb.com` and `green.myweb.com` would go to the same Ingress endpoint, and, from there, they would be forwarded to `blue-service`, and `green-service`, respectively
 - Here, we have seen an example of a Name-Based Virtual Hosting Ingress rule

```
apiVersion: extensions/v1beta1
kind: Ingress
metadata:
  name: web-ingress
spec:
  rules:
    - host: blue.myweb.com
      http:
        paths:
          - backend:
              serviceName: blue-service
              servicePort: 80
    - host: green.myweb.com
      http:
        paths:
          - backend:
              serviceName: green-service
              servicePort: 80
```

Ingress

- We can also have Fan Out Ingress rules, in which we send requests like `myweb.com/blue` and `myweb.com/green`, which would be forwarded to `blue-service` and `green-service`, respectively
- The Ingress resource does not do any request forwarding by itself
- All of the magic is done using the Ingress Controller



Ingress Controller

- An [Ingress Controller](#) is an application which watches the Master Node's API Server for changes in the Ingress resources and updates the Layer 7 load balancer accordingly
 - K8s has different Ingress Controllers, and, if needed, we can also build our own
 - [GCE L7 Load Balancer](#) and [Nginx Ingress Controller](#) are examples of Ingress Controllers
 - Start the Ingress Controller with minikube
 - Minikube v0.14.0 and above ships the Nginx Ingress Controller setup as an add-on
- ```
$ minikube addons enable ingress
```

# Deploy an Ingress Resource

- Once the Ingress Controller is deployed, we can create an Ingress resource using the `kubectl create` command
- For example, if we create a `myweb-ingress.yaml` file with the content that we saw on the Ingress II slide, then

```
$ kubectl create -f myweb-ingress.yaml
```

# Access Services Using Ingress

- With the Ingress resource we just created, we should now be able to access the `blue-service` or `green-service` services using `blue.myweb.com` and `green.myweb.com` URLs
- As our current setup is on minikube, we will need to update the host configuration file (`/etc/hosts` on Mac and Linux) on our workstation to the minikube's IP for those URLs:
  - `$ cat /etc/hosts`
  - `127.0.0.1 localhost`
  - `::1 localhost`
  - `192.168.99.100 blue.myweb.com green.myweb.com`
- Once this is done, we can now open `blue.myweb.com` and `green.myweb.com` on the browser and access the application

# **Advanced Topics -**

# **Overview**

# Annotations

- With [Annotations](#), we can attach arbitrary non-identifying metadata to objects, in a key-value format:

```
"annotations": {
 "key1" : "value1",
 "key2" : "value2"
}
```

- In contrast to Labels, annotations are not used to identify and select objects. Annotations can be used to:
  - Store build/release IDs, PR numbers, git branch, etc.
  - Phone/pager numbers of persons responsible, or directory entries specifying where such information can be found
  - Pointers to logging, monitoring, analytics, audit repositories, debugging tools, etc.
  - Etc.

# Annotations

- For example, while creating a Deployment, we can add a description like the one below:

```
apiVersion: extensions/v1beta1
kind: Deployment
metadata:
 name: webserver
 annotations:
 description: Deployment based PoC dates 2nd
 June '2017
...
...
```

# Annotations

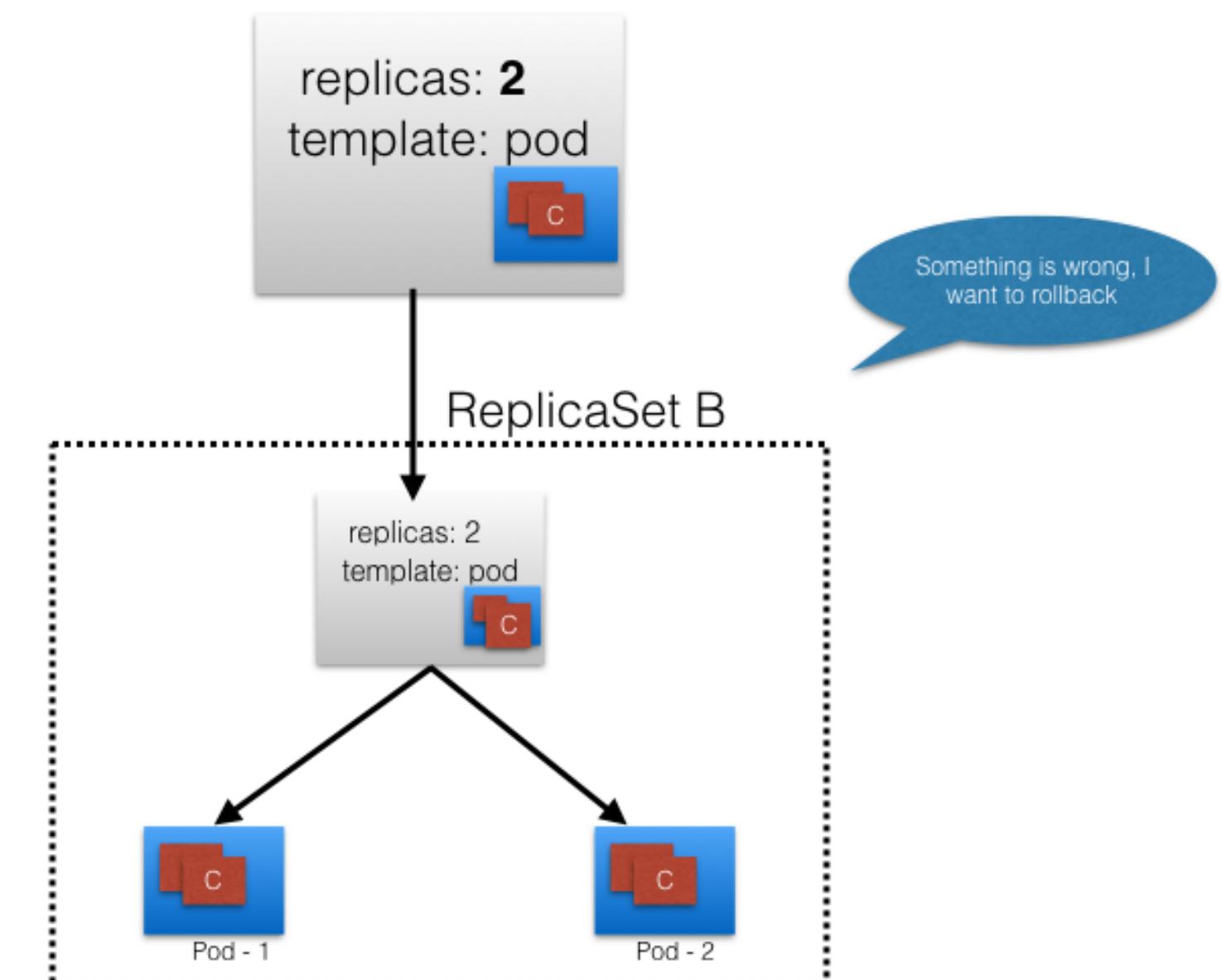
- We can look at annotations while describing an object:

```
$ kubectl describe deployment webserver
Name: webserver
Namespace: default
CreationTimestamp: Sat, 03 Jun 2017 05:10:38 +0530
Labels: app=webserver
Annotations: deployment.kubernetes.io/revision=1
 description=Deployment based PoC dates 2nd June '2017
...
...
```

# Deployment Features

- Earlier, we have seen how we can use the Deployment object to deploy an application
- We can do more interesting things, like recording a Deployment - if something goes wrong, we can revert to the working state
- The graphic below depicts a situation in which our update fails

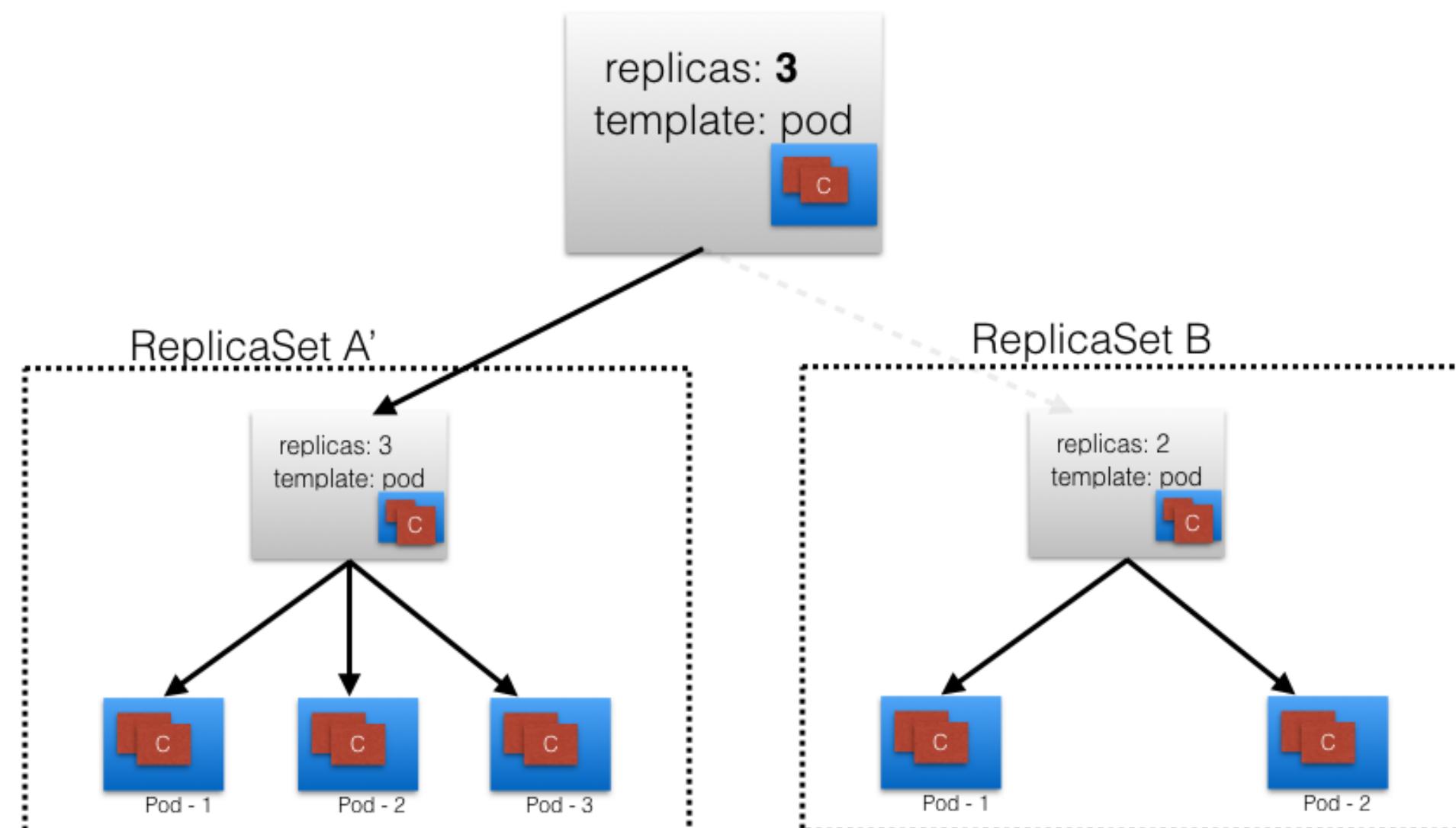
## Deployment - Rollback



# Deployment Features

- If we have recorded our Deployment before doing the update, we can revert back to a known working state
- In addition, the Deployment object also provides
  - Autoscaling
  - Proportional scaling
  - Pausing and resuming

## Deployment - Rollback



# Jobs

- A [Job](#) creates one or more Pods to perform a given task
- The Job object takes the responsibility of Pod failures
  - It makes sure that the given task is completed successfully
  - Once the task is over, all the Pods are terminated automatically
- Starting with the Kubernetes 1.4 release, we can also perform Jobs at specified times/dates, such as [cron jobs](#)

# Quota Management

- When there are many users sharing a given k8s cluster, there is always a concern for fair usage
- To address this concern, administrators can use the [ResourceQuota](#) object, which provides constraints that limit aggregate resource consumption per Namespace
- We can have the following types of quotas per Namespace:
  - **Compute Resource Quota:** We can limit the total sum of compute resources (CPU, memory, etc.) that can be requested
  - **Storage Resource Quota:** We can limit the total sum of storage resources (persistentvolumeclaims, requests.storage, etc.) that can be requested
  - **Object Count Quota:** We can restrict the number of objects of a given type (pods, ConfigMaps, persistentvolumeclaims, ReplicationControllers, Services, Secrets, etc.)

# DaemonSets

- In some cases, like collecting monitoring data from all nodes, or running a storage daemon on all nodes, etc., we need a specific type of Pod running on all nodes at all times
  - A [DaemonSet](#) is the object that allows us to do just that
- Whenever a node is added to the cluster, a Pod from a given DaemonSet is created on it
- When the node dies, the respective Pods are garbage collected
- If a DaemonSet is deleted, all Pods it created are deleted as well

# StatefulSets

- Before k8s 1.5, the [StatefulSet](#) controller was referred to as *PetSet*
- The StatefulSet controller is used for applications which require a unique identity, such as name, network identifications, strict ordering, etc
  - For example, [MySQL cluster](#), [etcd cluster](#)
  - The StatefulSet controller provides identity and guaranteed ordering of deployment and scaling to Pods

# Role Based Access Control (RBAC)

- Role-based access control (RBAC) is an authorization mechanism for managing permissions around k8s resources
  - It is added as a beta resource in k8s 1.6 release.
- Using the RBAC API, we define a role which contains a set of additive permissions
  - Within a Namespace, a role is defined using the *Role* object
  - For a cluster-wide role, we need to use the *ClusterRole* object
- Once the roles are defined, we can bind them to a user or a set of users using *RoleBinding* and *ClusterRoleBinding*

# Kubernetes Federation

- With the [K8s Cluster Federation](#) we can manage multiple k8s clusters from a single control plane
  - We can sync resources across the clusters, and have cross cluster discovery
  - This allows us to do Deployments across regions and access them using a global DNS record
- The **Federation** is very useful when we want to build a hybrid solution, in which we can have one cluster running inside our private datacenter and another one on the public cloud
  - We can also assign weights for each cluster in the Federation, to distribute the load as per our choice

# Third Party Resources (Objects)

- In most cases, the existing k8s objects are sufficient to fulfill our requirements to deploy an application, but we also have the flexibility to do more
- Using the [ThirdPartyResource](#) object type, we can create our own API objects
- In this case, we will need to write a controller, which can listen to their creation/update/deletion
- The controller would then perform operations accordingly

# Third Party Resources (Objects)

- For example, the [etcd-operator](#) uses the ThirdPartyResource to create objects, and, depending on that, its controller creates/configures/manages `etcd` clusters on top of k8s
- ThirdPartyResource is getting deprecated with Kubernetes 1.7
- A new object type called **Custom Resource Definition (CRD)** was introduced in beta with the K8s 1.7 release, which will help you create new custom resources
- For more details, please checkout out the [example from CoreOS](#)

# Helm

- To deploy an application, we use different k8s manifests, such as Deployments, Services, Volume Claims, Ingress, etc
- Sometimes, it can be **tiresome** to deploy them one by one
- We can bundle all those manifests after templating them into a well-defined format, along with other metadata
- Such a bundle is referred to as Chart
  - These Charts can then be served via repositories, such as those that we have for **rpm** and **deb** packages

# Helm

- Helm is a package manager (analogous to yum and apt) for k8s, which can install/update/delete those Charts in the k8s cluster
- Helm has two components:
  - A client called *helm*, which runs on your user's workstation
  - A server called *tiller*, which runs inside your k8s cluster
- The client *helm* connects to the server *tiller* to manage Charts
  - Charts submitted for k8s are available [here](#)

# Monitoring and Logging

- In k8s, we have to collect resource usage data by Pods, Services, nodes, etc, to understand the overall resource consumption and to take decisions for scaling a given application
- Two popular k8s monitoring solutions are Heapster and Prometheus
  - [Heapster](#) is a cluster-wide aggregator of monitoring and event data, which is natively supported on k8s
  - [Prometheus](#) (part of CNCF), can also be used to scrape the resource usage from different k8s components and objects
    - Using its client libraries, we can also instrument the code of our application

# Monitoring and Logging

- Another important aspect for troubleshooting and debugging is **Logging**, in which we collect the logs from different components of a given system
- In k8s, we can collect logs from different cluster components, objects, nodes, etc
- The most common way to collect the logs is using [Elasticsearch](#), which uses [fluentd](#) with custom configuration as an agent on the nodes. fluentd is an open source data collector, which is also part of CNCF

# Kubernetes Community

# Kubernetes Community

- With more than [35 thousand GitHub stars](#), k8s is one of the most popular open source projects
  - The Community members not only help with the source code, but they also help with sharing the knowledge
  - The Community engages in both online and offline activities
- Currently, there is a project called [K8sPort](#), which recognizes and rewards Community members for their contributions to k8s
  - This contribution can be in the form of code, attending and speaking at meetups, answering questions on Stack Overflow, etc

# Weekly Meetings and Meetup Groups

- **Weekly Meetings**
  - A weekly community meeting happens using video conference tools. You can get a calendar invite from [here](#)
- **Meetup Groups**
  - There are many [meetup groups around the world](#), where local community members meet at regular intervals to discuss about k8s and its ecosystem
  - There are some online meetup groups as well, where community members can meet virtually

# Slack Channels and Mailing Lists

- **Slack Channels**
  - Community members are very active on the k8s Slack
  - There are different channels based on topics, and anyone can join and participate in the discussions
  - You can discuss with the k8s team on the [#kubernetes-users](#) channel
- **Mailing Lists**
  - There are k8s [users](#) and [developers](#) mailing lists, which can be joined by anybody interested

# SIGs and Stack Overflow

- **Special Interest Groups**
  - Special Interest Groups (SIGs) focus on specific parts of the k8s project, like scheduling, authorization, Networking, Documentation, etc
  - Each group may have a different workflow, based on its specific requirements
  - A list with all the current SIGs can be found [here](#). Depending on the need, a new SIG can be created
- **Stack Overflow**
  - Besides Slack and mailing lists, Community members can get support from [Stack Overflow](#), as well
  - Stack Overflow is an online environment where you can post questions that you cannot find an answer for
    - The K8s team also monitors the posts tagged **Kubernetes**

# CNCF Events

- CNCF organizes numerous international conferences on Kubernetes, as well as other CNCF projects
- Two of the major conferences it organizes are:
  - CloudNativeCon + KubeCon Europe
  - CloudNativeCon + KubeCon North America.

# What's Next on Your Kubernetes Journey?

- Now that you have a better understanding of k8s, you can continue your journey by:
  - Participating in activities and discussions organized by the k8s community
  - Attending events organized by the Cloud Native Computing Foundation and The Linux Foundation
  - Expanding your Kubernetes knowledge and skills by enrolling in online courses (offered by The Linux Foundation for example)
  - Preparing for the upcoming Kubernetes Certified Administrator exam, which will be offered by the Cloud Native Computing Foundation
  - And many other options