

Kubernetes Technical Primer



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Content Notes



This guide is not intended to be delivered as a complete presentation

It can be used as a learning guide or hand out

Alternatively take out sections or slides and use/present as needed

Target Audience



Technical architects, developers and platform engineers

Those wanting to learn the core fundamentals of Kubernetes

Not for those trying to deploy Kubernetes from scratch or get into internals

Introduction To Kubernetes

What is Cloud Native?
The need for orchestration
Kubernetes: the industry leading orchestrator
The elements of orchestration
Why Choose Kubernetes?
Kubernetes – A Modern Orchestrator
Core Concepts and Terms
Simplified Architecture
Internal Architecture
Highly Extensible

Core Components

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Services
Services – Illustrated
DNS and Service Discovery
Data Volumes & Mounts
Persistent Volumes
Stateful Sets
Daemon Sets
Jobs & CronJobs
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Role Based Access Control (RBAC)
Putting It All Together

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Commands & Arguments

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External DNS
Cert Manager
Putting It All Together

Debugging and Troubleshooting Workloads

Describing Objects
Container Logs
Get Shell Access

Advanced Pod Configuration

Deeper Dive on Manifests
Init Containers
Node Selector
Affinity and Taints
Sidecars

Scaling

Manually Scaling
Horizontal Pod Autoscaler (HPA)
Cluster Autoscaler (CA)

Extending Kubernetes

Custom Resource Definitions
Operators

DevOps

Modern Infrastructure
DevOps Containers Lifecycle Loop
Cluster Isolation Patterns: Physical Isolation
Cluster Isolation Patterns: Logical Isolation
Helm Introduction
Helm – The Basics

Azure Kubernetes Service

Managed Kubernetes on Azure – AKS
AKS Virtual Nodes
AKS Networking Models
AKS Advanced Networking
Azure Active Directory
'HTTP application routing' Add-On
'Monitoring' Add-On
Bridge To Kubernetes

Additional Resources

MAIN SECTIONS

Introduction To
Kubernetes



Core Components



Using Kubernetes



Beyond The Basics



DevOps



Azure Kubernetes
Service



Introduction To Kubernetes



What is Cloud Native?

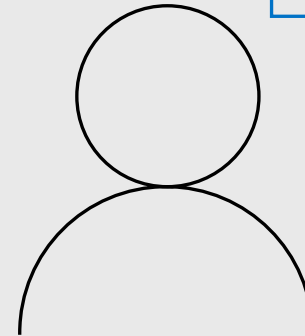
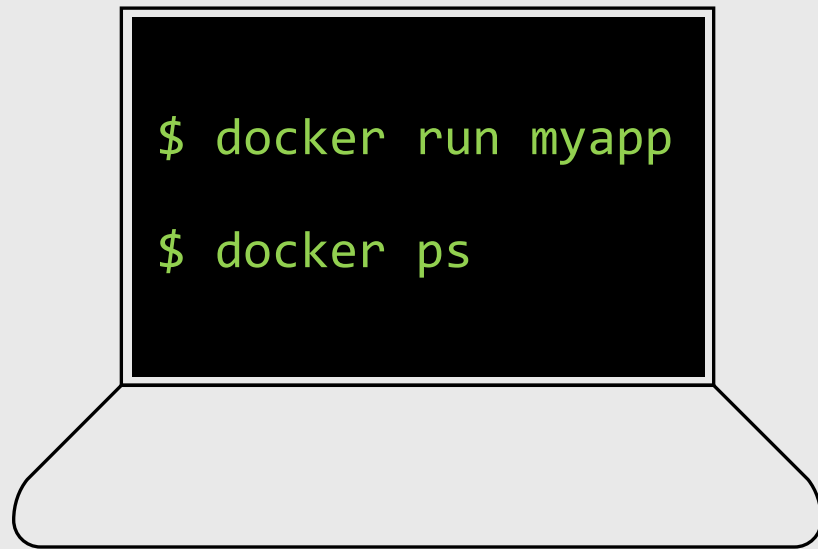
“Cloud native technologies empower organizations to build and run scalable applications in **modern, dynamic environments** such as public, private, and hybrid clouds. **Containers, service meshes, microservices**, immutable infrastructure, and declarative APIs exemplify this approach.

These techniques enable **loosely coupled systems** that are **resilient, manageable, and observable**. Combined with **robust automation**, they allow engineers to make high-impact changes frequently and predictably with minimal toil.”



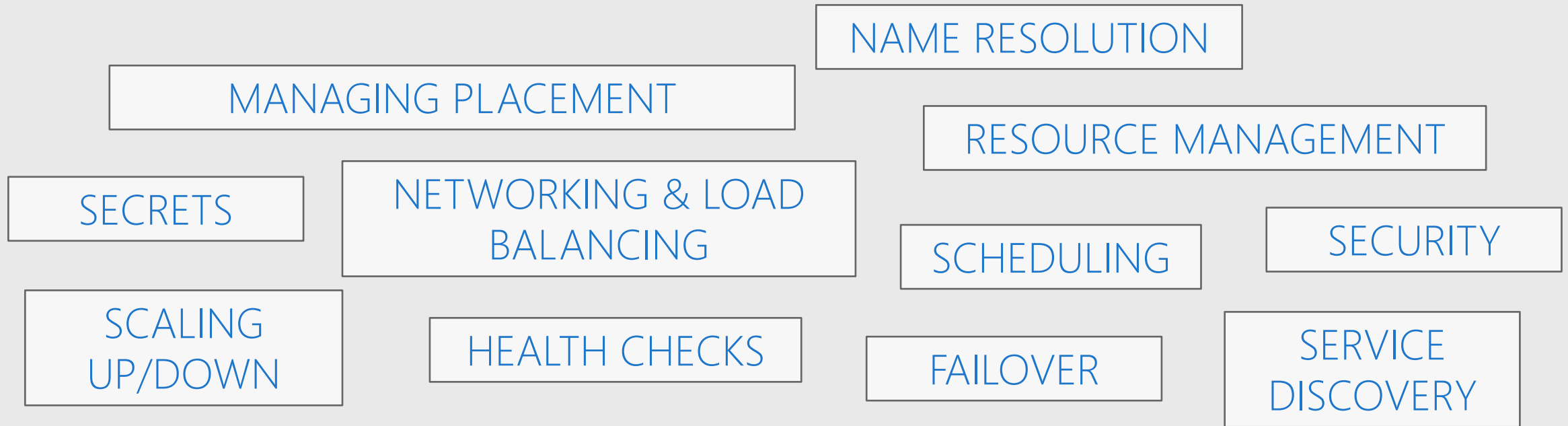
CLOUD NATIVE
COMPUTING FOUNDATION

The need for orchestration



OK great,
But now what?

The need for orchestration



Production And At Scale

Kubernetes - production grade orchestration



Portable

Public, private, hybrid,
multi-cloud

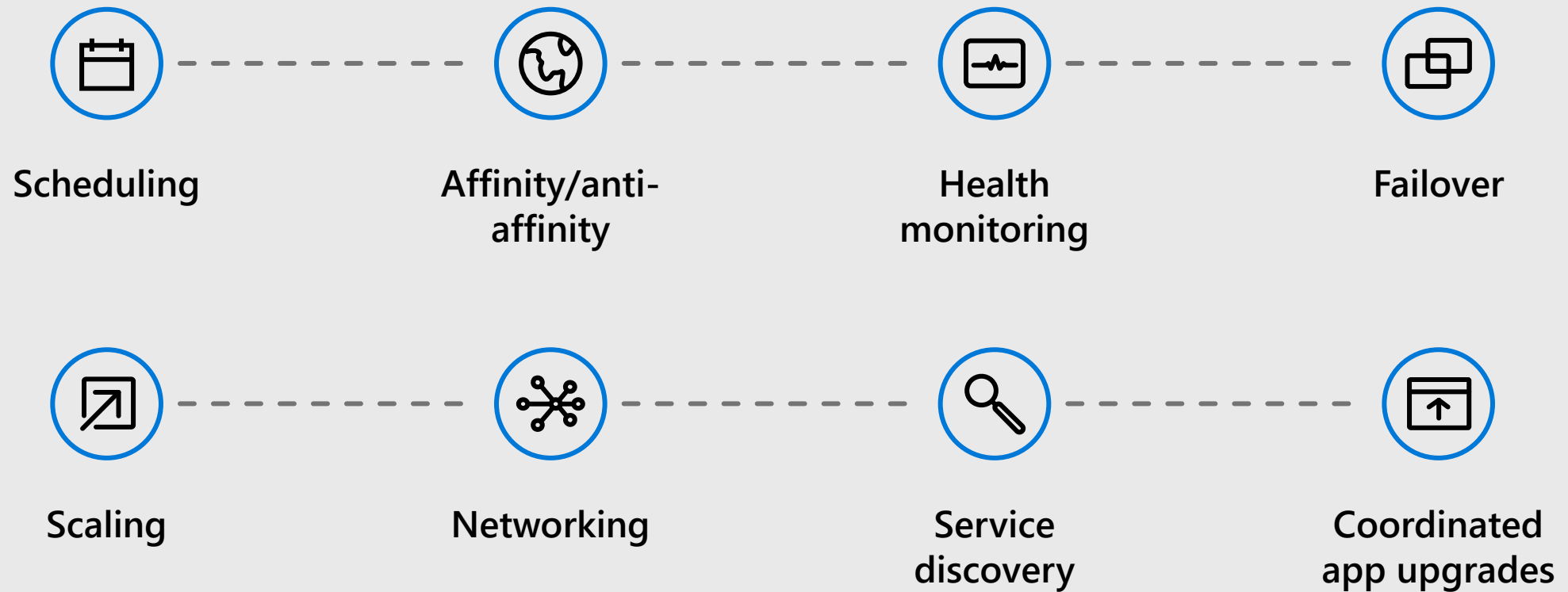
Extensible

Modular, pluggable,
hookable, composable

Self-healing

Auto-placement, auto-restart,
auto-replication, auto-scaling

The elements of orchestration



Why Choose Kubernetes?



Cornerstone of cloud native approach



Run anywhere



Industry adoption



Open Source with high degree of support



Avoids lock-in



Skills availability

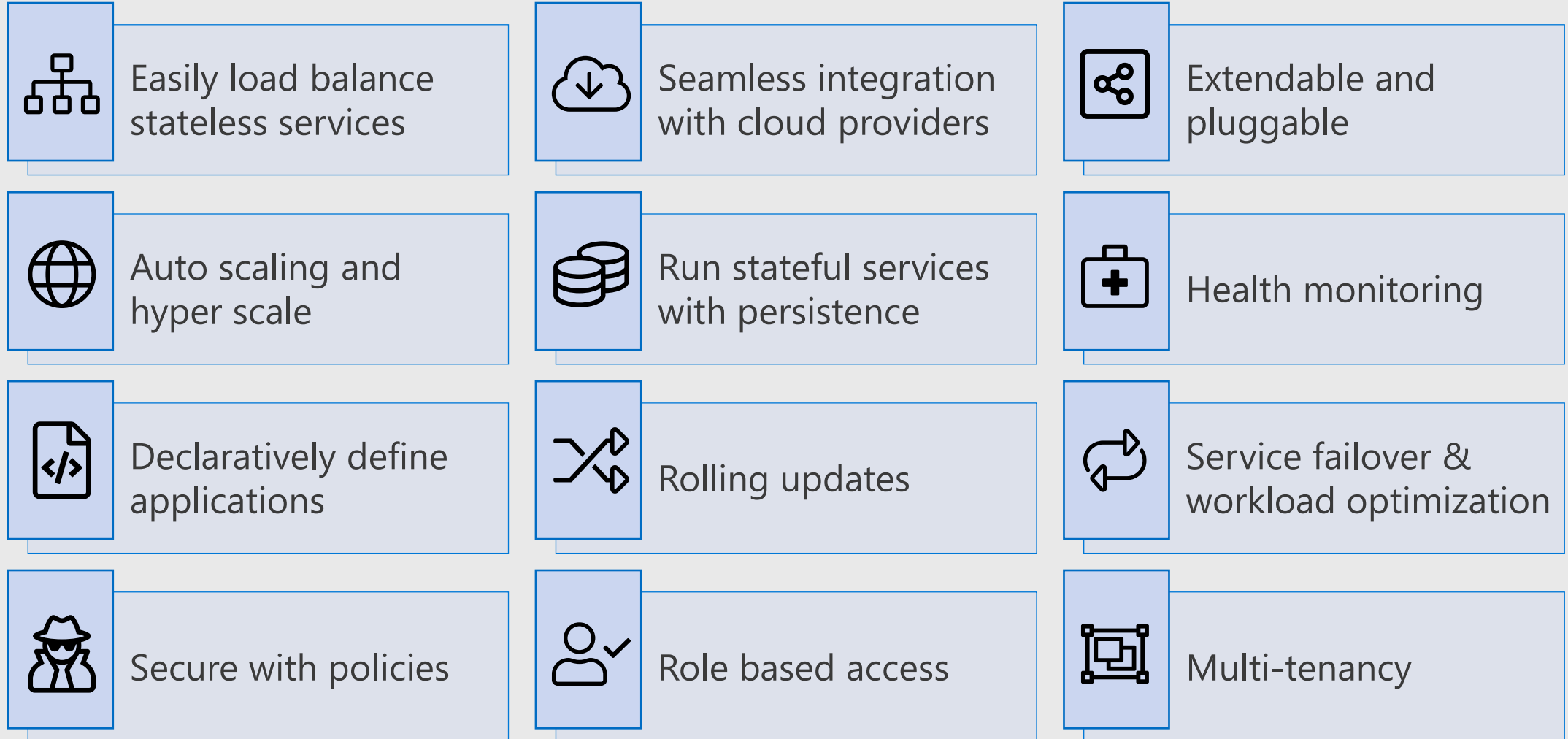


Large & growing ecosystem

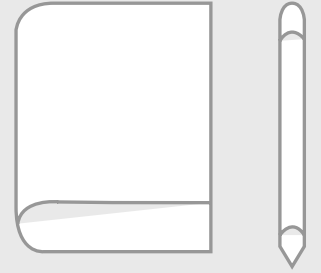


Rise of microservices & containers

Kubernetes – A Modern Orchestrator



Core Concepts and Terms



Node

A worker machine (VM) normally clustered, each capable of running pods



Deployment

A logical object for managing a replicated application (i.e. set of pods)



Label

Metadata attached to any object for configuration and selection



Pod

A group of one or more containers that is lifecycle managed



Service

Network access to a resource, e.g. pod or port. Typically load balanced

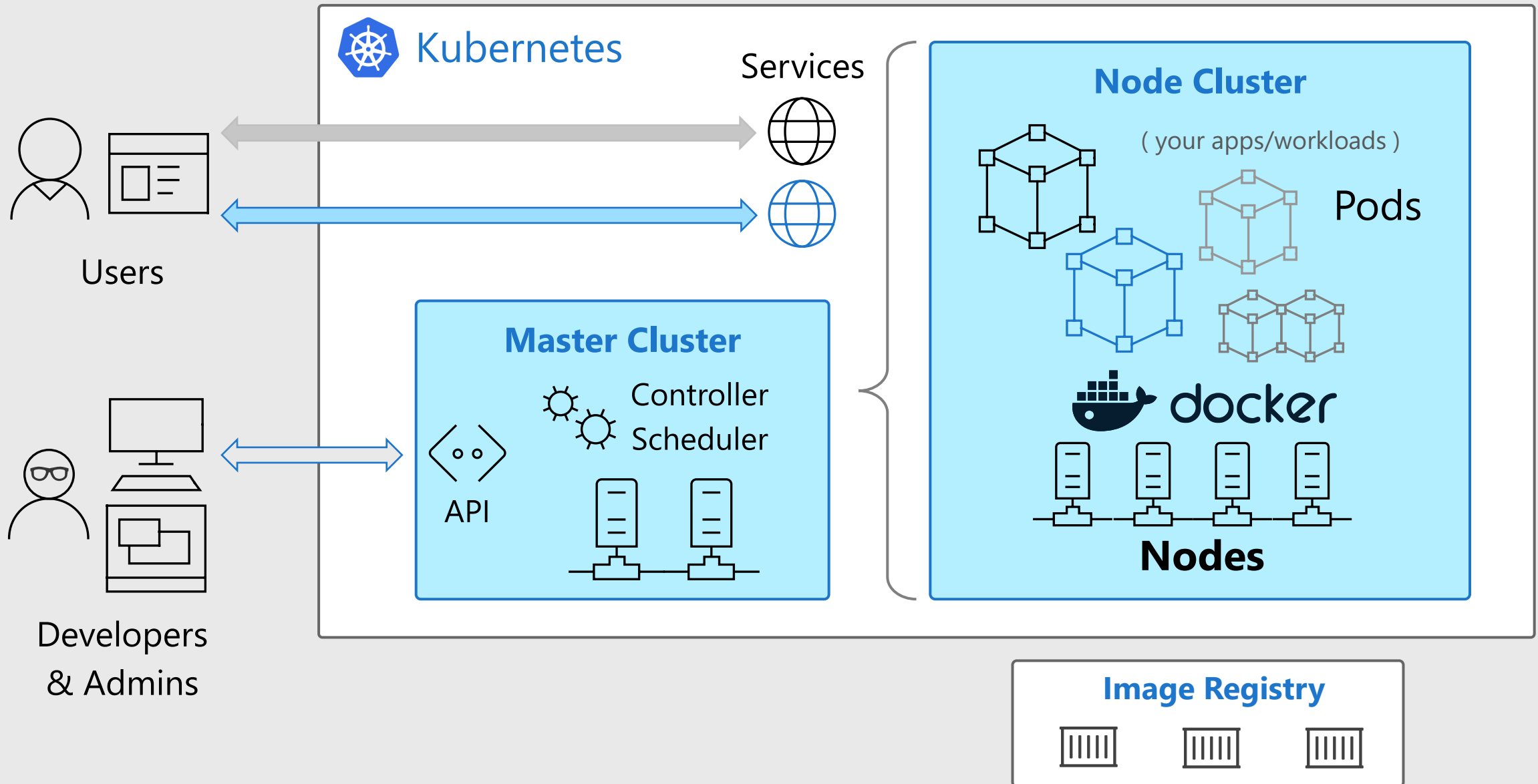


Replica Set

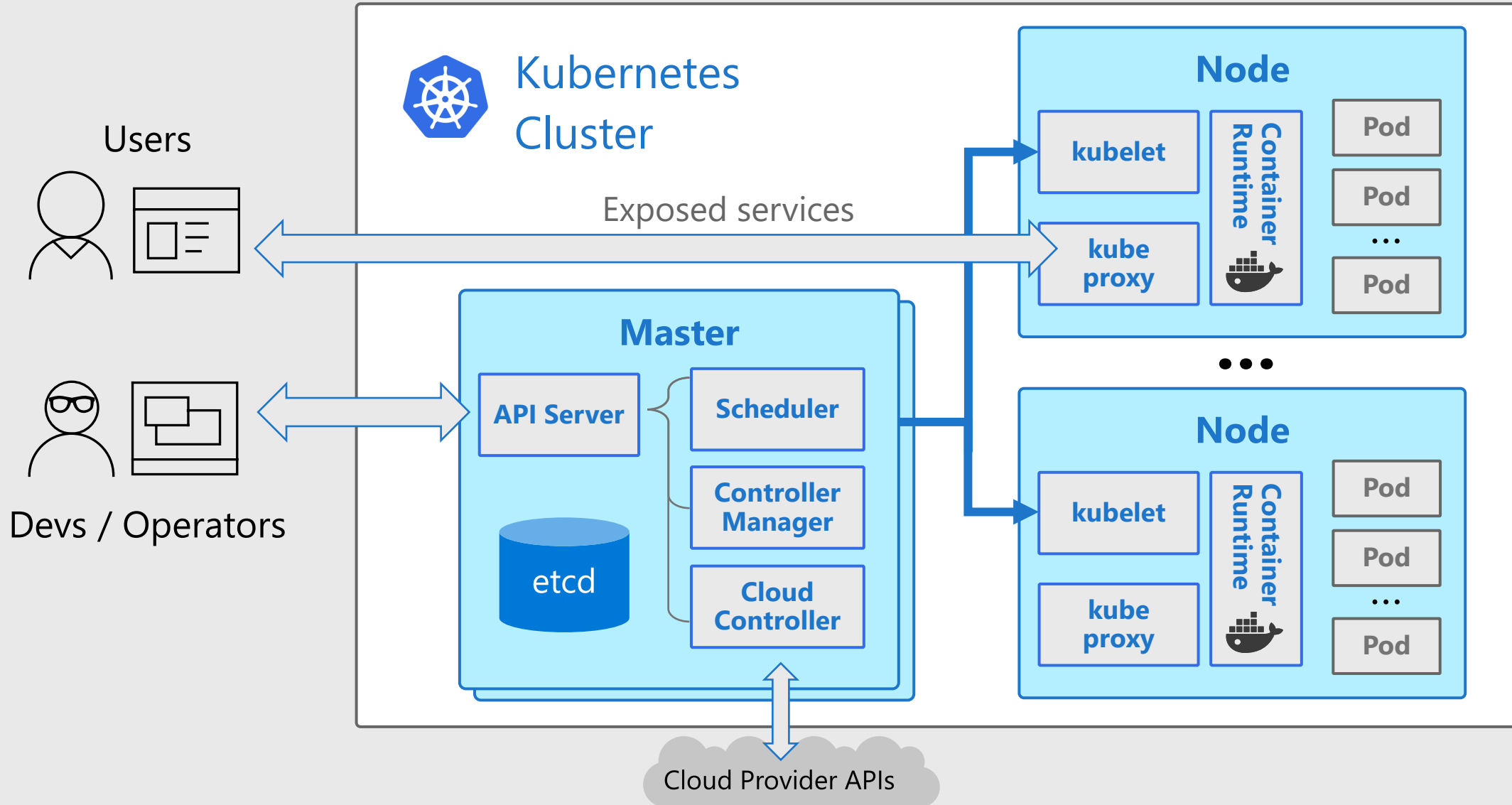
A set of one or more pods that is distributed and replicated across Nodes



Simplified Architecture



Internal Architecture



Highly Extensible / Unopinionated

- Kubernetes is not a rigid pre-configured system
- Extendable by design – many optional components
- Defers to addons and extensions for specific tasks



Kubernetes Tool Box

Auto Scaler

Log Collection

TLS Cert
Manager

Custom
Resource

Dashboard

Nginx Ingress

External DNS

Service Catalog

Virtual Kubelet

Helm



Core Components



Pods

Fundamental building block of Kubernetes

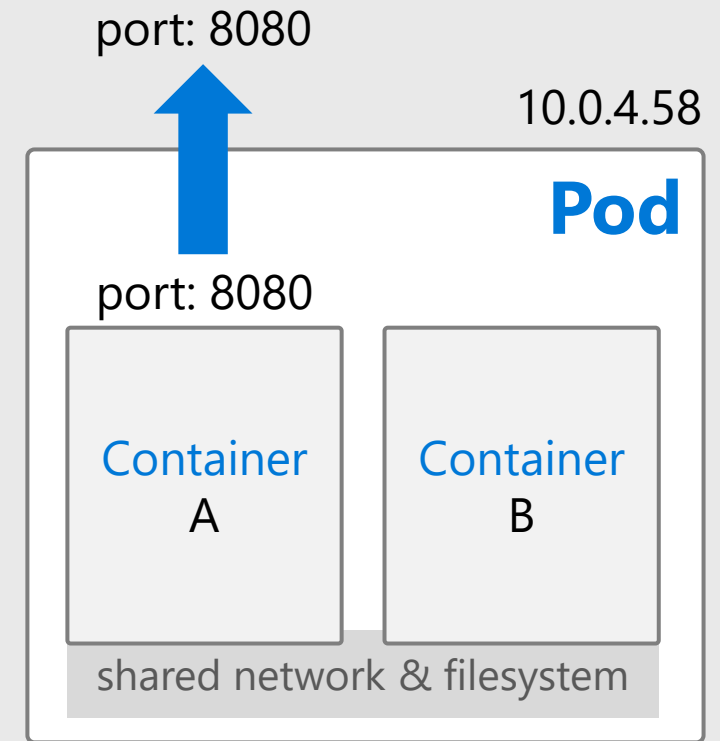
Pods run **one or more** containers

Containers in a pod **share network/storage**

Pods each have their own IP address

Pods expose **one or more** ports

Pods are scheduled and run on a *Node*



Example Pod

Pods are the primary way of running your workloads in Kubernetes

Deployments & Replica Sets

Scale and run pods across multiple nodes

Deployments describe a **replicated** set of *Pods*

A *Deployment* represents **desired state**

- Rolling updates used to safely roll out changes

You **scale** *Deployments* up & down

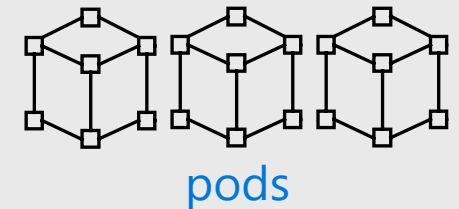
Deployments typically run **stateless** workloads

Deployments use *ReplicaSets*

```
Deployment
- name: MyApp
- replicas: 3
```



```
ReplicaSet
- replicas: 3
```



Deployments let you run & scale stateless workloads in Kubernetes

Services

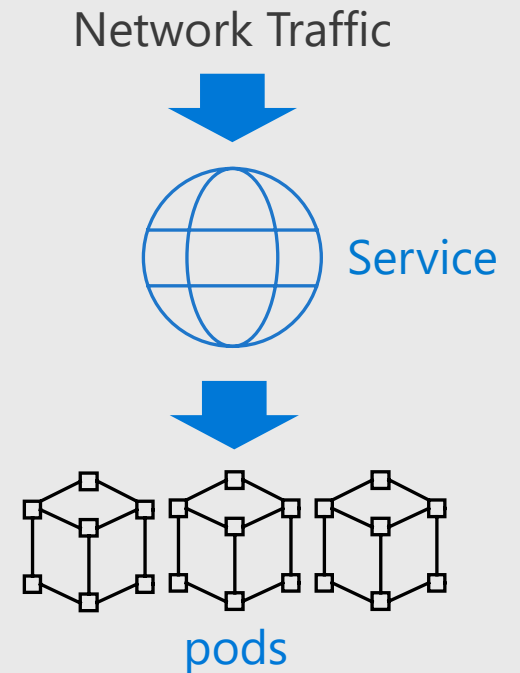
Network access to Pods

Pods are ephemeral - they can move/die/change without notice. In general, users do not directly access *Pods*

Services are an abstraction which defines a **logical set** of *Pods* and a policy by which to access them

Services use labels and selectors to map to *Pods*

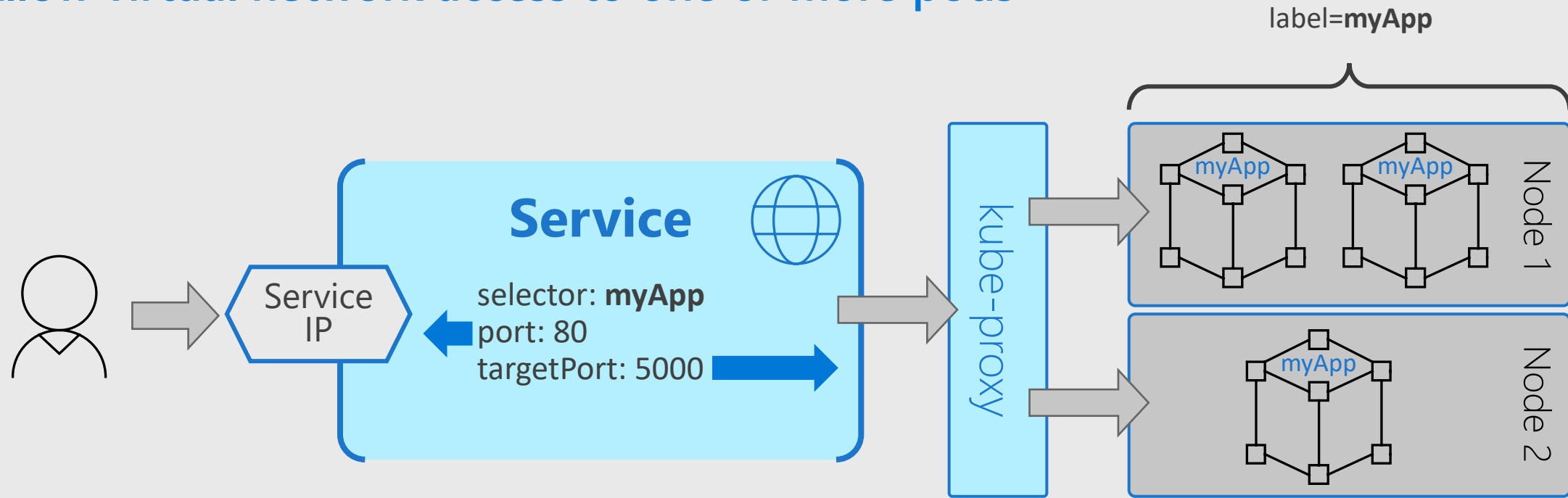
Services are assigned IP addresses and DNS names



Services are how you connect to Pods over the network

Services – Illustrated

Allow virtual network access to one or more pods



EXTERNAL

LoadBalancer

Uses cloud provider to present an external load-balanced IP

INTERNAL

ClusterIP

Internal virtual IP, only accessible by other pods/services

Note. Uses 'round robin' to select pods

DNS and Service Discovery

Naming for Pods and Services

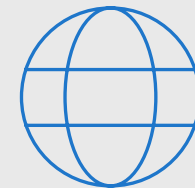
DNS in cluster is handled automatically by Kubernetes

All ClusterIP (internal) *Services* get assigned a DNS record based on the service's name

Pods also get DNS names, but this is less useful

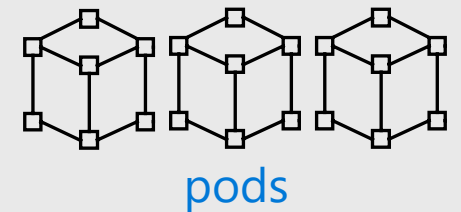
External public DNS can also be configured – See “Additional Network Services” section later

```
$ nslookup myapp  
Address: 10.200.4.30
```



```
Service  
- name: myapp
```

Service IP: 10.200.4.30



Connect to your workloads using DNS and Services

Data Volumes & Mounts

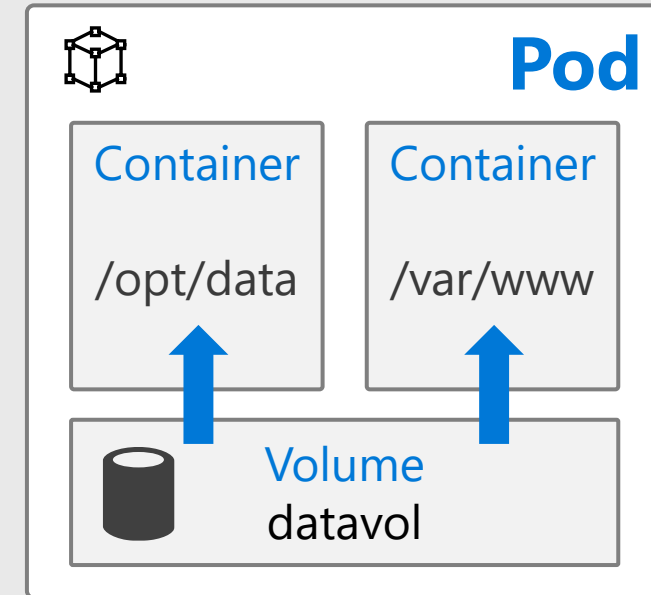
Handling State & Data

Filesystem of running containers is ephemeral. All data written will be lost on a restart

Use **Volumes** to hold data or state you want to keep, or to inject data into a *Pod*

Volumes are mounted into a container at a **mountPath**

Many types of storage can be used to back the Volume



Warning! A volume shares lifecycle with the Pod, so are not persistent

Volumes hold data and state for Pods and containers

Persistent Volumes

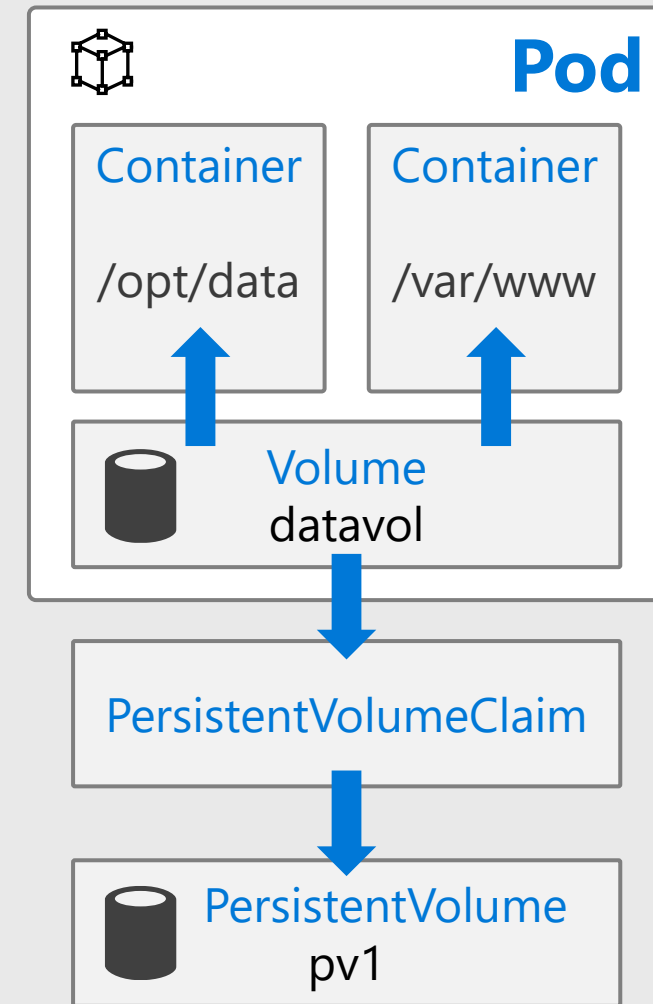
Handling State & Data

A *PersistentVolume* allows you to hold data independent of Pod lifecycle

A pod uses a *PersistentVolumeClaim* to bind to a *PersistentVolume*

- **ReadWriteOnce** - mounted on a single Node (e.g. db)
- **ReadWriteMany** - mounted on multiple Nodes

Many **storage plugins** exist: NFS, iSCSI, Azure (Disk & Files), Flocker, Ceph, Gluster, AWS



Persistent Volumes retain data long term, outside of Pods

Stateful Sets

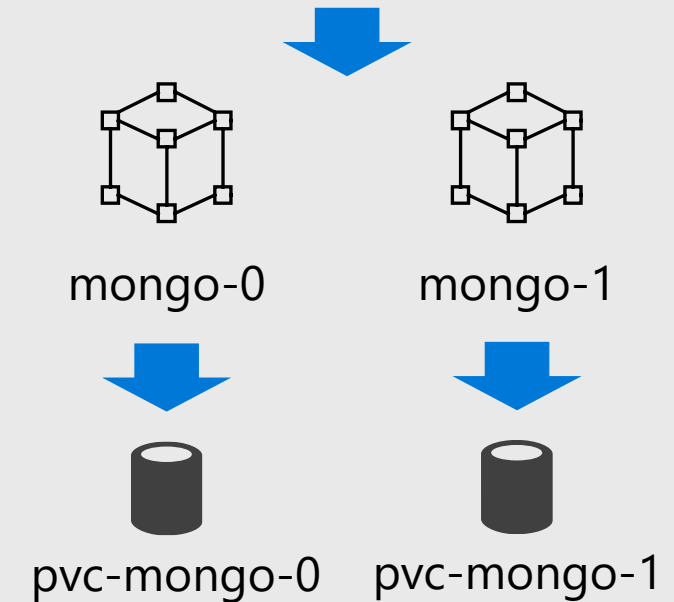
Handling Stateful workloads

A *StatefulSet* is like a *Deployment* except *Pods* get well defined names and replicas start in **ordered sequence**

StatefulSets **retain identity** regardless of which *Node* they run on

Each *Pod* in a *StatefulSet* will bind to the same defined *PersistentVolumeClaim*

```
StatefulSet
- name: MyDbSet
- serviceName: "mongo"
- replicas: 2
```



Use a StatefulSet rather than Deployment for stateful workloads

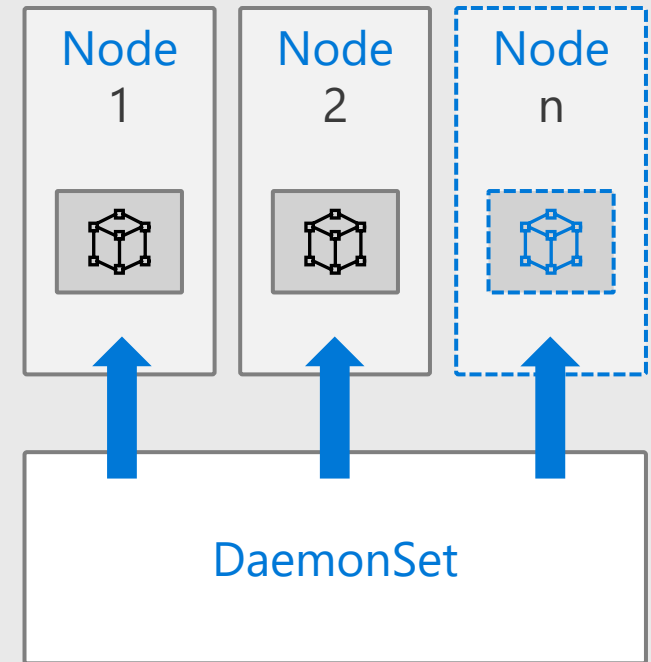
Daemon Sets

Running Pods across all Nodes

A *DaemonSet* ensures that all *Nodes* in the cluster run a given *Pod*. *Pods* will be **created/removed as *Nodes* are added/removed**

Used for special system and cluster daemons, logging, storage, etc.

DaemonSets are **not** often used for normal app workloads



DaemonSets run system Pods for monitoring & network

Jobs & CronJobs

Workloads that run to completion

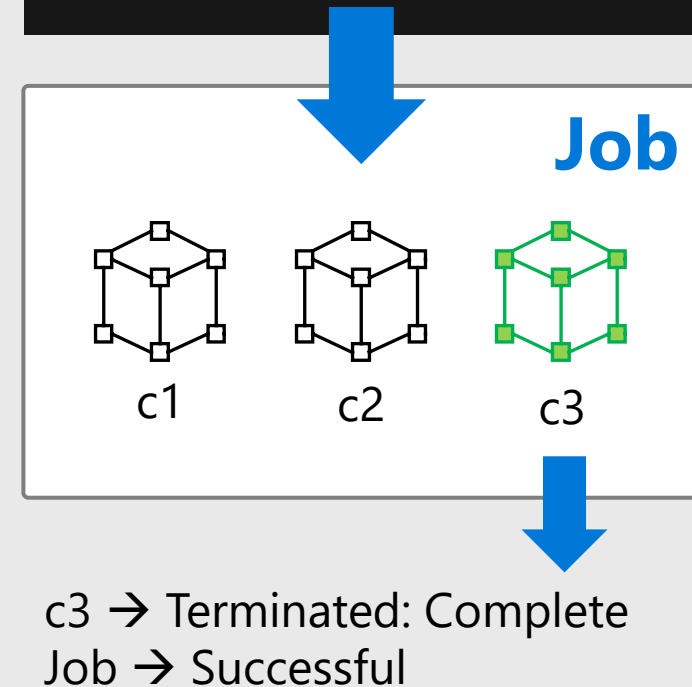
A *Job* creates one or more pods and ensures that a specified number of them successfully terminate

Jobs can run in **serial** or **parallel**

Control of number of failures, completions, restart policy and level of parallelism

CronJobs allows you to **schedule** *Jobs* to be run

```
kind: Job
spec:
  completions: 1
  parallelism: 3
```



Use Jobs for any workloads that run in batch or perform one off tasks

Namespaces

Logical Separation & Cluster Organisation

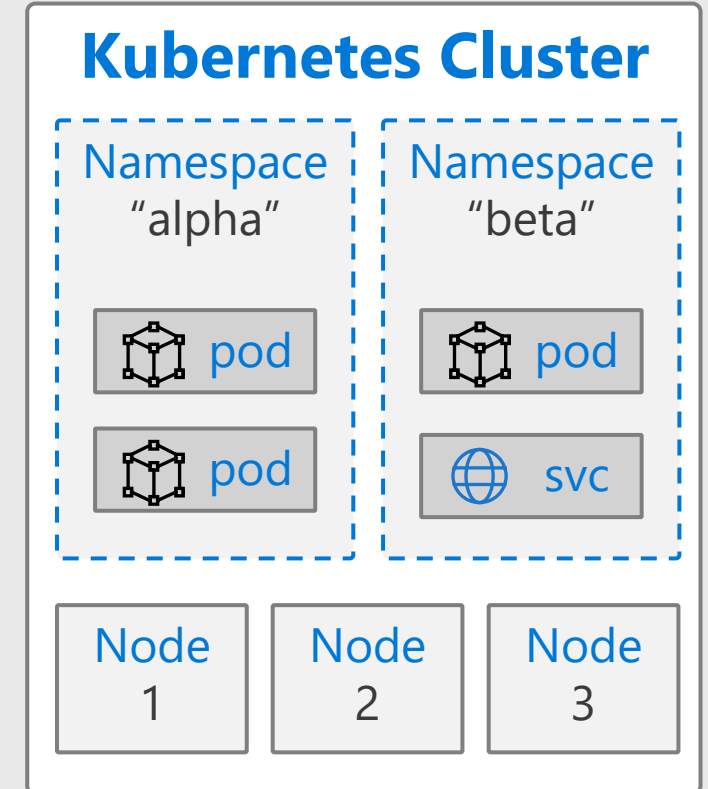
Most Kubernetes objects live inside a *Namespace*

Kubernetes starts with two *Namespaces*: **default** and **kube-system**

You can create *Namespaces* to **logically partition** a cluster, e.g. for dev/test or different customers

Nodes will be **shared** across *Namespaces*

A namespace does ***not*** provide isolation & multi-tenancy



When first learning Kubernetes use the default Namespace

Role Based Access Control (RBAC)

Regulating & governing access

RBAC controls user and system access to the API and Kubernetes resources

Roles define privileges as sets of **verbs** and API resources

RoleBinding grants *Roles* to *Users* and *ServiceAccounts*

Kubernetes has many authentication and authorization schemes. This complex area is deemed out of scope for this guide



RoleBinding



```
kind: Role
name: pod-reader
rules:
  resources: ["pods"]
  verbs: ["get", "watch", "list"]
```



Verb: **get, delete, create, list, update, watch**

API: **pods, secrets, services, jobs, nodes, ingresses**

RBAC is optional, but is becoming standard for any cluster

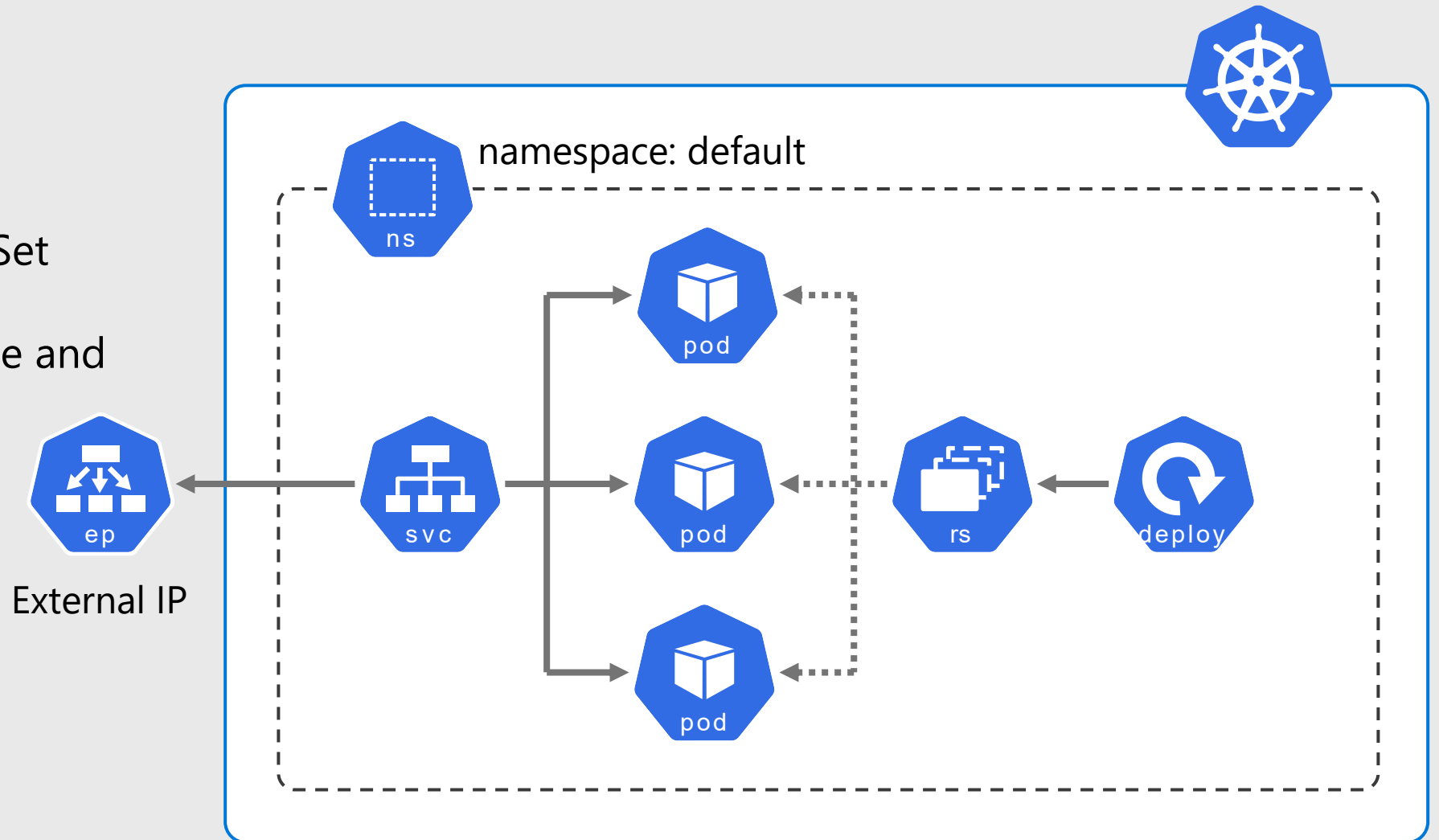
Putting It All Together

Sample Architecture – Simple App

Basic web application

Running in 3 pods via a
Deployment and ReplicaSet

With LoadBalancer service and
external IP



Using Kubernetes



Command Line - kubectl

Main management & control
interface to Kubernetes

Single executable binary

Can manage several clusters

Secure interface to Kubernetes API

Used for cluster ops and application
deployment & management

```
ben@Azure:~$ kubectl get nodes
NAME                                STATUS    ROLES    AGE
aks-agentpool-25884925-0           Ready     agent     35d
aks-agentpool-25884925-1           Ready     agent     28d
aks-agentpool-25884925-2           Ready     agent     28d
ben@Azure:~$
ben@Azure:~$
ben@Azure:~$ kubectl run nginx --image nginx
deployment.apps/nginx created
ben@Azure:~$
ben@Azure:~$ kubectl get deploy
NAME            DESIRED    CURRENT    UP-TO-DATE    AVAILABLE
data-api        3          3          3             3
frontend        2          2          2             2
nginx           1          1          1             1
party-clippy    1          1          1             1
ben@Azure:~$
```


Kubectl – Common Commands

get	delete	apply	run	describe
Display one or many resources	Delete resources	Create resources from YAML	Directly start and run pods	Get details of any resource
<pre>get nodes get pods get all get pod/myPod get nodes -w</pre>	<pre>delete deploy/mydeploy delete -f myapp.yaml delete -l app=foo</pre>	<pre>apply -f myapp.yaml</pre>	<pre>run nginx --image=nginx --replicas=3 run myapp --image=foo/img --port=8080</pre>	<pre>describe pod/pod138 describe svc/myservice describe pod -l app=myapp</pre>



kubernetes.io/docs/reference/kubectl/cheatsheet

kubernetes.io/docs/reference/kubectl/overview

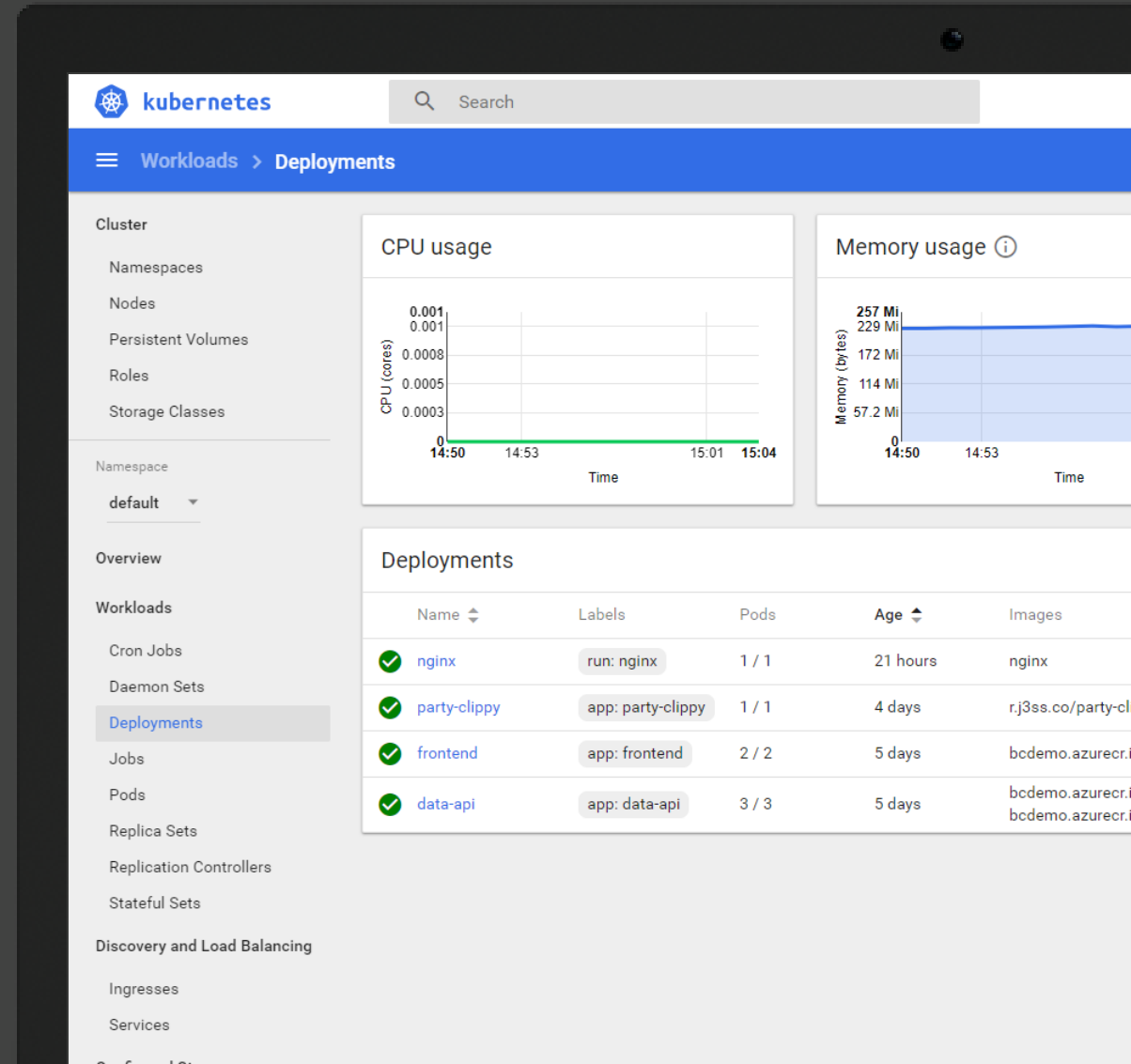
Dashboard

Management web UI

Runs inside Kubernetes as a pod

Not secure, should never be exposed externally

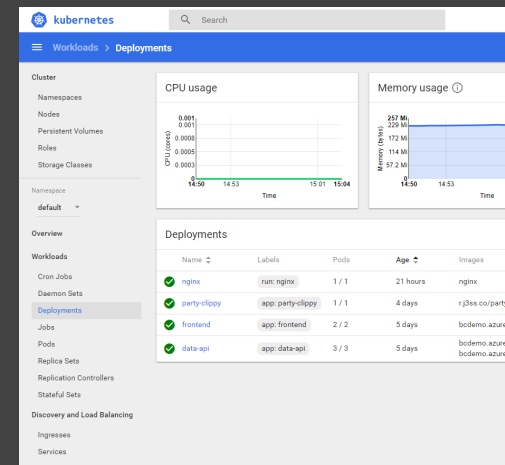
Optional, not required to run Kubernetes



Accessing the Dashboard

- Open proxy to Kubernetes API server
- Run command: `kubectl proxy`
- Access this URL

<http://localhost:8001/api/v1/namespaces/kube-system/services/kubernetes-dashboard/proxy>



Kubernetes Object Management

Three methods of managing Kubernetes



kubernetes.io/docs/concepts/overview/object-management-kubectl

Management Technique	Operates On	Recommended Environment	Learning Curve	Infrastructure As Code
Imperative commands	Live objects	Dev projects	Lowest	No
Imperative object configuration	Individual files	Production use	Moderate	Limited
Declarative object configuration	Individual & multiple files	Production use	Highest	Yes

File based declarative object configuration
is the most common approach used

Introduction to the Declarative Model

YAML or JSON documents

Describe any Kubernetes object

Objects & properties map directly to the Kubernetes API

You can combine multiple objects into a single file (separate with ---)

Note. JSON is also supported, but YAML is recommended for readability

```
kind: Deployment
apiVersion: apps/v1
metadata:
  name: mydeploy
spec:
  replicas: 4
  selector:
    matchLabels:
      app: myapp
  template:
    metadata:
      labels:
        app: myapp
    spec:
      containers:
      - name: mycontainer
        image: bencuk/vuego-demoapp
        ports:
        - containerPort: 4000
```



This is a deployment object, called '**mydeploy**'



It will run 4 replicas of a pod matching the label **app=myapp**



Each pod will be labelled with **app=myapp** and



Runs a container from image **bencuk/vuego-demoapp**



Port 4000 will be exposed from the container

Idempotent Updates & Desired State

Files can describe **desired state** of the objects you configuring

```
kubectl apply
```

Kubernetes applies updates in **idempotent** way, modifying objects only if needed

Idempotency: "The definition of the target state can be applied multiple times and if the system's state is unchanged, no changes are made to the system"

```
$ kubectl apply -f myconfig.yaml
```

```
deployment.apps/mydeploy created
```



```
$ nano myconfig.yaml
```



myapp.yaml

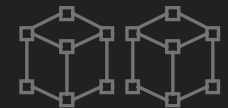
```
spec:  
  replicas: 4
```



```
spec:  
  replicas: 2
```

```
$ kubectl apply -f myconfig.yaml
```

```
deployment.apps/mydeploy configured
```



Labels & Selectors



kubernetes.io/docs/concepts/overview/working-with-objects/labels

Kubernetes makes extensive use of labels and selectors

Labels are metadata on any object and are just `key:value` pairs of your choosing

Selectors are lookups that match one or more objects based on their **labels**

Uses

- Which pods are in a service
- Which nodes to run a pod on
- Which pods are in a deployment
- Logically group & tag resources

```
kind: Deployment
...
metadata:
  labels:
    app: myapp
    type: frontend
```

```
kind: Service
spec:
  type: LoadBalancer
  selector:
    app: myapp
```

This is a deployment labels its pods with **app: myapp** & **type: frontend**

This service will look for any pods labelled with **app=myapp**

Note. There might be zero, one or many matches

Configuring Basic Workloads



Environmental Variables



kubernetes.io/docs/tasks/inject-data-application/define-environment-variable-container/

Environmental variables are the standard way to **configure containers at runtime**

Containerized app consumes environmental variables in standard way

Key value pairs

Application/container specific

Uses
<ul style="list-style-type: none">- Application configuration- Parameter passing


```
apiVersion: v1
kind: Pod
metadata:
  name: envar-demo
  labels:
    purpose: demonstrate-envars
spec:
  containers:
  - name: envar-demo-container
    image: gcr.io/google-samples/node-hello:1.0
    env:
      - name: DEMO_GREETING
        value: "Hello from the environment"
      - name: DEMO_FAREWELL
        value: "Such a sweet sorrow"
```

Secrets

Hold **sensitive information** such as passwords, certs and API keys

Don't place sensitive values as plain text in deployment files

Don't "bake" secrets into your container images

Can be mounted in pods as files or environmental variables

Uses

- TLS certificates
- Application configuration
- Authentication with private registry



kubernetes.io/docs/concepts/configuration/secret

```
$ kubectl create secret generic my-secret  
--from-literal=connString='blahblah_this_is_secret'
```

secret/my-secret created

myapp.yaml

```
containers:  
  - name: my-web-server  
  env:  
    - name: DATABASE_CONNECTION_STRING  
      valueFrom:  
        secretKeyRef:  
          name: my-secret  
          key: connString
```



ConfigMaps

Hold application **configuration data**

Key value pairs (like secrets), YAML or free format (e.g. XML, conf)

Pass to containers as env vars or mount as volume



kubernetes.io/docs/tasks/configure-pod-container/configure-pod-configmap

Uses
<ul style="list-style-type: none">- Application configuration

```
$ kubectl create configmap my-config  
--from-file=/path/to/foobar.conf
```

configmap/my-config created

```
containers:  
- name: my-foobar-server  
  volumeMounts:  
  - name: config-vol  
    mountPath: /etc/config  
volumes:  
- name: config-vol  
  configMap:  
    name: my-config
```

myapp.yaml



Mount into container at given path

Reference to config map object

Resource Management



kubernetes.io/docs/concepts/configuration/manage-compute-resources-container

Define compute (CPU & memory)
resource limits and requests for
containers

Allows Kubernetes to make **better
scheduling placement decisions**

Limits are enforced, **requests** aren't

CPU resources are fractions of 1
vCore

Uses

- Efficient use of cluster resources
- Prevent rogue workloads starving the cluster
- Good practice

```
apiVersion: v1
kind: Pod
metadata:
  name: demo-app
spec:
  containers:
  - name: db
    image: mysql
    resources:
      requests:
        memory: "64M"
        cpu: "0.25"
      limits:
        memory: "512M"
        cpu: "2.0"
```

Certain capabilities such as auto scaling
are dependant on setting resources

Specifying limits & requests is optional
but **STRONGLY** recommended

Liveness & Readiness Probes



kubernetes.io/docs/tasks/configure-pod-container/configure-liveness-readiness-probes

Liveness probes tell Kubernetes your **container is "alive"**

Readiness probes tell Kubernetes your container is **accepting traffic**

Liveness probe failure can **restart the container**

HTTP, TCP and command checks

Uses

- Maintain availability
- Restart/termination of unhealthy containers
- Efficient traffic routing

...

```
livenessProbe:
  httpGet:
    path: /status
    port: 8080
  initialDelaySeconds: 25
  periodSeconds: 10
  failureThreshold: 3
```

...

```
readinessProbe:
  exec:
    command: ["mysqladmin", "ping"]
  initialDelaySeconds: 30
  periodSeconds: 20
```

Specifying a liveness probe is optional but recommended

Commands & Arguments



kubernetes.io/docs/tasks/inject-data-application/define-command-argument-container/

Using the **command** property pass a starting command to a container

Use **args** to pass arguments to the container, pass an array of strings

Note. These correspond to the Docker **Entrypoint** and **Cmd** parameters

```
kind: Pod
metadata:
  name: command-demo
spec:
  containers:
  - name: command-demo-container
    image: debian
    command: ["printenv"]
    args: ["HOSTNAME", "KUBERNETES_PORT"]
```

Uses
<ul style="list-style-type: none">- Use base images to run utilities & scripts- Debugging & trouble shooting- Application configuration- Parameter passing

Description	Docker field name	Kubernetes field name
The command run by the container	Entrypoint	command
The arguments passed to the command	Cmd	args

Beyond The Basics



Service Mesh

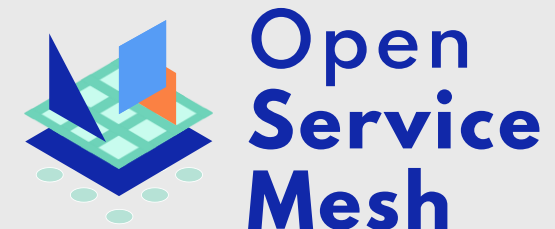
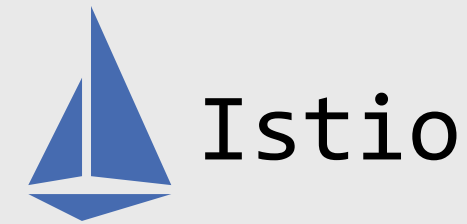
Facilitates **services to service** calls **inside** Kubernetes

Features:

- Observability / tracing
- Error handling / retries / backoff
- Encryption / mTLS
- Routing / balancing

Typically runs as a proxy sidecar in all your pods

Adds complexity & overhead

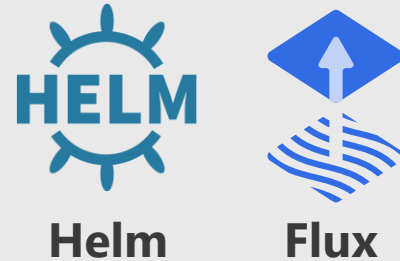


Kubernetes Ecosystem – *Many* Projects

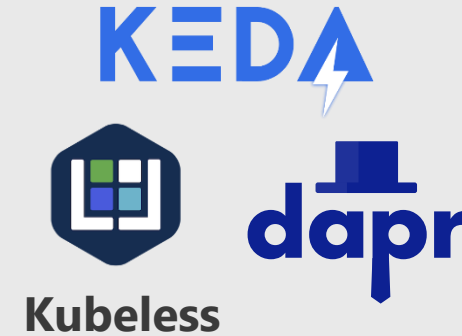
Security / Policy



DevOps



Serverless



Monitoring



Network Plugins



Load Balancing & Discovery



Storage



landscape.cncf.io

The Kubernetes API

It's Kind Of Important!



[kubernetes.io/docs/reference/
#api-reference](https://kubernetes.io/docs/reference/#api-reference)

Every object in Kubernetes and any interactions with the cluster are shaped by the API and the API spec

- YAML manifests schema
- `kubectl` commands

Served by the API server running on master node(s)

Kubernetes version dependant

Aggregated - hosts multiple APIs at multiple versions

`kubectl proxy` – Create a local tunnel to the API server



Additional Network Services



Ingress

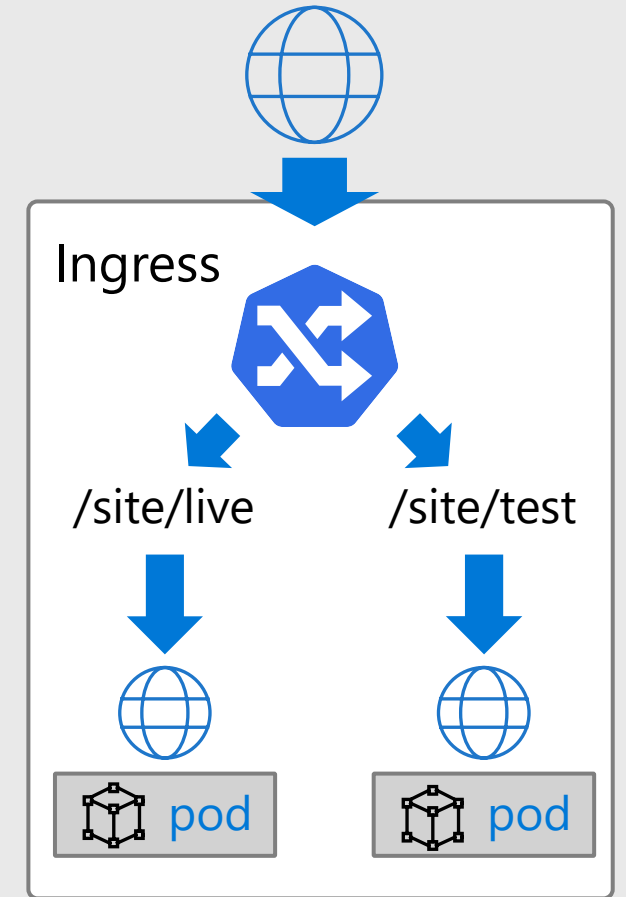
External access for HTTP and HTTPS

An *Ingress* allows you to **route** HTTP/HTTPS traffic to **services** based on URL and/or domain host name

Ingress object is a **set of rules** picked up and implemented by the *Ingress Controller*

Ingress Controller has a **public IP** and *LoadBalancer* service, it routes traffic to internal *ClusterIP* services

Various controllers exist, NGINX is commonly used



Use an Ingress when you want to route HTTP(S) traffic into your workloads and pods

External DNS

Optional Addon – Auto configuration of public DNS

Allows for **dynamic configuration** of DNS records

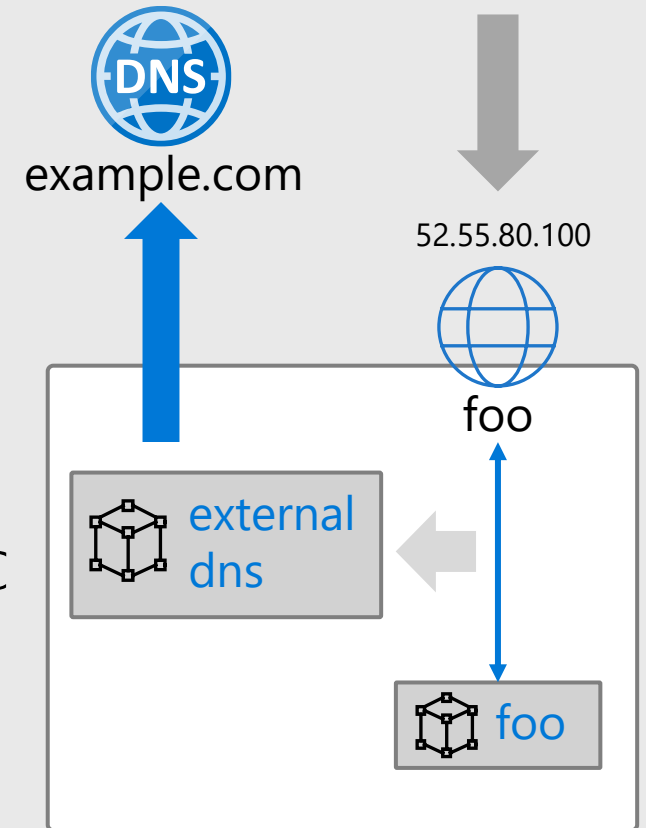
Seamlessly keep **public DNS** in sync with your Ingress and external services

Supports Azure DNS, AWS, CloudFlare, Google DNS etc

Incubation project:

github.com/kubernetes-incubator/external-dns

A record: `foo.example.com`
IP: `52.55.80.100`



Commonly used with an Ingress for host based external routing

Cert Manager

Optional Addon – Automate issuing of TLS certs

Ensures **certificates are valid** and up to date

Tightly coupled to *Ingress*, e.g. host rules

Renew certificates before expiry

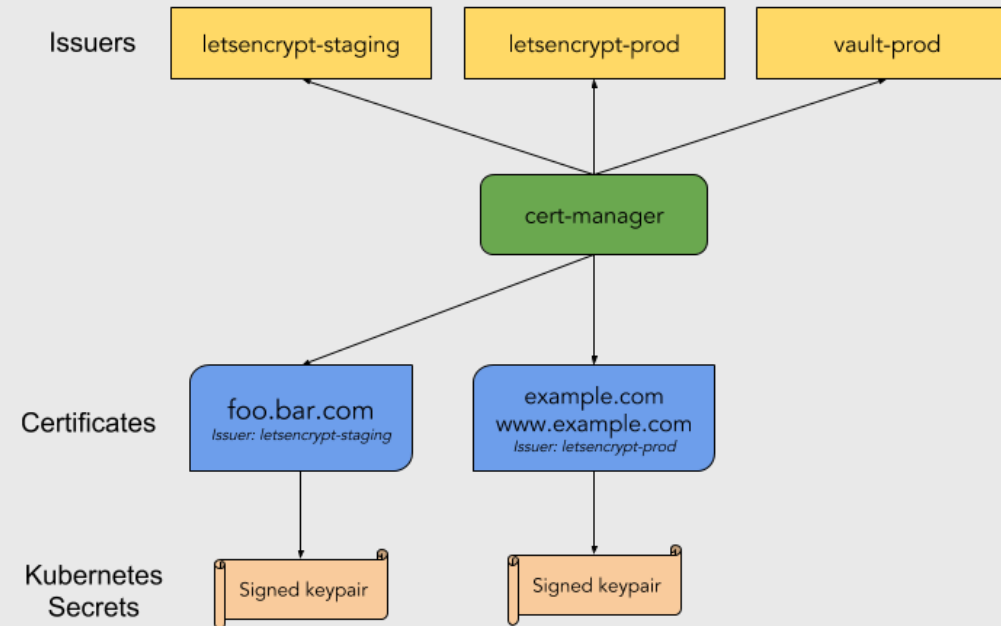
Uses ACME issuers, i.e. **Let's Encrypt**

Project:

github.com/jetstack/cert-manager



github.com/jetstack/cert-manager



Issue TLS certs for HTTPS access to services & Ingress

Putting It All Together

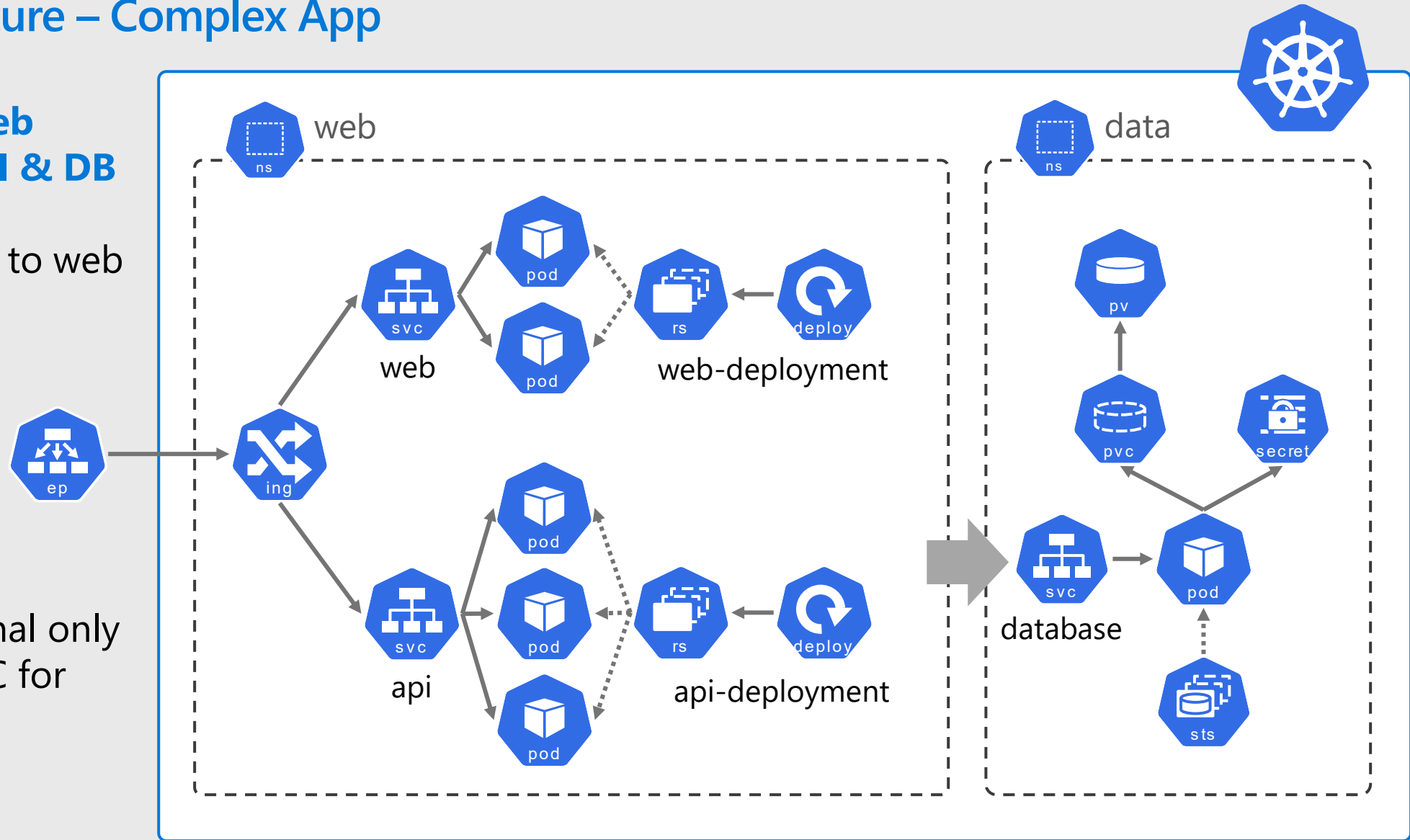
Sample Architecture – Complex App

Multi component web application, with API & DB

Ingress routing traffic to web and API pods

Ingress is exposed to the internet

Database running in StatefulSet with internal only service and using PVC for storage, plus secrets



Debugging and Troubleshooting Workloads



Describing Objects



kubernetes.io/docs/tasks/debug-application-cluster

Use `kubectl describe` to inspect status of any object in your cluster

Returns events and all properties & status details

Use label selectors to query multiple objects

Uses

- View and understand the status of anything in your cluster
- Troubleshoot pending/failed workloads

```
$ kubectl describe deploy/data-api
$ kubectl describe pod/data-api-84fb56497b-6cgth
$ kubectl describe service/frontend
$ kubectl describe pod -l app=data-api
```

```
Limits:
  cpu:    100m
  memory: 256M
Requests:
  cpu:    100m
  memory: 256M
Liveness: http-get http://:4000/api/info delay=3s timeout=1s period=20s #success=1 #failure=3
Environment:
  MONGO_CONNSTR:      mongodb://mongodb-svc.default
  KUBERNETES_PORT_443_TCP_ADDR: bckube-d587b0d8.hcp.northeurope.azmk8s.io
  KUBERNETES_PORT:      tcp://bckube-d587b0d8.hcp.northeurope.azmk8s.io:443
  KUBERNETES_PORT_443_TCP: tcp://bckube-d587b0d8.hcp.northeurope.azmk8s.io:443
  KUBERNETES_SERVICE_HOST: bckube-d587b0d8.hcp.northeurope.azmk8s.io
Mounts:
  /var/run/secrets/kubernetes.io/serviceaccount from default-token-hvcxv (ro)
Conditions:
  Type            Status
  Initialized      True
  Ready            False
  ContainersReady  True
  PodScheduled     True
Volumes:
  default-token-hvcxv:
    Type: Secret (a volume populated by a Secret)
    SecretName: default-token-hvcxv
    Optional: false
QoS Class:   Guaranteed
Node-Selectors: <none>
Tolerations: node.kubernetes.io/not-ready:NoExecute for 300s
              node.kubernetes.io/unreachable:NoExecute for 300s
Events:
  Type     Reason      Age   From                                     Message
  ----     -
  Normal   Scheduled   22m   default-scheduler                       Successfully assigned default/data-api-84fb56497b-6cgth to aks-agentpool-25884925-3
  Normal   Pulling     22m   kubelet, aks-agentpool-25884925-3      pulling image "bcdemo.azurecr.io/smlr/data-api"
  Normal   Pulled      22m   kubelet, aks-agentpool-25884925-3      Successfully pulled image "bcdemo.azurecr.io/smlr/data-api"
  Normal   Created     22m   kubelet, aks-agentpool-25884925-3      Created container
  Normal   Started     22m   kubelet, aks-agentpool-25884925-3      Started container
  Normal   Pulling     21m   kubelet, aks-agentpool-25884925-3      pulling image "bcdemo.azurecr.io/smlr/data-api:stable"
  Normal   Pulled      21m   kubelet, aks-agentpool-25884925-3      Successfully pulled image "bcdemo.azurecr.io/smlr/data-api:stable"
  Normal   Created     21m   kubelet, aks-agentpool-25884925-3      Created container
```

Container Logs

Access stdout & stderr output
from pods with:

`kubectl logs`

Get output from a `deployment` or
`pod` or `single container`

Follow logs with `-f`

Uses
<ul style="list-style-type: none">- View any errors output from containers- See what your workloads are doing


```
$ kubectl logs deploy/data-api
```

```
Found 3 pods, using pod/data-api-84fb56497b-6cgth
```

```
> smilr-data-api@3.2.0 start /home/app
```

```
> node server.js
```

```
### Node environment mode is 'production'
```

```
### Connection attempt 1 to MongoDB server mongodb-  
svc.default
```

```
### Yay! Connected to MongoDB server
```

```
### Server listening on 4000
```

Get Shell Access

Create **interactive shell** into running containers

Use **kubectl exec**

Use **-it** switch and sh or bash for shell

Can also run single non-interactive command

Uses

- Low level debugging
- Interactive troubleshooting



kubernetes.io/docs/tasks/debug-application-cluster/get-shell-running-container

```
$ kubectl exec frontend-58b84f7d7-fb6rg -- ps -ef
```

PID	USER	TIME	COMMAND
1	root	0:00	npm
22	root	0:00	node server.js
36	root	0:00	ps -ef

```
$ kubectl exec -it frontend-58b84f7d7-fb6rg -- bash
```

```
bash-4.4# ls -la
node_modules      package.json      server.js
```

```
bash-4.4# uname
Linux
```

Advanced Pod Configuration



Deeper Dive on Manifests

Manifests for *Deployments*, *StatefulSets* and *DaemonSets* have a similar pattern & structure

The **spec** part contains **replicas** and a **selector** and also a **template** for the objects it will replicate

The **template** will contain another **spec**, typically a *Pod spec*

A *Pod spec* contains one or more **containers**

?? So what do all these labels mean ??

```
kind: Deployment
apiVersion: apps/v1
metadata:
  name: my-deployment
  labels:
    cheese: cheddar
spec:
  replicas: 1
  selector:
    matchLabels:
      thing: my-app
  template:
    metadata:
      labels:
        thing: my-app
        cake: chocolate
    spec:
      containers:
      - name: my-container
        image: nginx
```

Deployment name will also be used as name prefix for the ReplicaSet and Pods

Labels for the deployment are optional

The selector of the spec **MUST** match one label in the template

Required field but mostly not important

Init Containers



kubernetes.io/docs/concepts/workloads/pods/init-containers

Init Containers are optional special containers that **run only once** when a pod is started

Init containers run to completion (**terminate**)

Main containers in a pod will **not start** until all Init Containers have run

Uses

- Application configuration
- Bootstrapping apps
- Running utility & start-up scripts
- Data injection

...

initContainers:

- name: init-mysql
image: bencuk/mysqlldb
command: ["../scripts/checkDB"]

...

initContainers:

- name: init-demodata
image: bcdemo.azurecr.io/smilr/data-api
command: ['sh', '-c', 'cd demoData && node demodb.js']
env:
 - name: MONGO_CONNSTR
value: mongodb://mongodb-svc.default
 - name: WIPE_DB
value: "true"

Node Selector



kubernetes.io/docs/concepts/configuration/assign-pod-node/#nodeselector

A simple **constraint** to which Nodes are eligible to run a Pod

Key value pairs of labels, to be matched against Node's labels

Not a 'hard rule', other Pods that have no nodeSelector **can still land on the node**

```
kind: Pod
metadata:
  name: machineLearning
spec:
  containers:
  - name: trainModel
    image: ml-image:latest
  nodeSelector:
    hardware: gpu
```

Pod



Can be scheduled on

```
Name:      aks-nodepool11-18655374-vmss000000
Roles:     agent
Labels:    agentpool=nodepool11
           beta.kubernetes.io/arch=amd64
           hardware=gpu
```

Node

Uses

- Assign workloads requiring special hardware or resources, e.g. GPU
- Physical partitioning of cluster
- Separating noisy Pods

Affinity and Taints



kubernetes.io/docs/concepts/configuration/taint-and-toleration/

kubernetes.io/docs/concepts/configuration/assign-pod-node/#affinity-and-anti-affinity

Affinity and **anti-affinity** provide advanced ways to control Pod placement

- 'Hard' rules and 'soft' rules
- Weighting and expressions

Taints and **Tolerations**. Taints are applied to *Nodes* and will not accept *Pods* that don't have a matching **Toleration**

Uses

- Assign workloads requiring special hardware or resources, e.g. GPU
- Physical partitioning of cluster
- Separating noisy Pods

```
$ kubectl taint nodes myNode001 team=team1:NoSchedule
node/myNode001 tainted
```

```
kind: Pod
spec:
  tolerations:
  - key: team
    operator: Exists
    value: "team1"
    effect: NoSchedule
```

```
kind: Pod
spec:
  affinity:
    nodeAffinity:
      requiredDuringSchedulingIgnoredDuringExecution:
      preferredDuringSchedulingIgnoredDuringExecution:
    podAffinity:
      requiredDuringSchedulingIgnoredDuringExecution:
      preferredDuringSchedulingIgnoredDuringExecution:
```

Unlike taints & nodeSelectors, affinity rules can also apply to **pods**. i.e. do or don't schedule these pods together

Sidecars

Pods **co-locate multiple containers** together, sharing network and storage

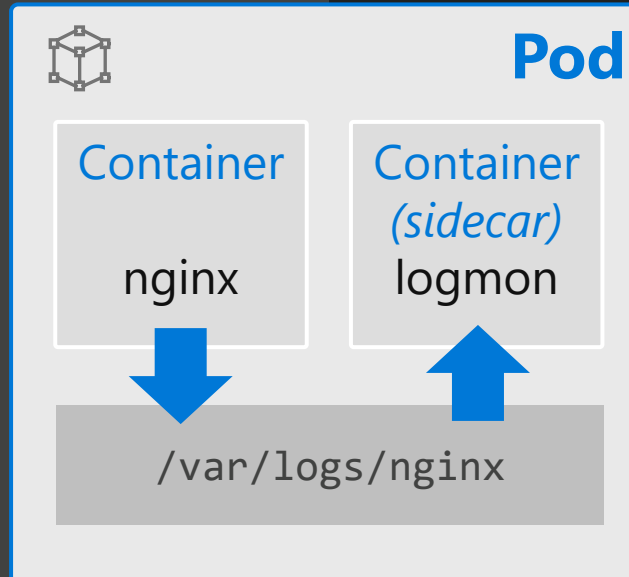
Sidecar is a pattern where additional containers provide enhancing/optional capabilities

Bind containers together to form a single cohesive unit of service

Uses

- Decompose architecture
- Build services incrementally
- Bolt on features

```
kind: Pod
metadata:
  name: monitored-webapp
spec:
  containers:
  - name: webserver
    image: nginx
  - name: log-monitor
    image: my-log-monitor
    args: ["--log-dir", "/var/logs/nginx"]
```



Scaling



Manually Scaling

Scale stateless workloads by controlling the number of **replicas** of a Deployment


Be careful scaling **StatefulSets**, unless the workload/application is "cluster aware"

DaemonSets don't require scaling

Uses
<ul style="list-style-type: none">- Horizontally scale- Distribute work around cluster- Remove single points of failure


```
$ kubectl scale deploy/myApp --replicas=5  
  
deployment.extensions/myApp scaled
```

OR

```
kind: Deployment  
apiVersion: apps/v1  
metadata:  
  name: myApp  
spec:  
  replicas: 5 
```

Horizontal Pod Autoscaler (HPA)

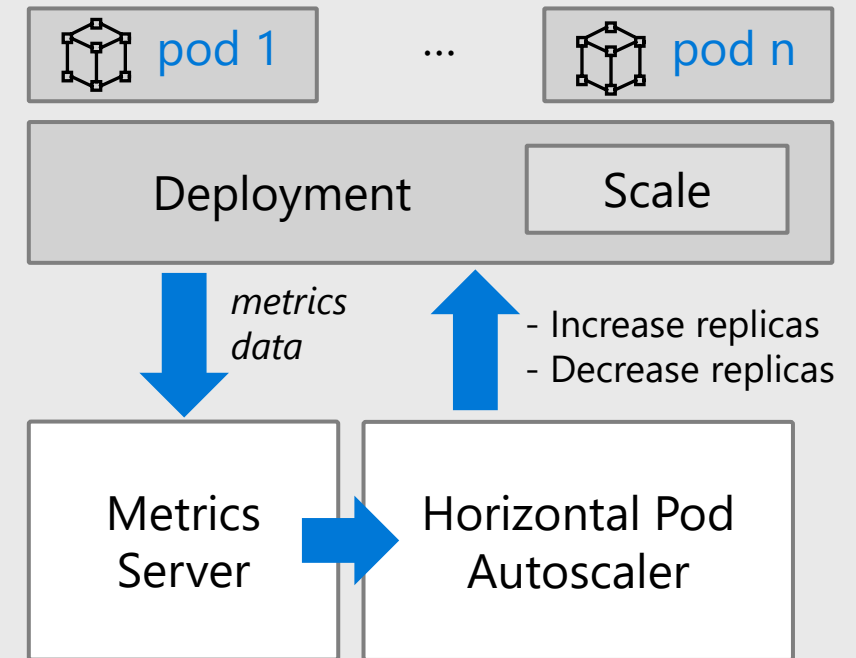
Automatically scale stateless workloads

Use to horizontally **scale stateless** *Pods* in *ReplicaSet/Deployment*

Rules define desired *Pod* replicas based on **observed metrics**

Takes metrics from the metrics API fed from the *Metrics Server* (Kubernetes 1.8+)

Supports extension via custom metrics



Dynamically scale stateless workloads across available nodes

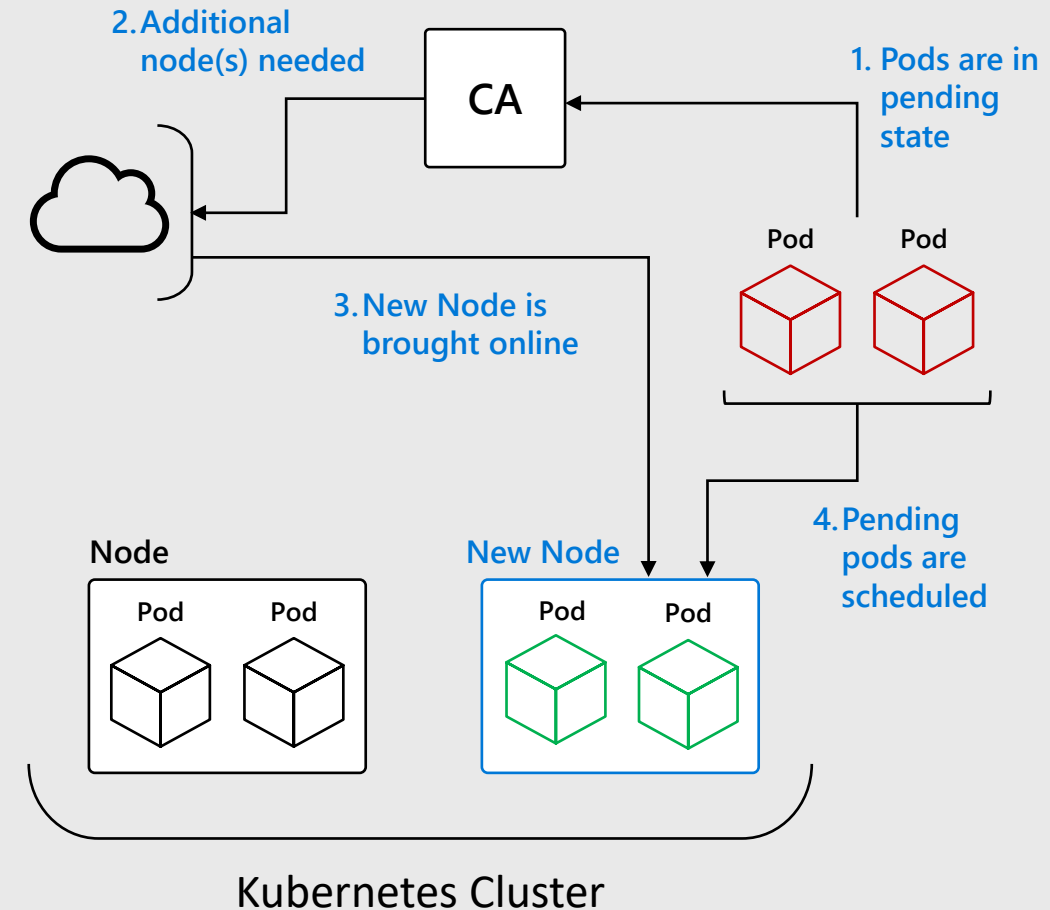
Cluster Autoscaler (CA)

Automatically scale cluster resources

Adjusts the size of the **Kubernetes cluster**, adding & removing *Nodes* when

- Pods are **pending** state due to insufficient resources (**scale out**)
- Nodes have been underutilized for a period of time (**scale in**)

Tightly coupled to the cloud and environment hosting the cluster & Nodes



Scale cluster wide by adding/removing Nodes

Extending Kubernetes



Extra Advanced

Custom Resources Definitions (CRDs)

Extend the Kubernetes API and object model

An **extension** of the Kubernetes API that is not available in a default Kubernetes installation

Can represent application specific or generalised entities, e.g. *BackupJob*, *Report*

A CRD is just schema & state it **doesn't** define behaviour

Manage via the API & kubectl just as standard resource types

```
apiVersion: apiextensions.k8s.io/v1
kind: CustomResourceDefinition
spec:
  names:
    plural: pets
    kind: Pet
  openAPIV3Schema:
    type: object
    properties:
      petName:
        type: string
```

```
$ kubectl get pets
```

Extend Kubernetes with new entities and data models

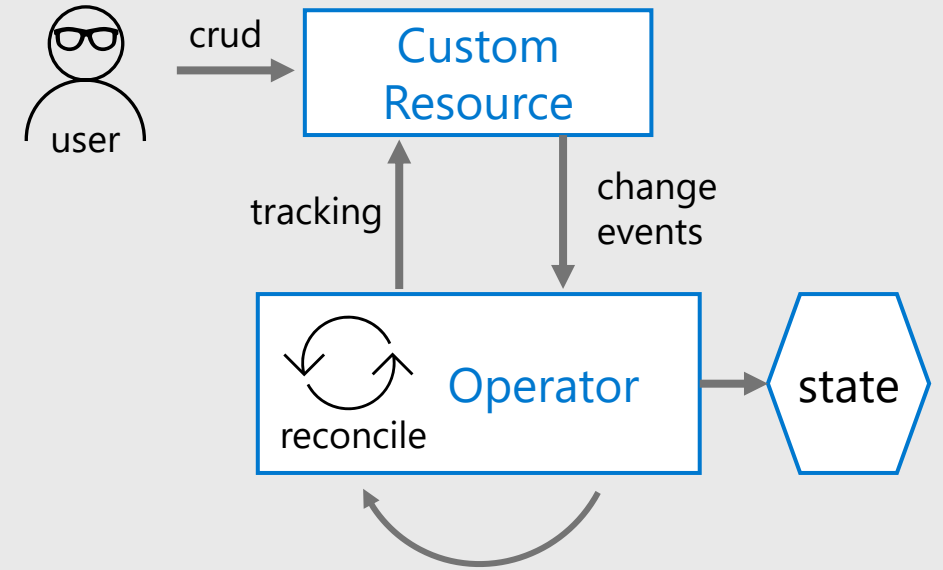
Operators

The Operator pattern: CRD + Custom Controller

An operator is custom controller that acts on a given set of CRDs – defines behaviour

Controller is run as a regular pod & deployment

Custom operator reconciler code subscribes to the Kubernetes API & watches for CRD changes



Discover & use:

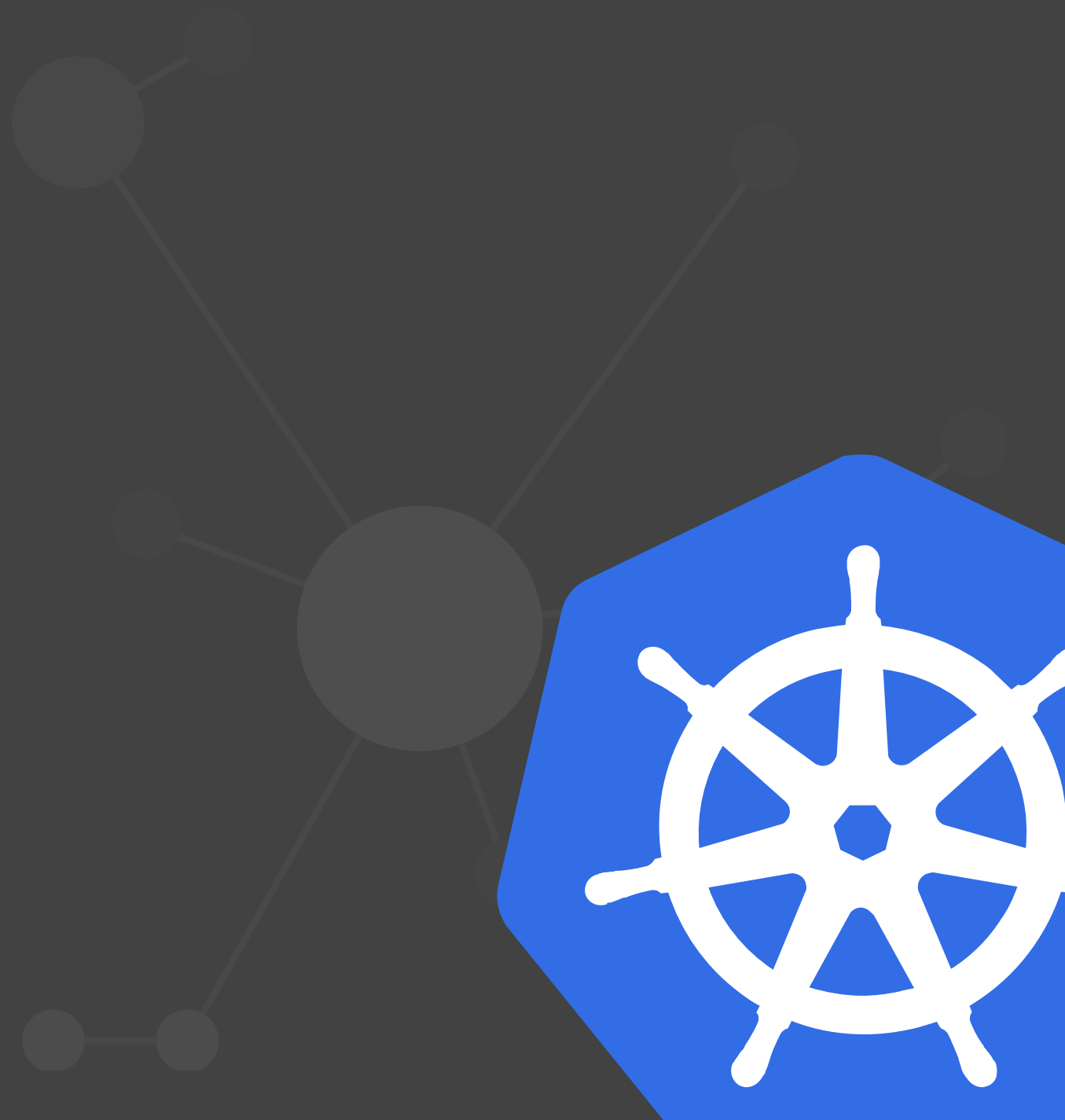
- artifacthub.io
- operatorhub.io

Build your own:



- [Kubebuilder](https://kubebuilder.io)
- [KUDO](https://kudo.dev)
- [Operator SDK](https://operator-sdk.io)

A common and easily understood way to extend Kubernetes

DevOps



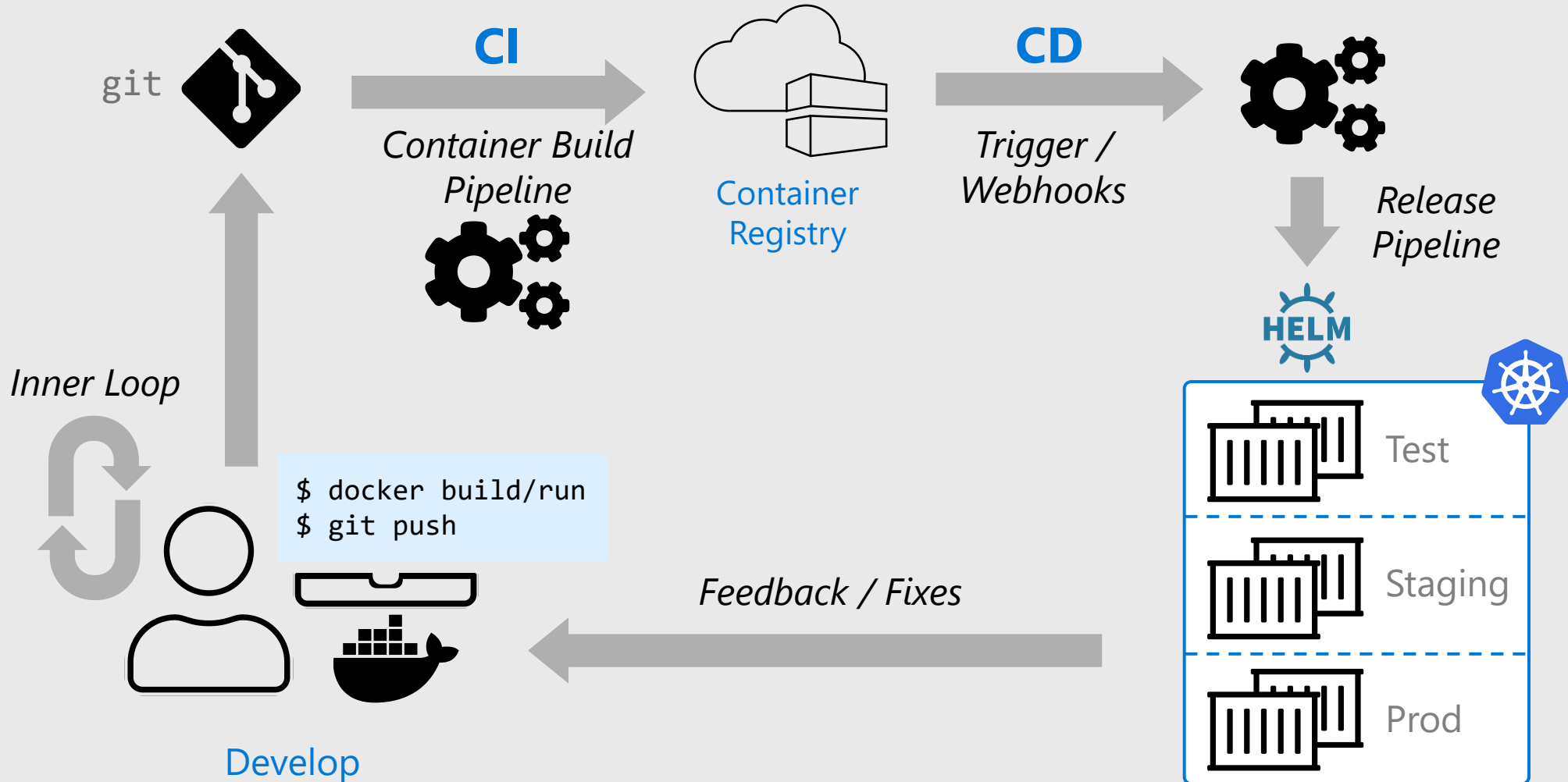
Virtual Machines

Pets Legacy Infrastructure 	Cattle Modern Infrastructure 
<ul style="list-style-type: none">Pets are given names like cutecat.petshop.comThey are unique, lovingly raised & cared forWhen they get ill, you nurse them back to health	<ul style="list-style-type: none">Cattle are given numbers like 10200713.cattlerancher.comThey are almost identical to other cattleWhen they get ill, you replace them and get another
Infrastructure is a permanent fixture in the data centre	Infrastructure is stateless, ephemeral , and transient
Infrastructure takes days to create, are served weekly, maintained for years, and requires migration project to move	Infrastructure is instantiated, modified, destroyed and recreated in minutes from scratch using automated scripts
Infrastructure is modified & patched in place and generally requires specialist config management tools	Infrastructure is IMMUTABLE Modify via source control & automation pipelines to rebuild and redeploy
Infrastructure requires several different teams to coordinate and provision the full environment	Infrastructure is self-service with the ability to provision computing, network and storage services with a single click
Infrastructure is static , requiring excess capacity to be dormant for use during peak periods of demands	Infrastructure is elastic and scales automatically , expanding and contracting on-demand to service peak usage periods

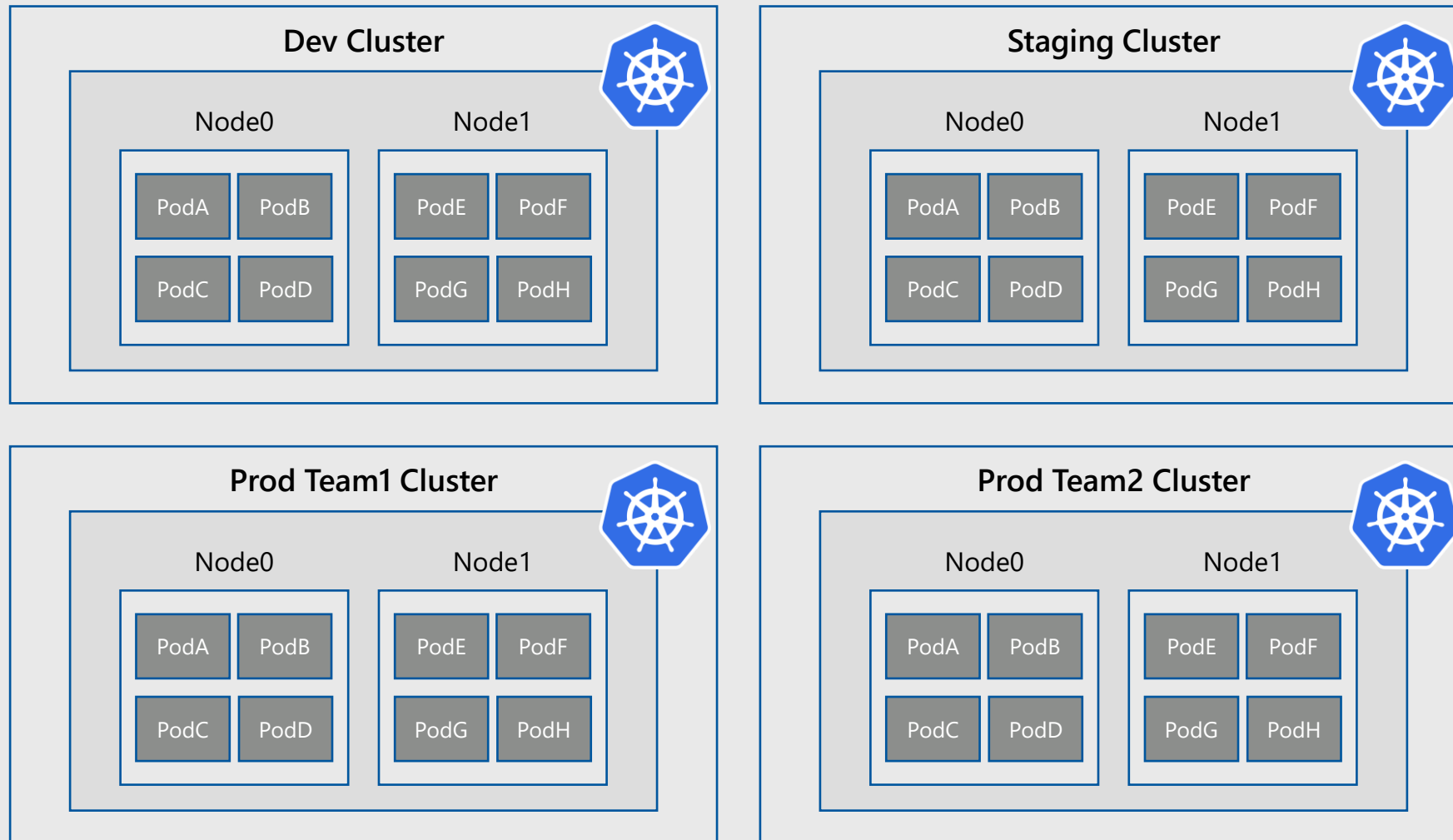
Containers

DevOps Containers Lifecycle Loop

Complete CI/CD Pipeline Loop

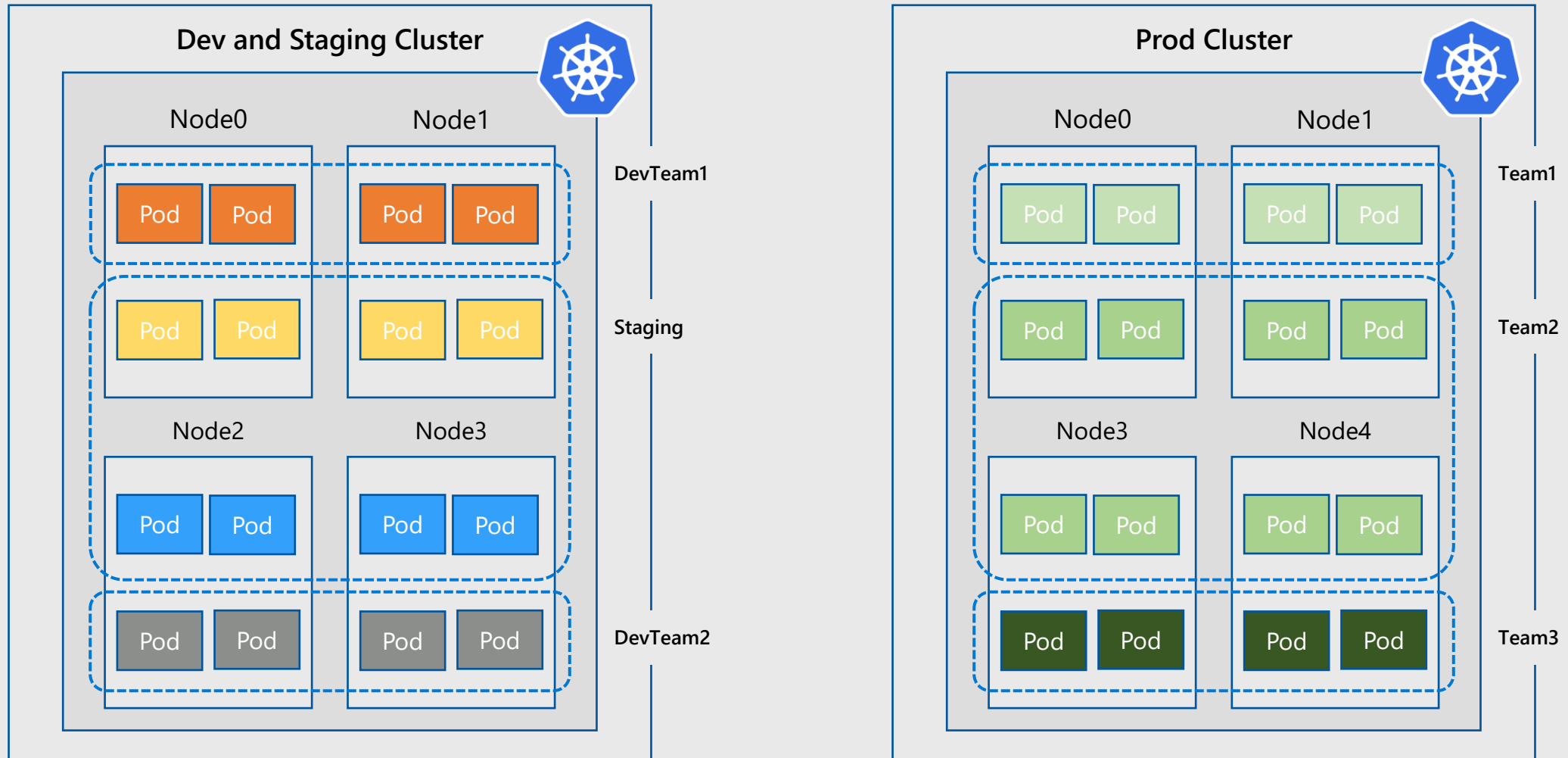


Cluster Isolation Patterns: Physical Isolation



Simple but can waste resources, management overhead

Cluster Isolation Patterns: Logical Isolation



Requires planning & some Kubernetes expertise

Helm

Package Manager for Kubernetes

Helm simplifies **deployment** into Kubernetes using *charts*

A chart consists of one or more Kubernetes YAML **templates** + supporting files

Helm charts support dynamic **parameters & functions** important for automated pipeline deployments

240+ charts exist for standard software/tools/packages
github.com/helm/charts



<https://helm.sh>

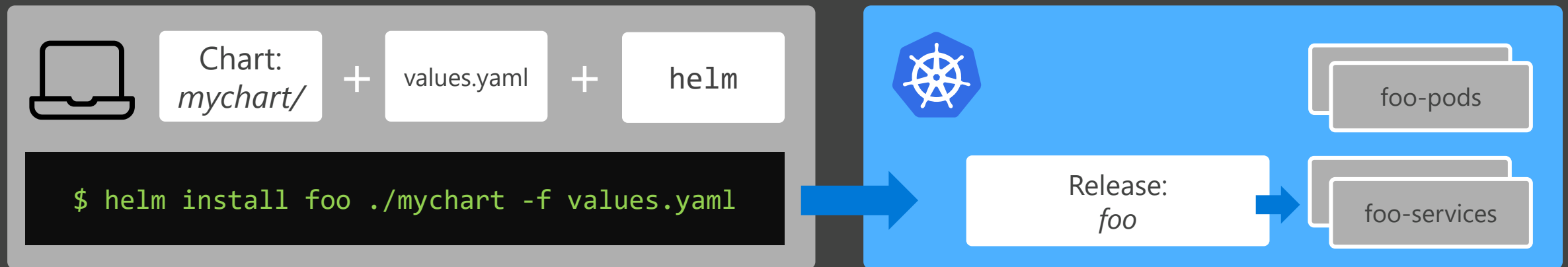


- Use Helm to install software/apps in your cluster
- Create Helm charts for your own apps, for CI/CD releases

Helm – The Basics

docs.helm.sh/glossary

helm	Client tool to manage and work with Helm
Chart	Package of Kubernetes resources in template form
Template	Kubernetes YAML with directives in Go template language format, e.g. {{ blah }}
Release	When installing a chart into Kubernetes it becomes a release
Values	Used at install time to customise the release, either from CLI or file
Dependency	A chart can require other external charts, Helm will automatically pull/update

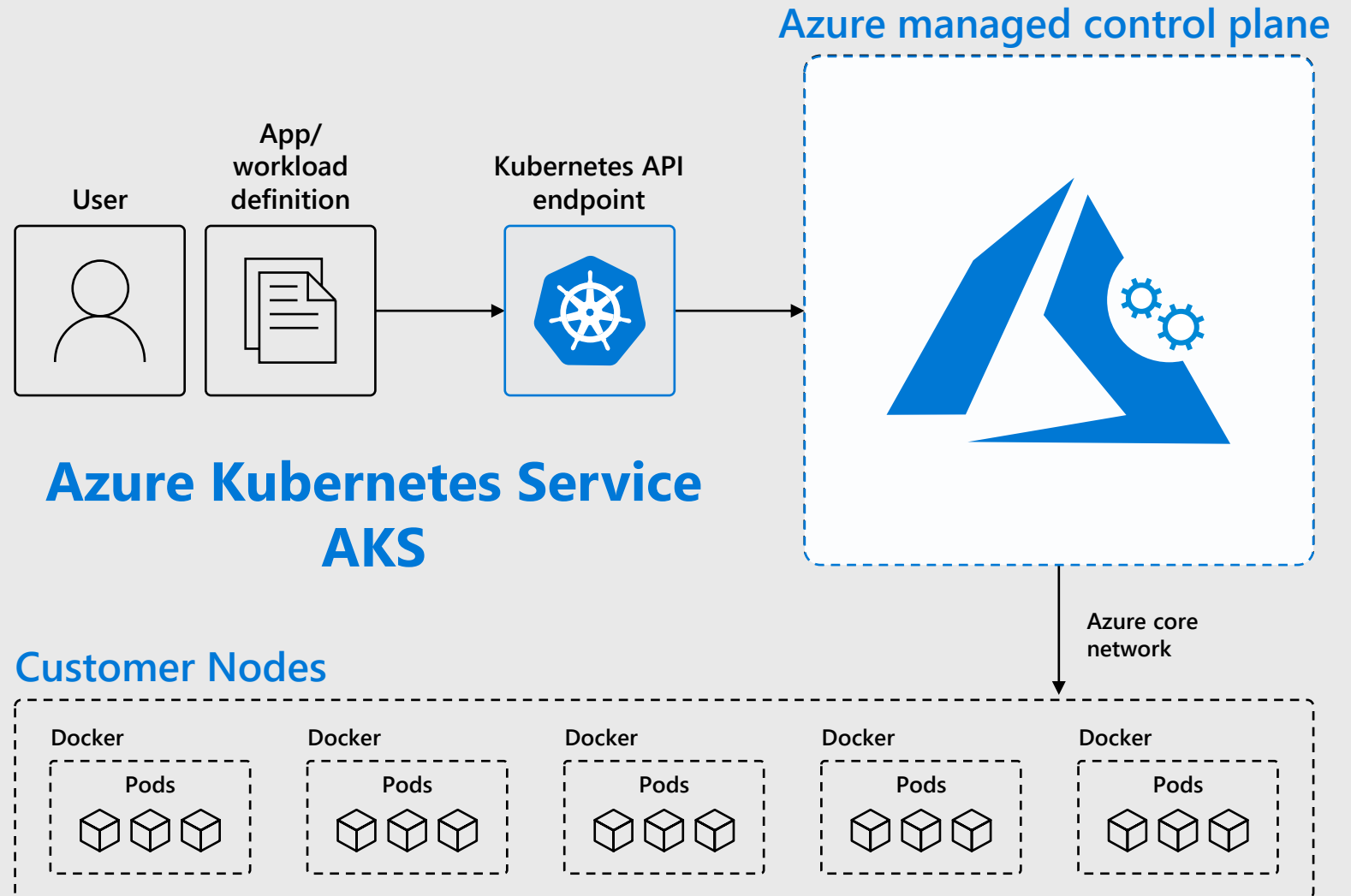


Azure Kubernetes Service



Managed Kubernetes on Azure – AKS

- Automated upgrades, patches
- High reliability, availability
- Easy, secure cluster scaling
- Self-healing
- API server monitoring
- At no charge



AKS Virtual Nodes

Elastically provision compute capacity in seconds

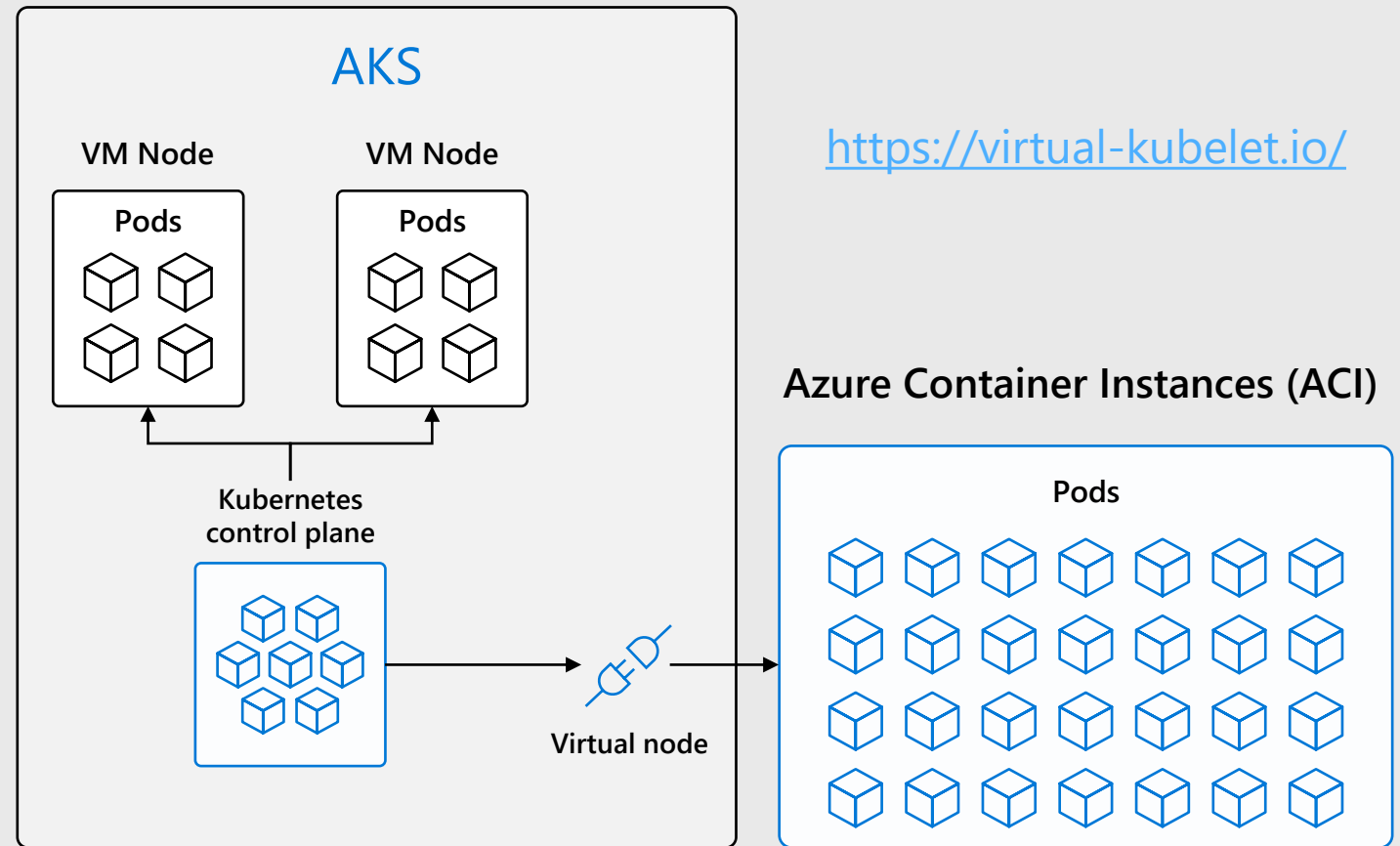
No infrastructure to manage

Builds on top of Azure Container Instances (ACI)

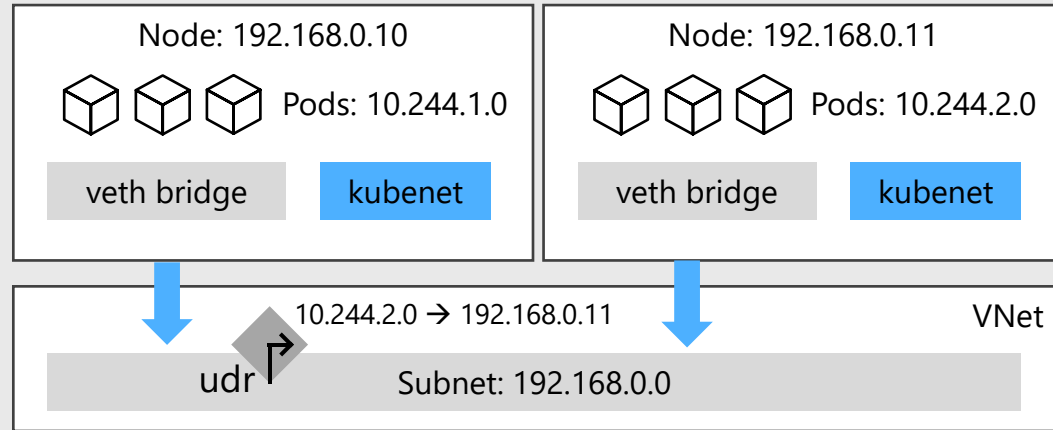
Uses Virtual Kubelet

Scenarios:

- Bursting
- CI/CD
- "Serverless Kubernetes"



AKS Networking Models



Basic

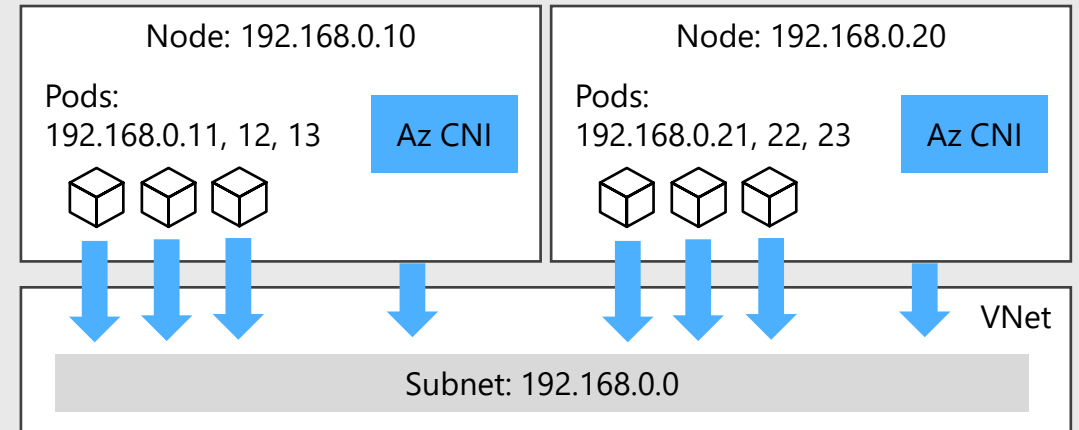
Uses **kubenet** network plugin

Pods are not in a VNet or same subnet as Nodes

Pods live behind bridge, and UDR is used

Simple but has limitations & performance impact

No need to allocate/reserve IPs for Pods



Advanced

Uses **Azure CNI** network plugin

Both Nodes and Pods on same subnet + VNet

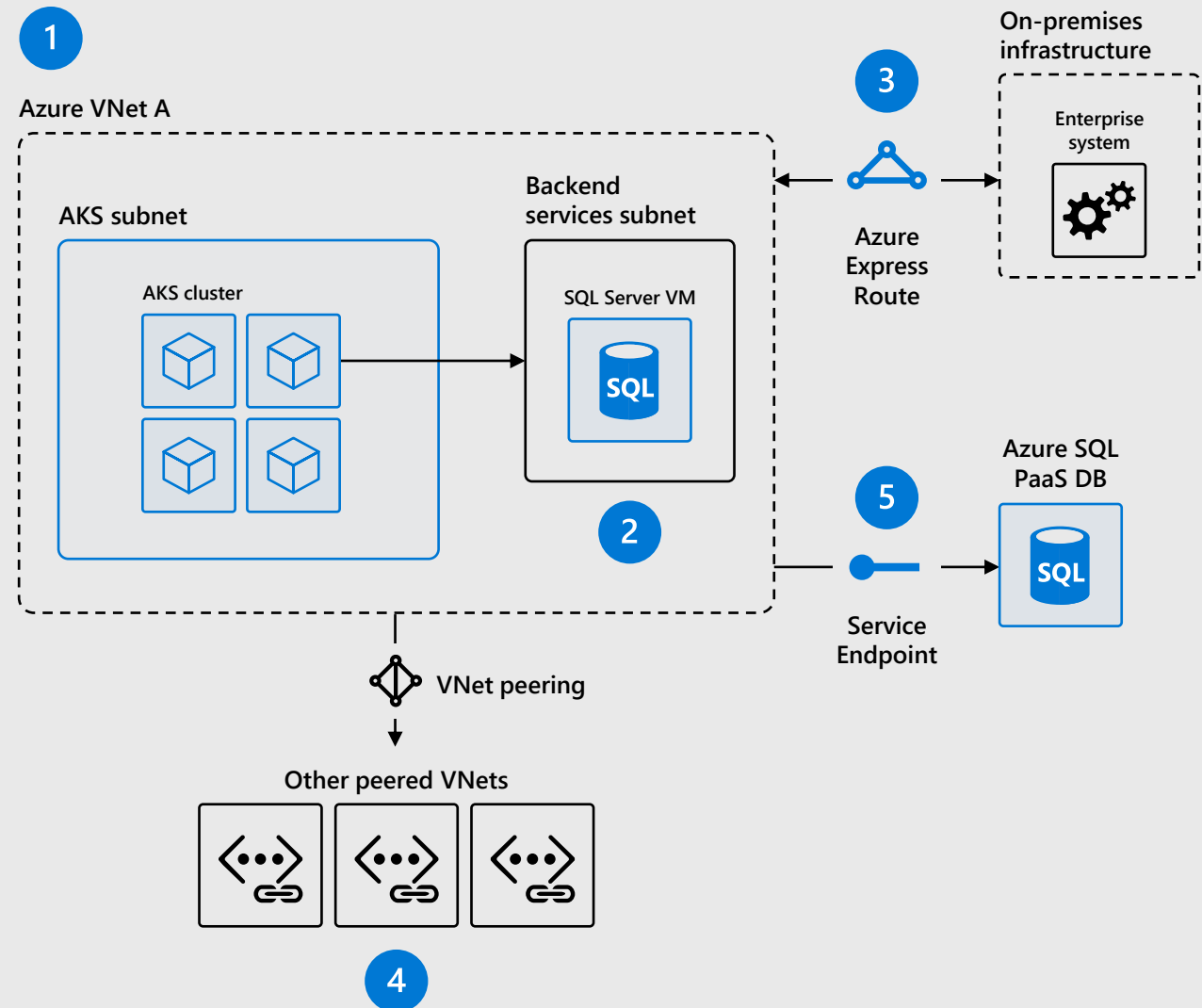
Works with peering, service endpoints, ExpressRoute

Better performance


Each pod requires an IP allocated to it

AKS Advanced Networking

1. Uses Azure subnet for both your pods and cluster VMs
2. Allows for connectivity to existing Azure IaaS/VMs in the same VNet
3. Use ExpressRoute to connect to on-premises infrastructure
4. Use VNet peering to connect to other VNets
5. Connect AKS cluster securely and privately to Azure PaaS using VNet endpoints



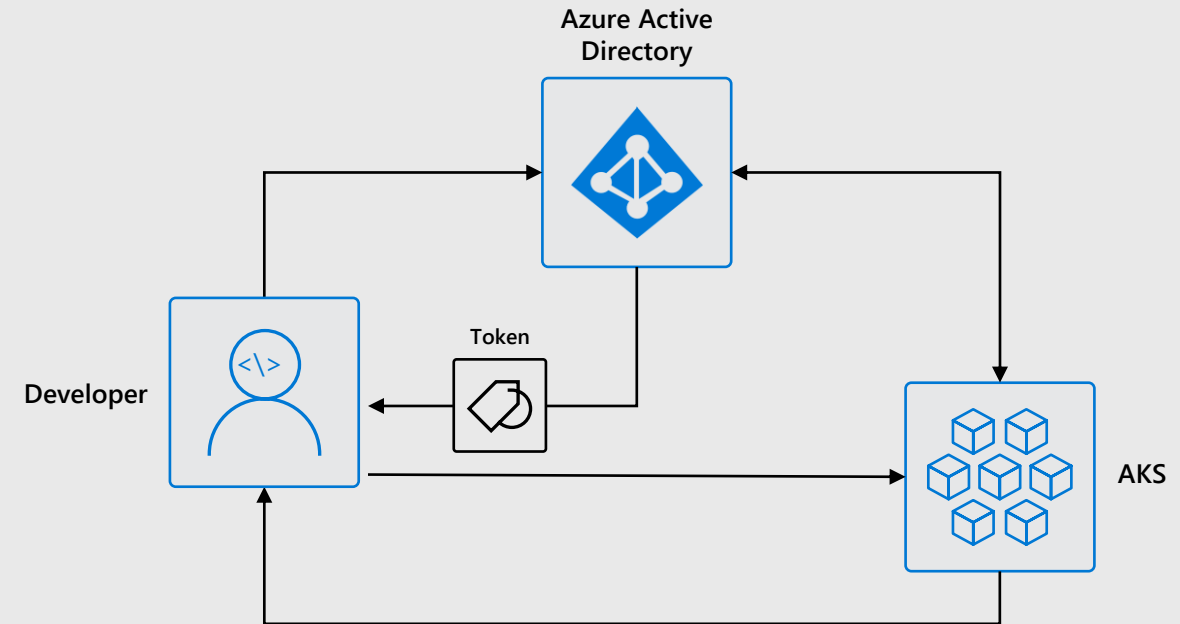
Azure Active Directory

 docs.microsoft.com/azure/aks/aad-integration

Use Azure Active Directory to authenticate AKS users

Assign roles & permissions in Kubernetes RBAC, based on AAD users & groups

Roles in AAD define who has access to the cluster



Azure Kubernetes Service Cluster Admin Role



Azure Kubernetes Service Cluster User Role

Note. Can only be enabled at cluster creation time

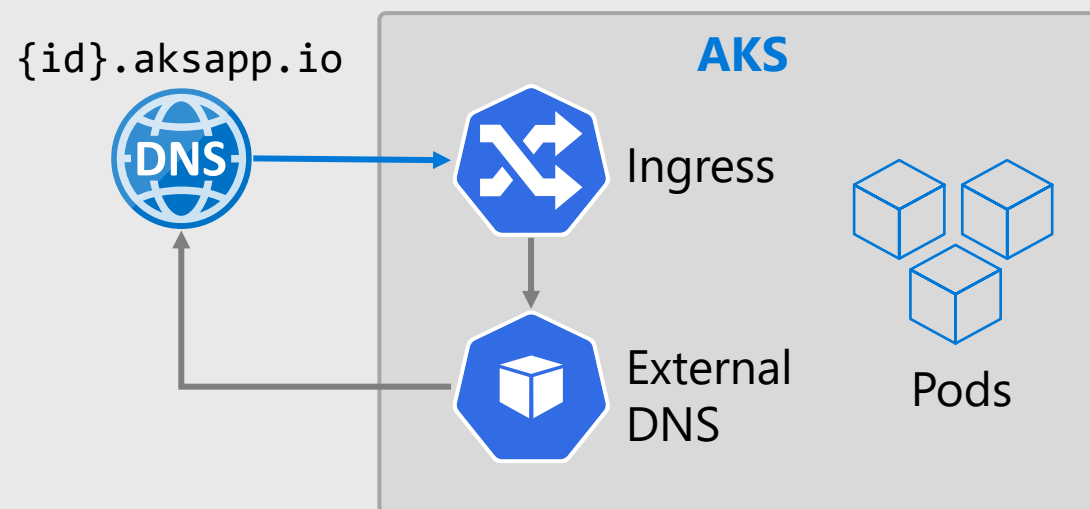
'HTTP application routing' Add-On

 [docs.microsoft.com/azure/aks/
http-application-routing](https://docs.microsoft.com/azure/aks/http-application-routing)

Simplifies Ingress and DNS for external access to HTTP services in cluster

Creates:

- NGINX Ingress controller (in cluster)
- External DNS helper (in cluster)
- aksapp.io DNS Zone (in Azure)



```
--enable-addons  
http_application_routing
```

The HTTP application routing add-on is designed to let you quickly create an ingress controller and access your applications. This add-on is not recommended for production use



'Monitoring' Add-On

Azure Monitor – Container Insights

Visualization

Visualize overall health and performance from clusters to containers with drill downs and filters

Insights

Provide insights with multi-cluster health roll up view

Monitor & Analyze

Monitor and analyze Kubernetes and container deployment performance, events, health, and logs

Response

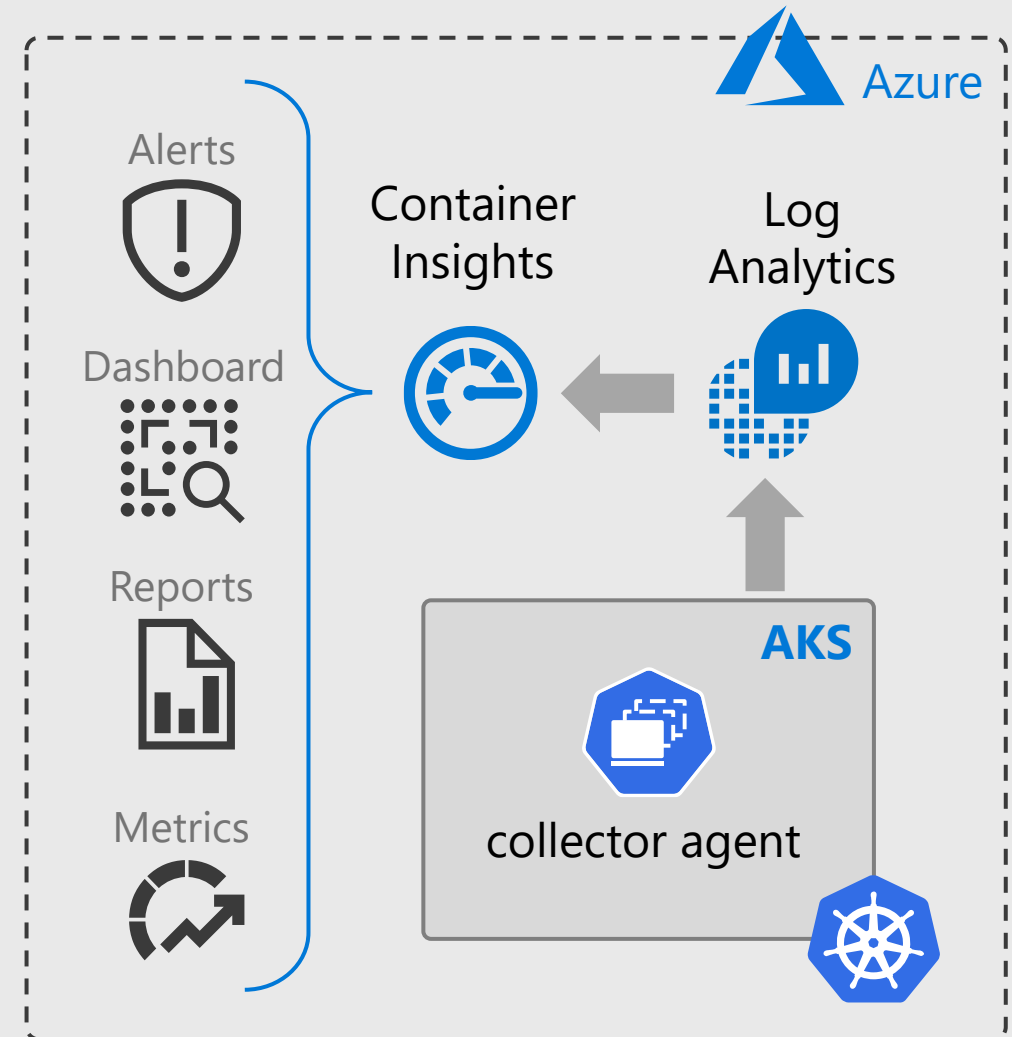
Native alerting with integration to issue managements and ITSM tools

Observability

Observe live container logs on container deployment status



docs.microsoft.com/azure/azure-monitor/insights/container-insights-overview



```
--enable-addons monitoring
--workspace-resource-id
{my-azure-monitor-logs-ws}
```

Cluster Auto Scaler

Autoscaling with Azure Scale Sets

Enables the standard Kubernetes Cluster Autoscaler (CA)

Uses VM Scale Sets (Preview)

While in preview - hidden behind CLI extension

```
--enable-vmss  
--enable-cluster-autoscaler  
--min-count 1  
--max-count 8
```

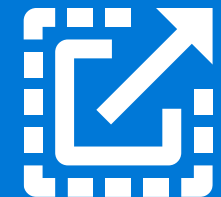


docs.microsoft.com/en-us/azure/aks/cluster-autoscaler

Azure managed control plane



Node Pool



Bridge to Kubernetes

Simplifying Development in Kubernetes



docs.microsoft.com/en-us/azure/dev-spaces/migrate-to-bridge-to-kubernetes

Extensions for VS Code & Visual Studio

Simplifying Microservice Development

Eliminate the need to manually source, configure and compile external dependencies on your development computer.

Easy Debugging

Debug your code as you normally would while taking advantage of the speed and flexibility of local debugging.

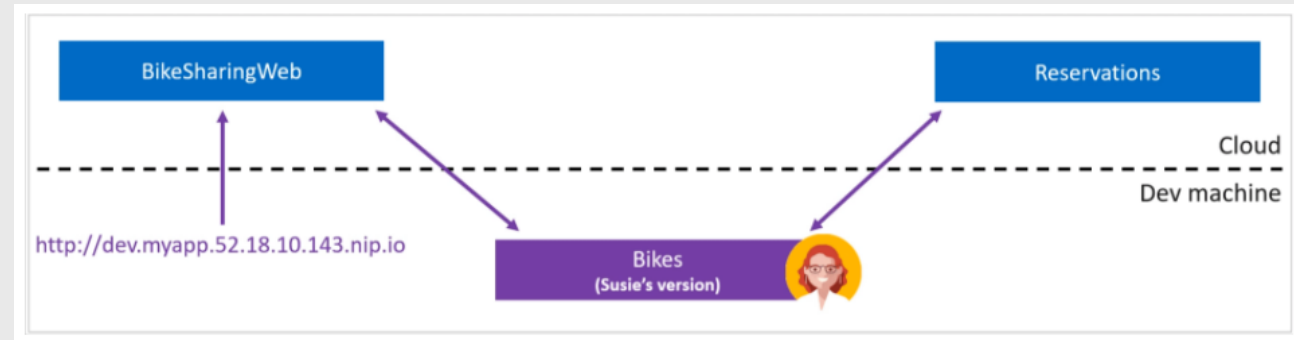
Developing and Testing End-to-End

Test end-to-end during development time. Route traffic to/from your development machine to in cluster deployments

Replacing Azure Dev Spaces (retiring 2023)



[Bridge to Kubernetes](#)
[Visual Studio Marketplace](#)



Additional Resources

Kubernetes Learning Path

Kubernetes
Docs

API Reference

Kubernetes
Hands On Lab

Kubernetes
Workshop

Katacoda
Courses

Udemy
Course



THANK YOU