
K8S
Kubernetes

What is Kubernetes ?

- Portable, extensible, open-source platform for managing containerized workloads and services
- Facilitates both declarative configuration and automation
- It has a large, rapidly growing ecosystem
- 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

① declarative config → YAML → manifest file

② automation → CLI

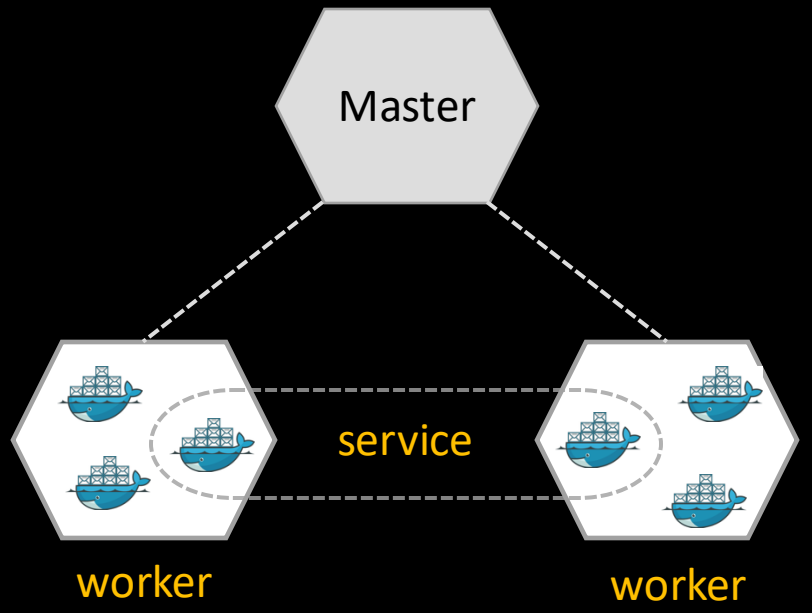
k8s installation

- → on-prem → self managed → installation / updating / security by org
- → cloud
  - → self-managed → ——
  - → managed service → installation/updation... → responsibility of cloud provider
    - → AWS → EKS → Elastic k8s service
    - → Azure → AKS → Azure k8s service
    - → GCP → GKE → GCP k8s Engine

Kubernetes Cluster

- 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 → production env

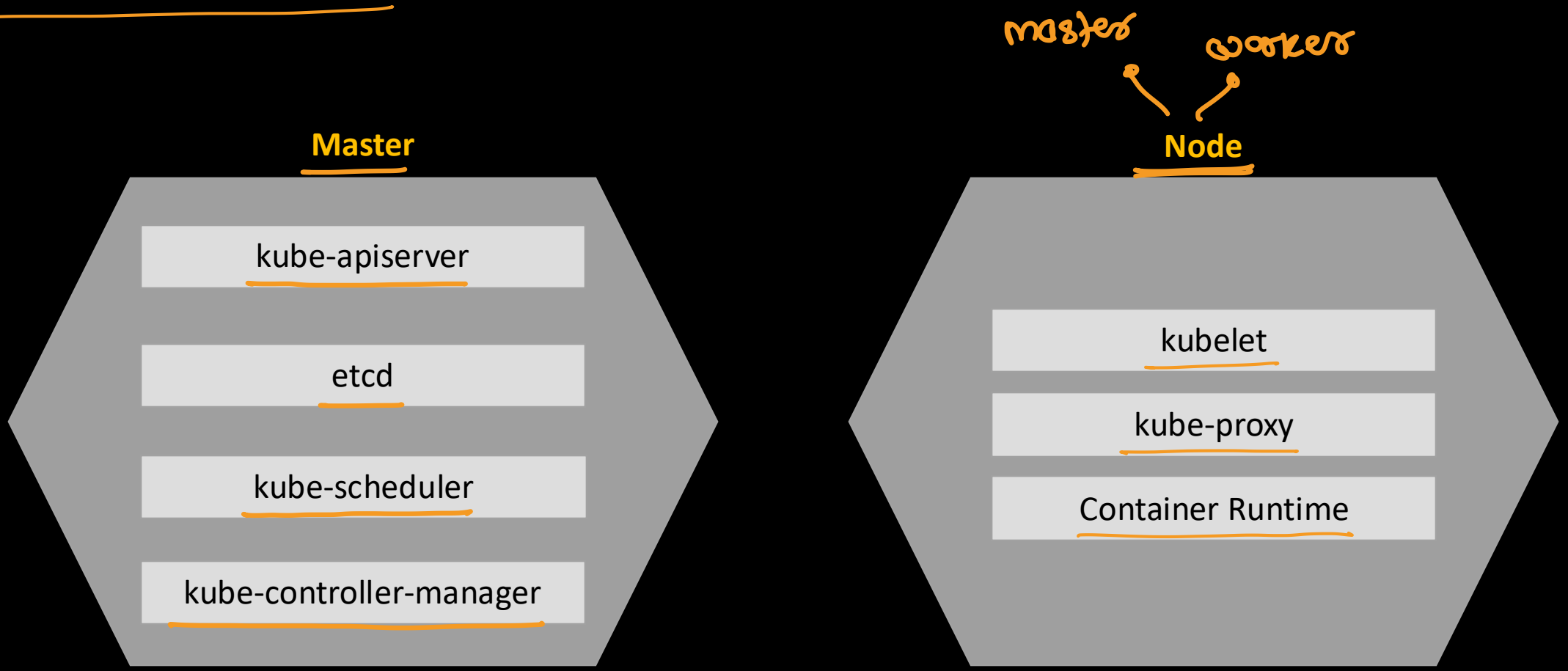
Roles
master
worker

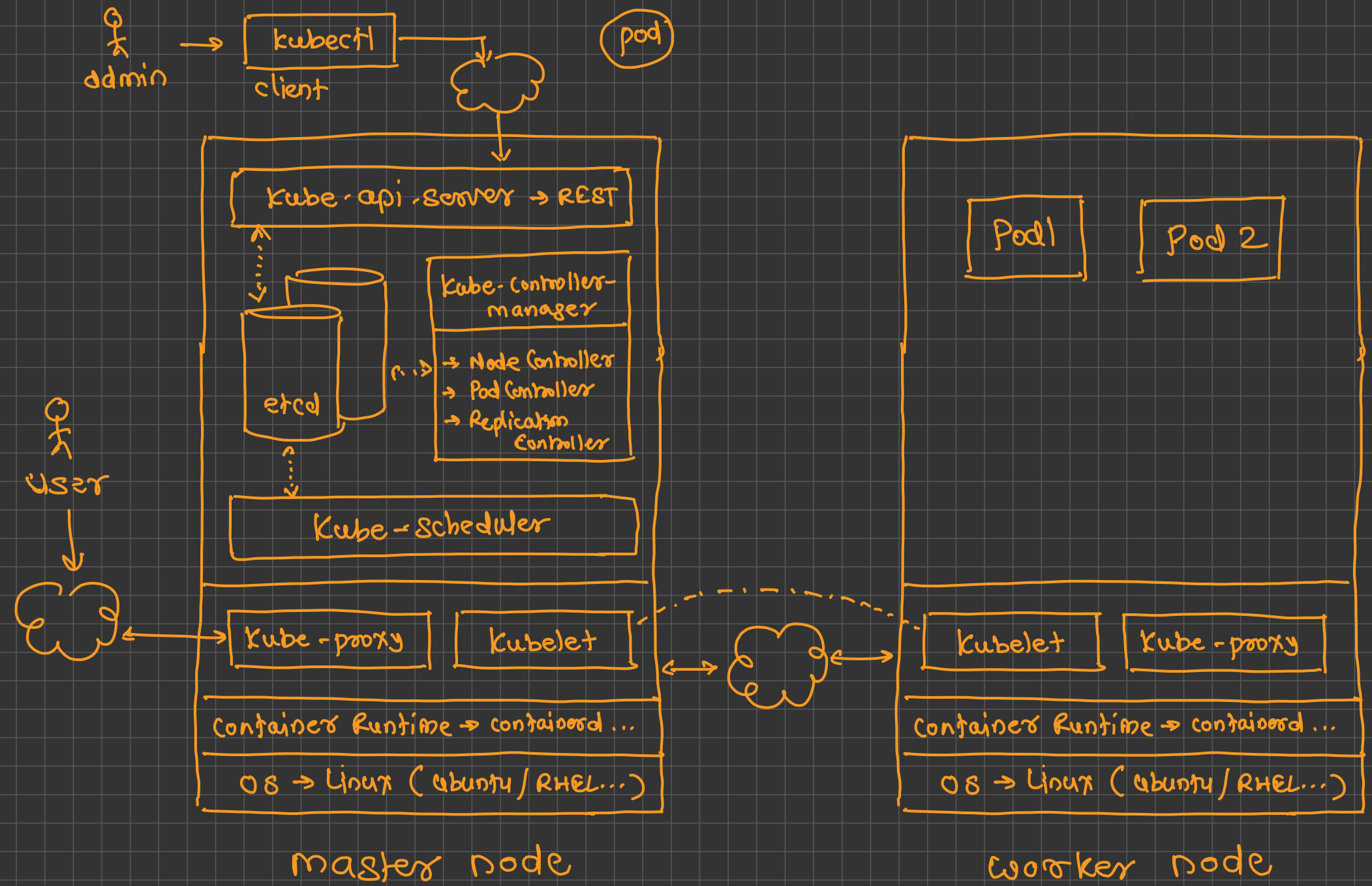


K8S cluster

- Single Node cluster
  - Simulated / virtual cluster
  - configured by tool → minikube
  - used only for learning
- multi node clusters
  - single master clusters
    - one master & one or more workers
    - used in dev or testing env
  - multi-master cluster
    - multiple masters with multiple workers
    - Highly Available cluster → HA
    - preferred in production env.
    - from multiple masters only one will be elected as leader
    - K8S uses Raft consus algo

Kubernetes Components




admin
kubectl
client
pod
Kube-api-server → REST
etcd
Kube-controller-manager
→ Node Controller
→ Pod Controller
→ Replication Controller
Kube-scheduler
User
Kube-proxy
Kubelet
Container Runtime → containerd ...
OS → Linux (Ubuntu / RHEL...)
master node
Pod1
Pod 2
Kubelet
Kube-proxy
Container Runtime → containerd ...
OS → Linux (Ubuntu / RHEL...)
worker node

Master Components

- These are the **brain** of the Kubernetes cluster — they make all the decisions about what runs where, how scaling happens, and how the system stays healthy.
- Master components can be run on any machine in the cluster

Component	Function
kube-apiserver	The **front door** of the Kubernetes control plane. It exposes the **Kubernetes API**, which is used by all components, kubectl, and external clients.
etcd	The **database** of Kubernetes — stores all cluster data, configurations, and states in a key-value format.
kube-scheduler	Decides **which node** each Pod should run on based on resource requirements and constraints.
kube-controller-manager	Ensures that the **actual state** of the cluster matches the **desired state** defined in manifests.
cloud-controller-manager (optional)	Manages integration between Kubernetes and your **cloud provider** (e.g., AWS, GCP, Azure).

Master Components

- **kube-apiserver** → brain → Exposes REST APIs → consumed by kubectl command
  - Acts as the **communication hub** between users, components, and the cluster.
  - Every kubectl command goes through it.
  - Validates requests and updates etcd accordingly.
  - It's a **stateless** service — you can run multiple instances for high availability → multiple masters

- **etcd**
  - A **distributed, consistent key-value store**. → database
  - Stores all cluster data, including:
    - Pod states
    - Configurations
    - Secrets
    - Node information
  - It's the **source of truth** for your cluster.
  - It's critical — if etcd is lost, your cluster loses its state.

Master Components

- **kube-scheduler** → created by Pod Controllers
  - Watches for **new Pods** that don't have a Node assigned.
  - Chooses the **best Node** to run the Pod based on:
    - Resource requests (CPU, memory)
    - Node affinity/anti-affinity
    - Taints and tolerations
    - Pod priorities
    - Custom policies
- **kube-controller-manager**
  - Runs a set of **controller loops**, each responsible for maintaining part of the system's desired state.
  - Examples of controllers:
    - **Node Controller** – manages node status.
    - **Replication Controller** – ensures the desired number of pod replicas are running.
    - **Endpoint Controller** – manages endpoint objects.
    - **Service Account & Token Controllers** – create default accounts and tokens.

→ Replicaset
→ DaemonSet
→ StatefulSet

↳ Security

Node Components

- Node components run on every node, maintaining running pods and providing the Kubernetes runtime environment
- **kubelet**
  - **Primary agent** that runs on every node.
  - Communicates with the **API Server**.
  - Ensures the containers defined in **PodSpecs** are running and healthy.
  - Reports node and pod status back to the control plane.
  - Watches for Pod definitions assigned to the node and runs them using the **container runtime**.
- **kube-proxy**
  - Maintains **network rules** on nodes.
  - Ensures that networking is consistent across the cluster.
  - Implements **Kubernetes Service abstraction** — enabling communication between different Pods and Services.
  - Uses **iptables** or **IPVS** to forward traffic to the correct Pod endpoints.
  - Supports load balancing between Pods behind a Service.
- **Container Runtime**
  - The actual **software responsible for running containers**.
  - The kubelet interacts with the runtime through the **Container Runtime Interface (CRI)**.
  - Common runtimes:
    - **containerd** (default on most modern clusters)
    - **CRI-O**
    - **Docker Engine** (deprecated as of K8s v1.24+)
    - **Mirantis Container Runtime**

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

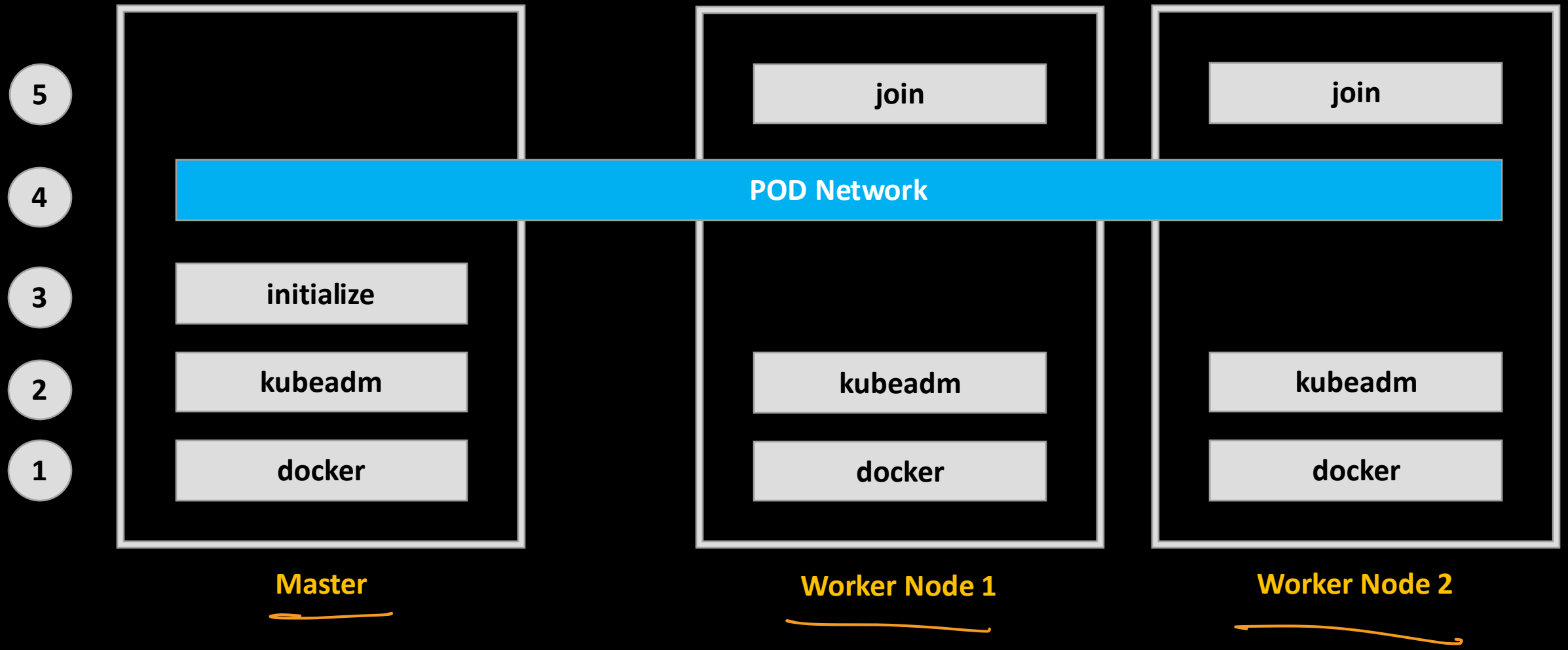
> kubectl apply -f https://raw.githubusercontent.com/coreos/flannel/2140ac876ef134e0ed5af15c65e414cf26827915/Documentation/kube-flannel.yml

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

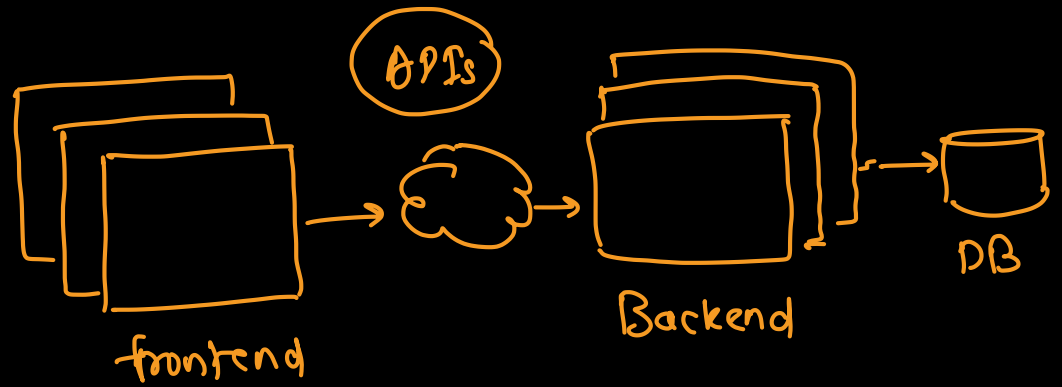
Namespace

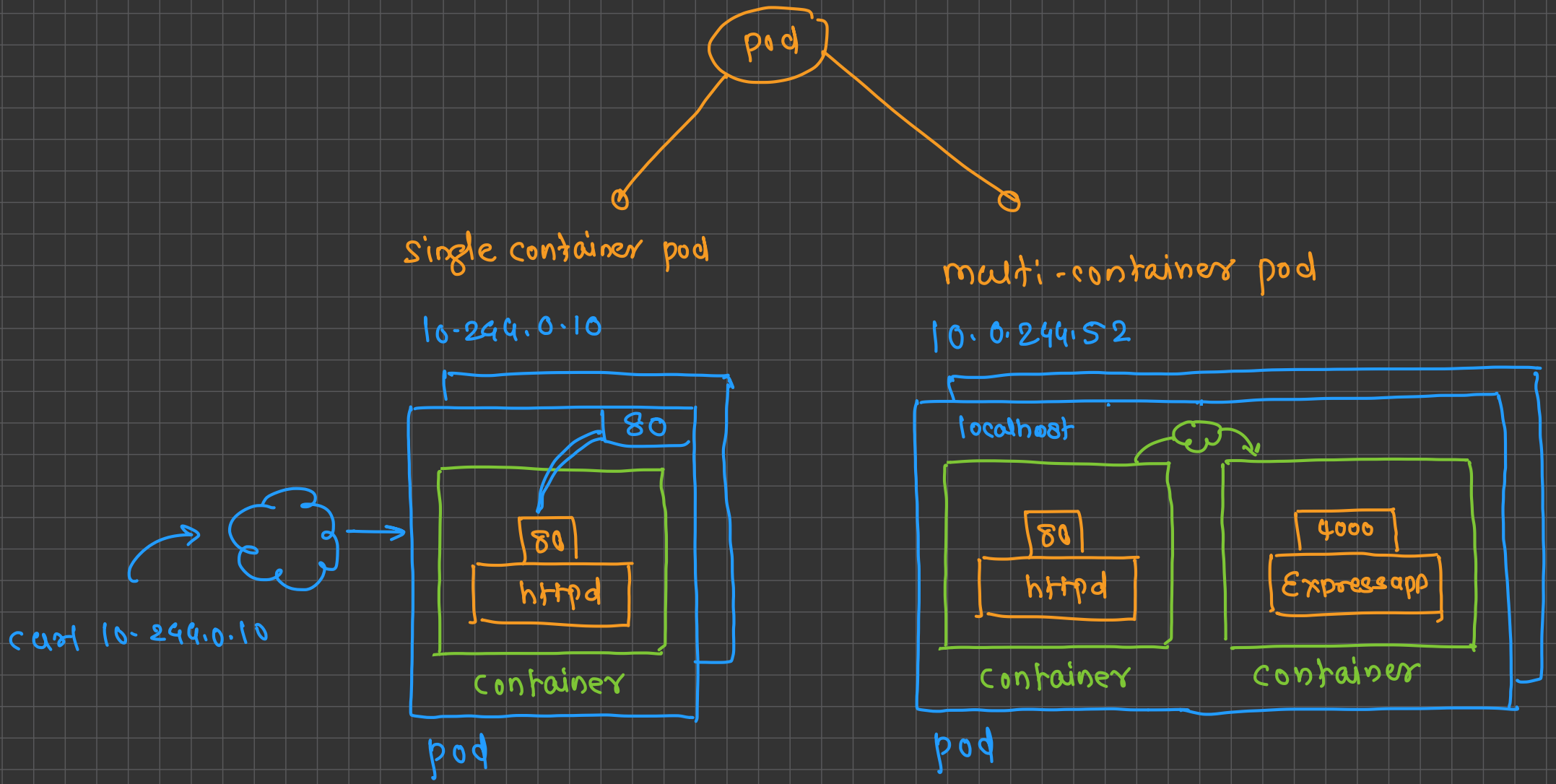
- Namespaces are intended for use in environments with many users spread across multiple teams, or projects
- Namespaces provide a scope for names
- Names of resources need to be unique within a namespace, but not across namespaces
- Namespaces can not be nested inside one another and each Kubernetes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

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

↳ configuration




pod
Single container pod
multi-container pod
10.244.0.10
10.0.244.52
80
80
httpd
container
pod
curl 10.244.0.10
localhost
80
httpd
4000
Expressapp
container
container
pod

YAML to create Pod

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

YAML for K8S objects

① apiVersion →
- version of K8S APIs
→ basic object → v1
higher level object = apps/v1

② Kind →
- type of object to be created
- eg. Pod, Service, Deployment

③ metadata →
- data (info about the object
- eg. name, labels, namespace

④ spec →
- specification/definition of object

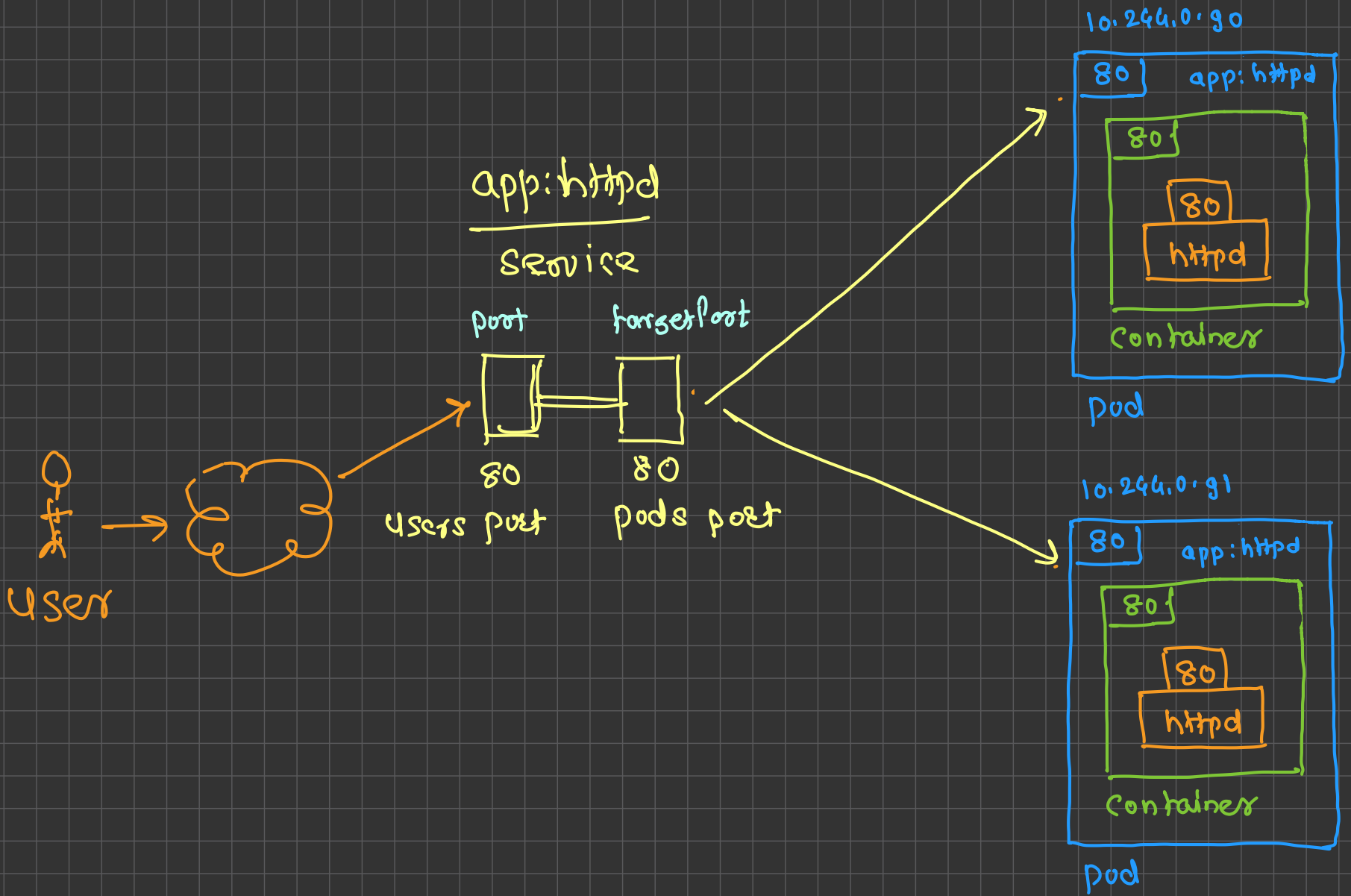
YAML → syntax used to write config files

→ scalar → 10, person1
→ map (key-value pair) → name: person1 (k: v)
→ list (collection) →
- cat
- dog
- horse

Service → load balancer

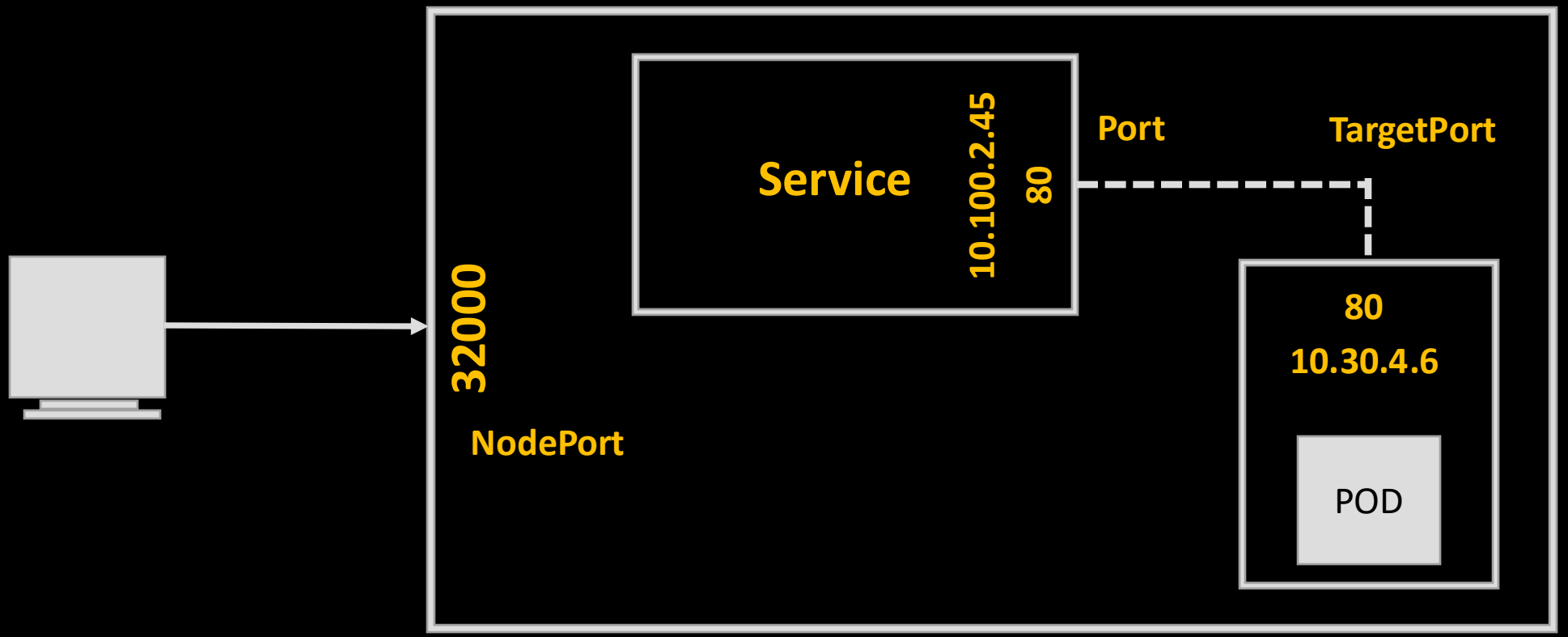
- An abstract way to expose an application running on a set of Pods as a network service
- Service is an abstraction which defines a logical set of Pods and a policy by which to access them (sometimes this pattern is called a micro-service)
- Service Types
  - ClusterIP
    - Exposes the Service on a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

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


app:httpd
service
port
targetPort
80
80
users port
pods port
user
10.244.0.90
80
app:httpd
80
80
httpd
container
pod
10.244.0.91
80
app:httpd
80
80
httpd
container
pod

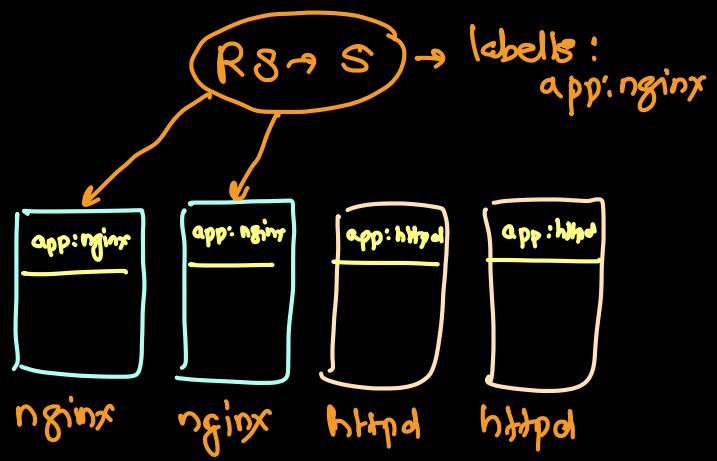
Service Type: NodePort

- 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




```yaml
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
```

must be same

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
```