Kubernetes

Container orchestration

What is Kubernetes ?

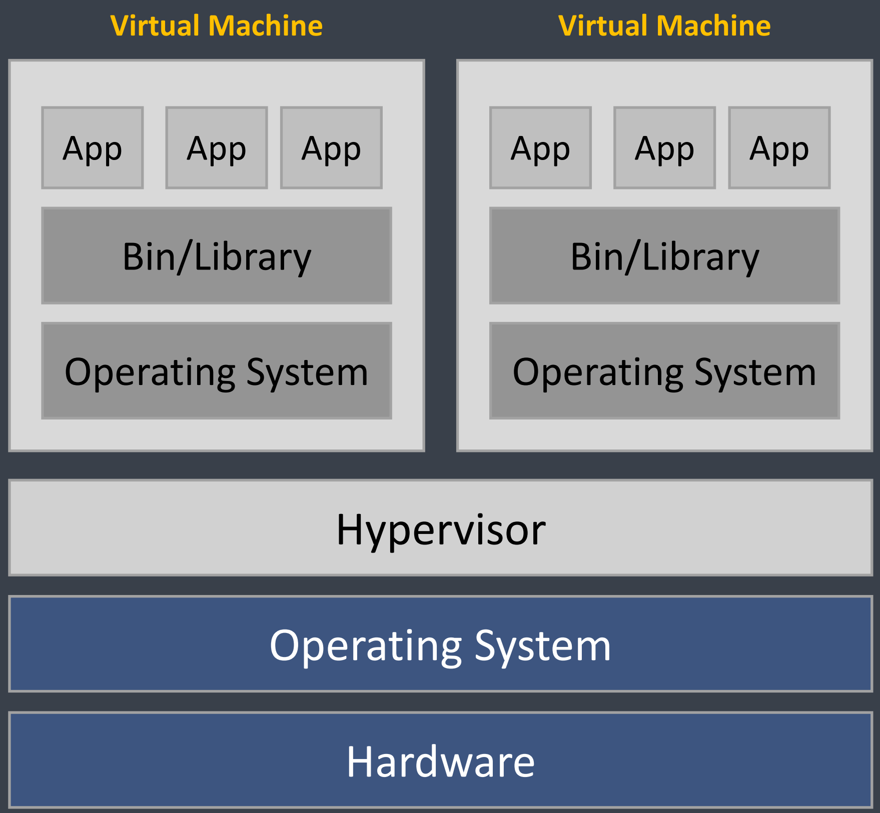
- Portable, extensible, open-source platform for managing containerized workloads and services
- Facilitates both declarative configuration and automation → config using YAML
- It has a large, rapidly growing ecosystem → prometheus, helm
- Kubernetes services, support, and tools are widely available
- The name Kubernetes originates from Greek, meaning helmsman or pilot
- Google open-sourced the Kubernetes project in 2014

Traditional Deployment - using physical machines → deprecated

- Early on, organizations ran applications on physical servers
- There was no way to define resource boundaries for applications in a physical server, and this caused resource allocation issues
- For example, if multiple applications run on a physical server, there can be instances where one application would take up most of the resources, and as a result, the other applications would underperform
- A solution for this would be to run each application on a different physical server
- But this did not scale as resources were underutilized, and it was expensive for organizations to maintain many physical servers

Virtualized Deployment – using virtual machines

- It allows you to run multiple Virtual Machines (VMs) on a single physical server's CPU
- Virtualization allows applications to be isolated between VMs and provides a level of security as the information of one application cannot be freely accessed by another application
- Virtualization allows better utilization of resources in a physical server and allows better scalability because
  - an application can be added or updated easily
  - reduces hardware costs
- With virtualization you can present a set of physical resources as a cluster of disposable virtual machines
- Each VM is a full machine running all the components, including its own operating system, on top of the virtualized hardware



Container deployment → using containers

- Containers are similar to VMs, but they have relaxed isolation properties to share the Operating System (OS) among the applications
- Therefore, containers are considered lightweight
- Similar to a VM, a container has its own filesystem, CPU, memory, process space, and more
- As they are decoupled from the underlying infrastructure, they are portable across clouds and OS distributions

Container benefits

- Increased ease and efficiency of container image creation compared to VM image use
- Continuous development, integration, and deployment
- Dev and Ops separation of concerns
- Observability not only surfaces OS-level information and metrics, but also application health and other signals
- Cloud and OS distribution portability
- Application-centric management:
- Loosely coupled, distributed, elastic, liberated micro-services
- Resource isolation: predictable application performance

What Kubernetes provide?

- Service discovery and load balancing → service object → load balancing
  - Kubernetes can expose a container using the DNS name or using their own IP address
  - If traffic to a container is high, Kubernetes is able to load balance and distribute the network traffic so that the deployment is stable
- Storage orchestration
  - Kubernetes allows you to automatically mount a storage system of your choice, such as local storages, public cloud providers, and more
- Automated rollouts and rollbacks
  - You can describe the desired state for your deployed containers using Kubernetes, and it can change the actual state to the desired state at a controlled rate
- Automatic bin packing
  - You provide Kubernetes with a cluster of nodes that it can use to run containerized tasks
  - You tell Kubernetes how much CPU and memory (RAM) each container needs
  - Kubernetes can fit containers onto your nodes to make the best use of your resources

What Kubernetes provide?

- **Self-healing**
  - Kubernetes restarts containers that fail, replaces containers, kills containers that don’t respond to your user-defined health check, and doesn’t advertise them to clients until they are ready to serve
- **Secret and configuration management**
  - Kubernetes lets you store and manage sensitive information, such as passwords, OAuth tokens, and ssh keys
  - You can deploy and update secrets and application configuration without rebuilding your container images, and without exposing secrets in your stack configuration

What Kubernetes is not

frontend → database
backend

- Does not limit the types of applications supported → cron jobs
- Does not deploy source code and does not build your application → build → ant / maven / gradle
- Does not provide application-level services as built-in services
- Does not dictate logging, monitoring, or alerting solutions → logging – prometheus, monitoring – Nagios
- Does not provide nor mandate a configuration language/system → YAML
- Does not provide nor adopt any comprehensive machine configuration, maintenance, management, or self-healing systems

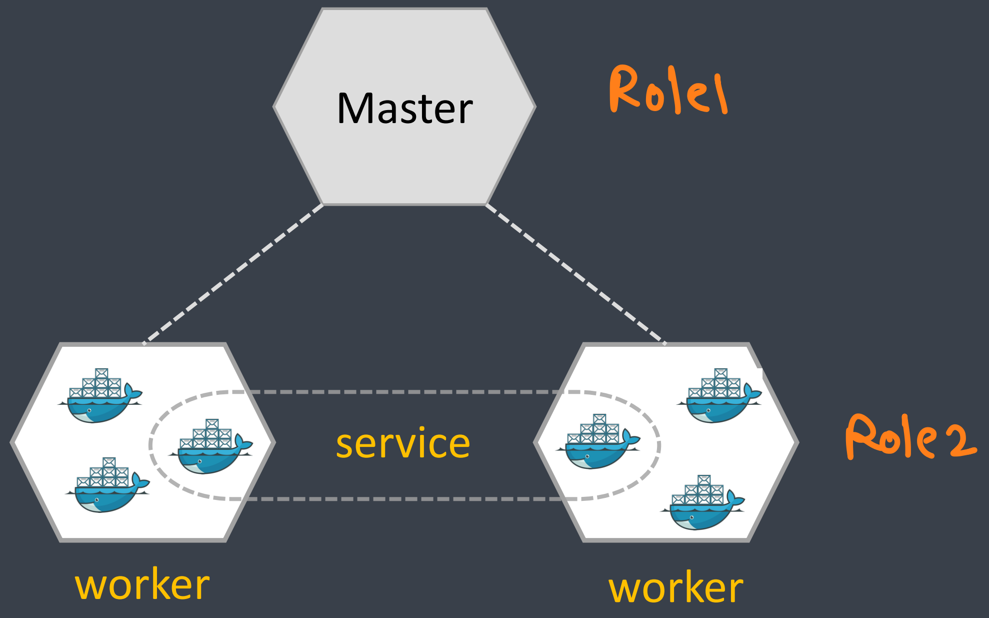
→ cluster of comodity machines

Kubernetes Cluster

pod → responsible for running containers

- When you deploy Kubernetes, you get a cluster.
- A cluster is a set of machines (nodes), that run containerized applications managed by Kubernetes
- A cluster has at least one worker node and at least one master node
- The worker node(s) host the pods that are the components of the application
- The master node(s) manages the worker nodes and the pods in the cluster
- Multiple master nodes are used to provide a cluster with failover and high availability

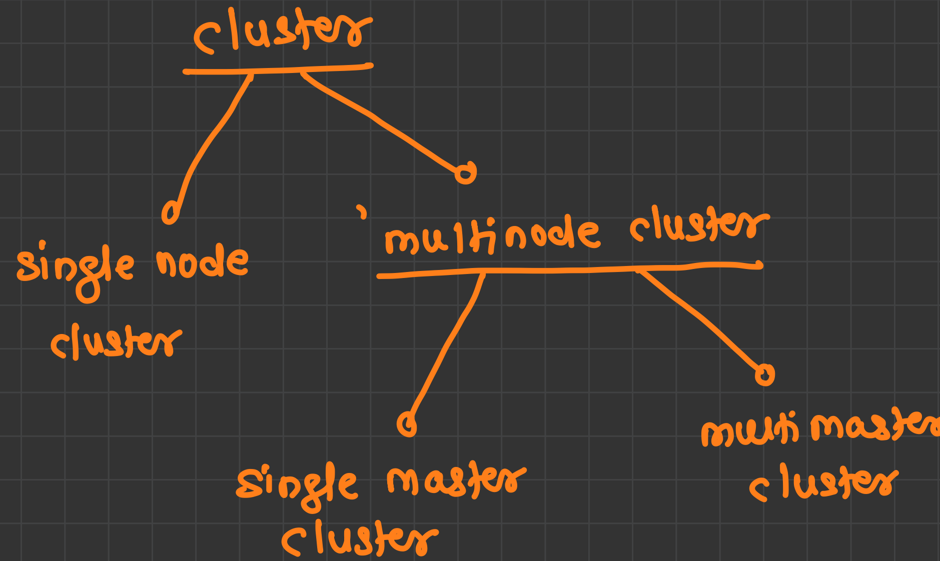
↳ horizontal scaling

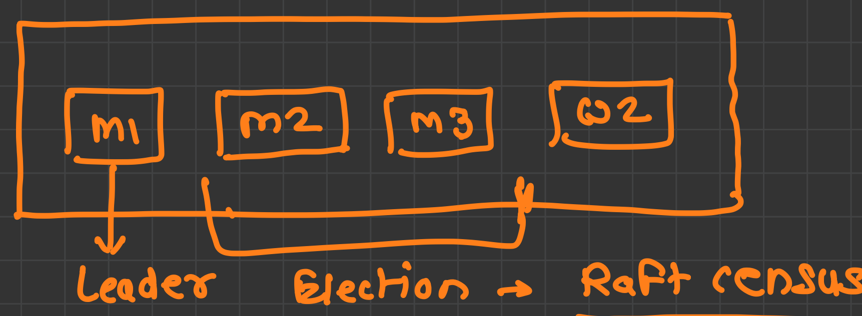


* single node cluster
  - → simulated cluster
  - → not a real cluster
  - → used only for learning
  - → minikube

* single master cluster
  - → has only one master
  - → development / testing

* mult-master cluster
  - → has >1 master nodes
  - → production





Kubernetes Components

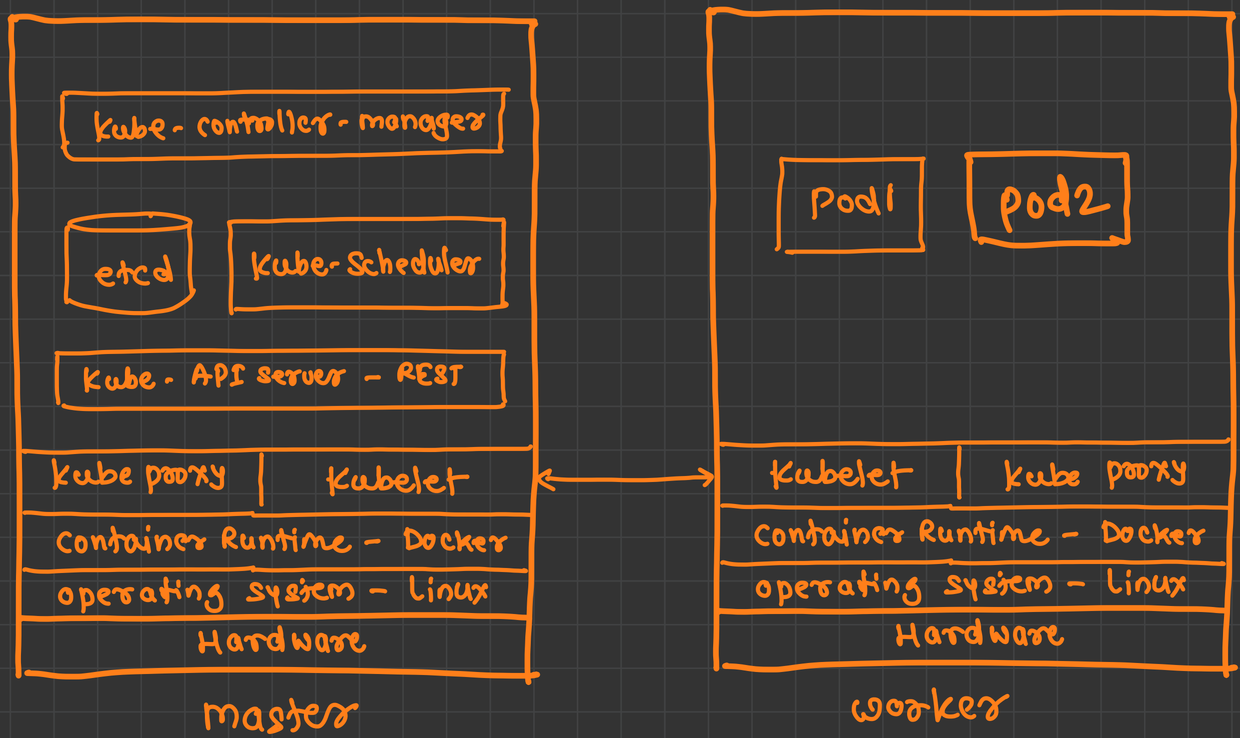
Master

1. kube-apiserver
2. etcd
3. kube-scheduler
4. kube-controller-manager
5. cloud-controller-manager

master worker

Node

1. kubelet
2. kube-proxy
3. Container Runtime


kube-controller-manager
etcd
kube-Scheduler
kube-API server - REST
kube proxy
kubelet
Container Runtime - Docker
operating system - linux
Hardware
master
Pod1
pod2
kubelet
kube proxy
Container Runtime - Docker
operating system - linux
Hardware
worker

Master Components

cluster

- Master components make global decisions about the and they detect and respond to cluster events
- Master components can be run on any machine in the cluster
- **kube-apiserver**
  - The API server is a component that exposes the Kubernetes API → REST
  - The API server is the front end for the Kubernetes → Brain
- **etcd**
  - Consistent and highly-available key value store used as Kubernetes' backing store for all cluster data
- **kube-scheduler**
  - Component on the master that watches newly created pods that have no node assigned, and selects a node for them to run on

Master Components

- **kube-controller-manager**
  - Component on the master that runs controllers
  - Logically, each controller is a separate process, but to reduce complexity, they are all compiled into a single binary and run in a single process
  - Types
    - Node Controller: Responsible for noticing and responding when nodes go down.
    - Replication Controller: Responsible for maintaining the correct number of pods for every replication controller object in the system
    - Endpoints Controller: Populates the Endpoints object (that is, joins Services & Pods)
    - Service Account & Token Controllers: Create default accounts and API access tokens for new namespaces
- **cloud-controller-manager**
  - Runs controllers that interact with the underlying cloud providers
  - The cloud-controller-manager binary is an alpha feature introduced in Kubernetes release 1.6

Node Components

- Node components run on every node, maintaining running pods and providing the Kubernetes runtime environment
- **kubelet**
  - An agent that runs on each node in the cluster
  - It makes sure that containers are running in a pod
- **kube-proxy**
  - Network proxy that runs on each node in your cluster, implementing part of the Kubernetes service concept
  - kube-proxy maintains network rules on nodes
  - These network rules allow network communication to your Pods from network sessions inside or outside of your cluster
- **Container Runtime**
  - The container runtime is the software that is responsible for running containers
  - Kubernetes supports several container runtimes: Docker, containerd, rktlet, cri-o etc.

Create Cluster

- Use following commands on both master and worker nodes

```
> sudo apt-get update && sudo apt-get install -y apt-transport-https curl
> curl -s https://packages.cloud.google.com/apt/doc/apt-key.gpg | sudo apt-key add -
> cat <<EOF | sudo tee /etc/apt/sources.list.d/kubernetes.list deb https://apt.kubernetes.io/kubernetes-xenial main EOF
> sudo apt-get update
> sudo apt-get install -y kubelet kubeadm kubectl
> sudo apt-mark hold kubelet kubeadm kubectl
```

Initialize Cluster Master Node

- Execute following commands on master node

> kubeadm init --apiserver-advertise-address=<ip-address> --pod-network-cidr=10.244.0.0/16

> mkdir -p $HOME/.kube

> sudo cp -i /etc/kubernetes/admin.conf $HOME/.kube/config

> sudo chown $(id -u):$(id -g) $HOME/.kube/config

- Install pod network add-on

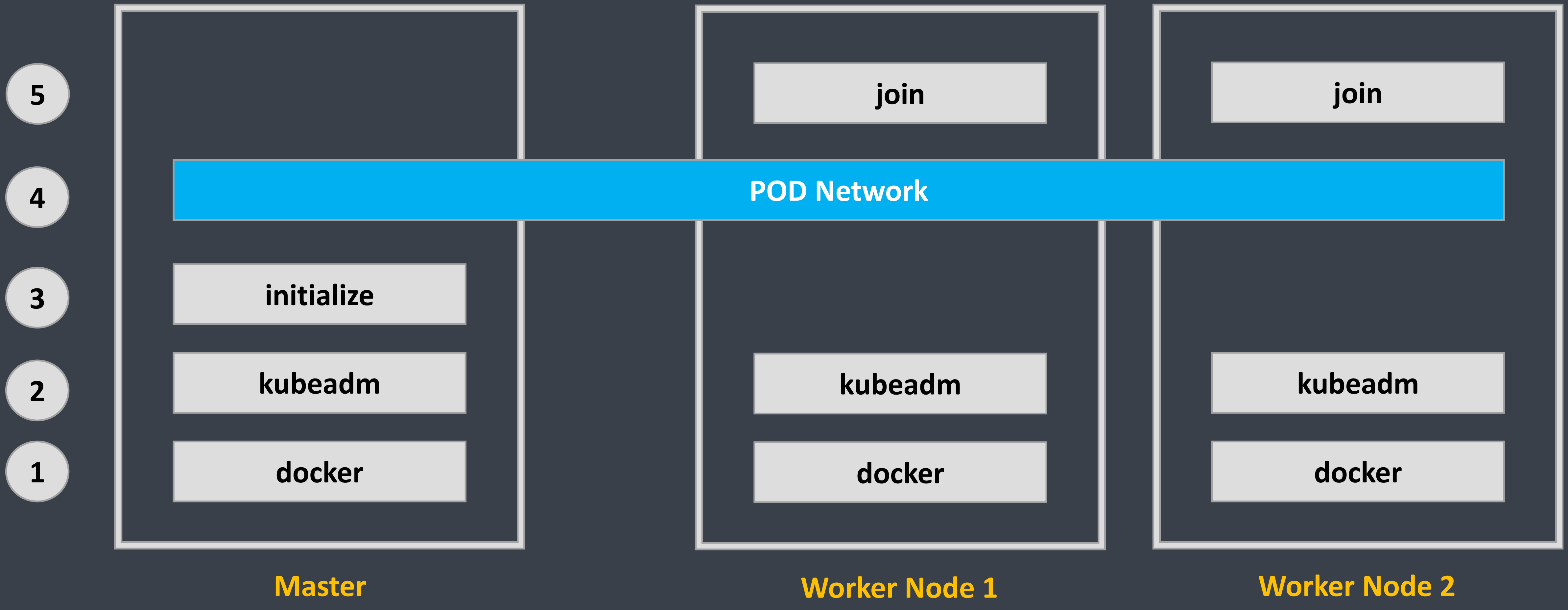
> kubectl apply -f https://raw.githubusercontent.com/coreos/flannel/2140ac876ef134e0ed5af15c65e414cf26827915/Documentation/kube-flannel.yml

Add worker nodes

- Execute following command on every worker node

```
> kubeadm join --token <token> <control-plane-host>:<control-plane-port> --discovery-token-ca-cert-hash sha256:<hash>
```

Steps to install Kubernetes



Kubernetes Objects

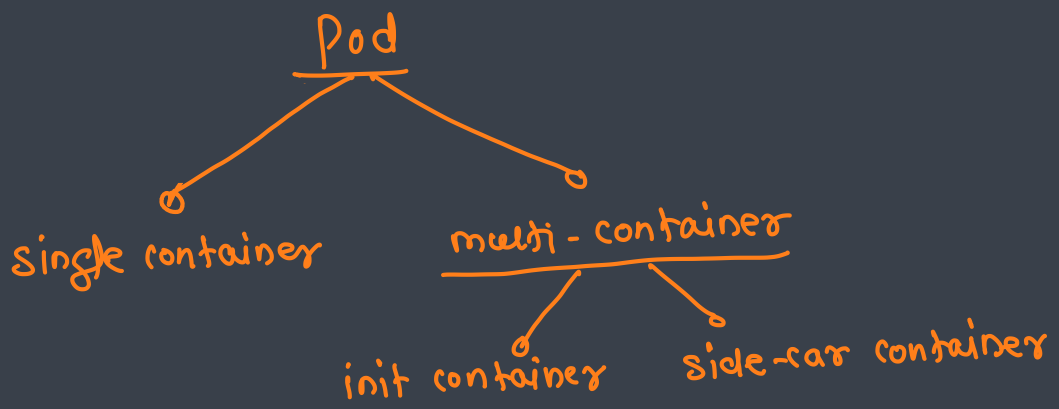
- The basic Kubernetes objects include
  - Pod **
  - Service
  - Volume
  - Namespace
- Kubernetes also contains higher-level abstractions build upon the basic objects
  - Deployment
  - DaemonSet
  - StatefulSet
  - ReplicaSet
  - Job

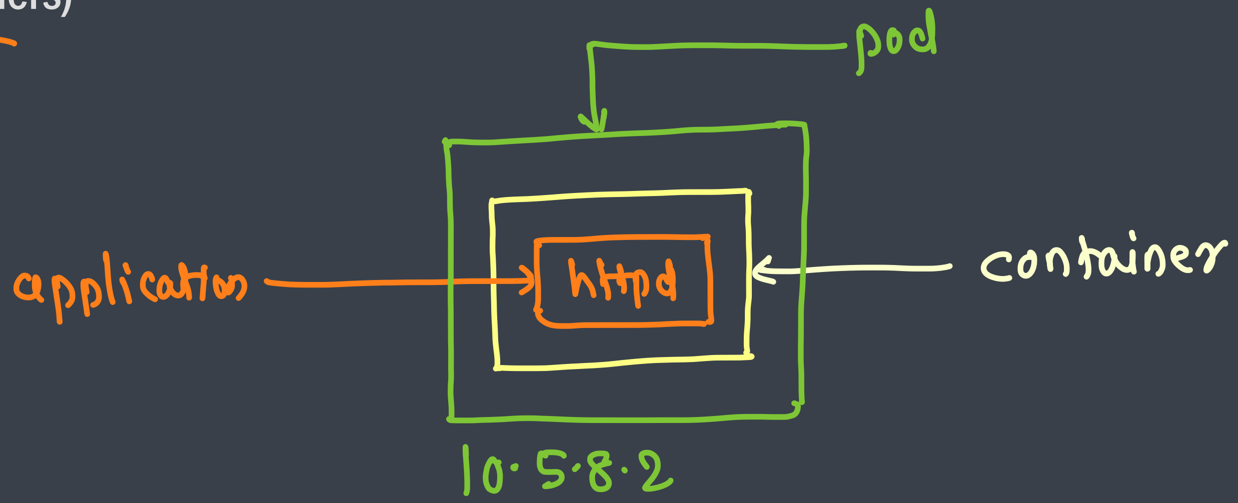
Namespace

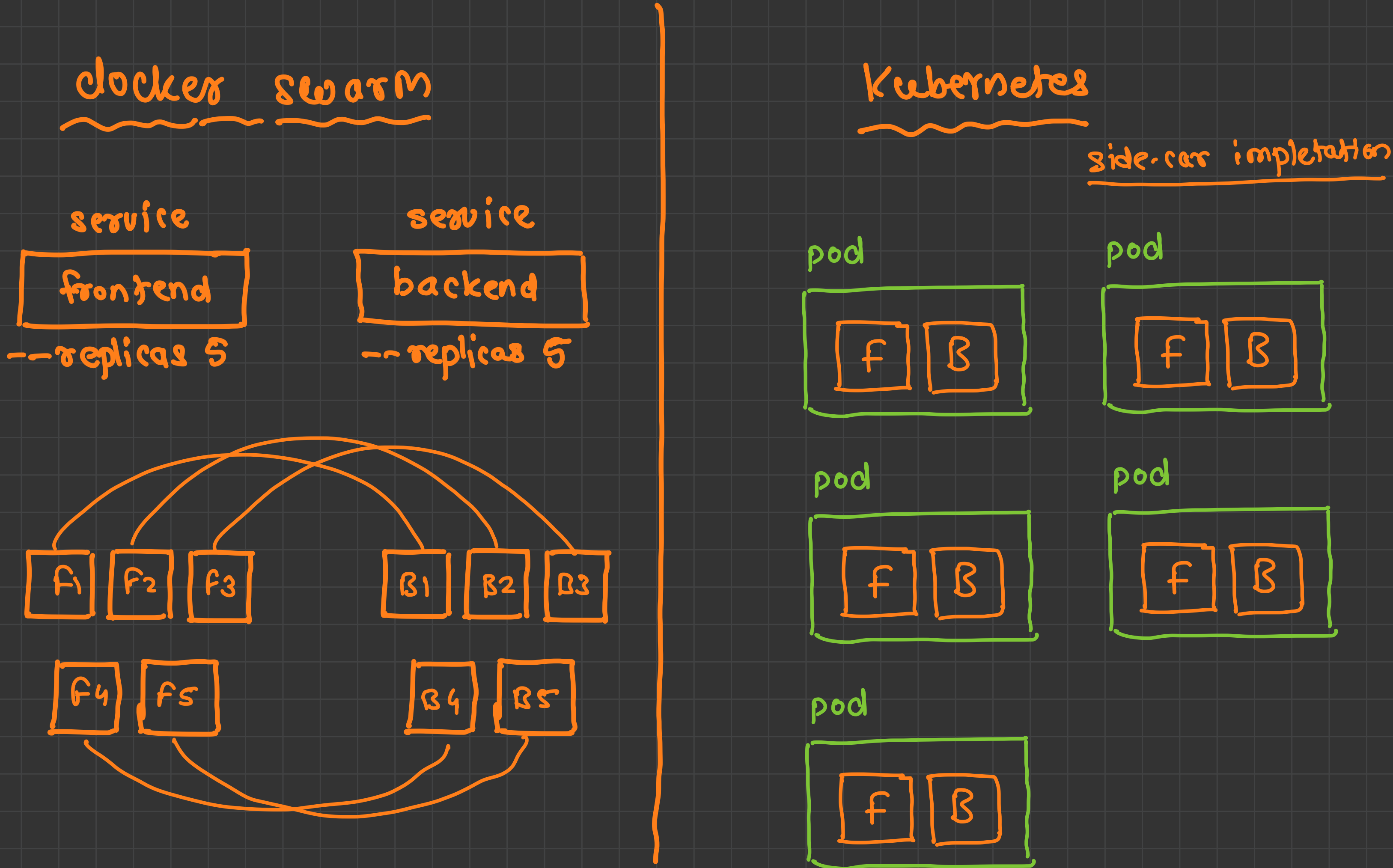
- Namespaces are intended for use in environments with many users spread across multiple teams, or projects
- Namespaces provide a scope for names
- Names of resources need to be unique within a namespace, but not across namespaces
- Namespaces can not be nested inside one another and each Kubernetes resource can only be in one namespace
- Namespaces are a way to divide cluster resources between multiple users / projects

Pod

- A Pod is the basic execution unit of a Kubernetes application
- The smallest and simplest unit in the Kubernetes object model that you create or deploy
- A Pod represents processes running on your Cluster
- Pod represents a unit of deployment
- A Pod encapsulates
  - application's container (or, in some cases, multiple containers)
  - storage resources
  - a unique network IP
  - options that govern how the container(s) should run






docker swarm
service
frontend
--replicas 5
service
backend
--replicas 5
F1
F2
F3
B1
B2
B3
F4
F5
B4
B5
Kubernetes
side-car impletation
pod
F
B
pod
F
B
pod
F
B
pod
F
B
pod
F
B

YAML to create Pod

```yaml
apiVersion: v1
kind: Pod
metadata:
  name: myapp-pod
  labels:
    app: myapp
spec:
  containers:
  - name: myapp-container
    image: httpd
```

* apiversion → api version in which resource is declared
  → for basic objects it is v1 [pod / service]
* kind → type of resource [Pod / Service..]
* metadata → data about data [resource to be created]
  → label, name, namespace etc
* spec → specification of resource to be created

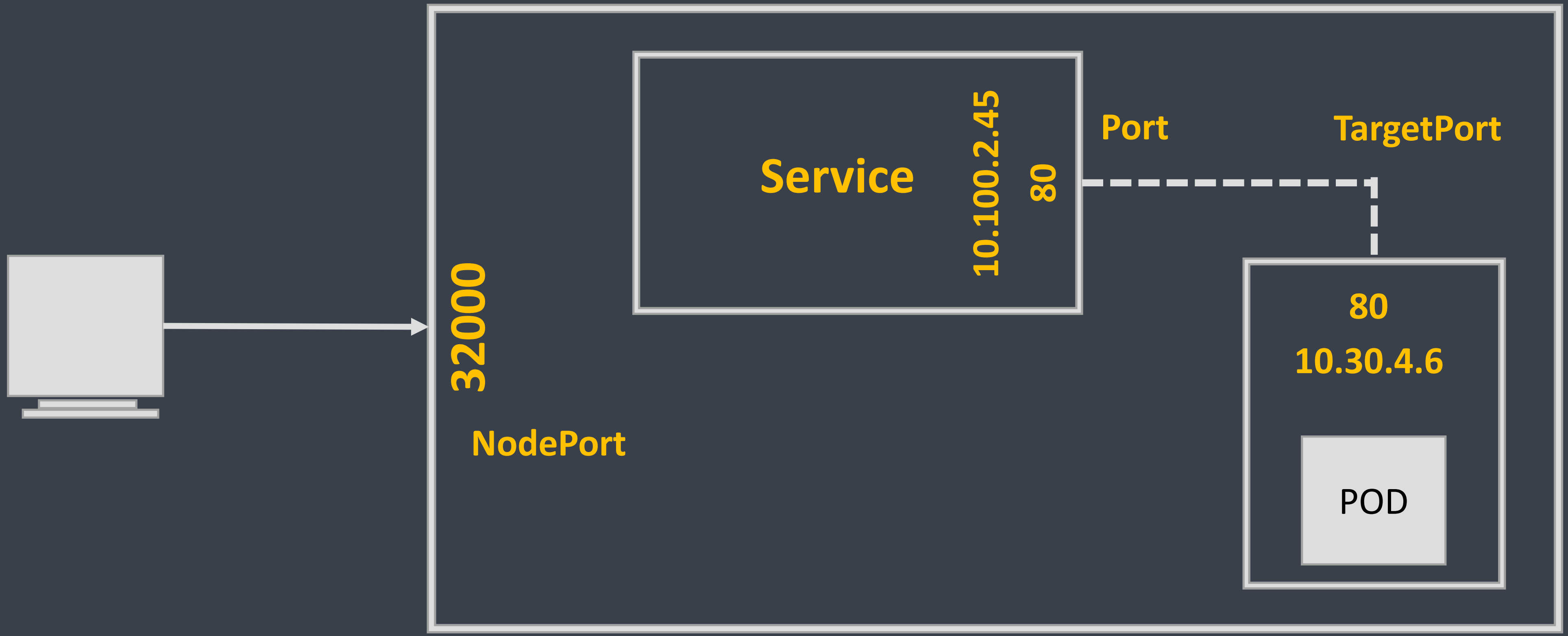
Service

- An abstract way to expose an application running on a set of Pods as a network service
- Service is an abstraction which defines a logical set of Pods and a policy by which to access them (sometimes this pattern is called a micro-service)
- Service Types
  - ClusterIP
    - Exposes the Service on a cluster-internal IP
    - Choosing this value makes the Service only reachable from within the cluster
  - LoadBalancer
    - Used for load balancing the containers
  - NodePort

```yaml
apiVersion: v1
kind: Service
metadata:
  name: my-service
spec:
  selector:
    app: MyApp
  ports:
    - protocol: TCP
      port: 80
      targetPort: 9376
```

Service Type: NodePort

- Exposes the Service on each Node’s IP at a static port (the NodePort)
- You’ll be able to contact the NodePort Service, from outside the cluster, by requesting <NodeIP>:<NodePort>



Replica Set

- A Replica Set ensures that a specified number of pod replicas are running at any one time
- In other words, a Replica Set makes sure that a pod or a homogeneous set of pods is always up and available
- If there are too many pods, the Replica Set terminates the extra pods
- If there are too few, the Replica Set starts more pods
- Unlike manually created pods, the pods maintained by a Replica Set are automatically replaced if they fail, are deleted, or are terminated

```
apiVersion: v1
kind: ReplicaSet
metadata:
 name: nginx
spec:
 replicas: 3
 selector:
  matchLabels:
   app: nginx
 template:
  metadata:
   name: nginx
   labels:
    app: nginx
  spec:
   containers:
   - name: nginx
    image: nginx
    ports:
    - containerPort: 80
```

Deployment

- A Deployment provides declarative updates for Pods and ReplicaSets
- You describe a *desired state* in a Deployment, and the Deployment Controller changes the actual state to the desired state at a controlled rate
- You can use deployment for
  - Rolling out ReplicaSet
  - Declaring new state of Pods
  - Rolling back to earlier deployment version
  - Scaling up deployment policies
  - Cleaning up existing ReplicaSet

```
apiVersion: apps/v1
kind: Deployment
metadata:
  name: website-deployment
spec:
  selector:
    matchLabels:
      app: website
  replicas: 10
  template:
    metadata:
      name: website-pod
      labels:
        app: website
    spec:
      containers:
      - name: website-container
        image: pythoncpp/test_website
        ports:
        - containerPort: 80
```

Volume

- On-disk files in a Container are ephemeral, which presents some problems for non-trivial applications when running in Containers
- Problems
  - When a Container crashes, kubelet will restart it, but the files will be lost
  - When running Containers together in a Pod it is often necessary to share files between those Containers
- The Kubernetes Volume abstraction solves both of these problems
- A volume outlives any Containers that run within the Pod, and data is preserved across Container restarts