Core Concepts

Containerization and Orchestration

Kubernetes Architecture & API. Basic Objects and Tools

kubernetes

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/groups/kubernetesnovember2025

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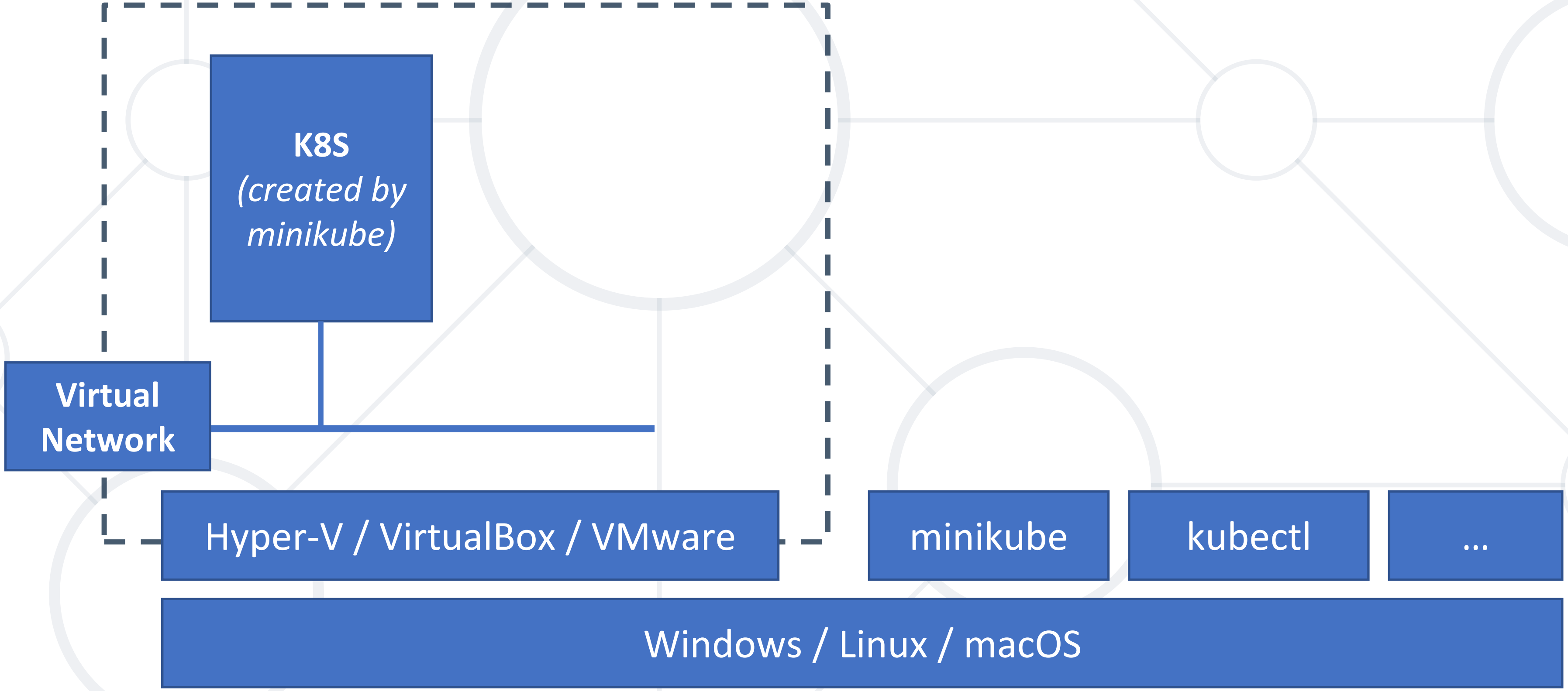


Containerization

Containerization

> " OS-level virtualization refers to an operating system paradigm in which the kernel allows the existence of **multiple isolated user space instances** known as **containers, zones, jails**, … "

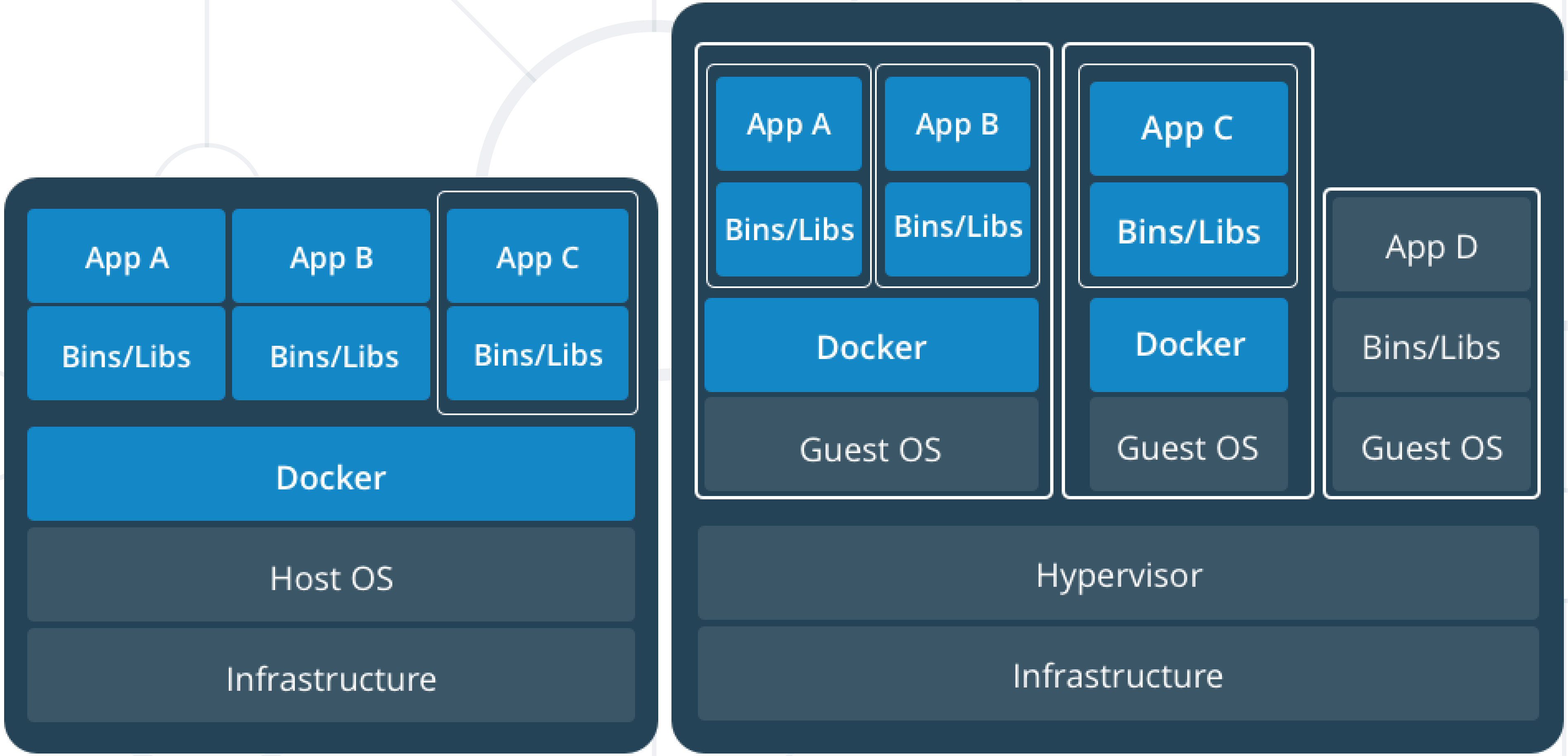
https://en.wikipedia.org/wiki/OS-level_virtualization

Virtual Machines vs Containers

- **Virtual Machines**
  - Virtualize the hardware
  - Complete isolation
  - Run almost any OS
  - Complete OS installation
  - Require more resources

- **Containers**
  - Virtualize the OS
  - Lightweight isolation
  - Run on the same OS
  - Shared kernel
  - Require fewer resources

Virtual Machines and Containers



https://www.docker.com/what-container

Definitions

- **Image**

  Read-only template built from layers. Provide a way for simpler software distribution

- **Container**

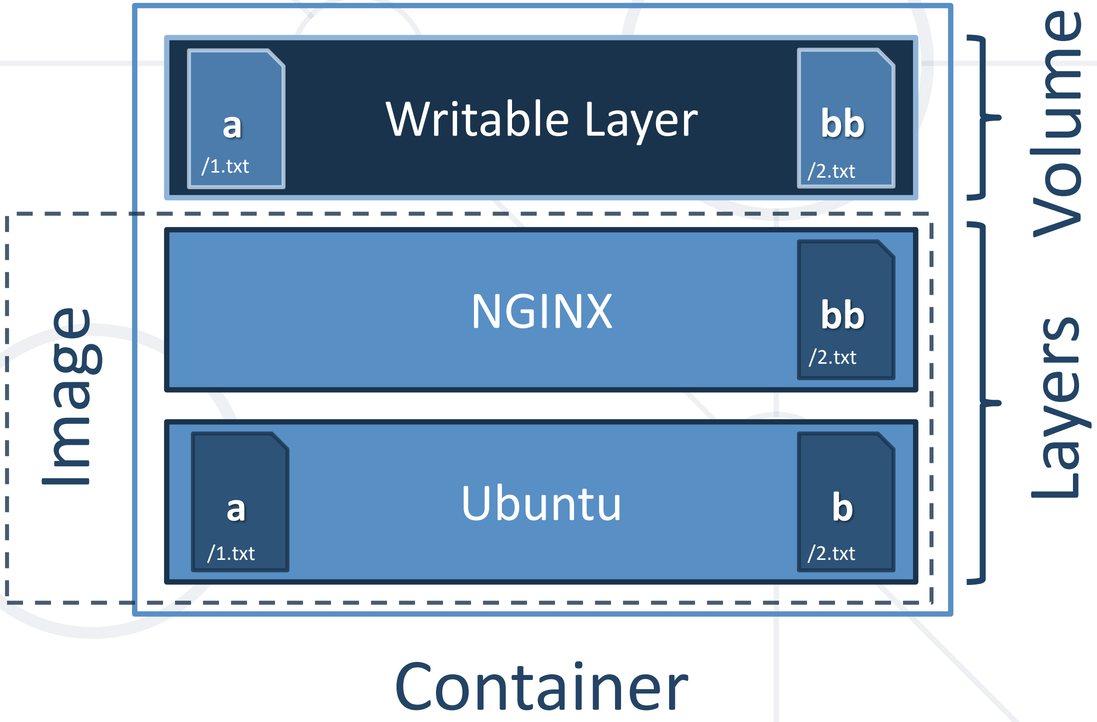
  Runnable instance of an image

- **Repository**

  Collection of different versions of an image identified by tags

- **Registry**

  Collection of repositories



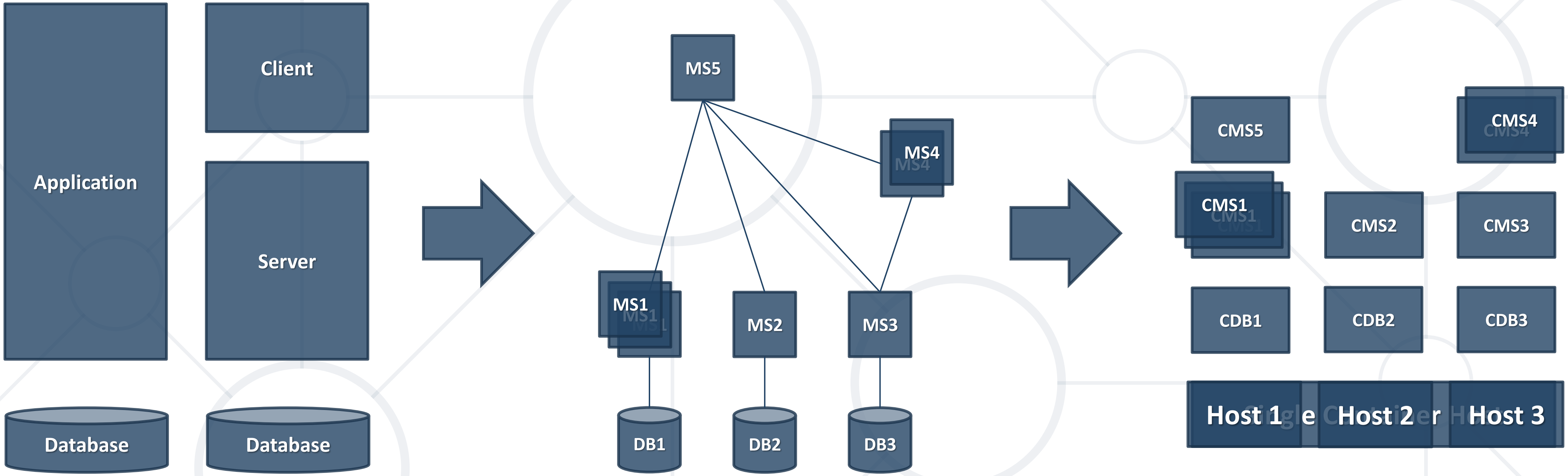
Orchestration

Application Evolution *

Monolithic Applications

Microservices

Containers



Microservices != Containers

New Demands*

- Workload deployment and distribution
- Resource governance
- Scalability and availability
- Automatization and management
- Internal and external communication

Container Orchestration

* Not an exhaustive list

Kubernetes Got You Covered*

- Runs a cluster of hosts
- Schedules containers to run on different hosts
- Facilitates the communication between the containers
- Provides and controls access to/from outside world
- Tracks and optimizes the resource usage

* Not an exhaustive list

Kubernetes Origin

- Born out of projects like **Borg** and **Omega** at **Google**
- Written **in Go**
- Donated to **CNCF** in **2014**
- Open source, licensed under **Apache 2.0**
- **Version 1.0** came into existence in **July 2015**. Current is **1.34.1**
- **κυβερνήτης** in Greek means **Helmsman** – s.o. who steers the ship
- Can be seen often as **k8s** $\text{(K}\overbrace{\cancel{\text{ubernete}}}^{8}\text{s)}$

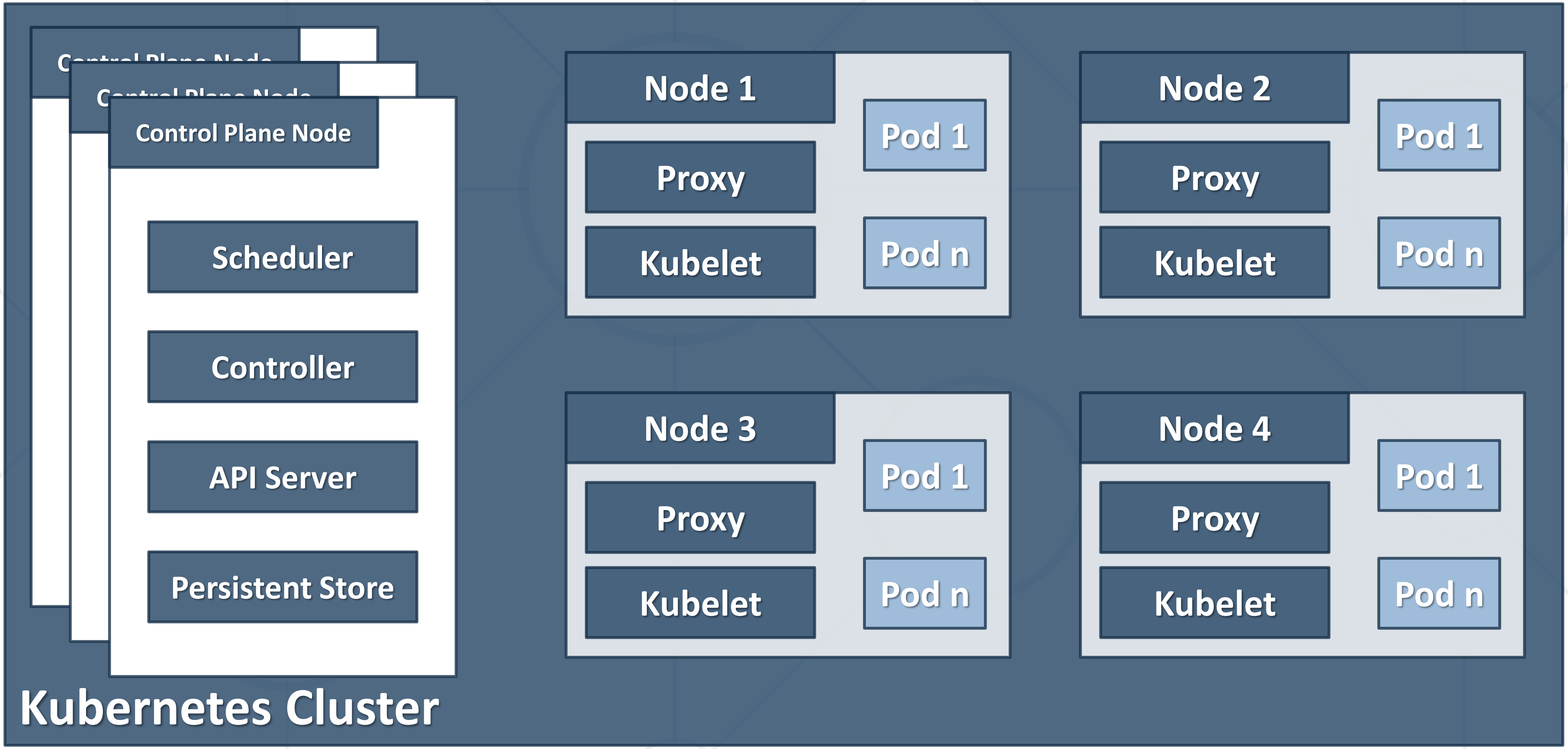
Other Solutions*

- Docker Swarm
- HashiCorp Nomad
- Apache Mesos + Marathon

* Not an exhaustive list

Kubernetes Architecture

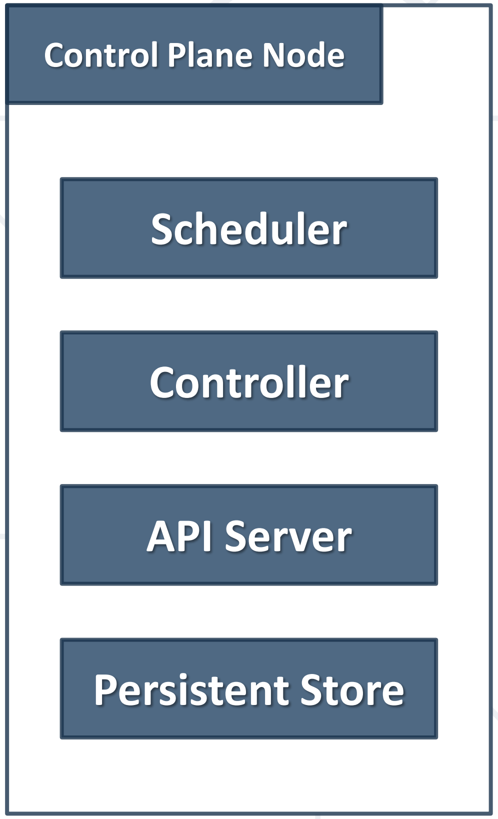
Architecture Overview *



* Not all components are shown

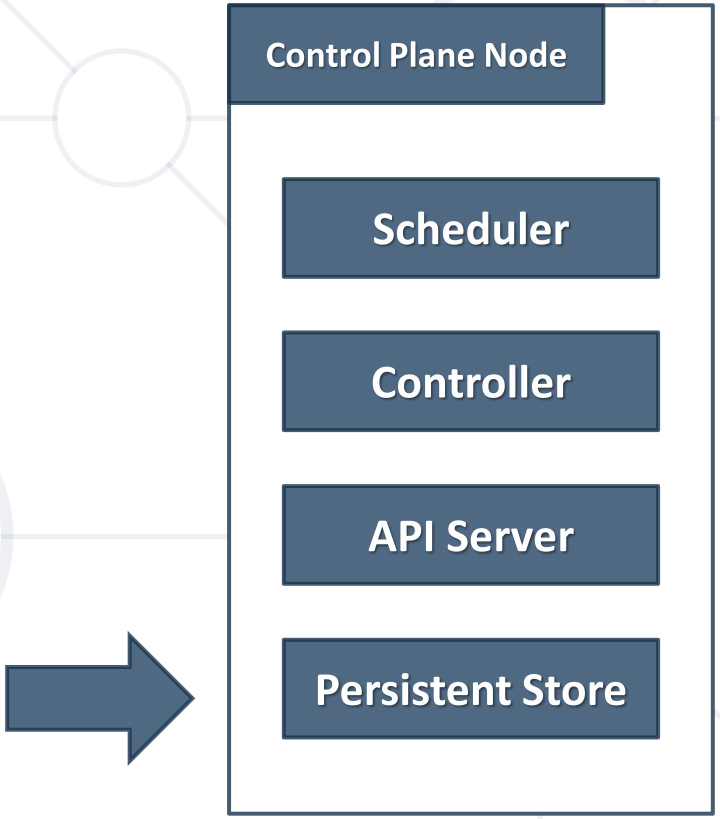
Control Plane (master) Nodes

- Responsible for **managing** the cluster
- Typically, **more than one** is installed
- In HA mode one node is the **Leader**
- It is **work-free** (this can be changed)
- Components running on master are also known as **Control Plane**
- Can be reached via **CLI** **(kubectl)**, **APIs**, or **Dashboard**



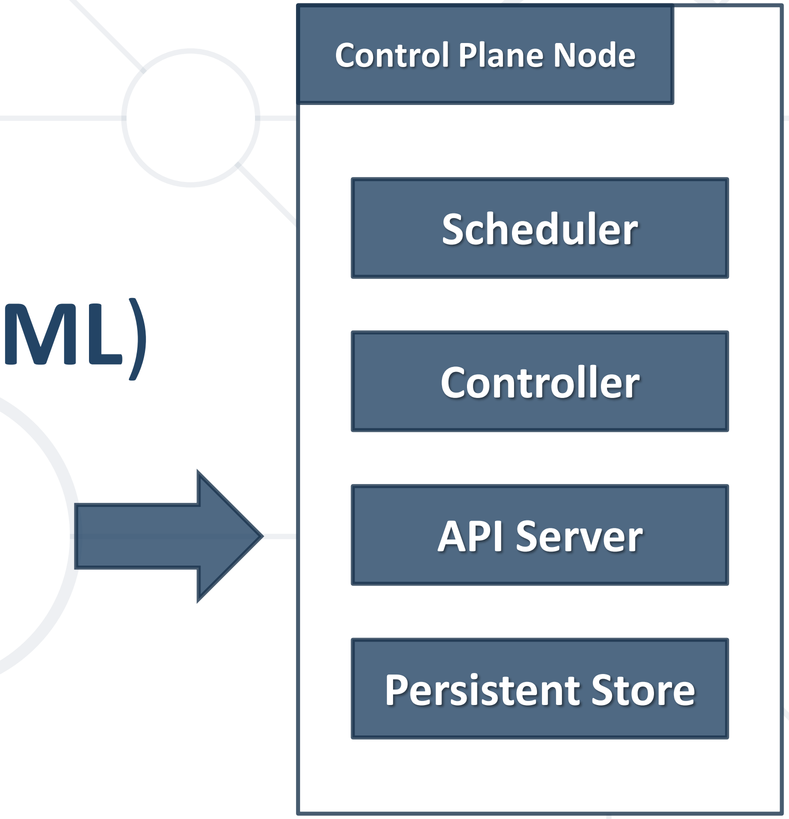
Control Plane Nodes: Persistent Store

- Based on **etcd**
- **Persistent** storage
- Cluster **state** and **configuration**
- **Distributed** and **consistent**
- Provides single **source of truth**
- Can be installed **externally**



Control Plane Nodes: API Server

- Exposes the **Kubernetes API** (**REST**)
- **Front-end** for the control plane
- **Administrative** tasks
- Consumes **JSON** via **Manifest files (YAML)**


Control Plane Node

Scheduler

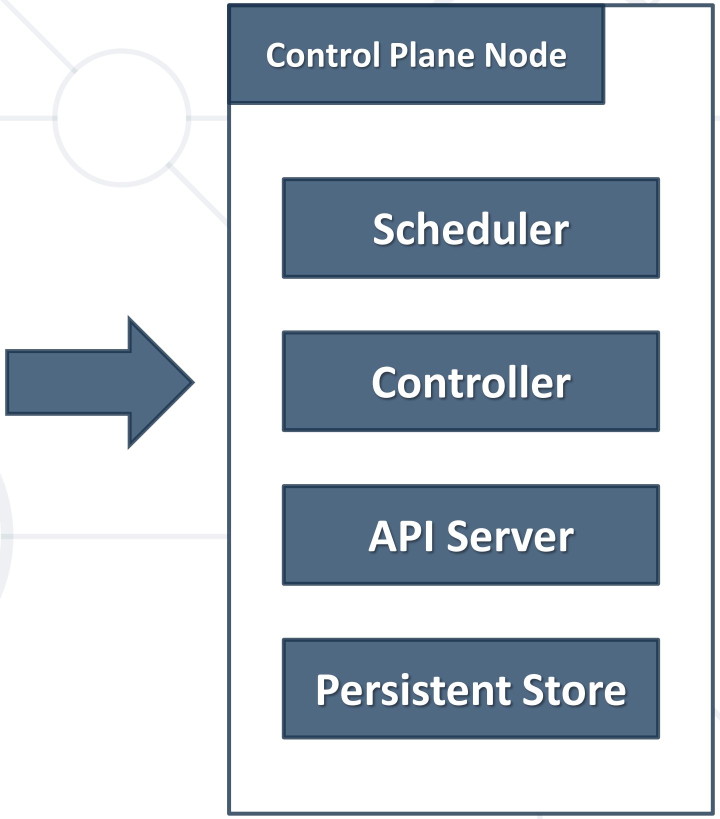
Controller

API Server

Persistent Store

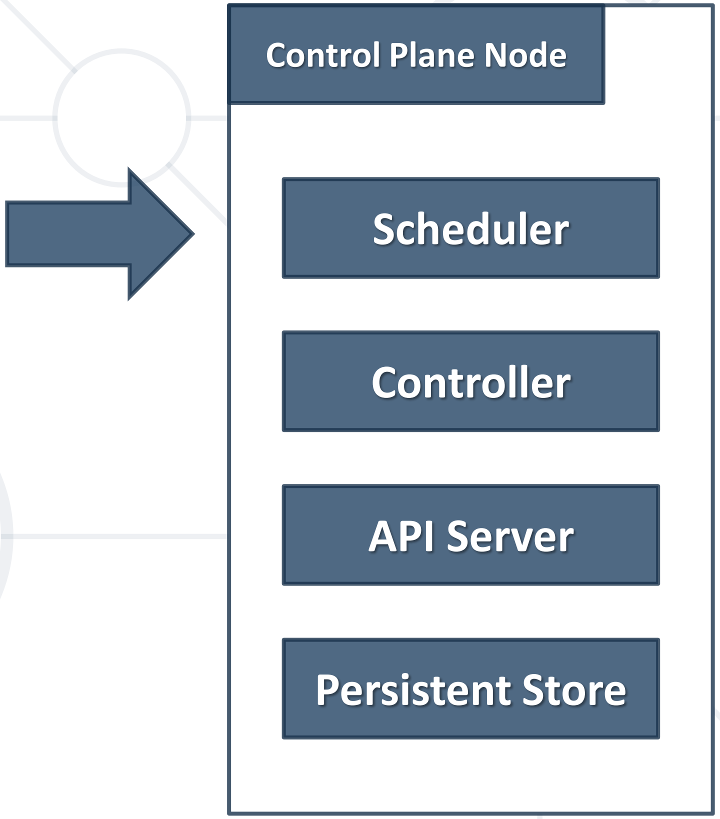
Control Plane Nodes: Controller

- Executes **control loops**
- Responsible for other controllers
  - Node controller
  - Endpoints controller
  - Namespace controller, etc.
- Watches for **changes**
- Maintains the **desired state**



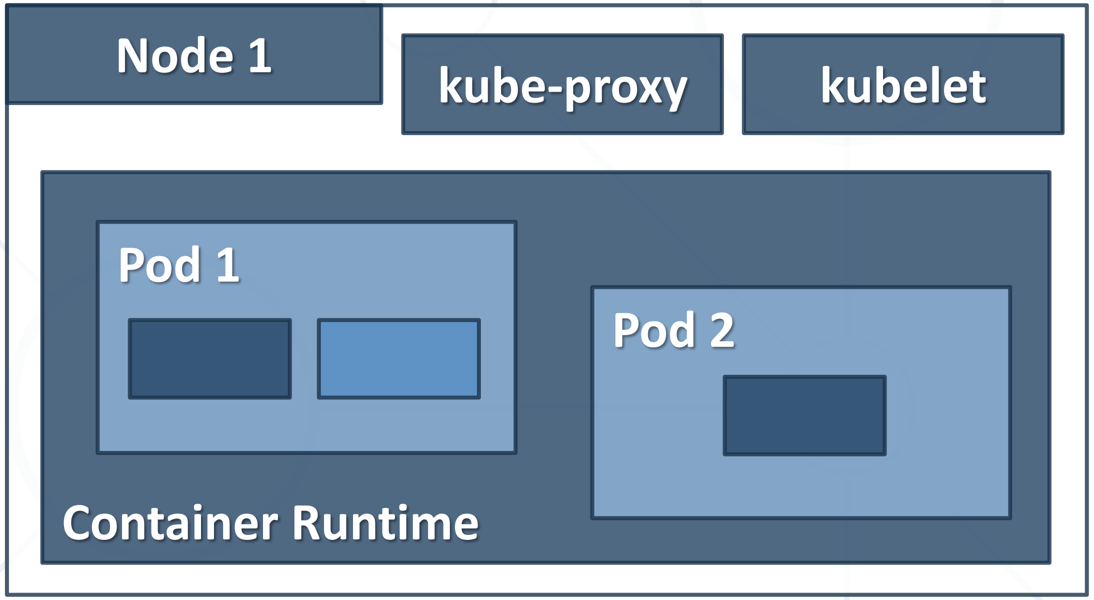
Control Plane Nodes: Scheduler

- **Listens** API Server for new work
- **Assigns work** to nodes



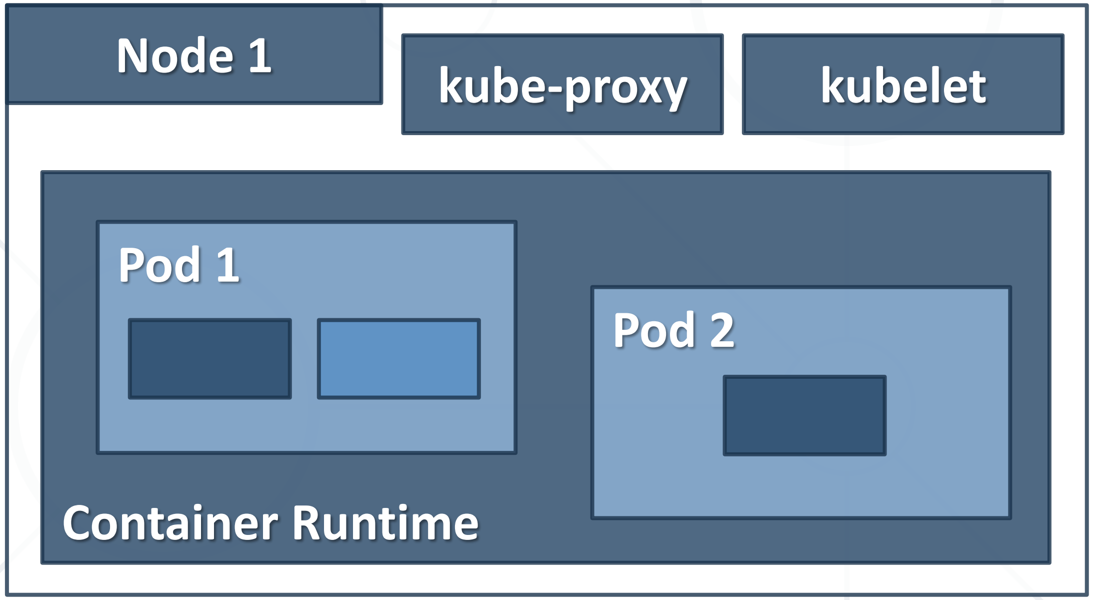
(Worker) Nodes

- **kubelet**
  - Communicates with the control plane
- **Container runtime**
  - containerd, CRI-O, etc.
- **kube-proxy**
  - Network proxy



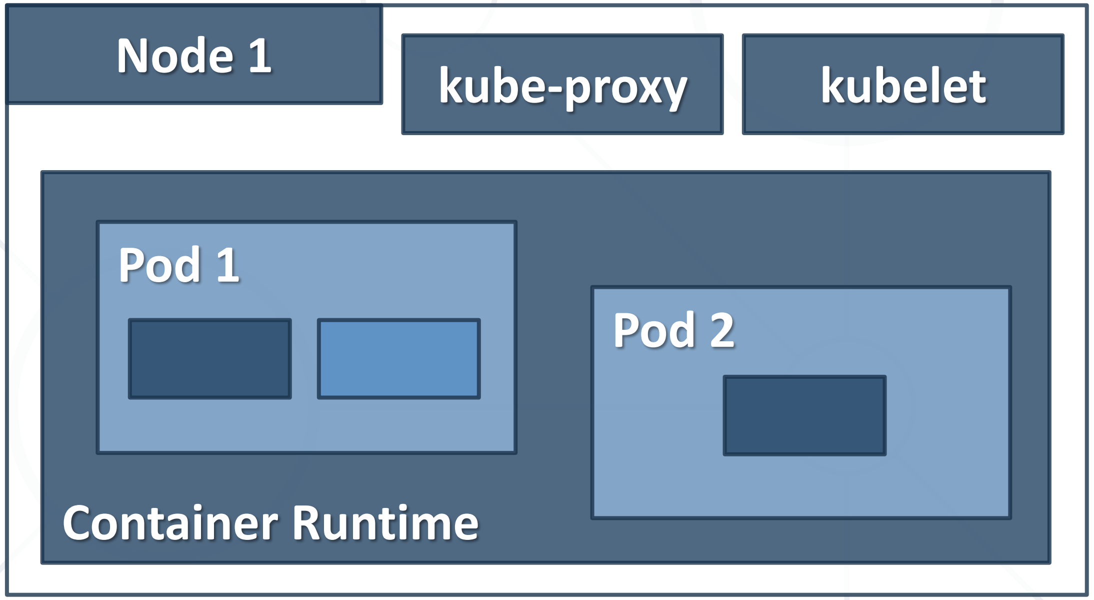
(Worker) Nodes: kubelet

- Main Kubernetes agent
- Registers node in the cluster
- Listens to the API Server
- Creates pods
- Reports back to the control plane
- Exposes endpoint on :10255
  - /spec
  - /healthz
  - /pods



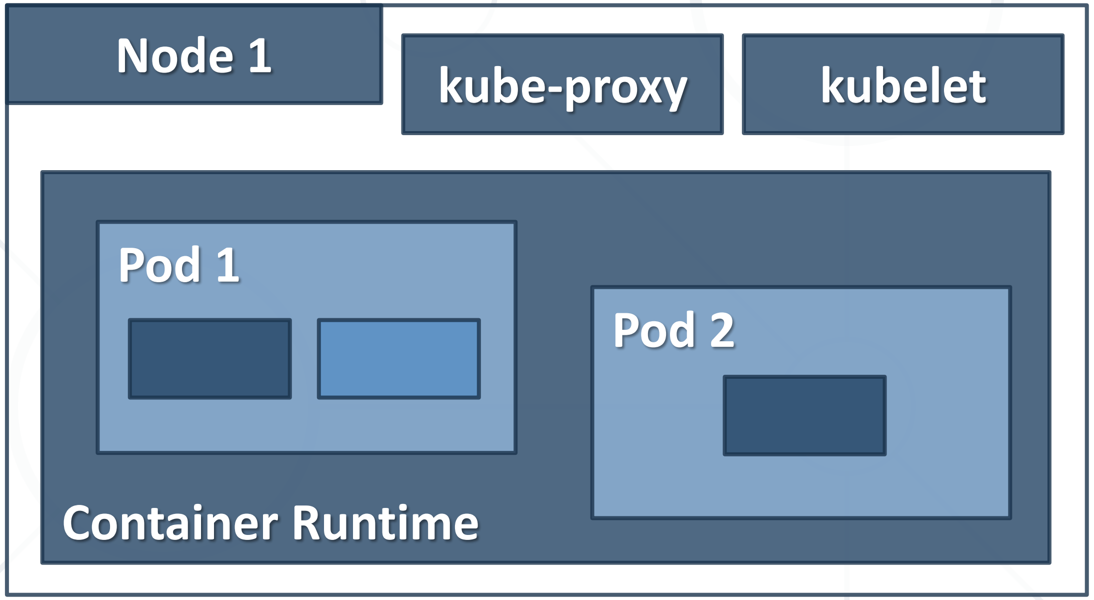
(Worker) Nodes: Container Runtime

- Container management
  - **Pulling** images
  - **Starting** and **stopping**
- It is **pluggable**



(Worker) Nodes: kube-proxy

- Provides the **networking**
- Each pod has its **own address**
- All containers in a pod share the **same IP** address
- Offers **load balancing** across all pods in a **service**



Work with Kubernetes

Kubernetes Distributions

- A software package that provides a pre-built version of Kubernetes
- Most distributions also offer installation tools or additional software integrations
- On-premise
  - ***KinD***, ***Minikube***, **MicroK8s**, **K3s**, **k0s**, **OpenShift**, **VMware Tanzu** …
- Cloud-based
  - **Azure Kubernetes Services** (**AKS**), **Elastic Container Service for Kubernetes** (**EKS**), **Google Kubernetes Engine** (**GKE**), …
- Usually, cloud versions are a few versions behind

Installation Scenarios and Tools

- Installation methods
  - **Localhost** (for test and development)
  - **On-Premise** (**VMs**, **Bare Metal**)
  - **Cloud** (**Hosted Solutions**, **Turnkey Solutions**, **Bare Metal**)
- Configurations
  - **All-in-One Single Node** and different **Multi Node** options
- Installation tools
  - Test/development - **KinD**, **Minikube**, etc.
  - Production - **kubeadm**, **KubeSpray**, **Kops**, etc.

kind

- Easiest way to test and start with Kubernetes
- **kind** stands for Kubernetes in Docker
- So, it requires **Docker** to be installed and configured

https://kind.sigs.k8s.io/docs/

minikube

- Easiest and recommended way for a **local all-in-one cluster**
- Requirements
  - **kubectl**
  - **Hypervisor** (VirtualBox, Hyper-V, KVM, xhyve, VMware Fusion)
  - **VT-x/AMD-v** enabled
  - Internet connection on first run
- Supports **Linux**, **macOS**, and **Windows**
- Provides **docker-machine**-like experience, but for **Kubernetes**

https://minikube.sigs.k8s.io/docs/

kubectl

- Controls Kubernetes clusters
- Expects a file named **config** in the **$HOME/.kube** directory
- Other files can be specified by setting the **KUBECONFIG** environment variable or by setting the **--kubeconfig** flag
- The syntax is

```
kubectl [command] [TYPE] [NAME] [flags]
```

https://kubernetes.io/docs/reference/kubectl/overview/

kubectl

- Where **command** is the operation (**run**, **get**, etc.) and **type** is the resource (**pod**, **service**, etc.). Note that **name** is case-sensitive
- Its version should +/- 1 minor version compared to the cluster
- For example, with kubectl version 1.22 we can work with clusters version 1.21, 1.22, and 1.23

https://kubernetes.io/docs/reference/kubectl/overview/

Dashboard

- A web-based Kubernetes user interface
- Deployment of containerized applications to a cluster
- Troubleshooting containerized application
- Managing the cluster resources

https://kubernetes.io/docs/tasks/access-application-cluster/web-ui-dashboard/

Practice

Live Exercise in Class (Lab)

Basic Kubernetes Objects 101

Namespaces. Pods. Services

Objects Overview

- Kubernetes objects are persistent entities
- They are used to represent the state of the cluster
- An object is a "**record of intent**". Once created, the Kubernetes system will constantly work to ensure that object exists
- Almost every object includes two nested object fields
  - **Spec** provides a description of the characteristics (**desired state**)
  - **Status** describes the **current state** of the object
- They include **Pods**, **Services**, **Namespaces**, **Volumes**, etc.

https://kubernetes.io/docs/concepts/overview/working-with-objects/kubernetes-objects/

Objects Management

- **Imperative commands**
  - Commands are invoked against live objects. We directly state what should be done. Good for development or test and for one-off tasks
- **Imperative object configuration**
  - Operations are specified together with at least one file, which contains the definition of target object(s). Can be used in production
- **Declarative object configuration**
  - Operates with local configuration files but the actions are not stated explicitly. Can work with files and folders

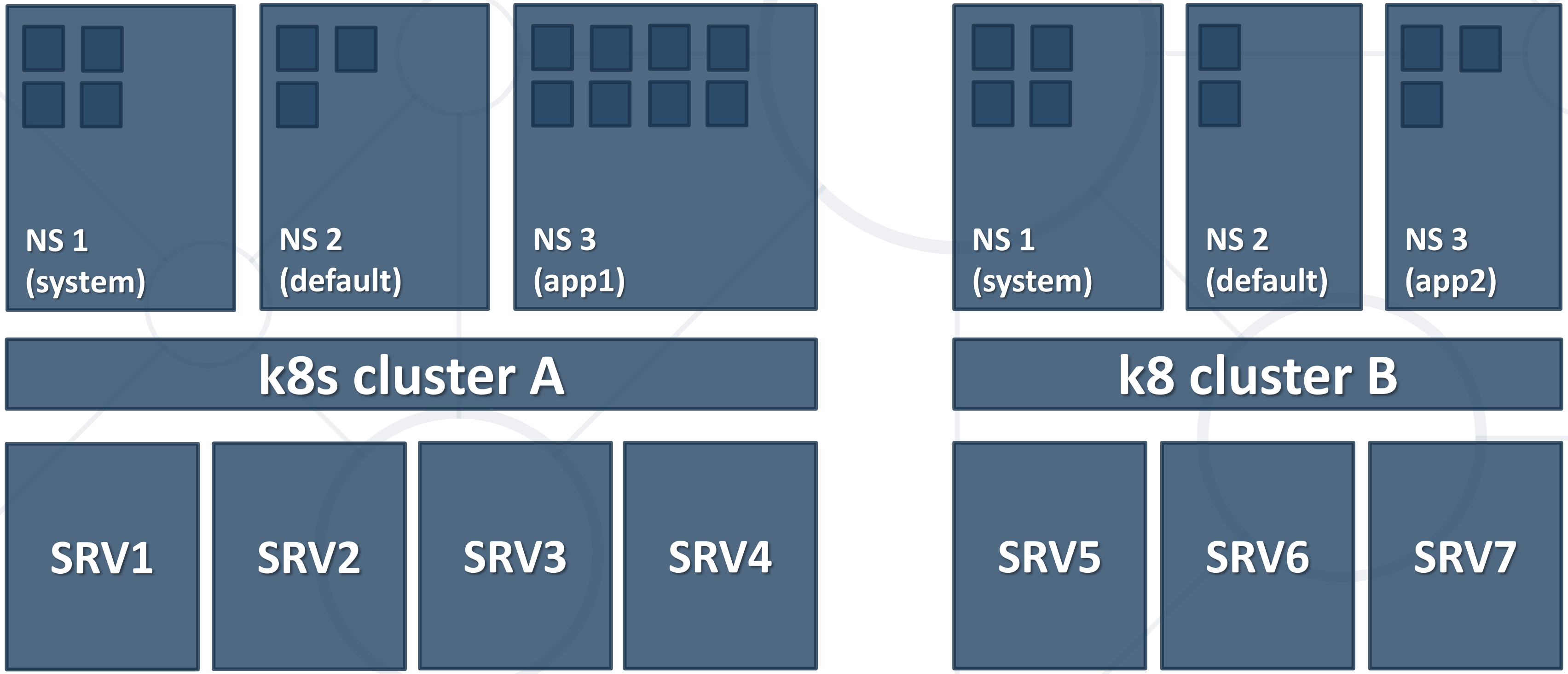
https://kubernetes.io/docs/concepts/overview/working-with-objects/object-management/

Namespaces

- Kubernetes supports multiple virtual clusters
- These virtual clusters are called **namespaces**
- Namespaces provide a **scope for names**
- Names of resources need to be **unique** within a namespace
- Namespaces **cannot be nested** inside one another
- Each Kubernetes resource can **only be in one** namespace
- Most Kubernetes resources are in some namespace
- Namespace resources are not themselves (and others such as **nodes**) in a namespace
- Deleting a Namespace will clean up everything under it

https://kubernetes.io/docs/concepts/overview/working-with-objects/namespaces/

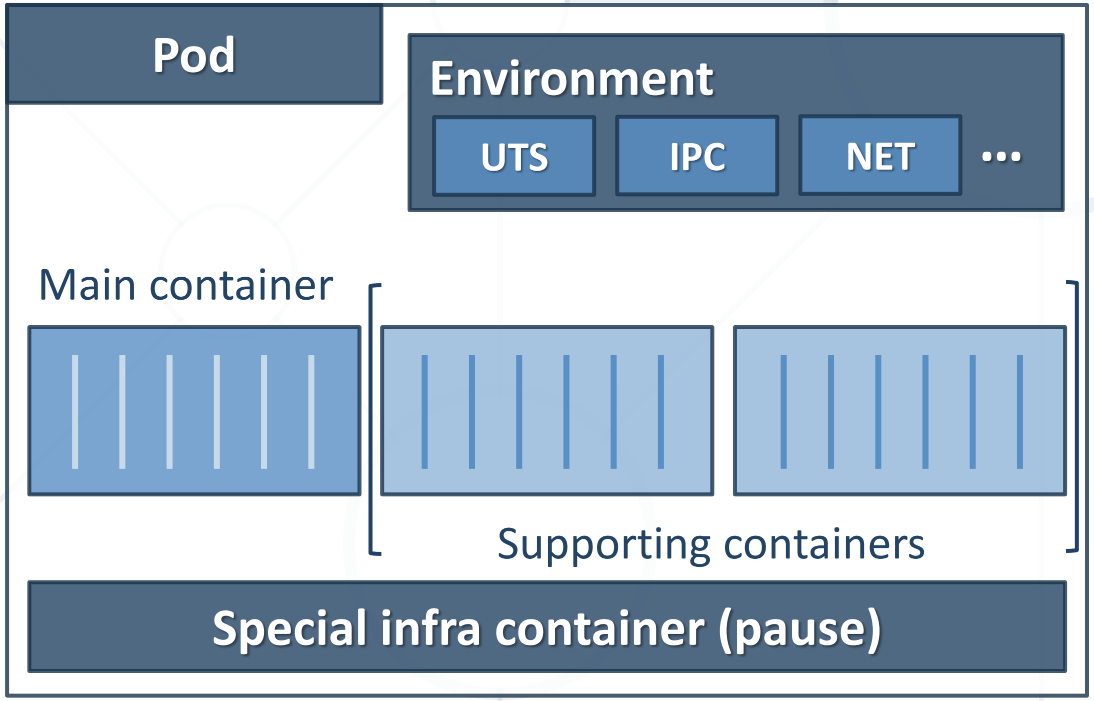
Namespaces vs Clusters vs Data Centers



Namespaces divide a k8s cluster to virtual clusters

k8s cluster abstracts the datacenter

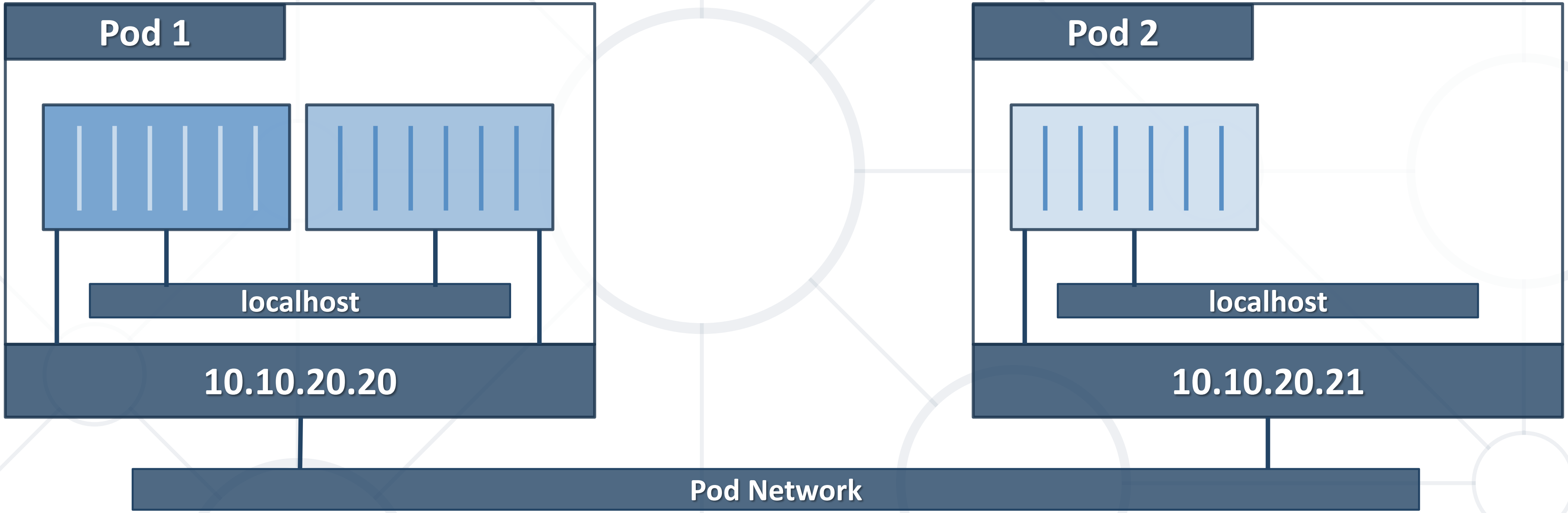
Pods



- Smallest **unit of scheduling**
- **Scheduled** on nodes
- **One** or **more** containers
- Containers **share** the pod **environment**
- **Deployed as one** and on **one node.** It is **atomic**
- Created via **manifest files**

https://kubernetes.io/docs/concepts/workloads/pods/

Pods



- Each pod has a **unique IP** address
- **Inter-pod** communication is via a **pod network**
- **Intra-pod** communication is via **localhost** and **port**

Pod Manifest *

```yaml
apiVersion: v1
kind: Pod
metadata:
  name: appa-pod
spec:
  containers:
  - name: appa-container
    image: shekeriev/k8s-appa:v1
    ports:
    - containerPort: 80
```

* Working but very simple one

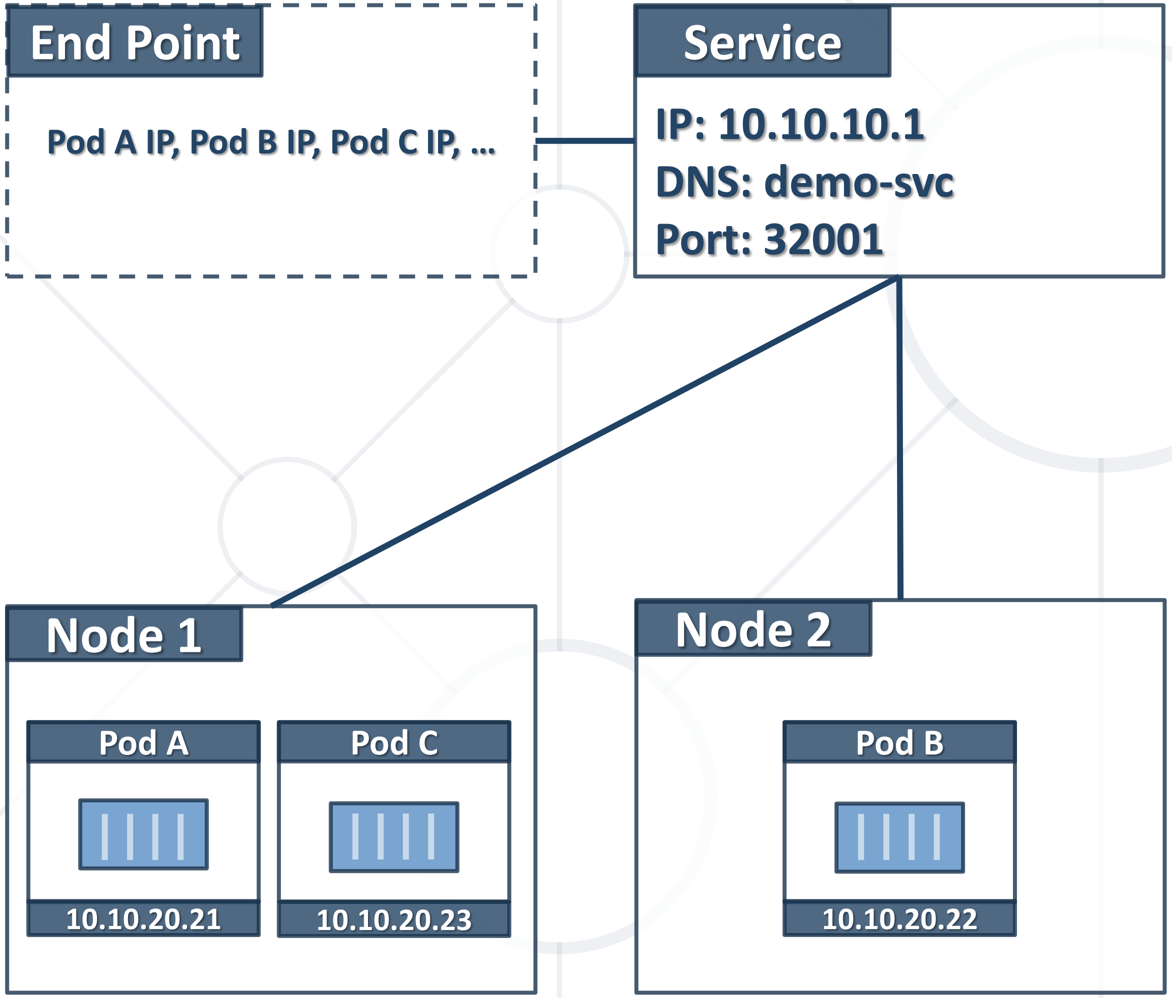
Labels and Annotations

- **Labels**
  - Key-value pairs attached to objects
  - Each object may have multiple labels
  - Each label may be attached to multiple objects
  - Used to identify and group sets of objects
  - Used with **label selectors** to select a group of objects

} Apply to **annotations** as well

- **Annotations**
  - Key-value pairs attached to objects
  - Used to store additional information (metadata) like description, creator, etc.

Services



- Provide reliable network endpoint
  - IP address
  - DNS name
  - Port
- Expose pods to the outside world
- Use **end point** object to track pods
- Use **label selectors** to do their magic

https://kubernetes.io/docs/concepts/services-networking/service/

Service Types

- **ClusterIP** exposes the Service on a **cluster-internal IP**
  - This way the Service will be only reachable from within the cluster
  - **This is the default**
- **NodePort** exposes the Service on each Node's IP at a static port specified by the NodePort
  - A ClusterIP Service, to which the NodePort Service routes, is automatically created
  - We can contact the NodePort Service, from outside the cluster, by requesting ***<NodeIP>:<NodePort>***
  - Default range is between **30000** and **32767**

Service Types

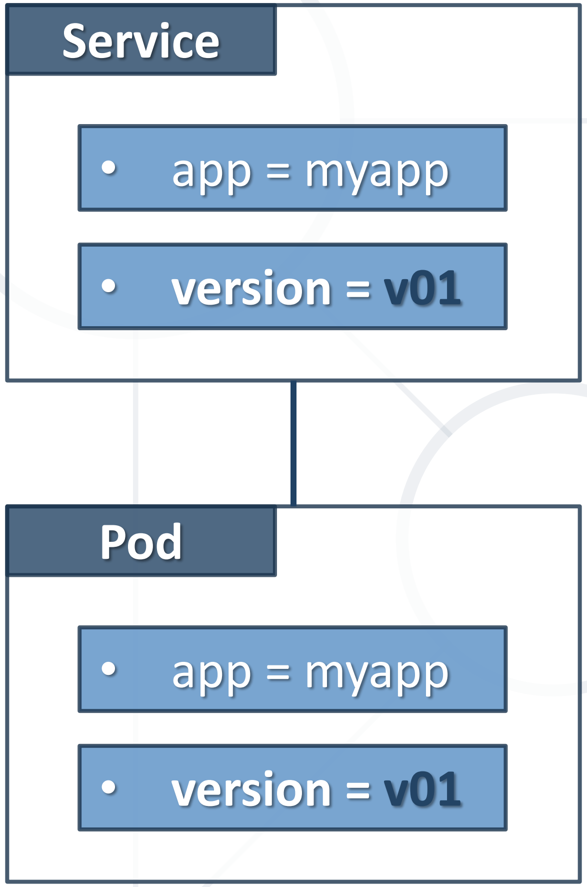
- **LoadBalancer** exposes the Service externally using a cloud provider's load balancer
  - NodePort and ClusterIP Services, to which the external load balancer routes, are automatically created
- **ExternalName** maps the Service to the contents of the **externalName** field (e.g. foo.bar.example.com), by returning a **CNAME** record with its value
  - No proxying of any kind is set up

Service Manifest *

```
apiVersion: v1
kind: Service
metadata:
  name: appa-svc
  labels:
    app: appa
spec:
  type: NodePort
  ports:
  - port: 80
    nodePort: 30001
    protocol: TCP
  selector:
    app: appa
```

* Working but very simple one

Services in Action



Service

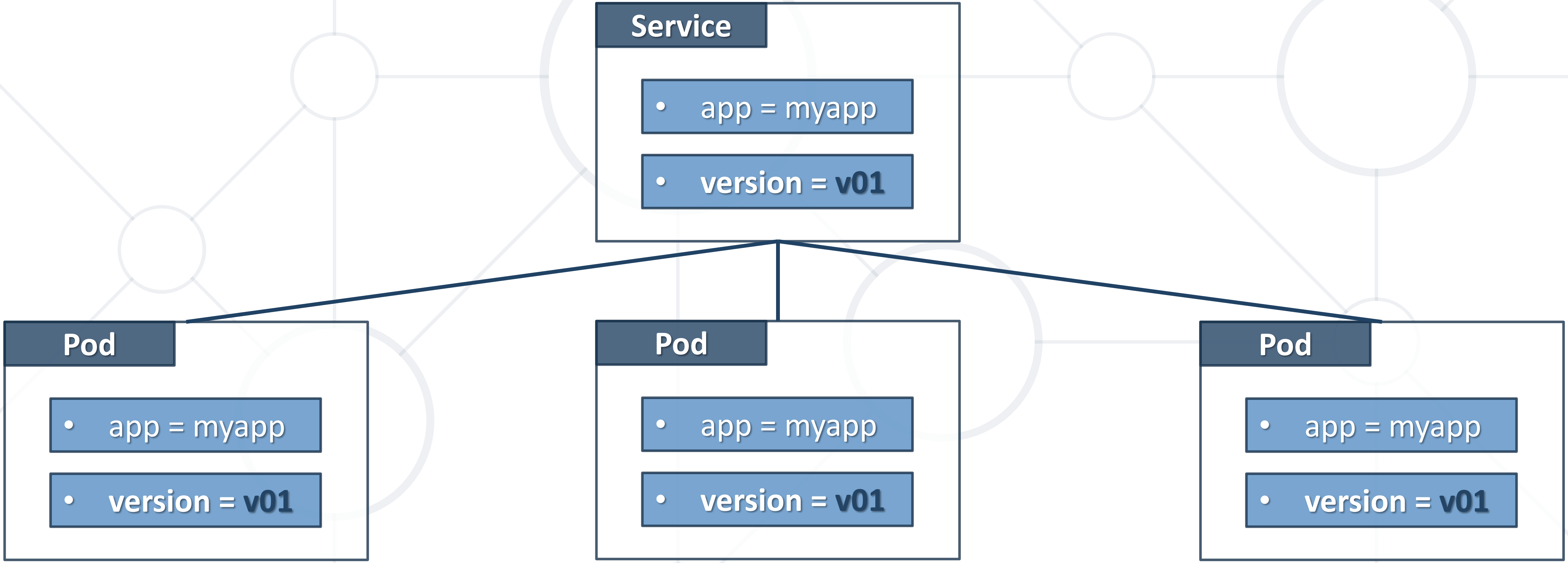
- app = myapp
- **version = v01**

Pod

- app = myapp
- **version = v01**

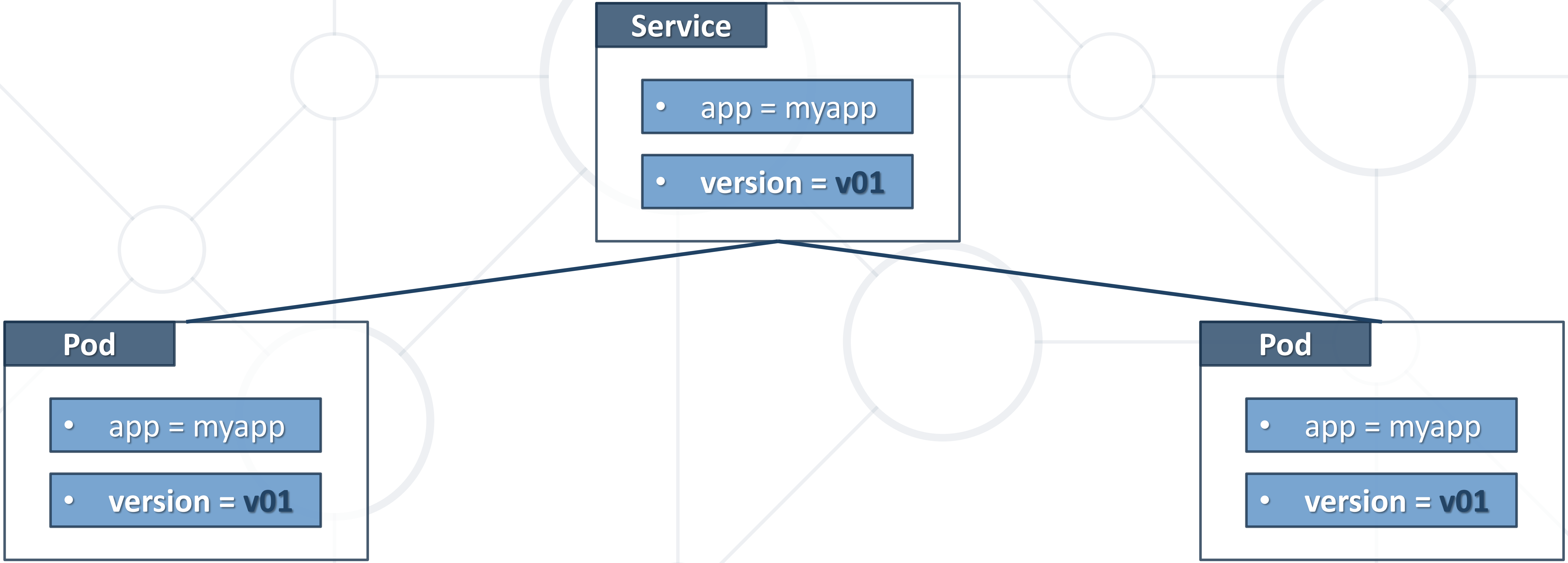
Initial deployment – one pod with version = v01

Services in Action (Scale Out)



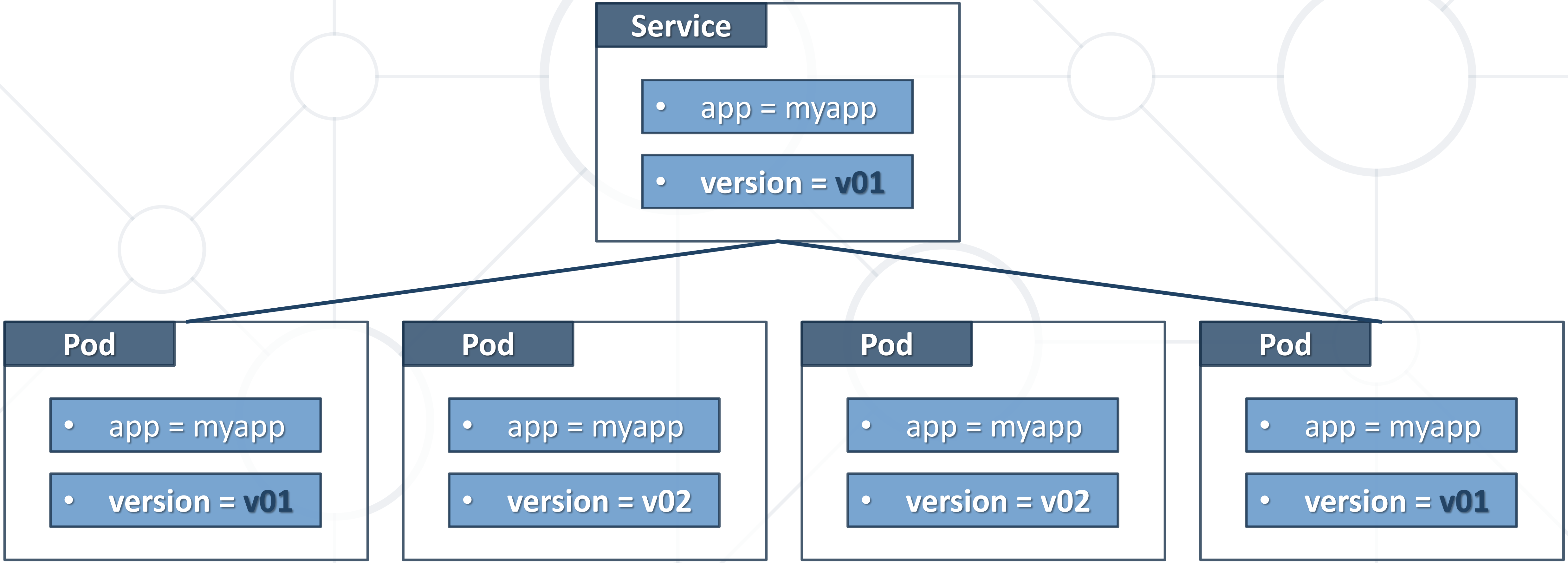
Scale out – two more pods with version = v01

Services in Action (Scale In)



Scale in – remove one pod and end up with two pods with version = v01

Services in Action (App Update)



Service
- app = myapp
- version = v01

Pod
- app = myapp
- version = v01

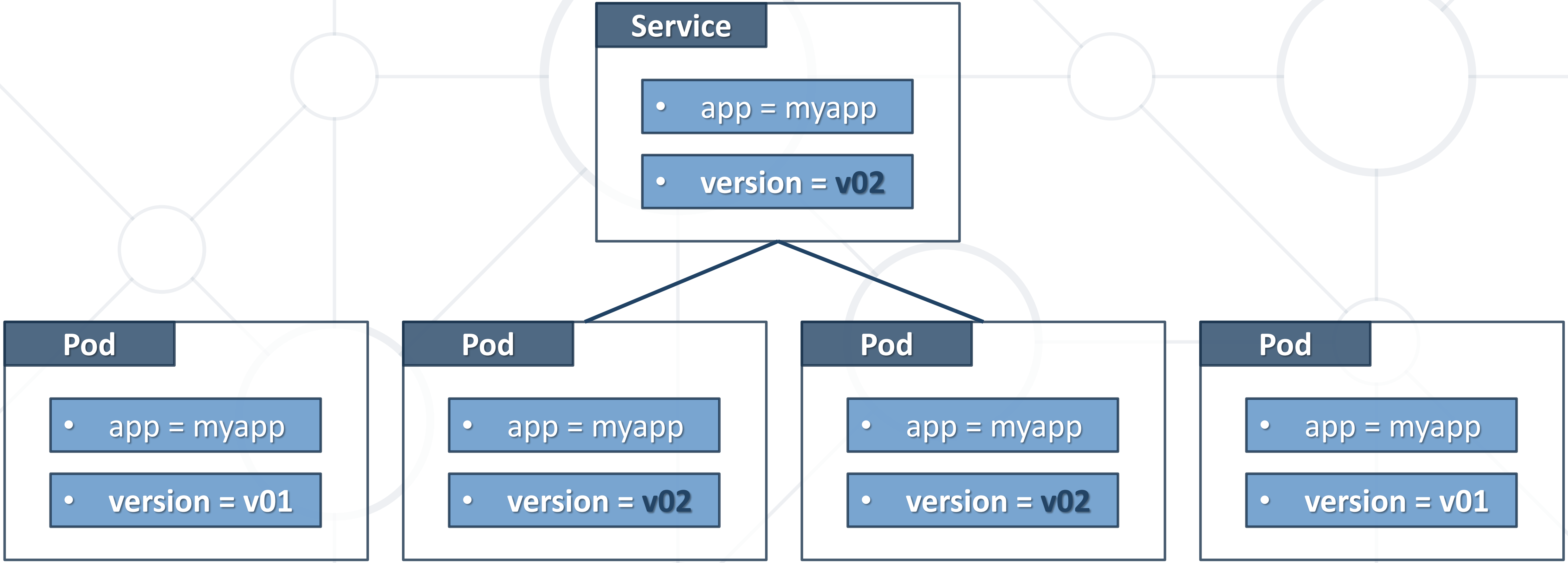
Pod
- app = myapp
- version = v02

Pod
- app = myapp
- version = v02

Pod
- app = myapp
- version = v01

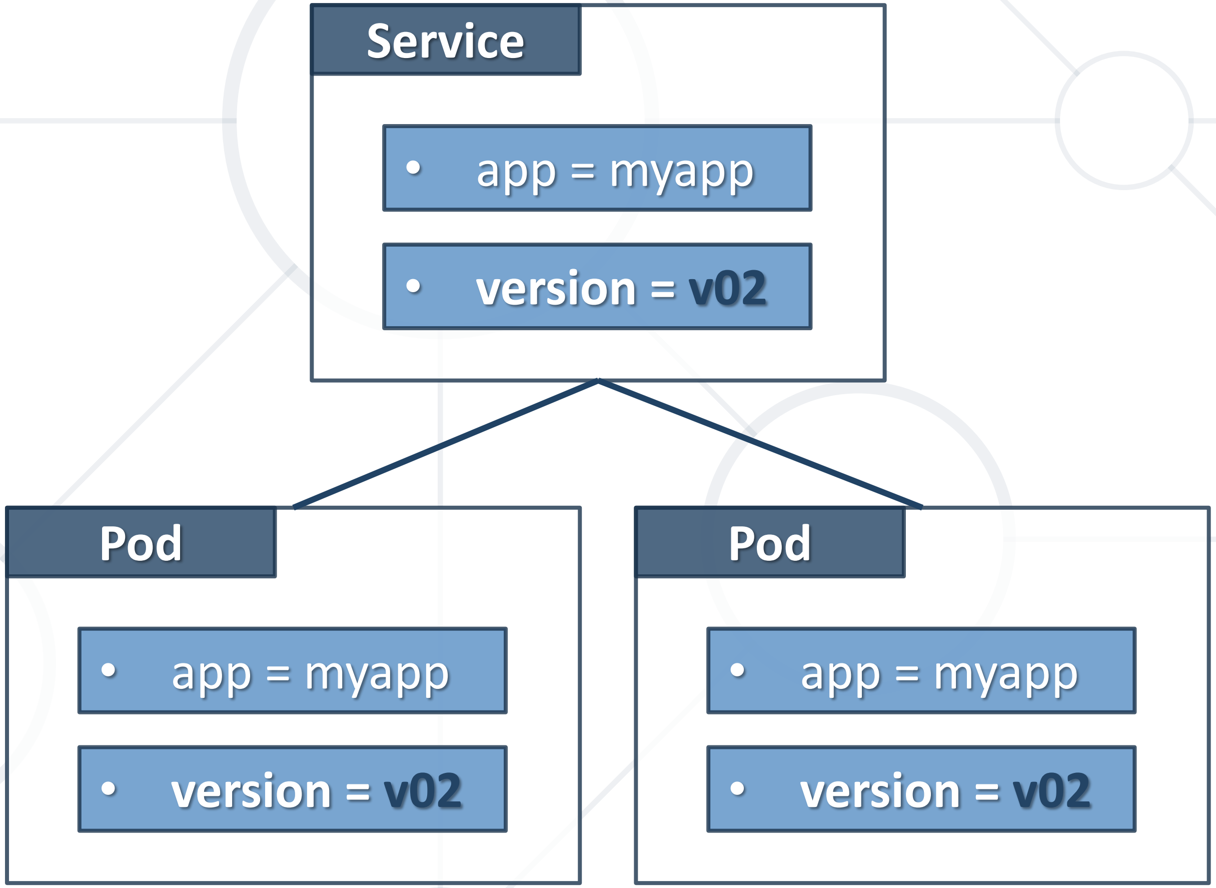
Next step – add two more pods with version = v02

Services in Action (App Update)



Next step – we update the service to look for version = v02

Services in Action (App Update)



Service

- app = myapp
- **version = v02**

Pod

- app = myapp
- **version = v02**

Pod

- app = myapp
- **version = v02**

Finally, all pods with version = v01 are destroyed

Practice

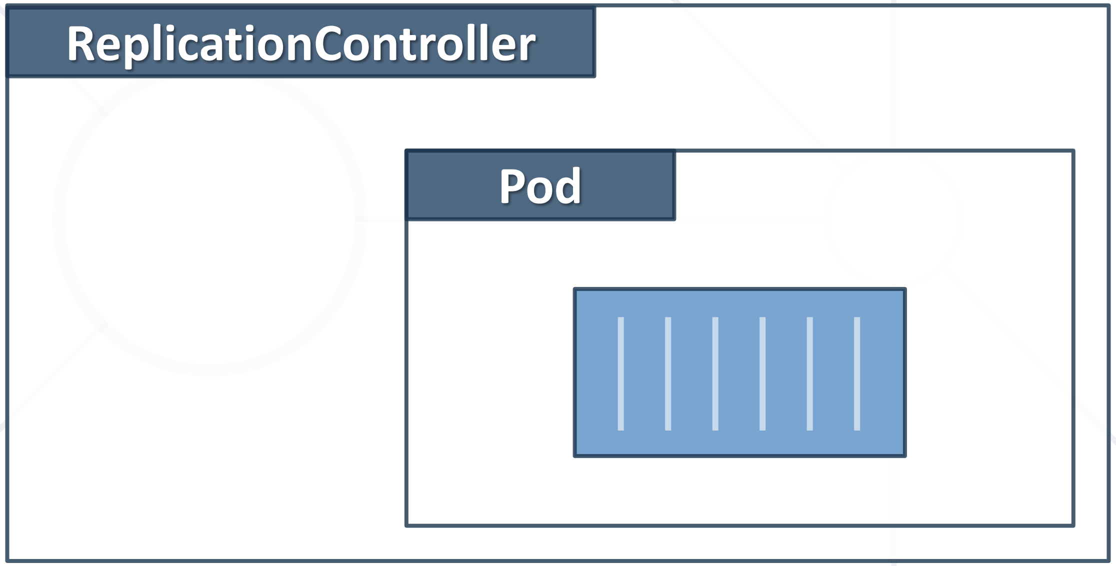
Live Exercise in Class (Lab)

Basic Kubernetes Objects 102

Replication Controllers. Replica Sets. Deployments

Replication Controllers

- **Higher** level workload
- Looks after **pod** or **set of pods**
- **Scale** out/in **pods**
- Sets **Desired State**
- Rarely used these days



https://kubernetes.io/docs/concepts/workloads/controllers/replicationcontroller/

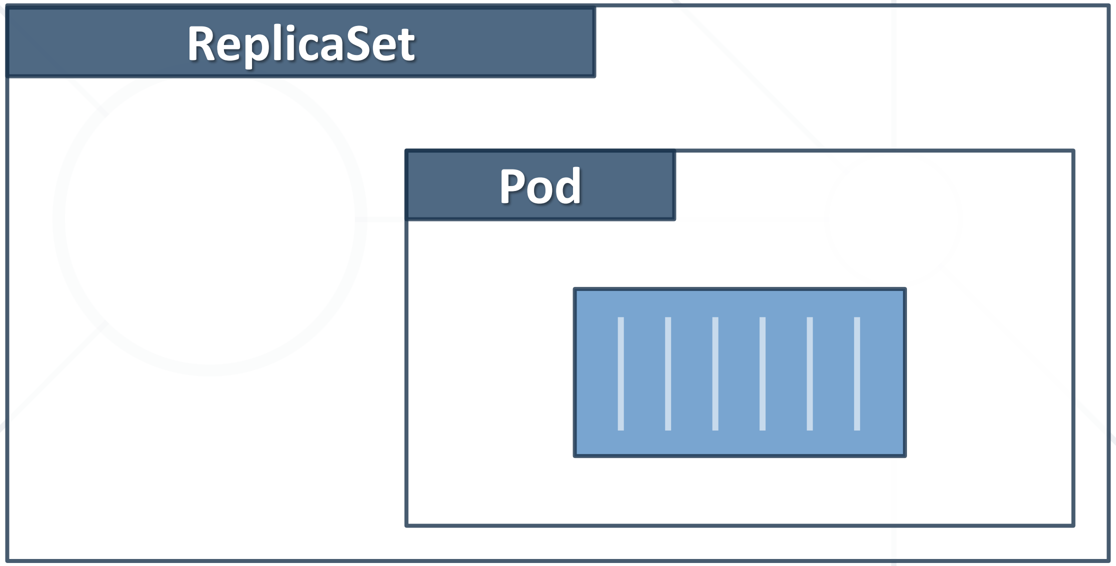
Replication Controller Manifest *

```
apiVersion: v1
kind: ReplicationController
metadata:
  name: appa-rc
spec:
  replicas: 3
  selector:
    app: appa
  template:
    … [POD definition] …
```

* Partial one but with the important parts included (except the pod definition)

Replica Sets

- **Higher** level workload
- Looks after **pod** or **set of pods**
- **Scale** out/in **pods**
- Sets **Desired State**
- Preferred over ***Replication Controllers***
- Rarely used alone by itself



https://kubernetes.io/docs/concepts/workloads/controllers/replicaset/

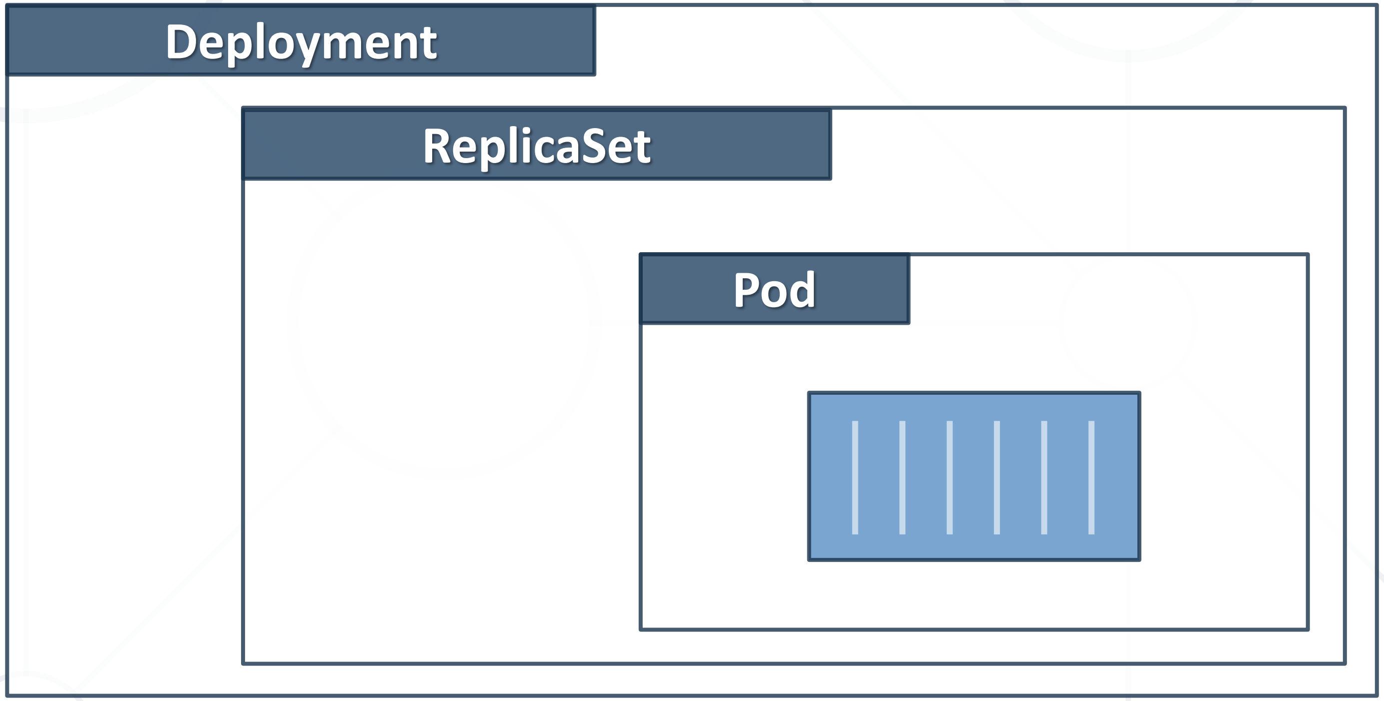
Replica Set Manifest *

```
apiVersion: apps/v1
kind: ReplicaSet
metadata:
  name: appa-rs
spec:
  replicas: 3
  selector:
    matchLabels:
      app: appa
  template:
     … [POD definition] …
```

* Partial one but with the important parts included (except the pod definition)

Deployments

- **Even higher-level** workload
- Simplifies **updates** and **rollbacks**
- **Declarative** and **imperative** approach
- Self-**documenting**
- Suitable for **versioning**



https://kubernetes.io/docs/concepts/workloads/controllers/deployment/

Deployment Manifest *

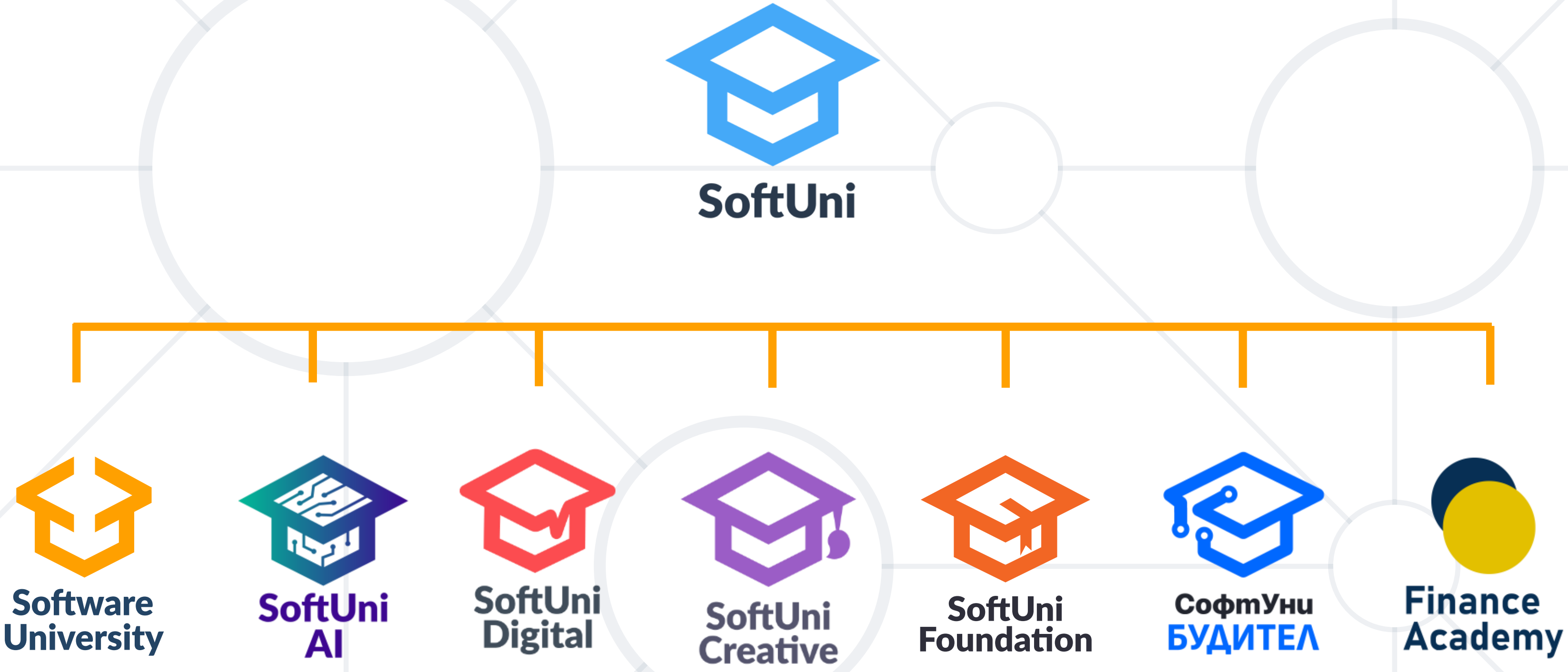
```
apiVersion: apps/v1
kind: Deployment
metadata:
  name: appa-deploy
spec:
  replicas: 3
  selector:
    matchLabels:
      app: appa
  minReadySeconds: 15        # optional, default 0
  strategy:                  # the whole block can be skipped
    type: RollingUpdate      # strategy to replace old pods, defaults to RollingUpdate
    rollingUpdate:
      maxUnavailable: 1      # maximum number of unavailable pods, defaults to 25%
      maxSurge: 1            # maximum number of pods that can be created in excess, defaults to 25%
  template:
     … [POD definition] …
```

* Partial one but with the important parts included (except the pod definition)

Practice

Live Exercise in Class (Lab)

Questions?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