Kubernetes Foundations

Part Two

Version 1.1.0

About Strigo

- Strigo is a web-based platform that provides the classroom environment for our courses.
- Let’s walk through the features of the platform.
- We’ll also get your lab environment initialized

Introductions

- About your instructor(s)

- Tell us about yourself
  - Would you classify yourself as a
    - developer
    - systems administrator
    - architect
    - It depends on the day/hour
  - What are your goals for learning and adopting Kubernetes?

Agenda

Part One

1. Introduction to Containers
2. Kubernetes Fundamentals
3. Kubernetes Architecture & Troubleshooting
4. Deployment Management
5. Pod & Container Configurations

Agenda

Part Two

6. Kubernetes Networking
7. Resource Organization
8. Storage & Stateful Applications
9. Dynamic Application Configuration
10. Additional Workloads
11. Security

Course Format

- This is a lab-intensive, hands-on course
- Each section will begin with the introduction of a new concept
- Each section contains a lab exercise where you will explore each new concept

Kubernetes Networking

Chapter 06

Agenda

Part Two

6. Kubernetes Networking
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Kubernetes Networking

- Within a Pod
- Pod to Pod
- Services to Pods
- External to Cluster

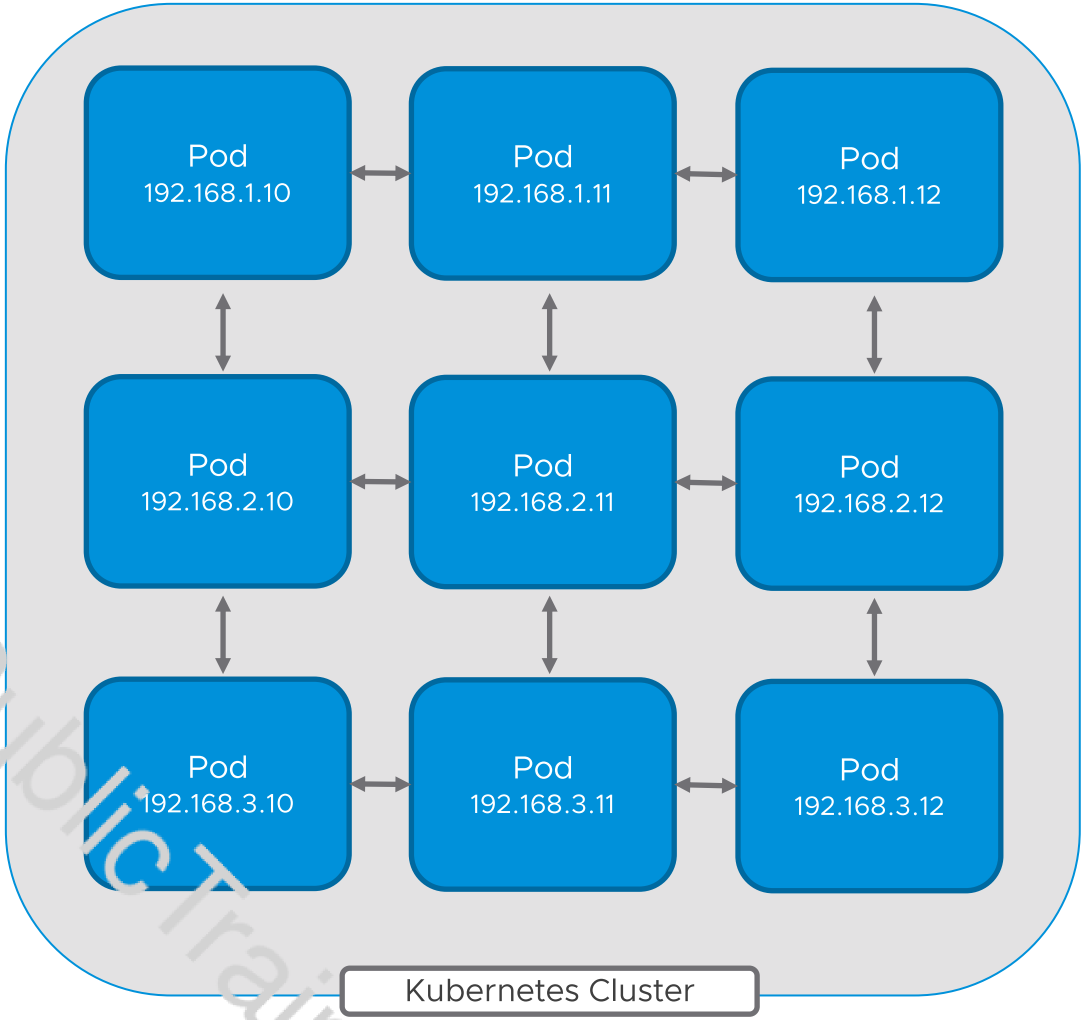
Networking - Within a Pod

- The containers within a pod
  - Can connect to each other using localhost
  - Share an IP address accessible throughout the cluster
  - Share a common port space, beware of conflicts

- These capabilities closely mimic those of multiple processes running on the same virtual machine

Networking - Pod to Pod

- Every pod is assigned an IP address
- This IP address is routable anywhere within the cluster

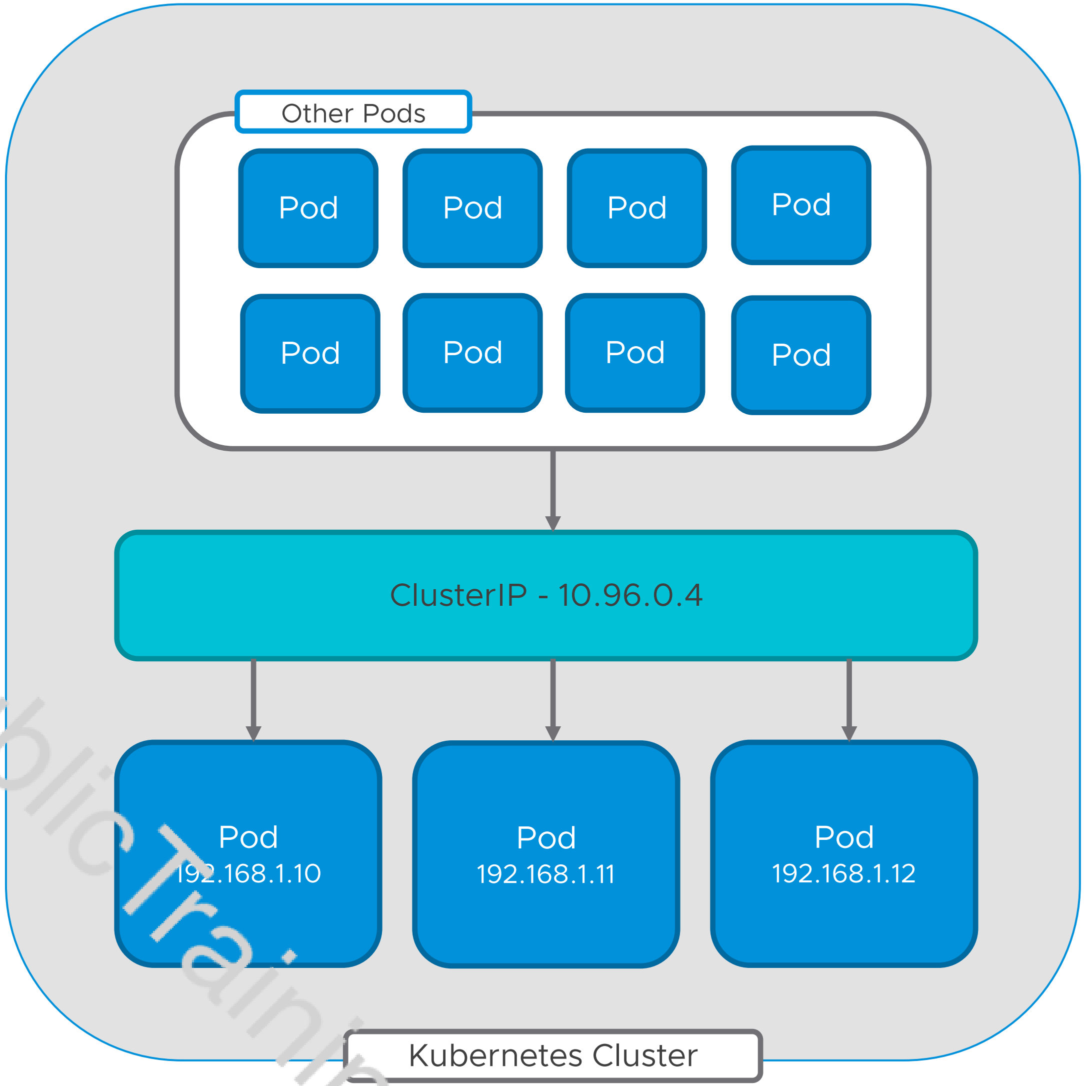


Networking - Services to Pods

- A service is a Kubernetes resource that
  - provides layer-4 load balancing for a group of pods
  - service discovery using the cluster's internal DNS
- Several types of Services are available
  - ClusterIP
  - NodePort
  - LoadBalancer

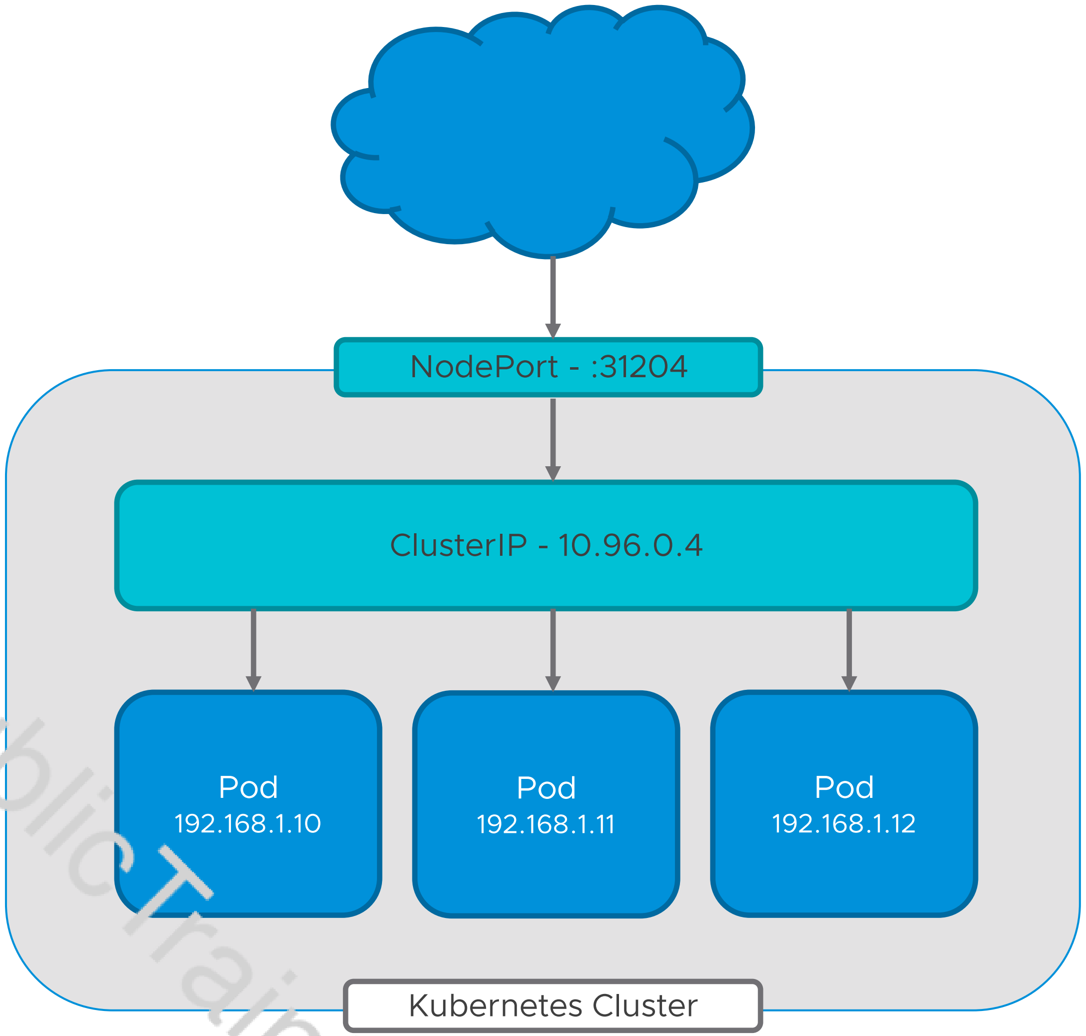
Service Type - ClusterIP

- Used for **internal**-facing services
- Implementation
  - a virtual IP address that load balances requests to a set of backend pods
  - accessible anywhere within the cluster
  - not externally accessible



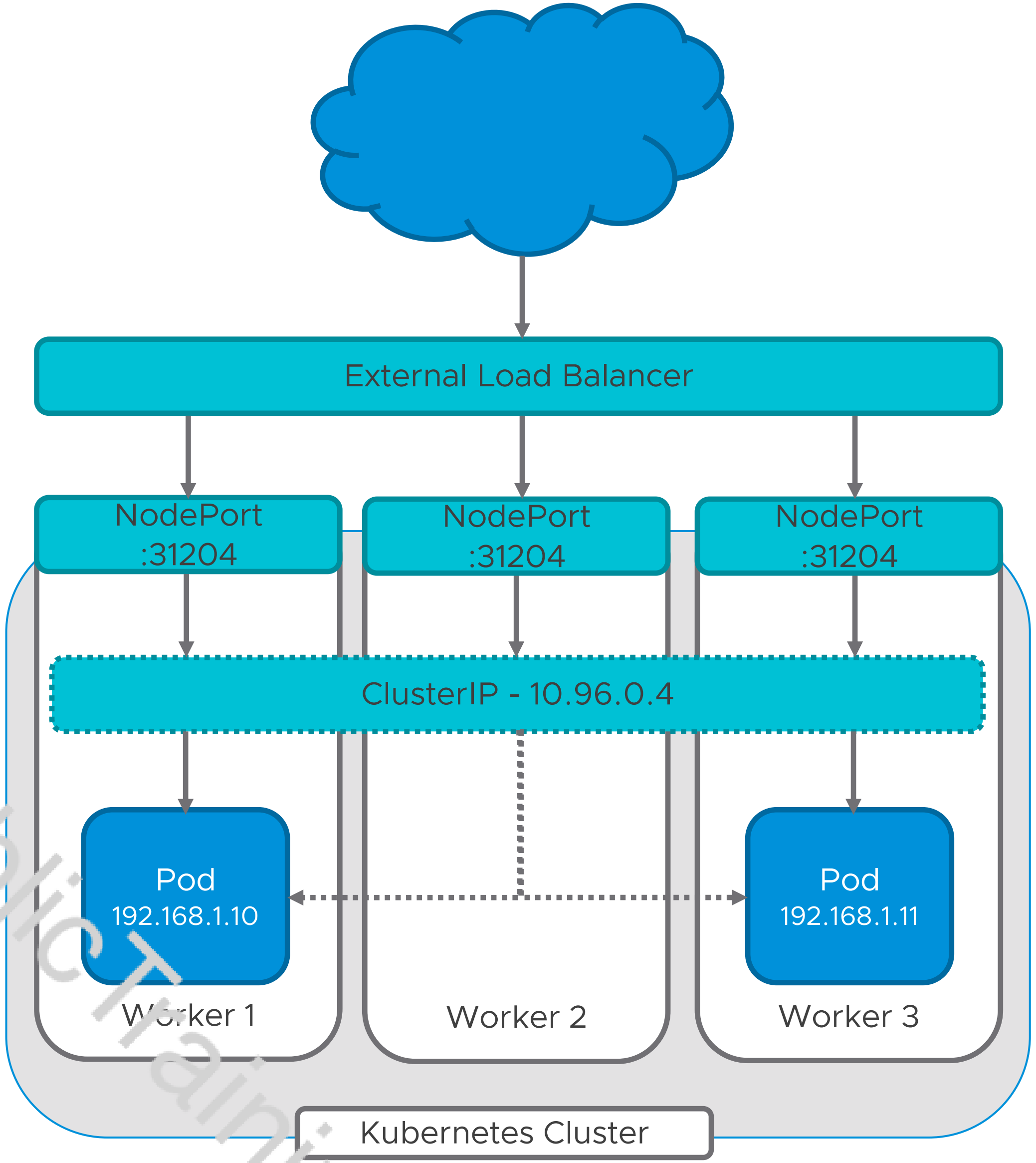
Service Type - NodePort

- Used for **external-facing services**
- Implementation
  - exposes a port on each worker node
  - externally accessible
  - leverages ClusterIP for load balancing to pods



Service Type - LoadBalancer

- Creates and manages an external load balancer
- Implementation
  - leverages NodePort for traffic ingress
  - leverages ClusterIP for load balancing to pods
  - plugins available for different Load Balancer implementations

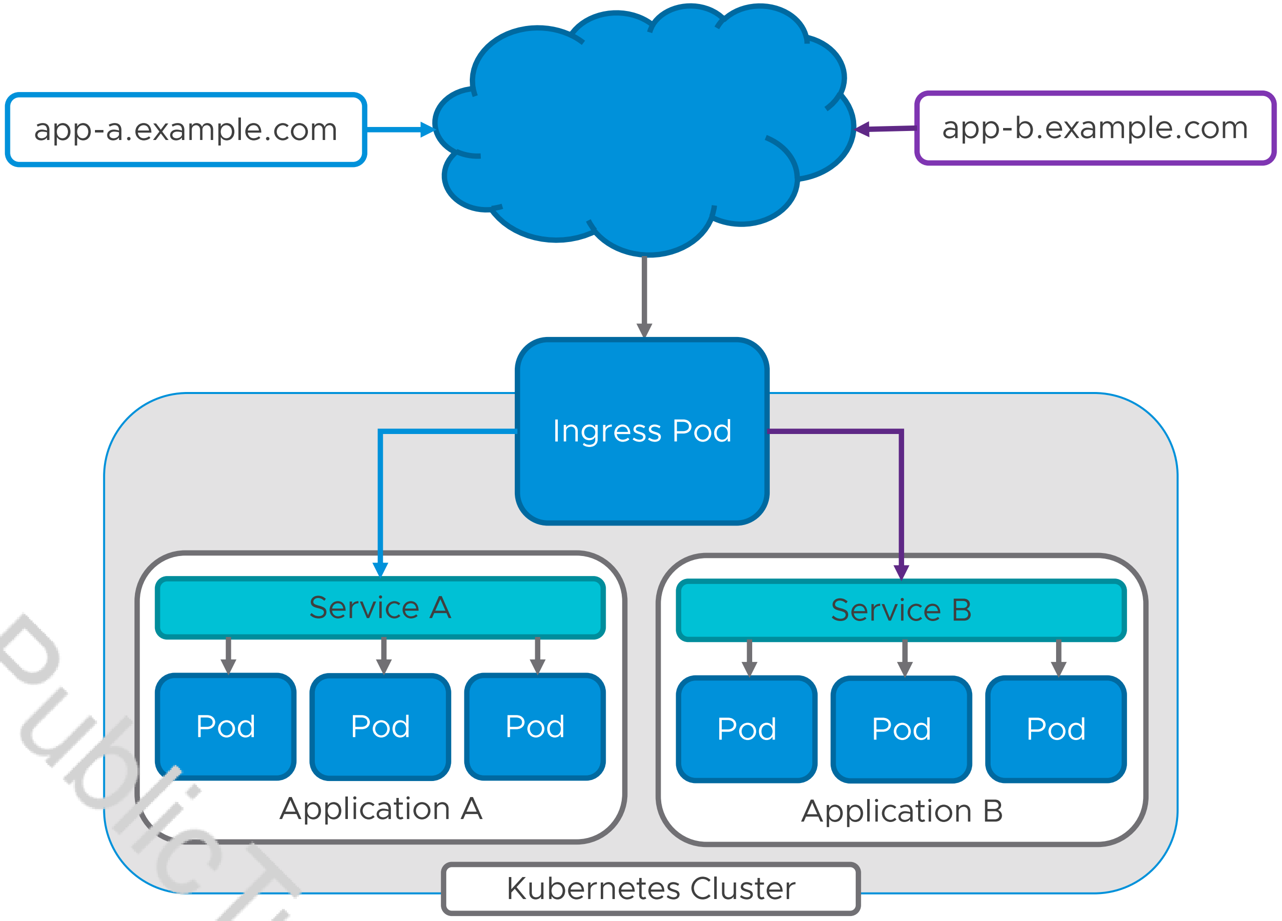


Networking - Ingress Controller to Pods

- An Ingress Controller is a feature which provides
  - layer-7 load balancing for one or more services
  - additional capabilities, depending on implementation
- Many Ingress Controller implementations are available
  - NGINX
  - Contour
  - Traefik
  - Amazon ALB, Google Layer-7 Load Balancer

Ingress Controller

- Used for external-facing layer 7 services
- Implementation
  - uses host header and path evaluation to direct traffic
  - externally accessible
  - configured with Ingress object



Ingress - Example

```
apiVersion: networking.k8s.io/v1beta1
kind: Ingress
metadata:
  name: my-layer7-apps
  annotations:
    nginx.ingress.kubernetes.io/rewrite-
target: /
spec:
```

```
  rules:
  - host: app-a.example.com
    http:
      paths:
      - path: /
        backend:
          serviceName: service-app-a
          servicePort: 8080
  - host: app-b.example.com
    http:
      paths:
      - path: /
        backend:
          serviceName: service-app-b
          servicePort: 8080
```

Lab 06

Exposing Services

Bootstrap lab to end of lab 05

Deploy an Ingress Controller

Expose Go Web App using an Ingress resource

Resource Organization

Chapter 07

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Resource Organization - Clusters

- Clusters
  - highest level of isolation but comes with extra management

- Examples
  - environments - prod vs qa vs dev
  - security - compliance requirement vs. no compliance
  - geography - different datacenters

Resource Organization - Namespaces

- Characteristics
  - names of resources must be unique within a namespace
  - scopes dns - <service-name>.<namespace-name>.svc.cluster.local
  - can apply resource and security/access restrictions

- Examples
  - teams - r&d, contractors, etc.
  - systems - email platform, company website, user facing app, etc.

Labels

- Characteristics
  - can exist on basically any resource in Kubernetes
  - nodes have labels too (including built-in ones)
  - keys/values are not enforced
  - not just labels… functionality tied to them (selectors and more)
- Tips
  - keep registration list and report of labels across
  - avoid compound label values:
    - `app: twitter-api` vs `app: twitter / tier: api`
  - be consistent across namespaces and clusters (imagine what labels you would need if everything was in one giant namespace)

kubectl - kubeconfig

- lives at ~/.kube/config

- sections of kubeconfig
  - clusters
  - contexts
  - users

```yaml
apiVersion: v1
clusters:
- cluster:
    certificate-authority-data: REDACTED
    server: https://clusterapi
  name: my_prod_cluster
contexts:
- context:
    cluster: my_prod_cluster
    user: admin
    namespace: myapp
  name: admin@kubernetes
current-context: admin@kubernetes
kind: Config
preferences: {}
users:
- name: admin
  user:
    client-certificate-data: REDACTED
    client-key-data: REDACTED
```

kubectl - global options

- namespace
  - `--namespace=kube-system`
    - run command for the specified namespace
  - kubectl config set-context <context> --namespace=<namespace>
    - change default namespace for a context

- output
  - -o custom-columns=myName:originalName,myName2:origName2
  - -o [json | yaml] - unfiltered json or yaml
  - -o jsonpath='{.metadata.name}' - filtered json with JSONpath syntax

- sorting
  - --sort-by=.metadata.name

Lab 07

Resource Organization

Exploring namespaces

DNS namespacing

Changing default namespacing

Filtering with kubectl and labels

Storage & Stateful Applications

Chapter 08

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Storage

- Volumes
  - exposed at Pod level and backed different ways
  - `emptyDir` - ephemeral scratch directory that lives for the life of pod
- Persistent Volumes
  - abstraction away from the storage provider (AWS EBS, GCE PD)
  - have a lifecycle independent of any individual pod that uses it
  - `hostPath` – requires node path knowledge; typically only for Ops use
- Persistent Volume Claims
  - request for storage with specific details (size, access modes, etc.)

Persistent Volumes

- By default, containers write to ephemeral storage
- As a result, when a pod is terminated, all data written by it's containers is lost
- We can attach Persistent Volumes to pods which persist any data written to them

Persistent Volumes

- Persistent volumes can be provisioned either statically or dynamically.
  - Static: A pre-provisioned pool of volumes such as iSCSI or Fiber Channel disk from a SAN
  - Dynamic: Volumes are created on demand by calling a storage provider’s API such as Amazon EBS
- Persistent Volumes have a lifecycle independent of the pods that use them.

Persistent Volume Claims

- Created by users to request a persistent volume
- Users can request various properties such as capacity and access modes (e.g., can be mounted once read/write or many times read-only)

Using Persistent Volumes

PersistentVolumeClaim

```
kind: PersistentVolumeClaim
apiVersion: v1
metadata:
  name: mysql-pvc
spec:
  accessModes:
    - ReadWriteOnce
  volumeMode: Filesystem
  resources:
    requests:
      storage: 8Gi
  storageClassName: slow
```

PVC in a Pod

```
kind: Pod
apiVersion: v1
metadata:
  name: mypod
spec:
  containers:
    - name: my-mysql
      image: mysql:5.6
      volumeMounts:
      - mountPath: "/var/lib/mysql"
        name: mysql-pd
  volumes:
    - name: mysql-pd
      persistentVolumeClaim:
        claimName: mysql-pvc
```

StatefulSets

- stable, unique pod indentifiers and DNS names
  - ${statefulset_name}-${ordinal}.${service_name}.${namespace}
- stable, persistent storage
  - one PV per VolumeClaimTemplate
  - sticky to pod for as long as the pod is declared in the API
- Controlled deployment order
  - pods created in asc order; deleted in desc order
  - before scaling all pods must be Running or Ready

StatefulSet - Example

```yaml
apiVersion: apps/v1
kind: StatefulSet
metadata:
  name: web
spec:
  selector:
    matchLabels:
      app: my-mysql
  serviceName: my-mysql
replicas: 1
  template:
    metadata:
      labels:
        app: my-mysql
```

```yaml
spec:
  containers:
  - name: mysql
    image: mysql:5.6
    volumeMounts:
    - name: mysql-pd
      mountPath: /var/lib/mysql
  volumeClaimTemplates:   # optional
   - metadata:
       name: mysql-pd
     spec:
       accessModes: [ "ReadWriteOnce" ]
       storageClassName: "my-storage-class"
       resources:
         requests:
           storage: 8Gi
```

Lab 08

Stateful Applications

Convert gowebapp-mysql Deployment to a StatefulSet

Simulate a pod failure

Verify data persistence

Dynamic Application Configuration

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Image Configurability

- All runtime configuration should be able to be injected and overridden
  - defaults inside a container image are fine
  - enables configuration to be supplied by Kubernetes and the environment

- Author can choose two approaches
  - provide defaults and startup if no configuration is provided
  - require configuration and fail to startup if none is provided

ConfigMaps

- Created from YAML or `kubectl create`
  - application build can produce ConfigMaps for each environment
  - namespace specific

```
apiVersion: v1
kind: ConfigMap
metadata:
  name: myapp-config-qa
  namespace: myapp-qa
data:
  server.properties: \
    MYAPP_MAX_THREADS = 25
    MYAPP_TLS_ENABLED = false
  job.properties: \
    MYJOB_NUM_THREADS = 5
```

```
apiVersion: v1
kind: ConfigMap
metadata:
  name: myapp-config-prod
  namespace: myapp-prod
data:
  server.properties: \
    MYAPP_MAX_THREADS = 100
    MYAPP_TLS_ENABLED = true
  job.properties: \
    MYJOB_NUM_THREADS = 10
```

Using ConfigMaps - As Environment Variables

- Load All Keys

```
image: myapp:v1.0.0
envFrom:
- configMapRef:
    name: myapp-config-prod
```

- Load Individual Keys

```
image: myapp:v1.0.0
env:
  - name: MYAPP_MAX_THREADS
    valueFrom:
      configMapKeyRef:
        name: myapp-config-prod
        key: MYAPP_MAX_THREADS
```

Using ConfigMaps - As Mounted Volumes

Load All Keys

```
containers:
  - name:
    image: myapp:v1.0.0
    volumeMounts:
    - name: myconfigvolume
      mountPath: /app/config
volumes:
  - name: myconfigvolume
    configMap:
      name: myapp-config-prod
```

Load Individual Key

```
containers:
  - name:
    image: myapp:v1.0.0
    volumeMounts:
    - name: myconfigvolume
      mountPath: /app/config
volumes:
  - name: myconfigvolume
    configMap:
      name: myapp-config-prod
      items:
      - key: MYAPP_MAX_THREADS
        path: maxWidgets
```

Using ConfigMaps - Variables vs Volumes

- Environment Variables
  - not reliant on filesystem nuances
  - easier when running containers outside of Kubernetes
  - changes require restart

- Mounted Volume
  - updates to ConfigMaps are reflected on the mounted volume

Secrets

- Resource that stores sensitive data such as a password, a token, or a key
  - Must be Base64 encoded
  - Like ConfigMaps, secrets can be exposed to a pod via environment variables and mounted volumes.

```yaml
apiVersion: v1
kind: Secret
metadata:
  name: mysecret
type: Opaque
data:
  username: YWRtaW4=
  password: MWYyZDFlMmU2N2Rm
```

Lab 09

Modify Docker Image

Update the gowebapp frontend image

Test application locally

Secrets and ConfigMaps

Create a secret for the MySQL password

Create a ConfigMap for gowebapp's configuration

Update the gowebapp and mysql deployments

Additional Workloads

Chapter 10

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Jobs

- Characteristics
  - run to completion
  - container/pod based
  - ensured to run to completion; retry forever by default

- Post job completion
  - Pod and Job resources will remain so can still view logs, output, etc.
  - up to the administrator to implement/determine cleanup rules

Jobs

An example Job that computes π to 2000 places

```yaml
apiVersion: batch/v1
kind: Job
metadata:
  name: pi
spec:
  template:
    spec:
      containers:
      - name: pi
        image: perl
        command: ["perl",  "-Mbignum=bpi", "-wle", "print bpi(2000)"]
```

Job Types

- Non-parallel Jobs
  - "normal" job with one pod. Job completes when Pod terminates successfully
- Parallel Jobs - fixed completion count
  - complete when there is one successful pod for each value in the range 1 to .spec.completions
  - example: process 1mil sequential records across 10 parallel jobs
- Parallel Jobs - work queue
  - when any pod terminates with success, no new pods are created
  - coordination is down with external service and all pods exist at same time

CronJobs

- Types
  - scheduled once at specified time
  - repeated at specified time

- Important Notes
  - new Job resource objects created for each run
  - by default 3 successful jobs are and 1 failed jobs are retained
  - jobs should be idempotent

CronJobs

```yaml
apiVersion: batch/v1beta1
kind: CronJob
metadata:
  name: hello
spec:
  schedule: "*/1 * * * *"
  jobTemplate:
    spec:
      template:
        spec:
          containers:
          - name: hello
            image: busybox
            args:
            - /bin/sh
            - -c
            - date; echo Hello from the Kubernetes cluster
          restartPolicy: OnFailure
```

DaemonSets

- A DaemonSet ensures that all Nodes run a copy of a Pod.
  - As nodes are added to the cluster, Pods are added to them
  - As nodes are removed from the cluster, those Pods are deleted
  - Often used for cluster administration functions

- Common use cases
  - Cluster-wide logging agents
  - Cluster-wide monitoring agents

Lab 10

Additional Workloads

Create a Job

Create a CronJob

Create a ParallelJob

Security

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Network Policy

Network Policy

- Specification of how groups of pods are allowed to communicate with:
  - each other
  - other network endpoints

- Use labels to select pods and define rules which specify what traffic is allowed to the selected pods

Isolated and Non-isolated Pods

- Pods are non-isolated (default)
  - Accept traffic from any source
- Pods become isolated by:
  - Defining a NetworkPolicy that selects them in a Namespace
  - Pod will reject any connections that are not explicitly allowed by a NetworkPolicy
  - Other Pods in the Namespace that are not selected by any NetworkPolicy will continue to accept all traffic

Network Policy Example – Inbound

```yaml
apiVersion: networking.k8s.io/v1
kind: NetworkPolicy
metadata:
  name: test-network-policy
  namespace: default
spec:
  podSelector:
    matchLabels:
      tier: backend
  policyTypes:
  - Ingress
```

```yaml
  ingress:
  # pods in gowebapp namespace OR are labeled gowebapp
  - from:
    - namespaceSelector:
        matchLabels:
          project: gowebapp
    - podSelector:
        matchLabels:
          app: gowebapp
    ports:
    - protocol: TCP
      port: 3306
```

Network Policy Example – Inbound Improved

```yaml
apiVersion: networking.k8s.io/v1
kind: NetworkPolicy
metadata:
  name: test-network-policy
  namespace: default
spec:
  podSelector:
    matchLabels:
      tier: backend
  policyTypes:
  - Ingress
```

```yaml
  ingress:
    # pods in gowebapp namespace AND are in tier frontend
    - from:
      - namespaceSelector:
          matchLabels:
            project: gowebapp
    - from:
      - podSelector:
          matchLabels:
            tier: frontend
      ports:
      - protocol: TCP
        port: 3306
```

Network Policy Example – Inbound and Outbound

```yaml
apiVersion: networking.k8s.io/v1
kind: NetworkPolicy
metadata:
  name: test-network-policy
  namespace: default
spec:
  podSelector:
    matchLabels:
      tier: backend
  policyTypes:
  - Ingress
  - Egress
```

```yaml
  ingress: # pods in gowebapp namespace AND are tier frontend
  - from:
    - namespaceSelector:
        matchLabels:
          project: gowebapp
  - from:
    - podSelector:
        matchLabels:
          tier: frontend
    ports:
    - protocol: TCP
      port: 3306
  egress: # allow the DB to connect to LDAP for auth
  - to:
    - ipBlock:
        cidr: 10.0.0.0/24
    ports:
    - protocol: TCP
      port: 389
```

Requesting Escalated Privileges for Pods and Containers

SecurityContext

- PodSpec section for defining container privileges
  - if defined at pod level, then defines defaults for all containers
  - can be overridden and specified per container as well
  - cluster administrators can enforce restrictions with policies

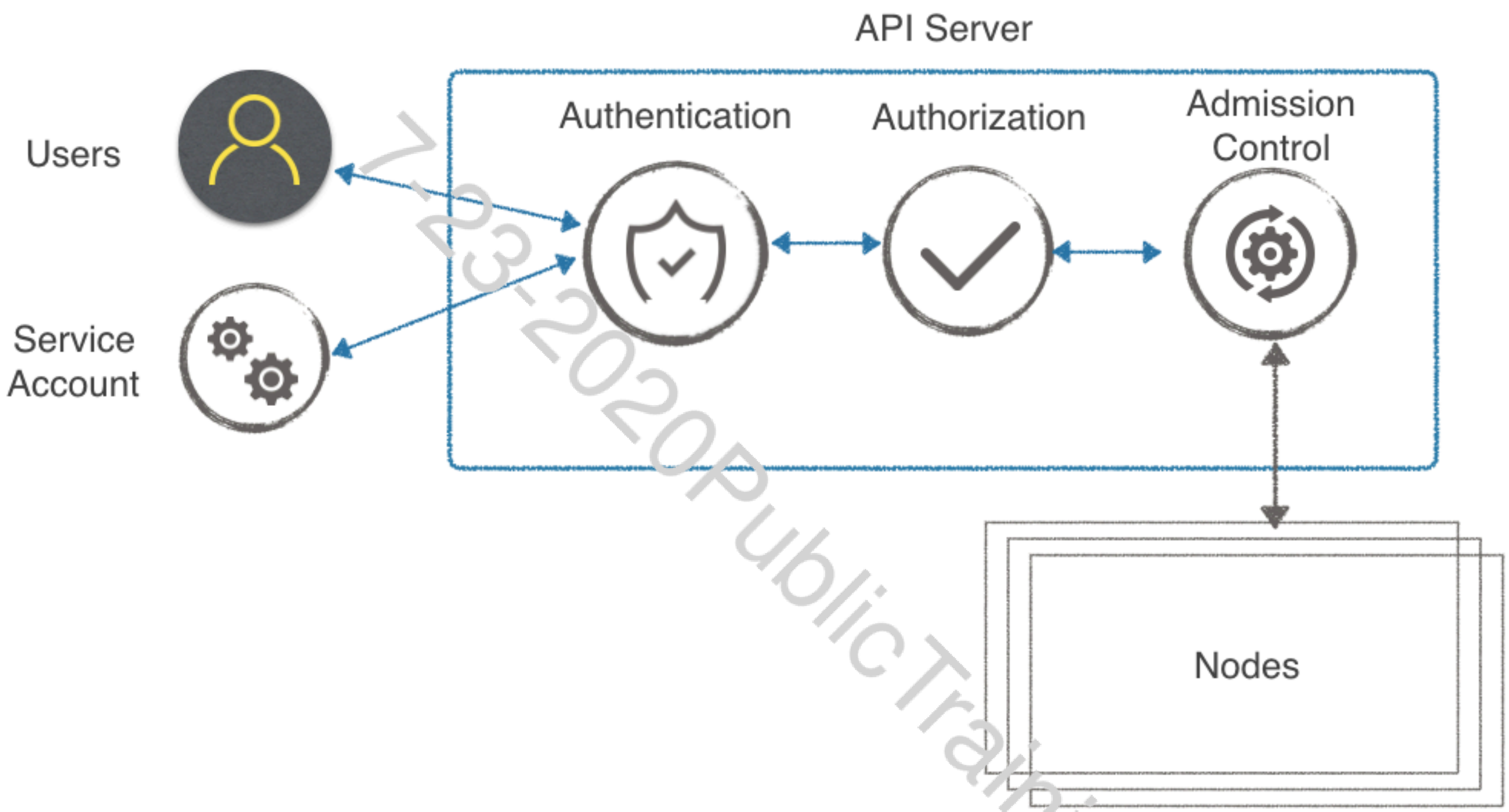
- Example settings
  - runAsUser / runAsGroup
  - SELinux
  - Linux Capabilities
  - Host file paths allowed to be mounted and accessed

SecurityContext - Example

```yaml
apiVersion: v1
kind: Pod
metadata:
  name: myapp
spec:
  securityContext:
    runAsUser: 1000
  containers:
  - name: myapp
    image: myapp:v1
    securityContext:
      allowPrivilegeEscalation: false
  - name: sidecar
    image: mysidecar:v1
    securityContext:
      runAsUser: 2000
```

Controlling Access

API Access Control



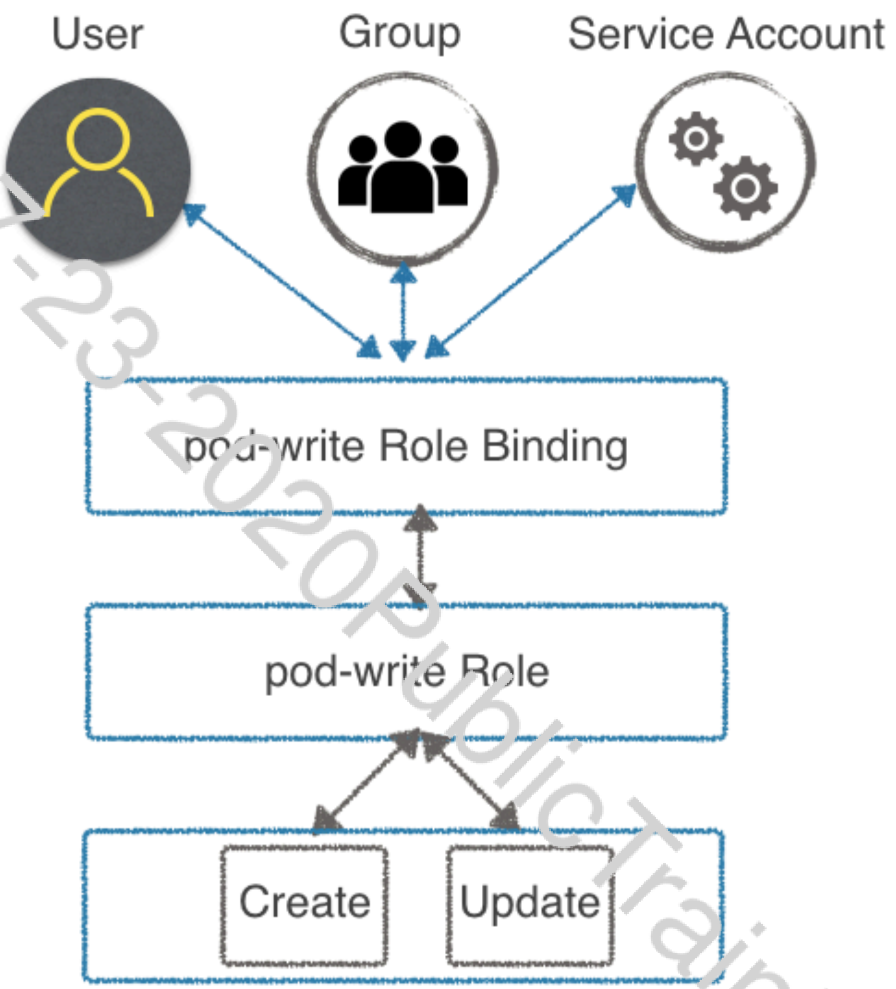
Authentication Methods

- Client Certificates
  - common usage: Cluster Components
- Tokens
  - common usage: Service Accounts
- External Authentication
  - common usage: Users

Authentication - Service Accounts

- Service Account Tokens
  - generated automatically when a ServiceAccount object is created
  - mounted inside pods /var/run/secrets/kubernetes.io/serviceaccount
  - spec.serviceAccountName - overrides default service account

Role-Based Access Control (RBAC)



Role

- Characteristics
  - collection of permissions (rules)
  - standalone and must be bound to a subject
  - namespace specific

```yaml
kind: Role
apiVersion: rbac.authorization.k8s.io/v1
metadata:
  namespace: default
  name: my-app-secret-reader
rules:
- apiGroups: [""]
  resources: ["secret"]
  verbs: ["get"]
```

ClusterRole

- Characteristics
  - same as Role, except is global to the cluster
  - reusable across entire cluster

```yaml
kind: ClusterRole
apiVersion: rbac.authorization.k8s.io/v1
metadata:
  name: pod-reader
rules:
- apiGroups: [""]
  resources: ["pods"]
  verbs: ["get", "watch", "list"]
```


RoleBinding

- Characteristics
  - connects a one or more subjects to a Role/RoleBinding

```yaml
kind: RoleBinding
apiVersion: rbac.authorization.k8s.io/v1
metadata:
  name: my-app-read-secret
  namespace: default
subjects:
- kind: ServiceAccount
  name: my-app
  apiGroup: rbac.authorization.k8s.io
roleRef:
  kind: Role
  name: my-app-secret-reader
  apiGroup: rbac.authorization.k8s.io
```

ClusterRoleBinding

- Characteristics
  - Same as RoleBinding, except is global to the cluster

```
kind: ClusterRoleBinding
apiVersion: rbac.authorization.k8s.io/v1
metadata:
  name: read-pods
subjects:
- kind: User
  name: jane
  apiGroup: rbac.authorization.k8s.io
roleRef:
  kind: ClusterRole
  name: pod-reader
  apiGroup: rbac.authorization.k8s.io
```

Built-in Roles

Default ClusterRole	Description
cluster-admin	Allows super-user access to perform any action on any resource. When used in a **ClusterRoleBinding**, it gives full control over every resource in the cluster and in all namespaces. When used in a **RoleBinding**, it gives full control over every resource in the rolebinding's namespace, including the namespace itself.
admin	Allows admin access, intended to be granted within a namespace using a **RoleBinding**. If used in a **RoleBinding**, allows read/write access to most resources in a namespace, including the ability to create roles and rolebindings within the namespace. It does not allow write access to resource quota or to the namespace itself.
edit	Allows read/write access to most objects in a namespace. It does not allow viewing or modifying roles or rolebindings.
view	Allows read-only access to see most objects in a namespace. It does not allow viewing roles or rolebindings. It does not allow viewing secrets, since those are escalating.

RBAC Example

RBAC Example

- Jack should have read-only access to the cluster

RBAC Example

- Jack should have read-only access to the cluster

```
kind: ClusterRoleBinding
apiVersion: rbac.authorization.k8s.io/v1
metadata:
  name: my-global-access
subjects:
- kind: User
  name: Jack
  apiGroup: rbac.authorization.k8s.io
roleRef:
  kind: ClusterRole
  name: view
  apiGroup: rbac.authorization.k8s.io
```

RBAC Example

- Jack should also have edit access to "foo" namespace

RBAC Example

- Jack should also have edit access to "foo" namespace

```
kind: RoleBinding
apiVersion: rbac.authorization.k8s.io/v1
metadata:
  name: my-team-access
  namespace: foo
subjects:
- kind: User
  name: Jack
  apiGroup: rbac.authorization.k8s.io
roleRef:
  kind: ClusterRole
  name: edit
  apiGroup: rbac.authorization.k8s.io
```

Lab 11

Security

Apply network policies

Create a service account

Apply permissions to a service account

Conclusion

Thank You