Kubernetes (K8s)

Background.

- **An open-source system for automating the deployment, scaling and management of containerized applications.**
  - **A container orchestration platform.**
- **Originally announced by Google in 2014.**
- **In 2015, Google donated it to the Cloud Native Computing Foundation (CNCF).**

- **Kubernetes is the Greek word for helmsman – a person that steers a ship that carries containers of goods.**

The problems it solves.

- **Problem 1: An application is comprised of multiple containers running on a cluster of nodes (on-premise server, Cloud VMs I e.g. AWS EC2). A container or an entire node crashes.**
- ➢ **K8s provides <u>monitoring</u> and <u>self-healing</u>, to ensure high <u>availability</u>.**

- **Problem 2: A container experiences a spike in traffic resulting in increased <u>latency</u>.**
- ➢ **K8s provides <u>auto-scaling</u> and <u>load balancing</u>. It replicates the container on the node and/or across the cluster of nodes and load balances the requests between them. It scales up and down based on demand.**

The problems it solves.

- **Problem 3: You regularly <u>upgrade</u> an image and want to apply the change to a fleet of running containers without effecting <u>downtime</u>.**
  - ➢ **K8s provides <u>rolling deployments</u> - delete and restart each container, one by one rather than all at once.**
  - ➢ **Also supports canary deployments.**

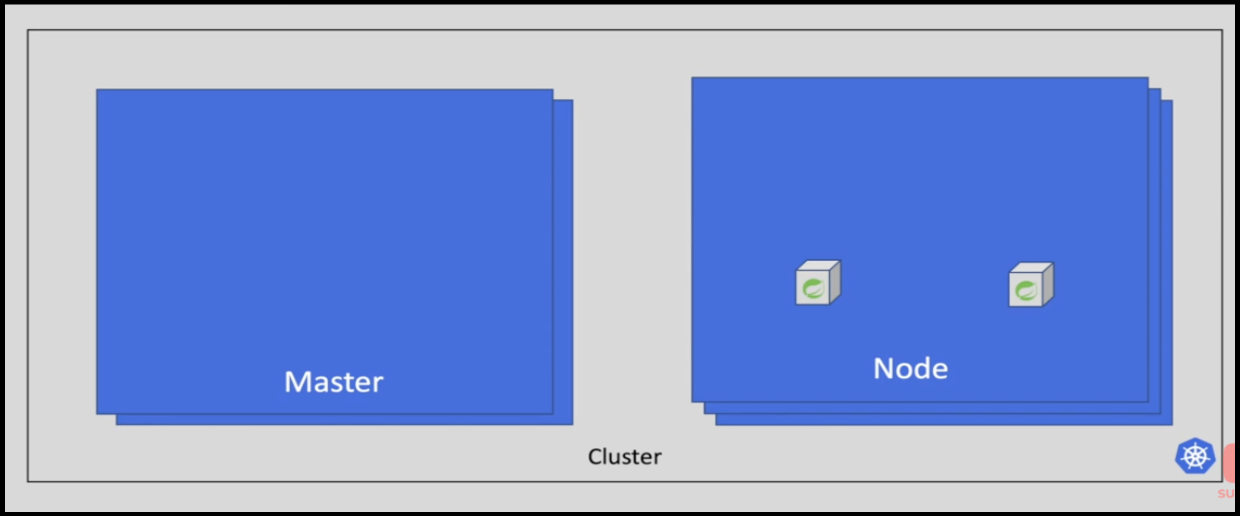
- **Problem 4: I want to upgrade my entire application from v1 to v2.**
  - ➢ **K8s provides automatic rollout and rollback.**

The problems it solves.

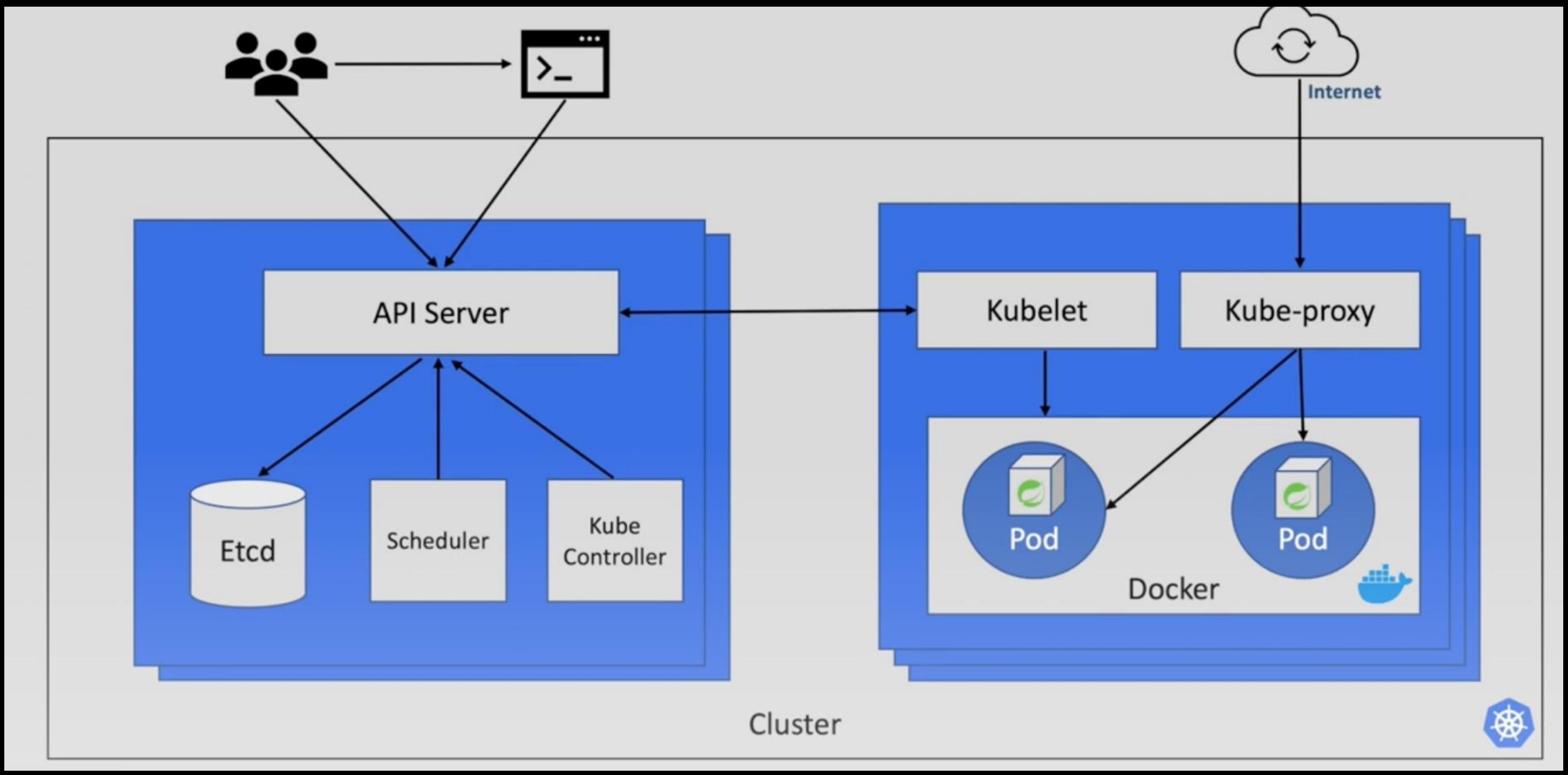
- **Problem 5: I want to reconfigure my application's without rebuilding images.**
- ➢ **K8s provides <u>secrets and configuration mappings</u> to safeguard sensitive data and avoid unnecessary rebuilding of images.**

K8s Architecture

- K8s is installed over a set of nodes (VMs)
- Worker nodes host containers - the Data plane
- Master nodes (Control plane) manages the workers – More than one master for fault tolerance and high availability.
- The set of masters and workers is called a cluster

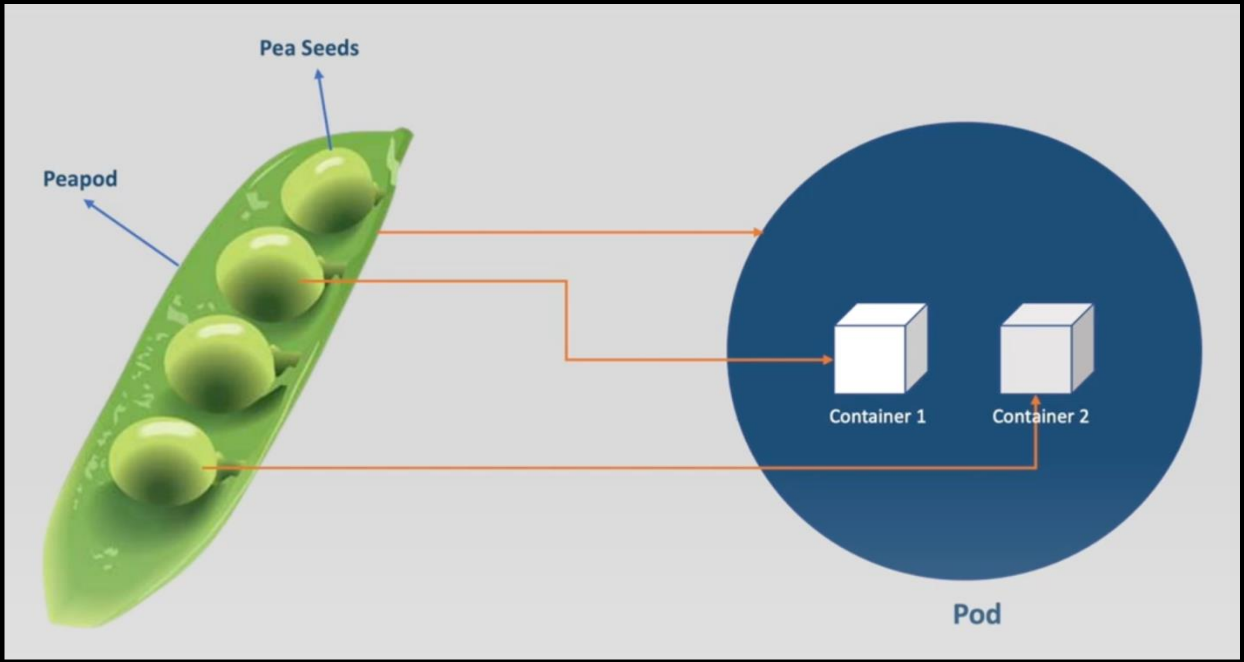


K8s Architecture



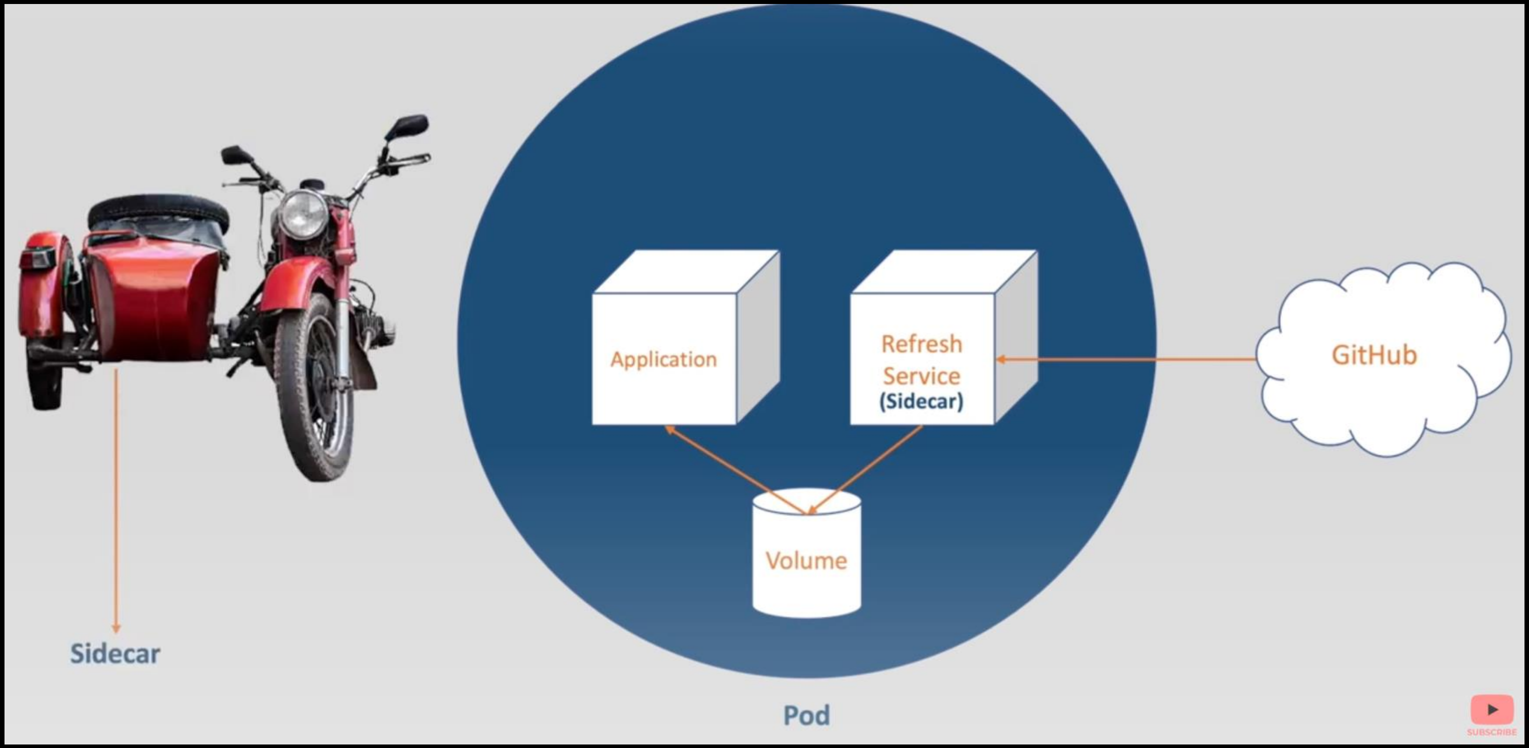
All about Pods

- The smallest unit of deployment is a pod.
- It encapsulates a group of containers, that share the same localhost network and storage.
- A pod is assigned a private IP address, but it’s dynamic.



All about Pods

- When a pair of containers are tightly coupled, they must reside on the same worker node. The pod construct ensures this is satisfied.



Pod basics

- The containers in a pod share the same network (localhost), but use different ports.
- Deleting a pod will delete all its containers.
- To scale an app, we replicate its pod, where each one has its own group of containers.

- IP addressing:
  - A pod is assigned a private IP address.
  - On scale up, each pod replica is assigned its own IP.
  - Pod IPs are <u>dynamic</u>.

Pod basics

```
❯ oc run nginx-pod --image=nginx:latest
pod/nginx-pod created

❯ oc get pods
NAME        READY   STATUS    RESTARTS   AGE
nginx-pod   1/1     Running   0          12s
```

- Creating Kubernetes resources (e.g. pods) from the command line is cumbersome; instead, we use declarative code files for better maintainability.
  - Files are termed manifests – yaml or json options.

Pod basics - Manifest files.

❯ oc apply -f 01-nginx-pod.yaml
pod/nginx-pod1 created

❯ oc get pods

NAME	READY	STATUS	RESTARTS	AGE
nginx-pod	1/1	Running	0	3d5h
nginx-pod1	1/1	Running	0	16s

❯ oc get pods -l team=integration (Pod labels)

NAME	READY	STATUS	RESTARTS	AGE
nginx-pod1	1/1	Running	0	2m7s

Pod basics - Attributes

- The etcd stores lots of attributes about pods

❯ oc get pod nginx-pod1 -o wide

NAME READY STATUS RESTARTS AGE IP NODE NOMINATED NODE READINESS GATES

nginx-pod1 1/1 Running 0 13m 10.130.1.156 worker1 <none> <none>

- Use describe command to get all etcd info:

❯ oc describe pod nginx-pod1

  – Response also shows the ‘events’ that occurred for a pod.

Pod basics - Debugging

- Three main options:

1. Port-forwarding is possible with cluster access:

```
❯ oc port-forward nginx-pod1  3000:80
Forwarding from 127.0.0.1:3000 -> 80
Forwarding from [::1]:3000 -> 80
```

2. Check container's logs:

```
❯ oc logs nginx-pod1
```

3. Open a terminal shell inside the container:

```
❯ oc exec -it nginx-pod1 -- /bin/bash
root@nginx-pod1:/#
```

ReplicaSets

- For high availability of an app (pod), K8s can create multiple copies in the cluster, called replica sets.

```
❯ oc apply -f 02-nginx-replica.yaml
replicaset.apps/nginx-replica created
❯ oc get pods
NAME                 READY   STATUS              RESTARTS   AGE
nginx-replica-dmfvn  0/1     ContainerCreating   0          7s
nginx-replica-wc7j9  0/1     ContainerCreating   0          7s
❯ oc get rs       (rs - replicaset)
NAME           DESIRED   CURRENT   READY   AGE
nginx-replica  2         2         2       14s
```

Self-healing

❯ oc delete pod nginx-replica-dmfvn

pod "nginx-replica-dmfvn" deleted

❯ oc get pods

NAME	READY	STATUS	RESTARTS	AGE
nginx-replica-kkhs2	0/1	ContainerCreating	0	3s
nginx-replica-wc7j9	1/1	Running	0	7m36s

- The new pod’s IP address is different to the one it replaced.
- A replica set’s spec.selector property determines the pods it controls.
  - A pod’s labels match the replica set’s selector

Deployments

- Deployments provide extra features over replica sets:
  - Rollout and rollback;
  - Deployment strategy.
  - Etc

- It automatically creates a replica set resource.
- The resource hierarchy:
  - A deployment manages a replica set.
  - A replica set manages a set of pods, based on matching the replica set’s selectors with a pod’s labels.
  - A pod manages its containers.

Deployments

```
❯ oc apply -f 03-nginx-deployment.yaml
deployment.apps/nginx-depl created
❯ oc get deployments
NAME        READY   UP-TO-DATE   AVAILABLE   AGE
nginx-depl  1/2     2            1           16s

❯ oc get rs
NAME                   DESIRED   CURRENT   READY   AGE
nginx-depl-7569b665c5  2         2         2       20s

❯ oc get po
NAME                         READY   STATUS    RESTARTS   AGE
nginx-depl-7569b665c5-dvxrj  1/1     Running   0          25s
nginx-depl-7569b665c5-nd77g  1/1     Running   0          25s
```

Deployment Updates

- Each Deployment update creates a new replica set

```
❯ oc apply -f 03-nginx-deployment.yaml.   (After update)
deployment.apps/nginx-depl configured
❯ oc get rs
NAME                  DESIRED   CURRENT   READY   AGE
nginx-depl-588f77bb97   2         2         1       15s
nginx-depl-7569b665c5   1         1         1       16m

❯ oc get rs
NAME                  DESIRED   CURRENT   READY   AGE
nginx-depl-588f77bb97   2         2         2       30s
nginx-depl-7569b665c5   0         0         0       16m
```

Deployment Rollout

❯ oc apply -f 03-nginx-deployment.yaml (1st deploy)

deployment.apps/nginx-depl created

❯ oc rollout history deployment nginx-depl

deployment.apps/nginx-depl

REVISION CHANGE-CAUSE

1 Initial deployment

- Suppose we edit and apply the YAML twice:

❯ oc rollout history deployment nginx-depl

deployment.apps/nginx-depl

REVISION CHANGE-CAUSE

1 Initial deployment

2 Change to Nginx 1.21.5

3 Change to port 82

Deployment Rollback

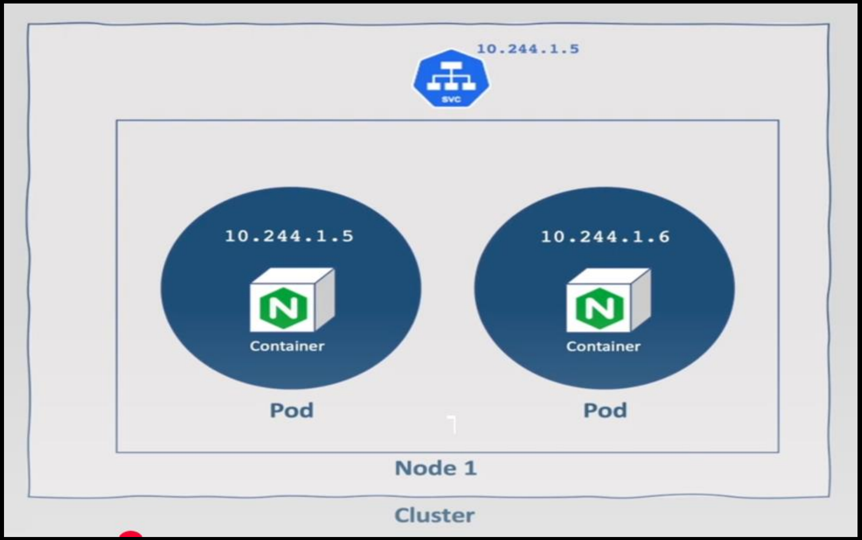
- Rollback – Undo a Deployment rollout.

```
❯ oc rollout undo deployment nginx-depl
          --to-revision=2
deployment.apps/nginx-depl rolled back

❯ oc rollout history deployment nginx-depl
deployment.apps/nginx-depl
REVISION  CHANGE-CAUSE
1         Initial deployment
3         Change to port 82
4         Change to Nginx 1.21.5
```

Services

- How do pods communicate with each other?
  - Pods are assigned IP addresses, BUT these are NOT static and are not accessible outside the cluster.
  - Most rollouts and rollback cause pods to be recreated, resulting in new IP address assignments.
- Solution: Services.



Services

- Services abstract a set of pods (typically a replica set).
  - They’re assigned a static IP address.
  - Unlike pods, a service is not assigned to a node.
  - Services load balance the workload between its pods.
  - Service Types:
    1. ClusterIP (Accessible inside the cluster only)
    2. NodePort
    3. LoadBalancer
    4. Ingress

ClusterIP Service creation

```
❯ oc apply -f 05-nginx-service.yaml
service/nginx-service created
❯ oc get svc
NAME          TYPE        CLUSTER-IP       EXTERNAL-IP                    PORT(S)    AGE
nginx-service   ClusterIP     172.30.250.186   <none>
                    8081/TCP   40s

❯ oc get endpoints nginx-service
NAME          ENDPOINTS                        AGE
nginx-service   10.130.0.75:80,10.131.1.91:80   2m10s
```

- These are the IPs (and ports) of its associated pods

ClusterIP Service access

- Service IPs are private (only accessible inside the cluster).

❯ curl 172.30.250.186:8081

^C

❯ oc exec -it nginx-depl-7569b665c5-2mfzg -- sh

 # curl 172.30.250.186:8081

 <!DOCTYPE html><html>. . .this works . . . </html>

 # curl http://nginx-service:8081

 <!DOCTYPE html><html> . . . . . </html>

  - K8s support domain name resolution and service discovery.
- Port-forwarding with services is also allowed.

Services – Load balancing

- A service load balances the traffic to the pods

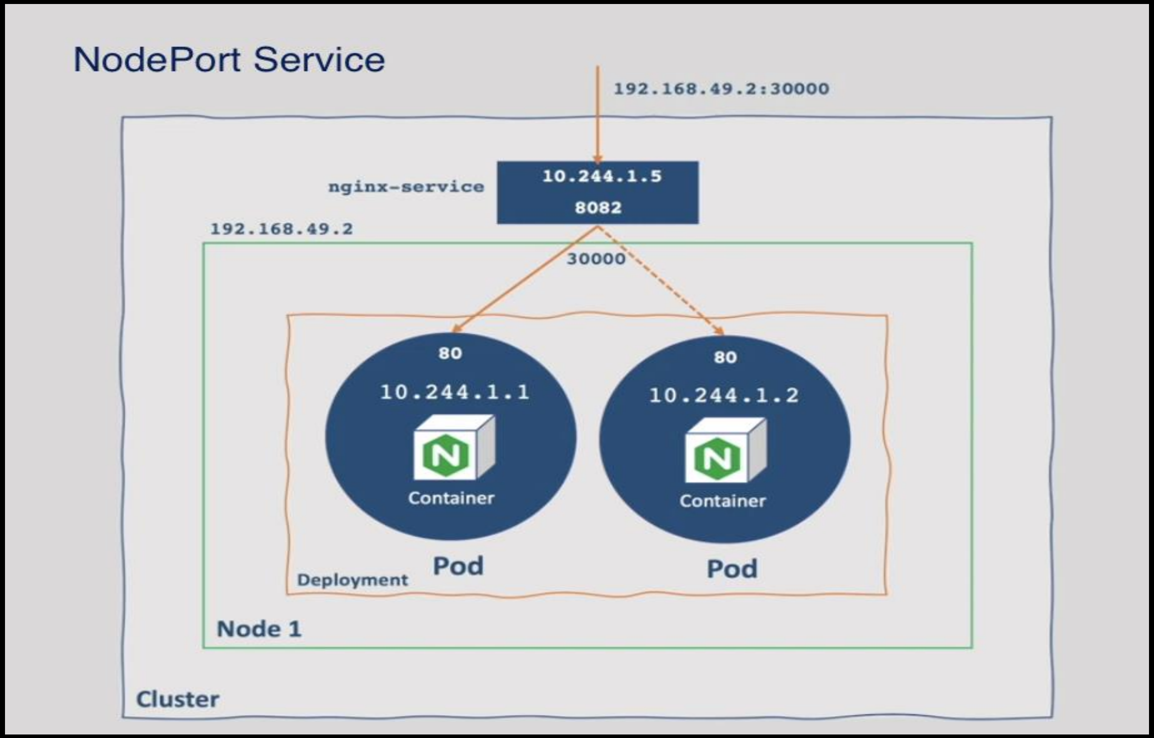
❯ oc exec -it nginx-depl-756965c5-2mfzg -- bin/bash

```
# i=1
while [ $i -le 20 ]
do
  curl nginx-service:8081;
  i=$(( $i + 1 ))
done
```

- Monitor the pods by streaming their logs:

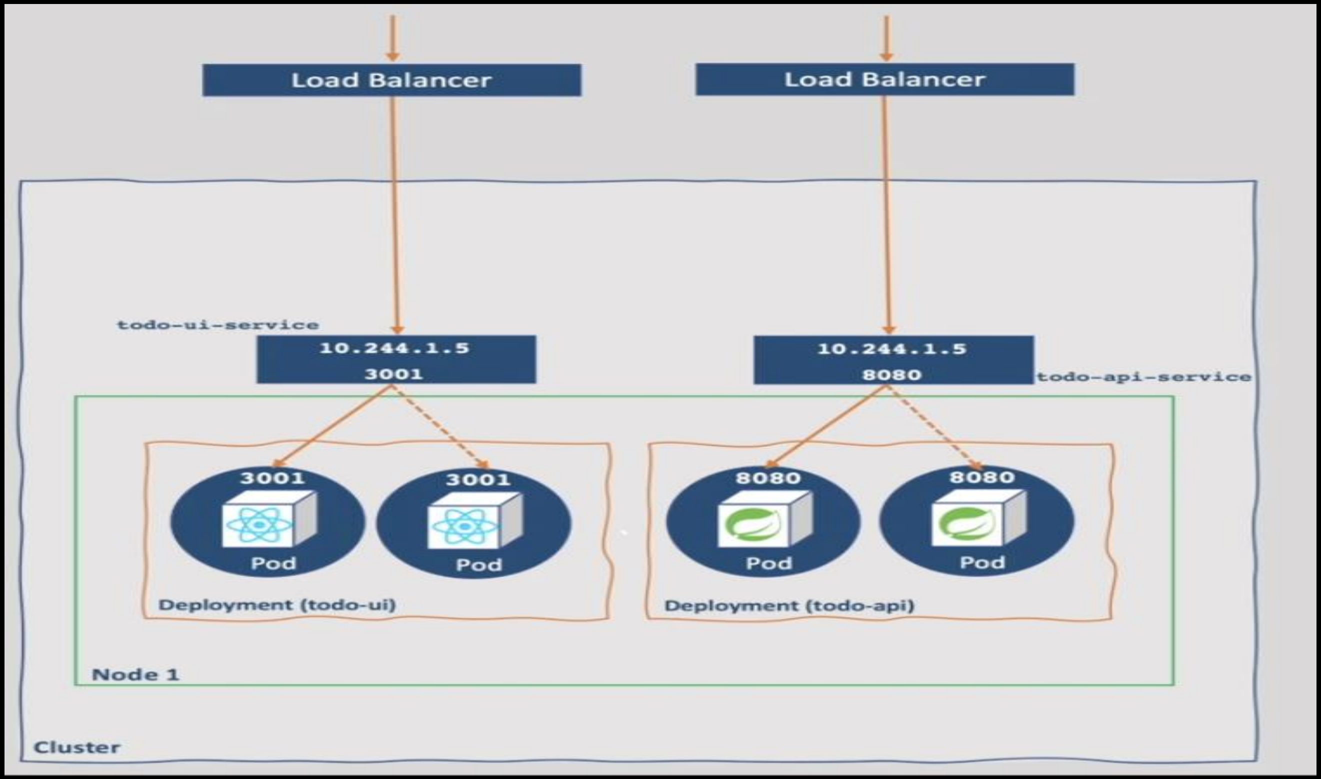
❯ oc logs nginx-depl-7569b665c5-2mfzg -f

NodePort Service



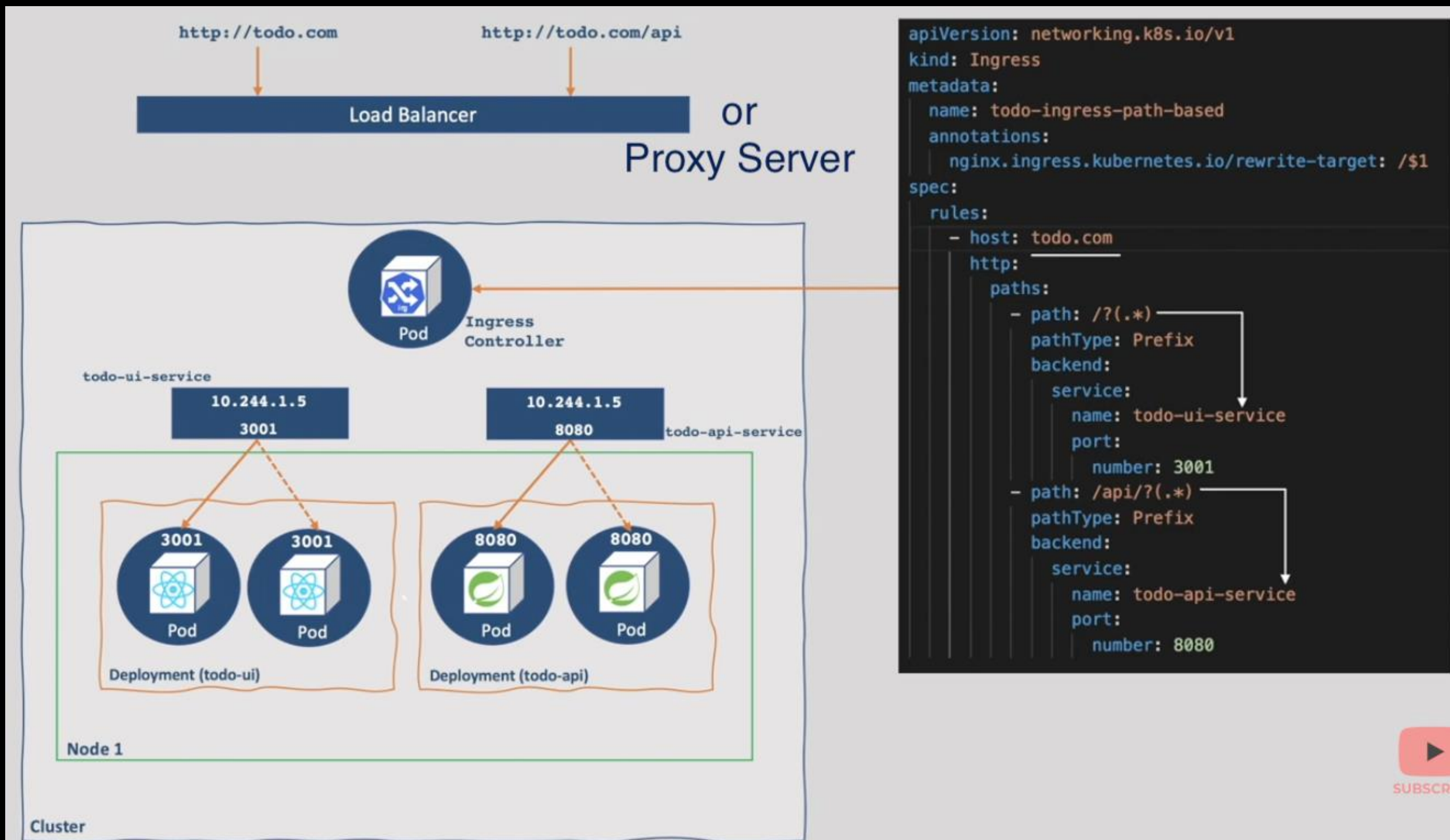
- Disadv: Insecure - Opens a worker's port – 1 port per service. Unstable – Node IPs change on rebooting.

LoadBalancer Service



- Disadv: Must configure an external Load Balancer, e.g. AWS Load Balancer. Costly, as each NP service needs its own LB.

Ingress Service



Ingress Service

```
❯ oc get ing
NAME          CLASS    HOSTS                                         ADDRESS                                           PORTS   AGE
nginx-ingress   <none>   doc-nginx.apps.ocp-setu.waltoninstitute.ie   router-default.apps.ocp-setu.waltoninstitute.ie   80     33m

❯ oc describe  ing/nginx-ingress
Name:           nginx-ingress
Labels:         <none>
Address:        router-default.apps.ocp-setu.waltoninstitute.ie
Rules:
  Host                                   Path  Backends
  ----                                   ----  --------
  doc-nginx.apps.ocp-setu.waltoninstitute.ie
                                         /   nginx-service:8081 (10.129.3.3:80,10.130.1.247:80)
```

Volumes

- Problem 1: When a pod crashes, its data is lost.
  - The same applies to a node crash.
- Problem 2: The pods in a set cannot share data.
- Use volumes to overcome the above problems.
- A volume is a directory containing data that is accessible to a pod.
- Three types of volumes:
  1. emptydir – data outside the container, but private to a pod. Development only.
  2. hostPath – data outside the pod, but private to a node. Development only.
  3. Persistent Volumes – data outside the cluster and accessible by a pod set (cross-node).

Persistent Volumes

- Three components (Kubernetes resources):
  1. Persistent Volumes (PV)
  2. Persistent Volumes claims (PVC)
  3. Storage Classes
  - All are represented as cluster resources.

- A *Persistent Volume* (PV) is a piace of storage that has been provisioned by an administrator or dynamically provisioned.
  - Created with a YAML manifest.
- Storage Classes – types of storage devices, e.g. AWS EBS, NFS server, etc.
  - A PV specifies the storage class, size, access mode, etc.

Persistent Volumes

- A persistent volume claim (PVC) is a declaration by a pod that it will require storage.
  - A PVC is bound to a PV by matching the storage class, size, etc
  - The PV is mounted to a container path.
- Pod(s) → PVC → PV

- PV access modes:
  - ReadWriteMany – volume can be mounted by many nodes.
  - ReadWriteOnce – volume can be mounted by one node only. All the pods must be running on one worker node.
  - ReadMany / ReadOnce
  - ReadWriteOncePod

Application Configuration

- To use an application in different environments (dev, staging, prod), we should externalize its configuration, i.e. Reusability.
- Techniques:
    1. Command line arguments
    2. Configuration files
    3. Environment variables

- Similar techniques with Docker images:
    - Build-time arguments accessed in Dockerfile.
    - Runtime – environment variables used by container.
        - Avoids rebuild an image for each environment

Kubernetes – Pod configuration

- Avoid hard-coding pod configuration data in the deployment manifest.
- K8s has two special “volumes” for externalising pod configuring pod data:
  1. ConfigMaps.
  2. Secrets.

Kubernetes – ConfigMap

- ConfigMap is a K8s resource that lets you store config data that can be reused across applications.
- Config data can be:
  1. Simple key/value pairs, or
  2. An entire configuration file – use YAML | tp denote a literal block, i.e. the value is a multiline string and newline characters are preserved.
- Limited to 1 MB in size.
- Set immutable property to true to prevent updates.
  - Must delete and recreate to affect a change in configuration.
  - For mutable ConfigMaps, affected pods may need to be restarted after data changes.

Kubernetes – Secrets

- For confidential configuration data, use Secrets instead of ConfigMaps.
- Manifest files are identical to ConfigMaps.
- Data values must be encoded in BASE64.

  $ echo –n plaintext | base64