Cloud Computing Applications and Services

(Aplicações e Serviços de Computação em Nuvem)

Virtualization (Part II)

University of Minho

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Containers

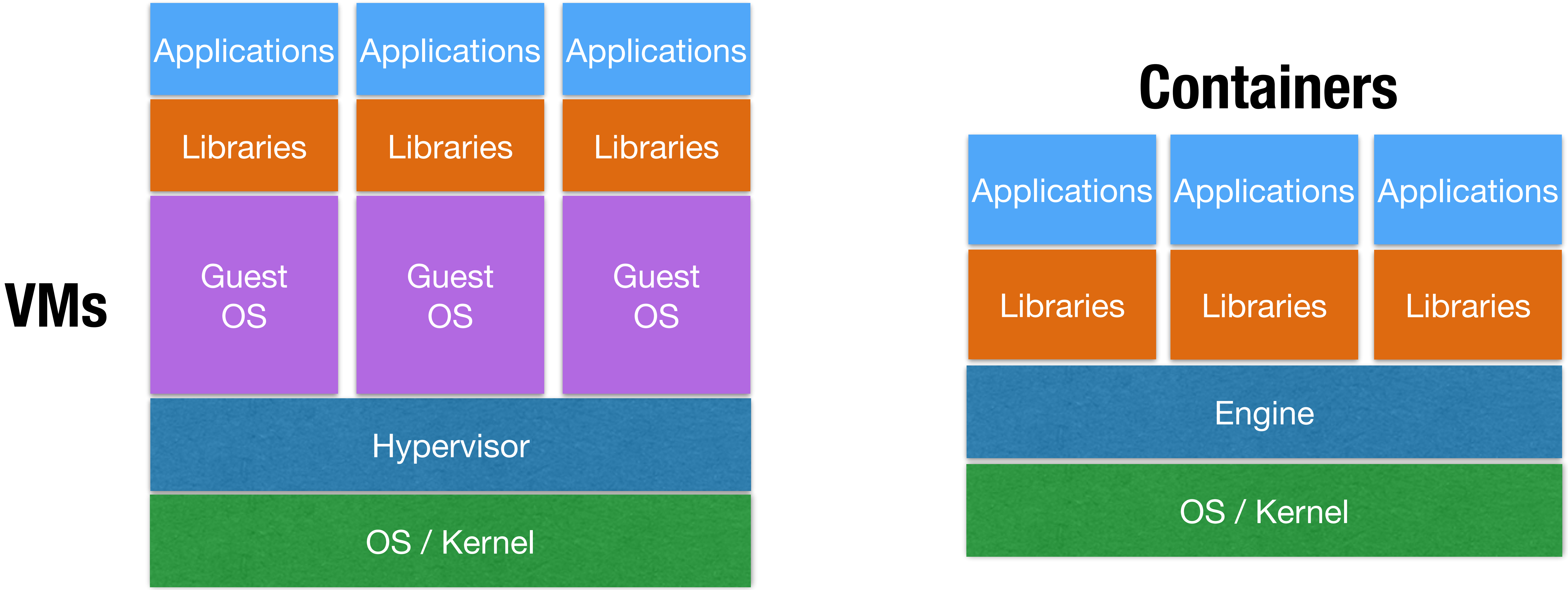
- **Lightweight virtual environment** that **groups and isolates a set of processes and resources** (memory, CPU, disk, …), from the host and any other containers

- Why are containers useful?
  - Running different isolated versions of the same software/application (*e.g.*, database) in a shared OS/Kernel environment
  - Portability/migration across servers
  - Easy packaging of software, applications and their dependencies

Linux Containers

Architecture

- Containers are lightweight, while **not requiring full virtualization** of CPU, RAM, network, and storage requests (as in VMs)

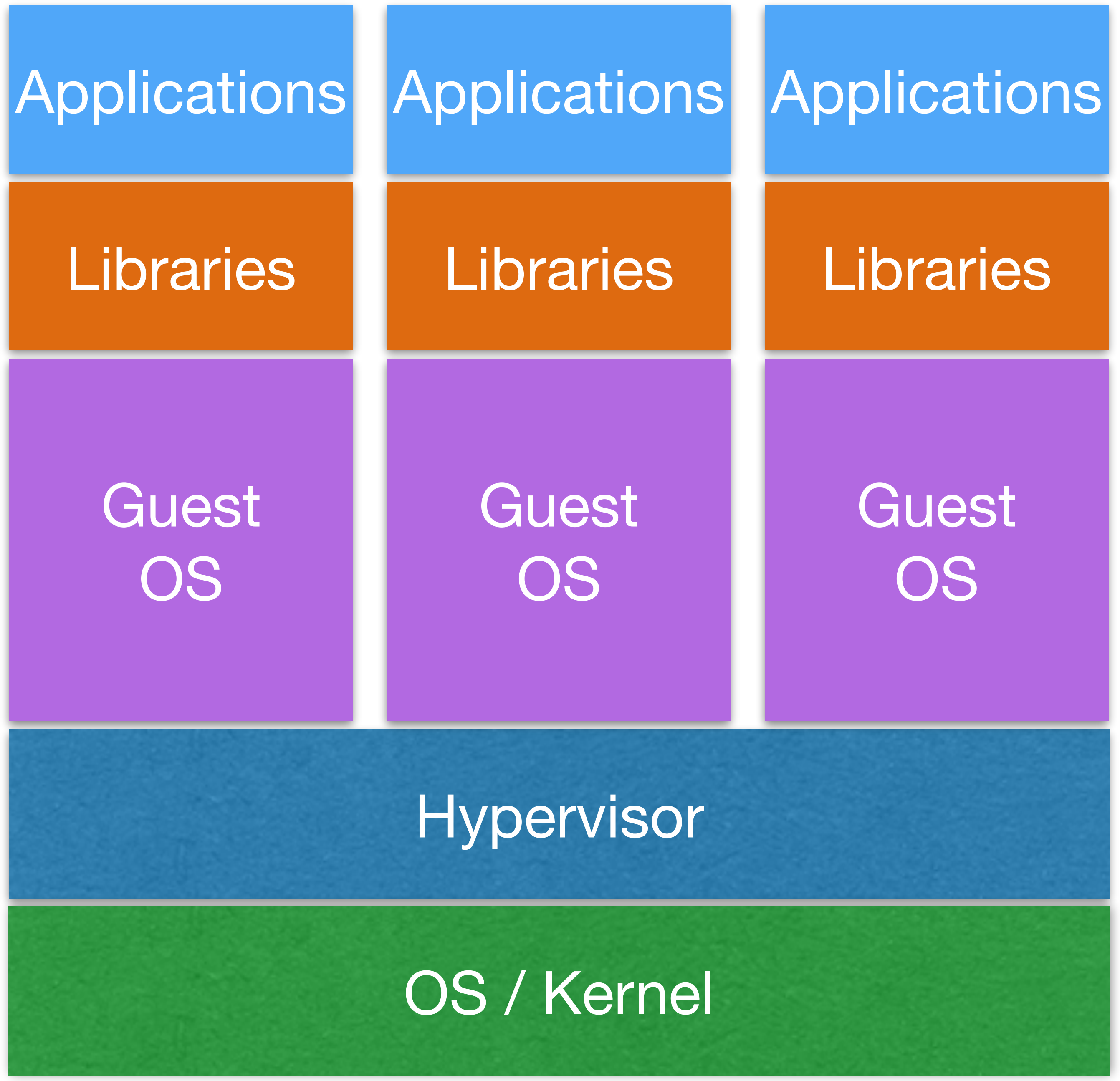


Linux Containers

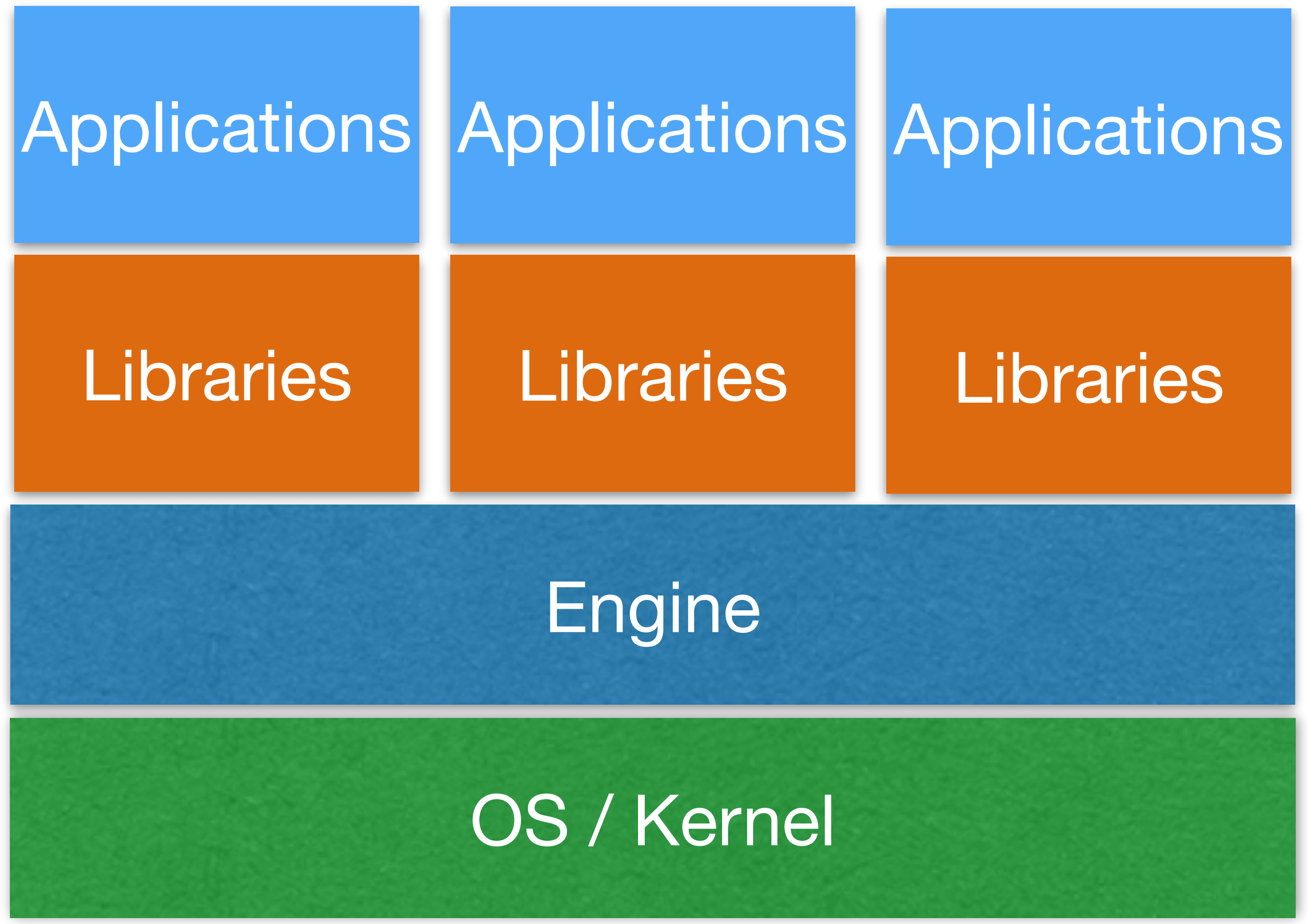
Engine

- The **engine** isolates and configures resources
  - Containers are isolated from each other, i.e., the host is compartmentalized in terms CPU, RAM, memory, disk
  - Each container shares the hardware and kernel/OS with the host system

VMs



Containers



Linux Containers

Building Blocks (components of Linux kernel)

- **Namespaces** (Isolation)
  - Host resources (e.g., network, filesystem) are **partitioned** into dedicated resources that are only accessible by a certain group of processes (under the same namespace)
  - Allow **isolating** host resources across different containers
- **Control Groups** (Resource Management)
  - Allow **allocating resources** (CPU, RAM, Disk, network) among groups of processes
  - **Limit the amount of resources** per container (*e.g.*, CPU cores, RAM/storage)
- **SELinux** (Security)
  - Provides **additional security** over namespaces so that a container is not able to compromise the host system and other containers
  - Enforces **access control and security policies**

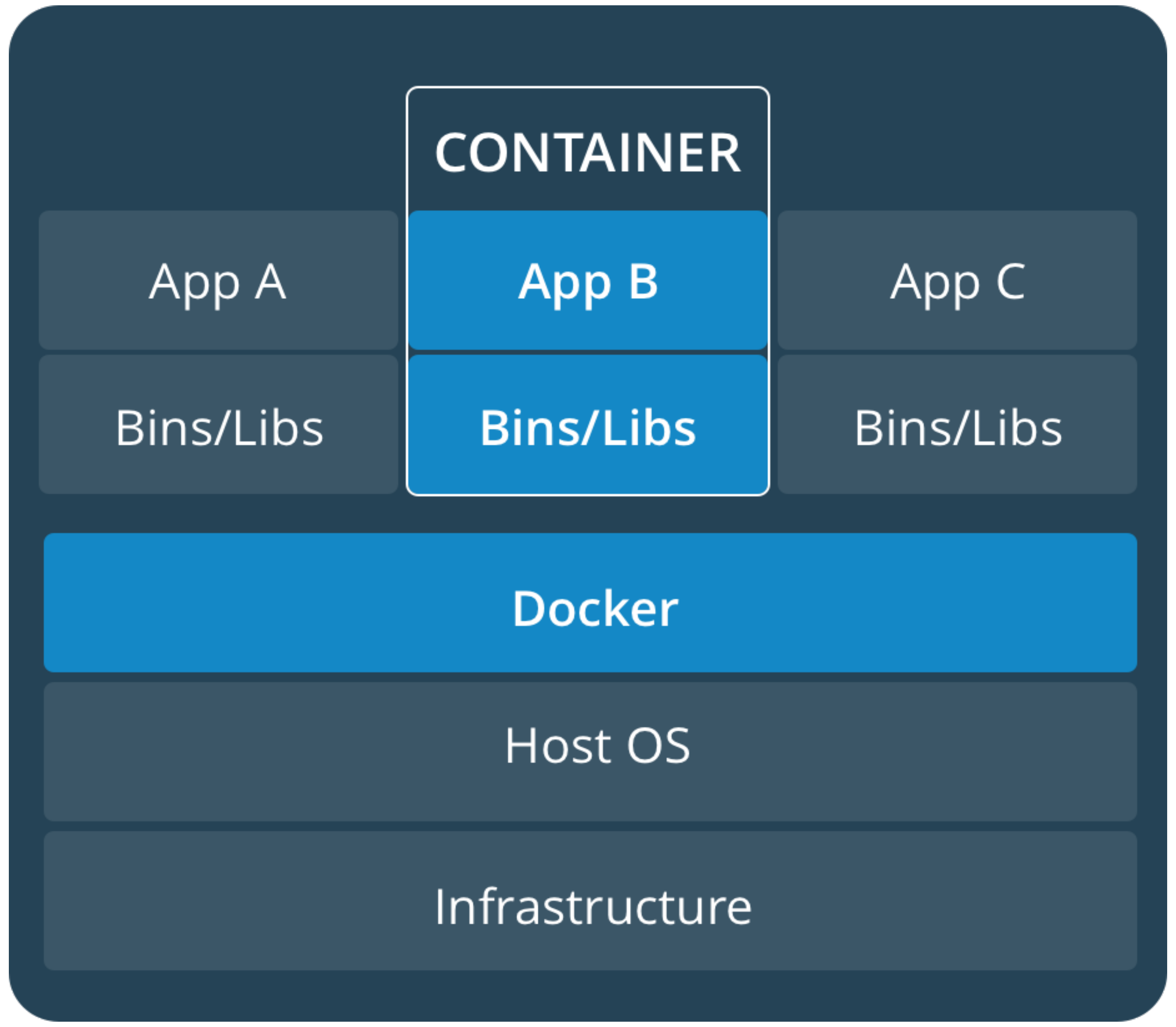
Linux Containers

Types

- **OS Containers** (*e.g.*, LXC)
  - Containers run multiple processes and simulate a “lightweight” operating system
- **Application Containers** (*e.g.*, Docker)
  - Focused on deploying applications
  - Each application is seen as an independent process

Docker

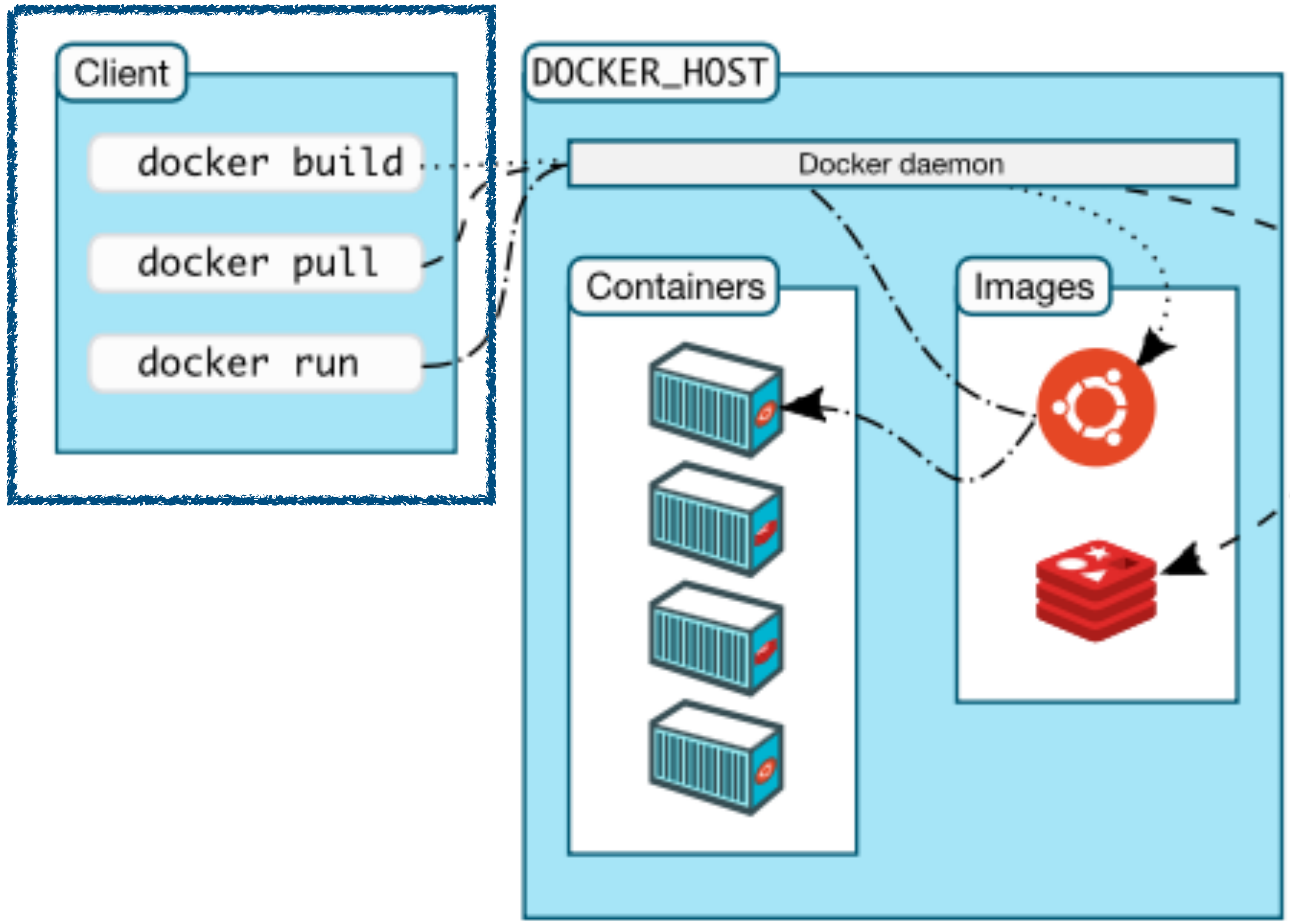
- Most widely-known container platform
- Supports Ubuntu, Fedora, RHEL, CentOS, Windows, etc
- https://www.docker.com



Docker

Docker Client

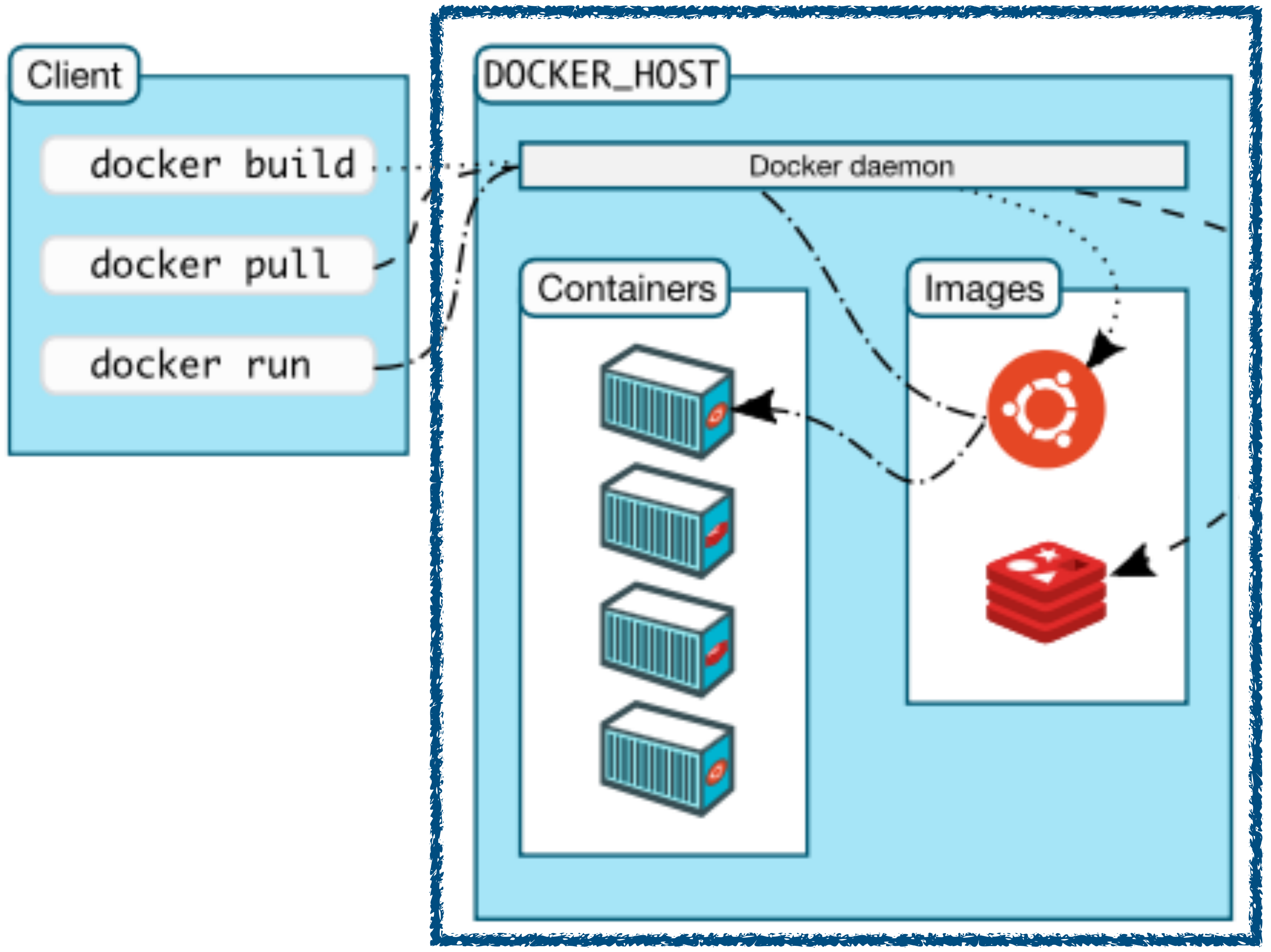
- Component used by users to interact with the Docker platform (daemon)
- Exposes the **Docker API** for:
  - Running and managing containers
  - Managing networks and volumes
  - Reading logs and metrics
  - Pulling and managing images
  - …



Docker

Docker Daemon and Objects

- Docker Daemon
  - Uses the Docker API for receiving requests from the Docker Client
  - **Manages Docker** Images, Containers, Volumes, Networks
- Docker Objects
  - **Image:** immutable (unchangeable) file that contains the source code, libraries, and other files needed for an application to run
  - **Container:** runnable instance of an image



Docker

Volumes

- Containers have an **internal file system** that is **ephemeral**
  i.e., the container's data is deleted once the container is removed

- Containers can **mount a file or directory from the host machine**. Stored data is independent from the container's internal file system and **persisted even if the container is removed**
  - **Bind mount:** Generic directory from the host. Any container or host process can access it
  - **Volume:** Special host directory managed by Docker and accessible only by containers

Find more about Docker Volumes at: https://docs.docker.com/storage/volumes/

Docker

Network

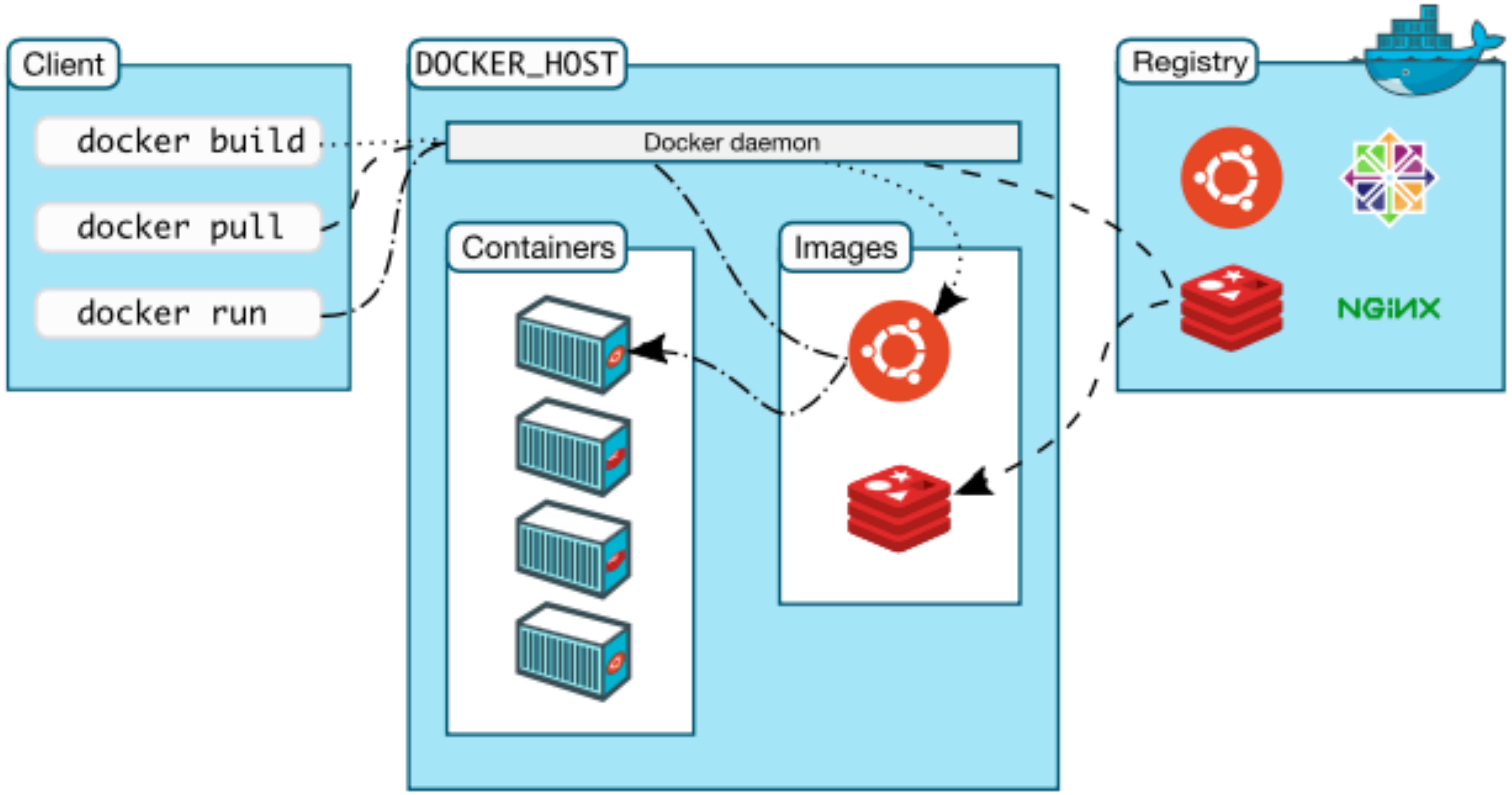
- **Host**:
  - Shares the host networking namespace
  - Container services are presented in the network as if run by the host
  - Ports are shared (e.g., port 80)
- **Bridge**:
  - The container is seen as another node in the physical network

Find more about Docker Networks at: https://docs.docker.com/network/

Docker

Docker Registry

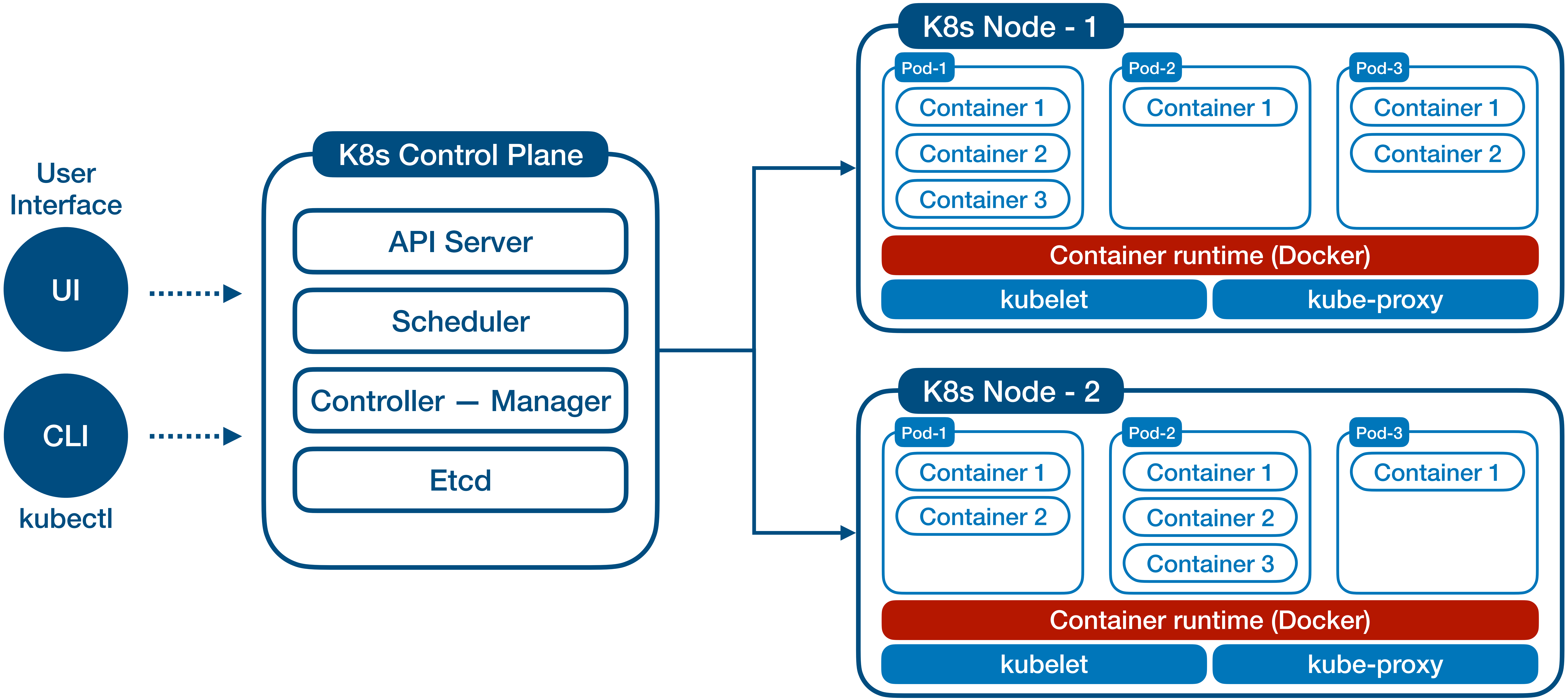
- ◉ Repository of Docker Images
- ◉ Example: https://store.docker.com



Kubernetes (aka K8s)

- Automates the deployment, scaling and management of containers
- Interesting Features:
  - Network management (*e.g.*, service discovery, load balancing)
  - Modular storage orchestration (*e.g.*, iSCSI, NFS, Ceph, AWS, GCP)
  - Simplified **scheduling**, **self-healing** and **scale out** for containers
- https://kubernetes.io

Kubernetes Components



Kubernetes Components

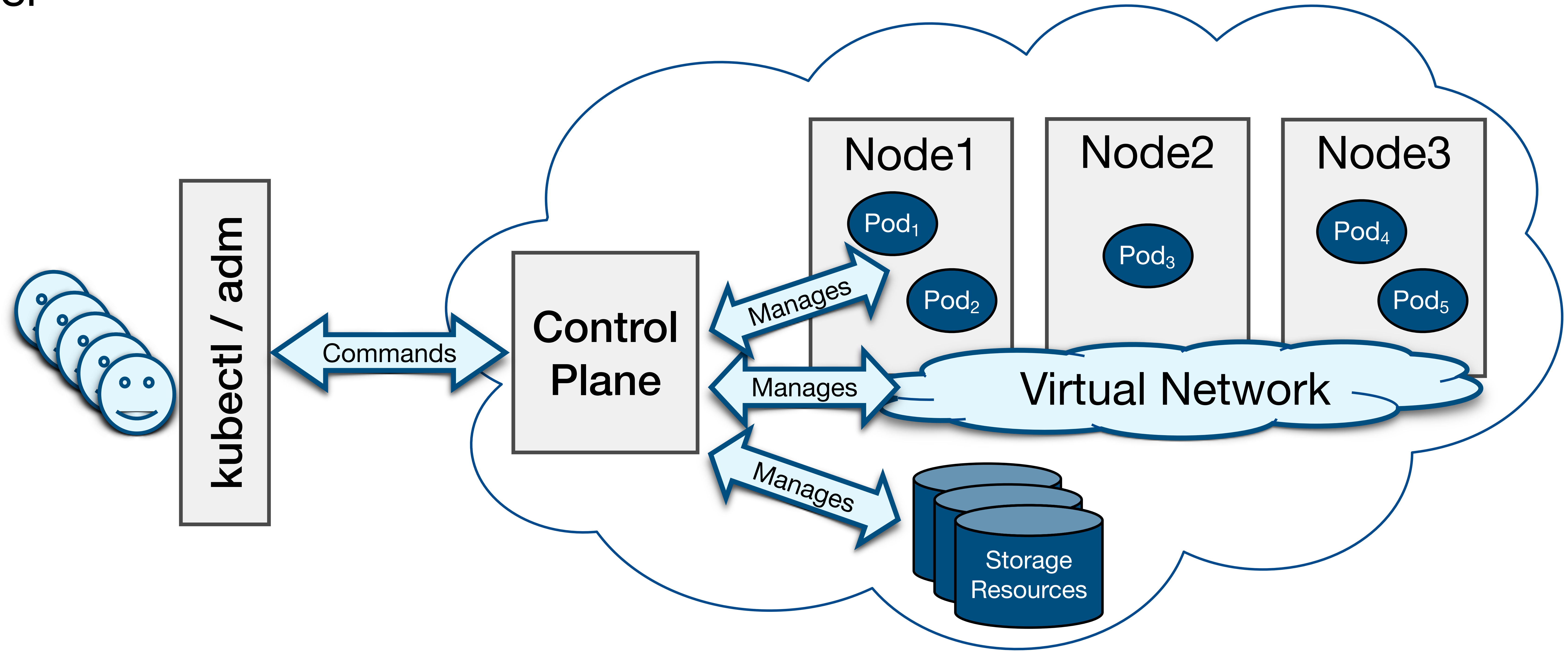
In brief…

- Control Plane Components
  - **API server:** The core component server that exposes the K8s HTTP API
  - **etcd:** Key-value store for all cluster configuration data
  - **Scheduler:** Distributes unscheduled pods across the available nodes
  - **Controller—Manager:** Runs controllers (e.g., for replication, namespaces, …) to implement K8s API behavior
- Node Components
  - **Kubelet:** Manages containers based on incoming Pod specification
  - **Kube-proxy:** Accepts and controls network connections to node's Pods
  - **Container runtime:** Software responsible for running containers (e.g., Docker)

Kubernetes Cluster

Components

- A K8s cluster is a group of **a Control Plane** and a **set of Nodes**
  - The **Nodes** host Pods that run containerized applications
  - The **Control Plane** manages the Nodes, Network, Storage and Pod resources in the cluster



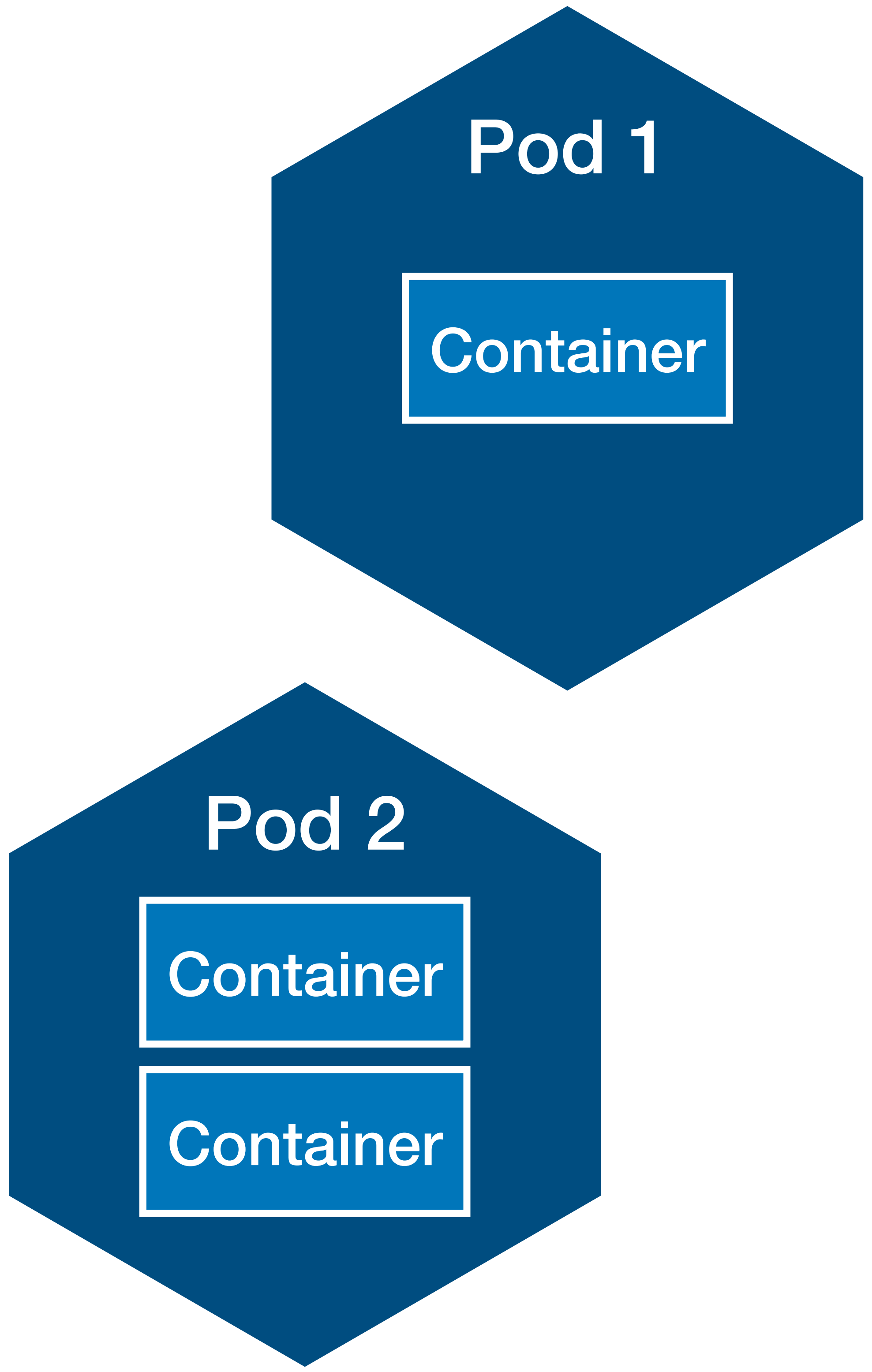
Kubernetes Cluster

Usage

- An **administrator** uses the **kubeadm** command-line tool to set up a cluster:
  - To initialize a cluster: kubeadm init
  - To destroy a cluster: kubeadm reset
- **Clients** interact with the cluster through the Control Plane using the **kubectl** command-line tool

Kubernetes Workloads
The Pod computing unit

- A **workload** is an application running on Kubernetes
  - Whether it is a single component or several that work together, on Kubernetes you run these inside a set of **Pods**
- A **Pod is** a group of **one or more containers** with shared storage and network resources and a specification for how to run the containers

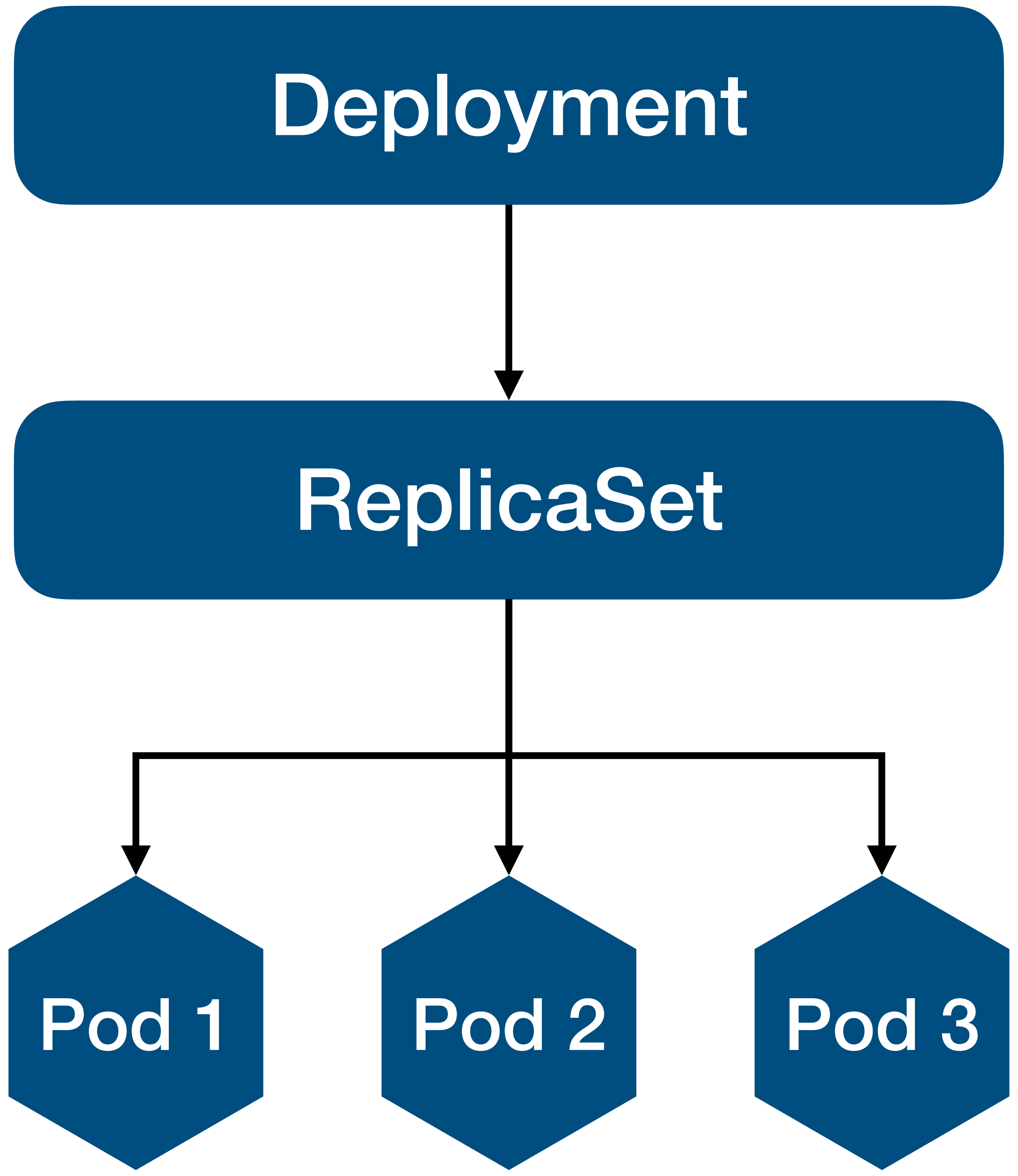


Find more about <u>*Pods*</u> *at:* https://kubernetes.io/docs/concepts/workloads/pods/

Kubernetes Workloads Resources

Runtime environment for Pods

- **Deployments** provide a declarative way to manage and scale a set of identical Pods (replicas)
  - These define a desired state for the application (e.g., the desired number of replicas) and manage the lifecycle of the corresponding Pods
- **ReplicaSets** ensure that a specified number of Pod replicas are running at any given time
  - The Deployment is a higher-level concept that automatically manages ReplicaSets.

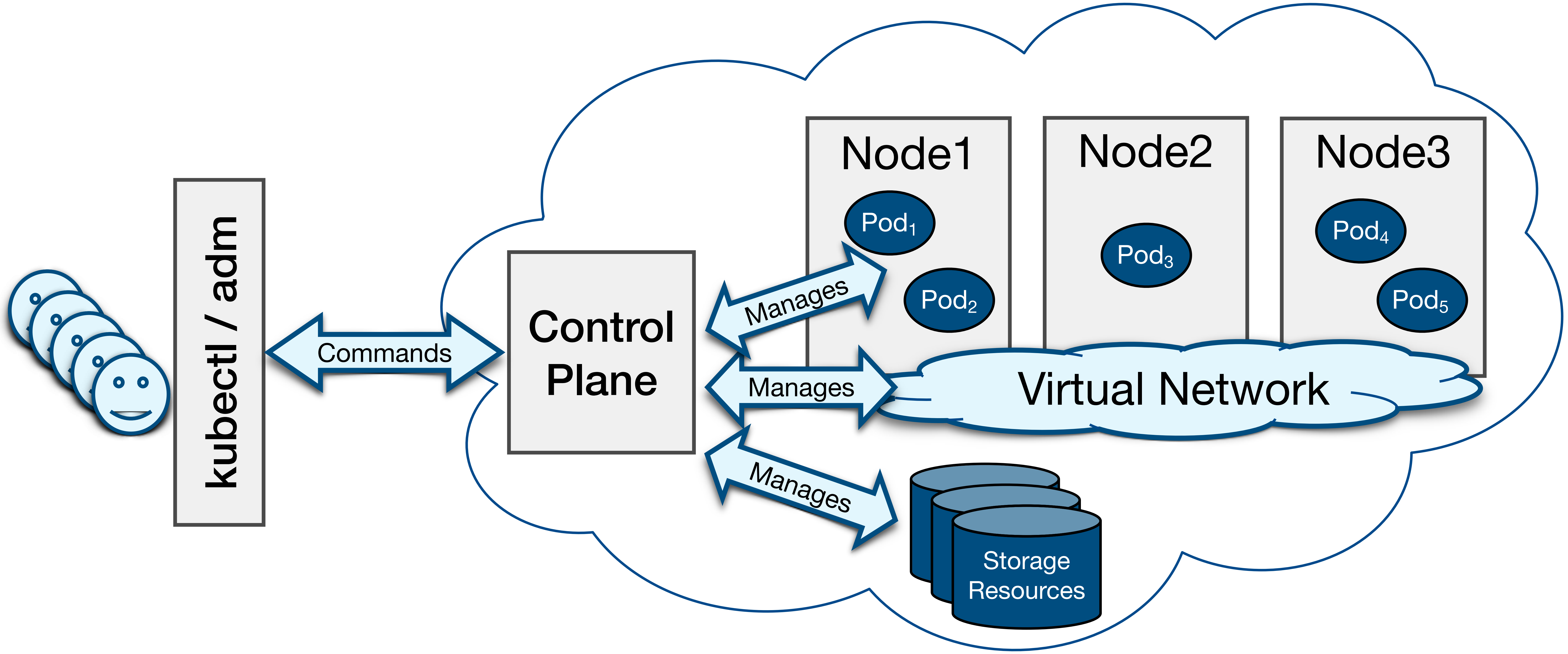


Find more about Workload Resources at: https://kubernetes.io/docs/concepts/workloads/controllers/

Kubernetes Network

Network Overlay

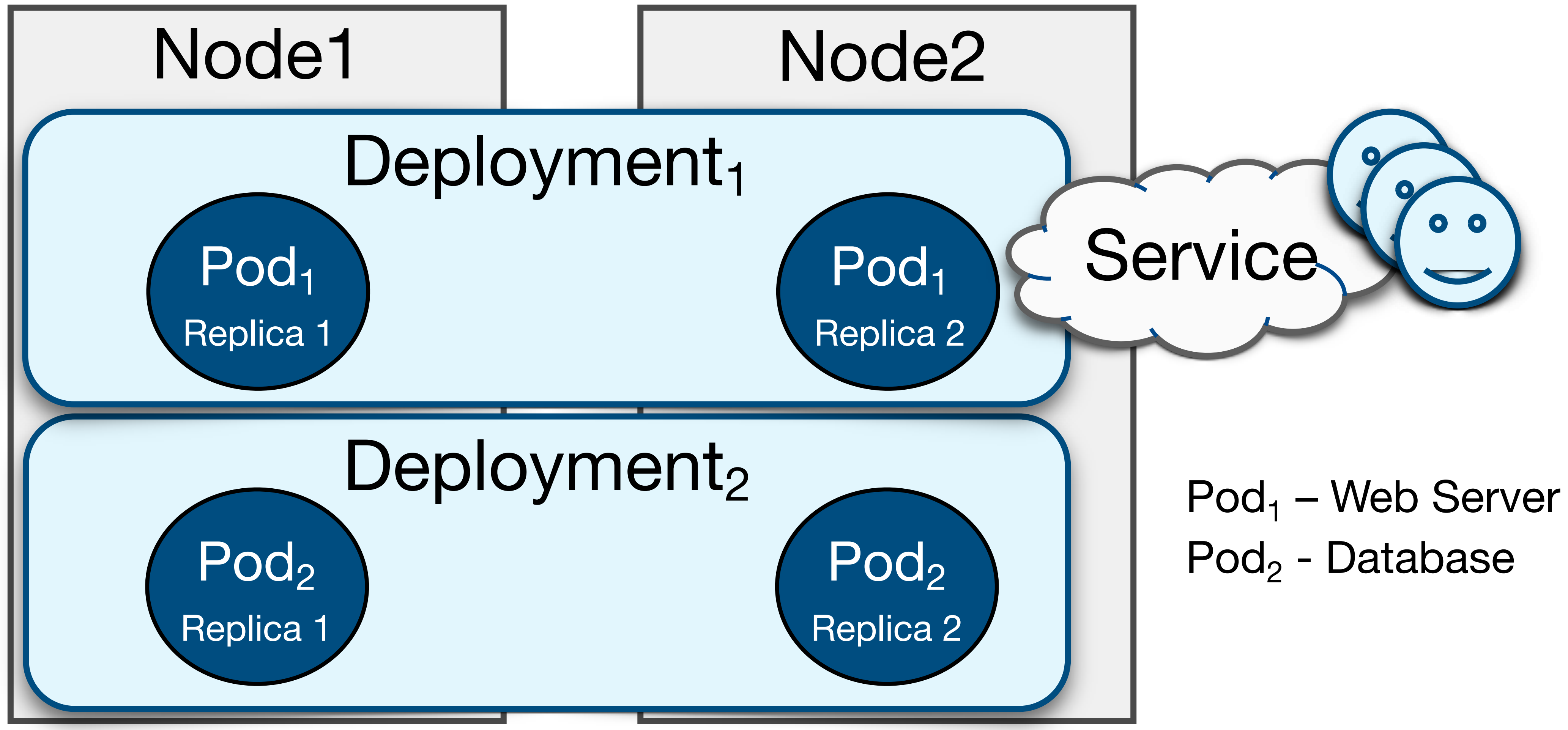
- Each pod has a unique cluster-wide IP address
  - **Networking across pods** (even in distinct worker nodes) is managed through **network overlays** (*e.g.*, Flannel, Calico)



Kubernetes Services

Exposing Pods as a network service

- A **Service** is an abstraction, built on top of the network overlay, for exposing groups of Pods over the network
  - Each Service object defines a logical set of endpoints (e.g., Pods) and a policy about how to make those pods accessible
  - Different types of Service policies:
    - **ClusterIP:** Exposes the Service on a cluster-internal IP
    - **NodePort:** Exposes the Service on each Node's IP at a static port
    - **LoadBalancer:** Exposes the Service externally using a external load balancer

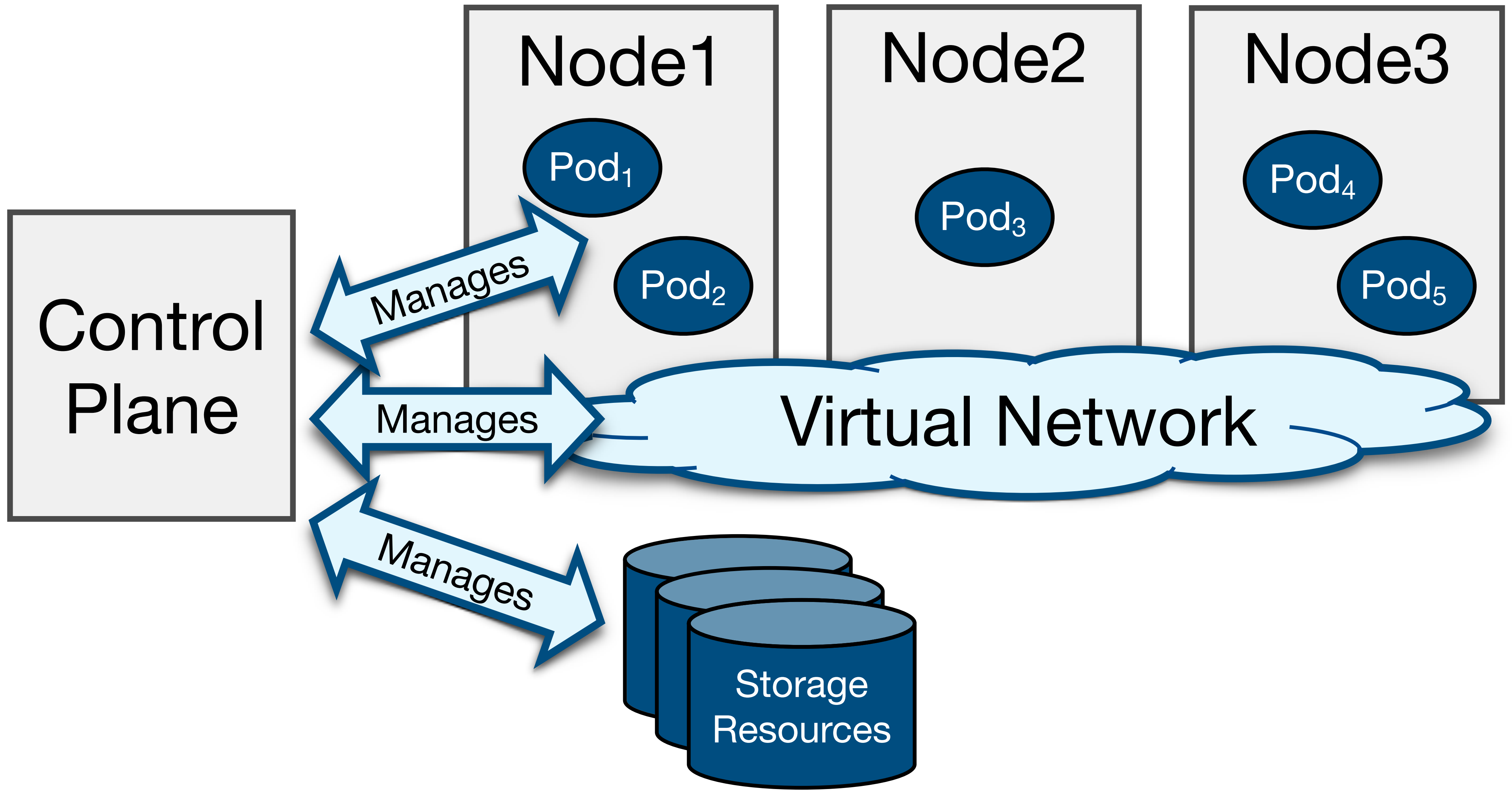


Find more about Services at: https://kubernetes.io/docs/concepts/services-networking/service/

Kubernetes Storage

Storage Types

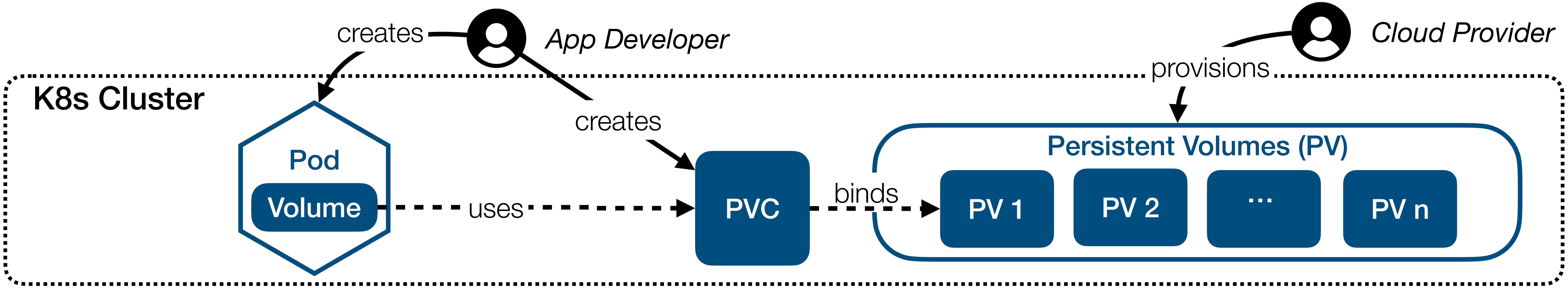
- Pods can access storage volumes provided by different storage backends (*e.g.*, iSCSI, NFS, AWS, GCP)
  - **Ephemeral** storage – available during the pod's lifetime
  - **Persistent** storage – available even if the pod is terminated



Kubernetes Volumes

for Pods

- **PersistentVolume (PV):** A piece of storage in the cluster provisioned by an administrator or dynamically provisioned using **Storage Classes**
- **PersistentVolumeClaim (PVC):** A user request of storage for a Pod
- **Storage Class (SC):** Provides a way for administrators to describe the types of storage they offer (e.g., faster/slower, local/remote storage)



Find more about Persistent Volumes at: https://kubernetes.io/docs/concepts/storage/persistent-volumes/

Kubernetes (level up!)

Enhancing your Pods configurations and security

- **ConfigMaps**
  - A k8s object for storing and updating **non-confidential** Pod configurations in a key-value pair format
    (e.g., environmental variables, command-line arguments)
- **Secrets**
  - A K8s object to safely store **confidential** data from Pods
    (e.g., passwords, tokens, keys)
- Useful for the practical assignment!

Find more at: *https://kubernetes.io/docs/concepts/configuration/configmap/*
and https://kubernetes.io/docs/concepts/configuration/secret/

Summary

Containers vs VMs – Disclaimer!

Each technology is built with different goals and the best one depends on the targeted use case!

- VMs are useful when **full server (OS) virtualization** is needed
- Containers are useful for managing virtual environments with heterogeneous libraries and/or applications

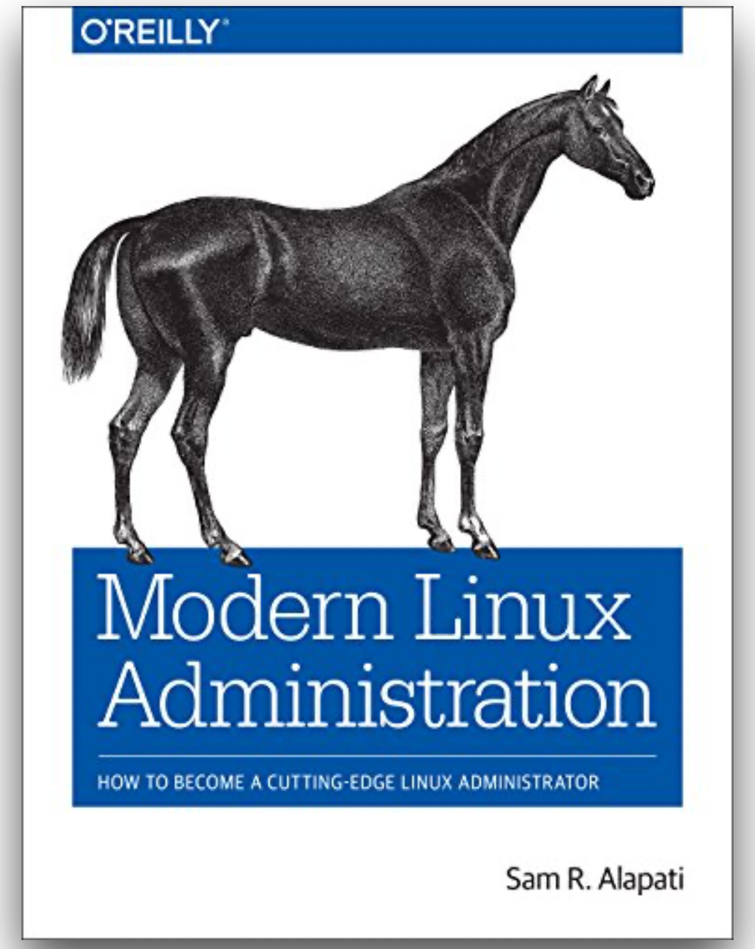
Advantages and Disadvantages

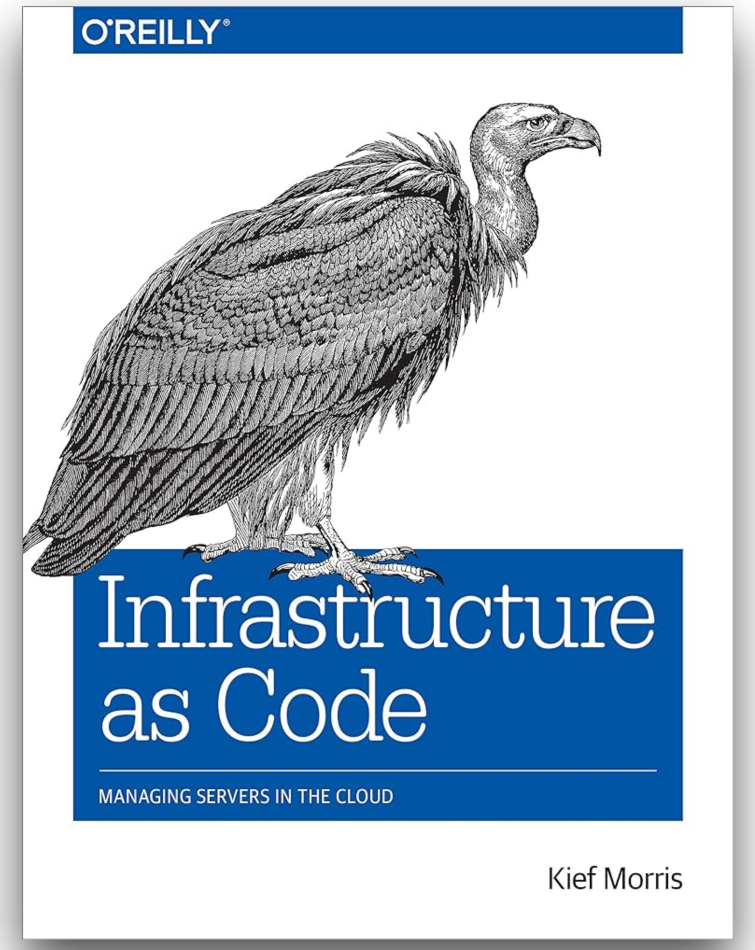
Containers vs VMs

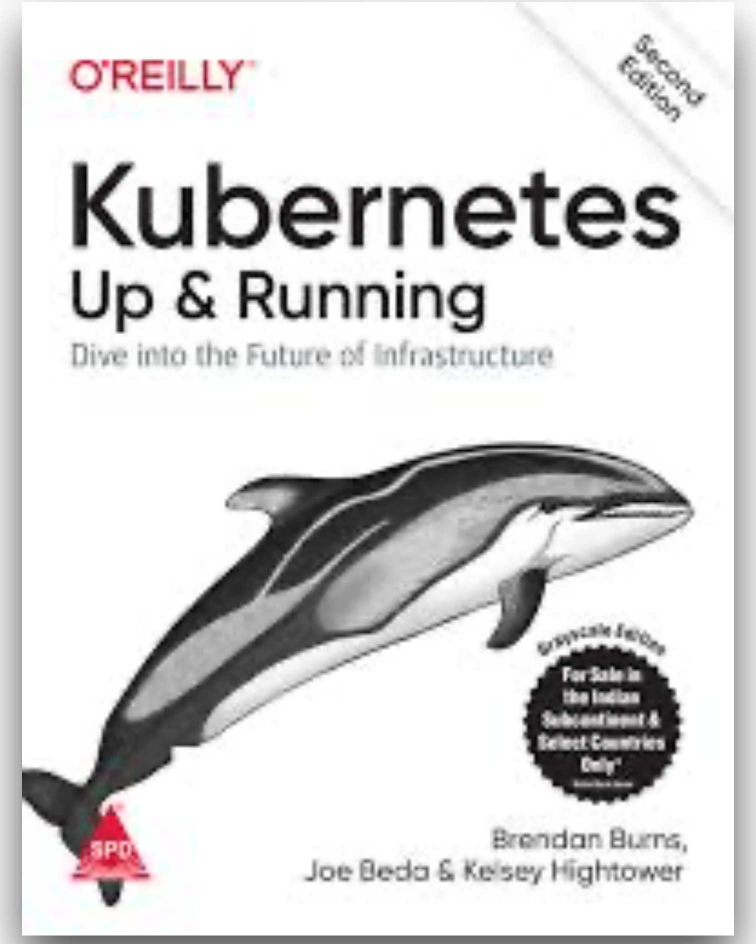
- **Advantages** of Containers over VMs
  - **Faster testing/provisioning/migration** (containers are more lightweight!)
  - **Better resource utilization and performance** (again, more lightweight…)
  - Can easily be **deployed** on both **physical and virtualized servers**
    - Some VM hypervisors provide nested virtualization (i.e., running a VM inside a VM)
- **Disadvantages** of Containers over VMs
  - **Weaker isolation/security** (remember that OS/Kernel are shared)
  - **Less flexibility in running different OSs** (*e.g.*, Linux, Windows, BSD, ...)

Further Reading

- S. Alapati. ***Modern Linux Administration: How to Become a Cutting-edge Linux Administrator***. O'Reilly, 2016
- K. Morris. ***Infrastructure as Code: Managing Servers in the Cloud***. O'Reilly, 2016
- B. Burns. ***Kubernetes Up & Running (Second Edition)***. O'Reilly, 2019.







Questions?