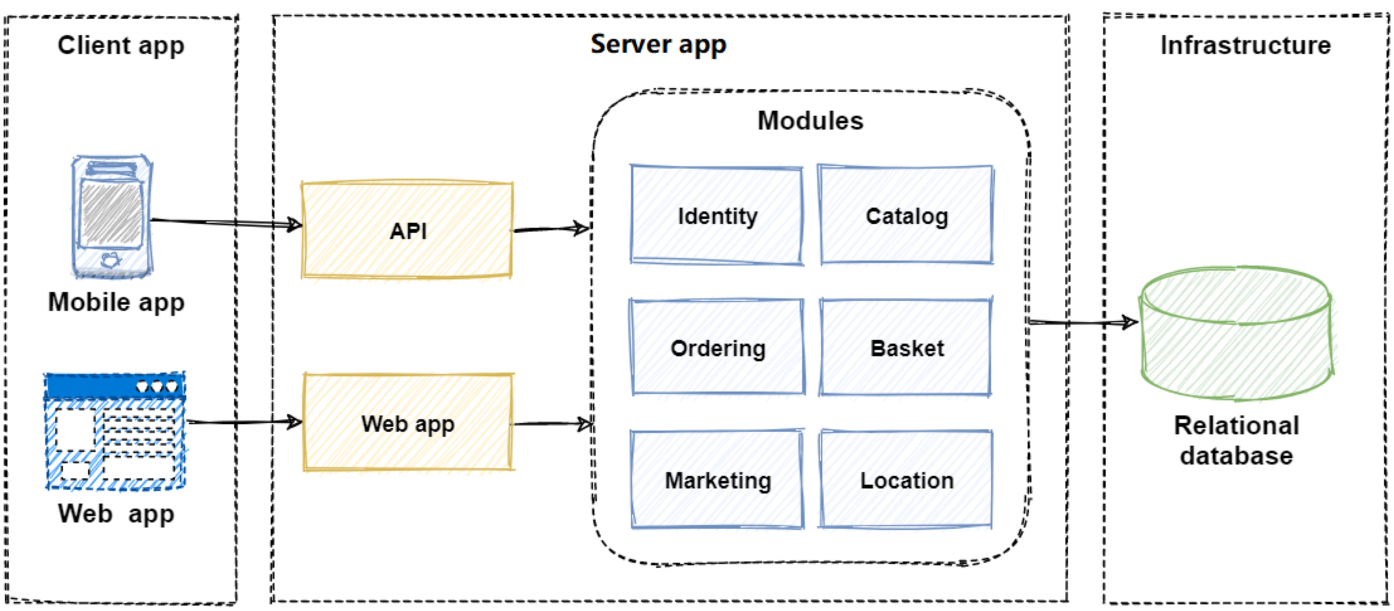
Introduction to Kubernetes

1. Evolution of Software Architecture

1.1 Monolithic Architecture



The concept of monolithic model lies in different components of an application being combined into a single program on a single platform.

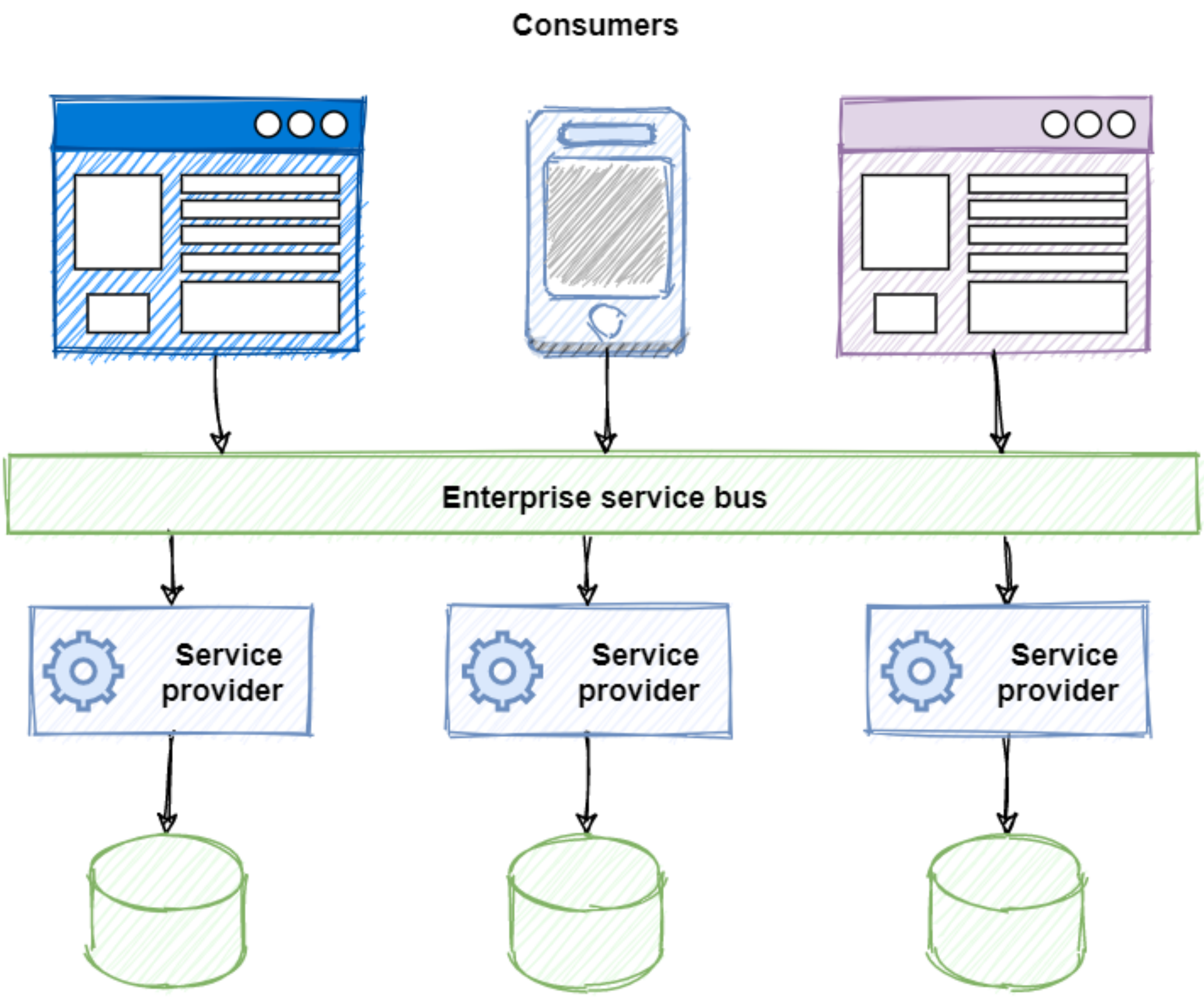
Pros

- Simpler development and deployment
- Fewer cross-cutting concerns
- Better performance
- Perfect for small projects.

Cons

- Codebase gets curbersome overtime
- The monolith is becoming so complicated that no single person can understand it.
- Difficult to adopt new technologies
- Limited agility
- One unstable component can crash the entire system.

1.2 Service-oriented Architecture (SOA)



In this model, **service consumers** and **service providers** collaborated via middleware messaging components, often referred to as an **Enterprise Service Bus**.

- Centralized service providers registered with the ESB
- Business logic would be built into the ESB to integrate providers and consumers.
- Service consumers could then find and communicate with these providers using the ESB.

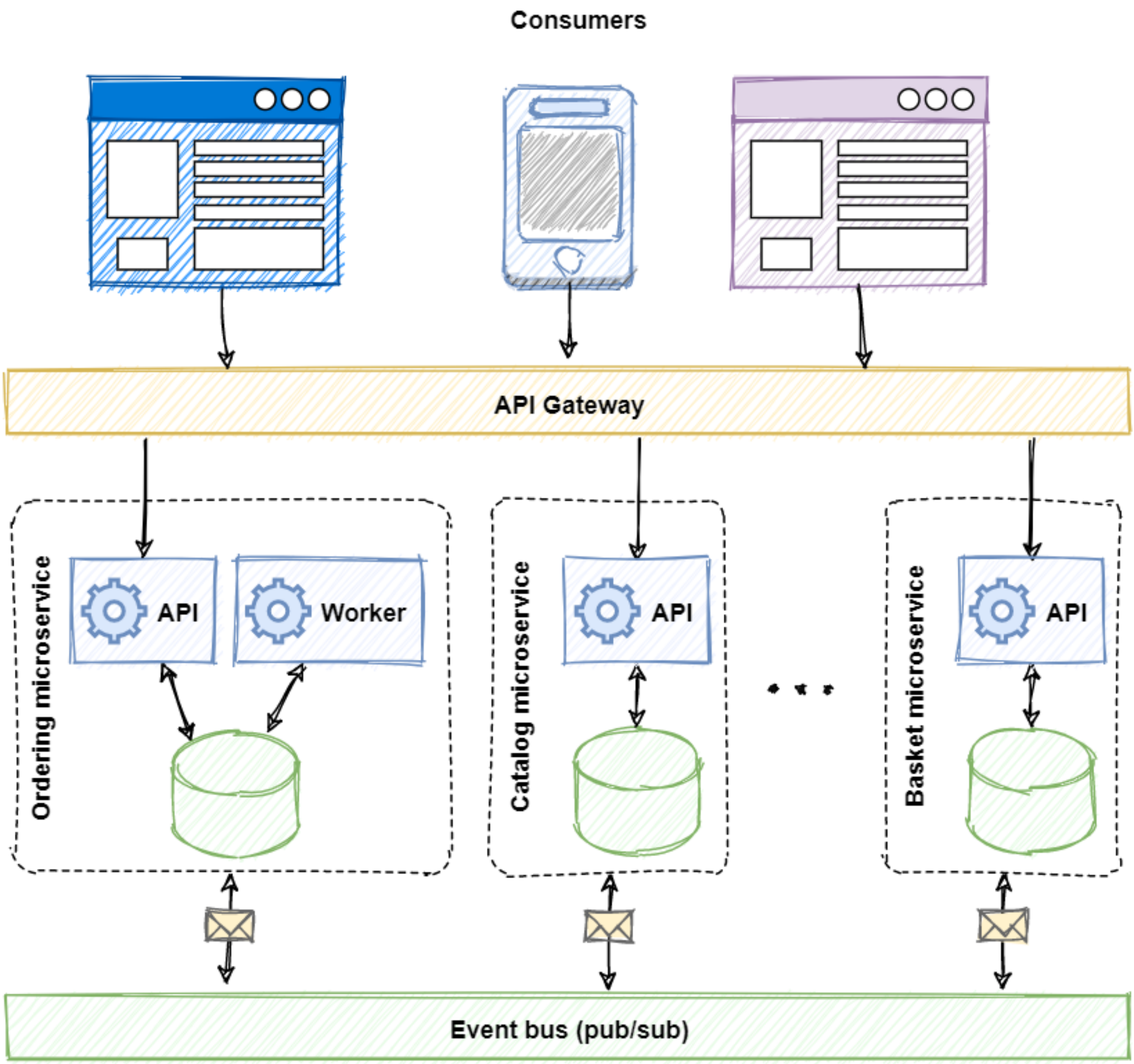
Pros:

- Reusability of services
- Better maintainability
- Higher reliability
- Parallel development

Cons:

- Complex management
- Maintenance costs became high and ESB middleware expensive.
- Services tended to be large. They often shared dependencies and data storage.
- Extra overload: when using multiple services, this increases response time and decreases overall performance.

1.3 Microservice Architecture



Microservice apps consist of **multiple independent components** that are glued together with **APIs**.

The microservices approach focuses mainly on **business priorities and capabilities**.

Pros

- Easy to develop, test, and deploy
- Increased agility: several teams can work on their services independently and quickly
- Ability to scale horizontally

Cons

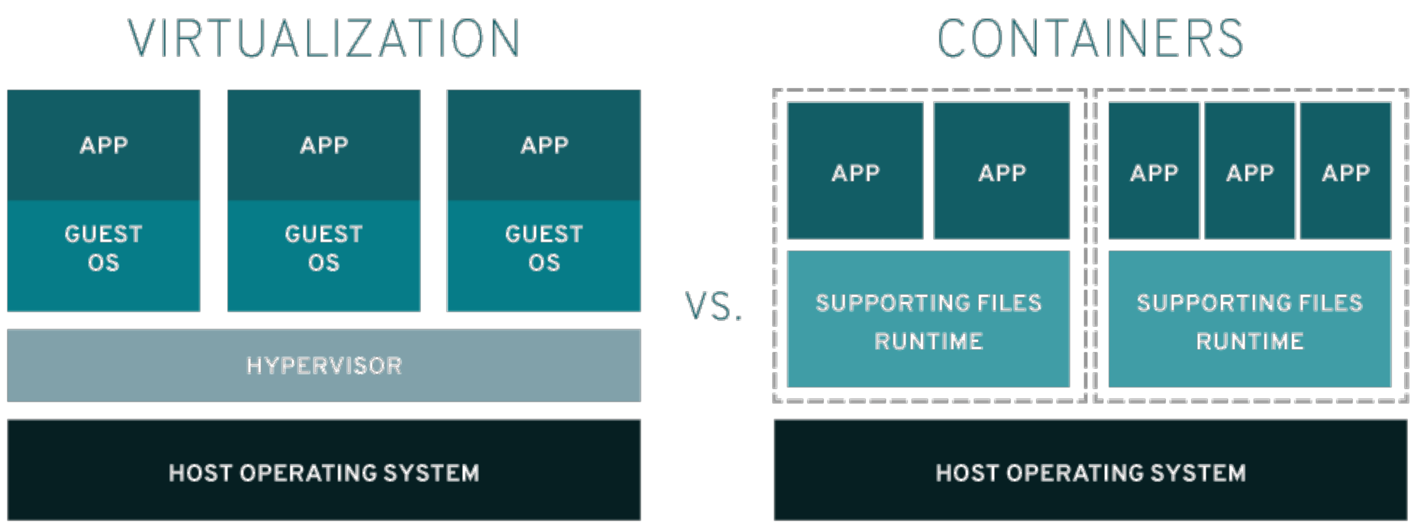
- Increased demand for automation, as every service should be tested and monitored
- Data consistency and transaction management becomes harder as each service has a database
- Security concerns
- Different programming languages

2. Containerization and docker

Microservices architecture presents a set of challenges

- Multiple Network Calls among services
- Multiple microservices deployed on the same host, services are less isolated

Virtualization vs containers



Containerization

Containerization packages together everything needed to run a single application or microservice (along with runtime libraries they need to run). The container **includes all the code, its dependencies** and even the operating system itself.

High level container runtimes , such as **Docker** simplify the process of creating and maintaining containers.

Linux Namespace

- A feature provided by Linux Kernel to isolate resources.
- For containers, a namespace is what **defines the boundaries of a process**' "awareness" of what else is running around it.
- Namespace resources: IPC, Network, PID, Mount, PTS, USR.

Linux Cgroups

- The mechinism provided by Linux Kernel to control or monitor one or more processes.
- Control CPU, Memory, I/O of processes.
- Cgroup driver: systemd as init system will be the cgroup manager, but Docker uses cgroupfs as driver by default.

UnionFS

- Unite several directories into a single virtual filesystem
- Set readonly, readwrite, whiteout-able permission for each directory
- Layered File System.

3. Need for container orchestration tool

Challenges from manage multi containers

- Increased usage of containers. In production, you can end up with dozens, even thousands of containers over time.
- Demand for a proper way managing those containers
- Integrate and orchestrate these modular parts
- Scale up and scale down based on the demand
- Make them fault tolerant

- Provide communication across a cluster

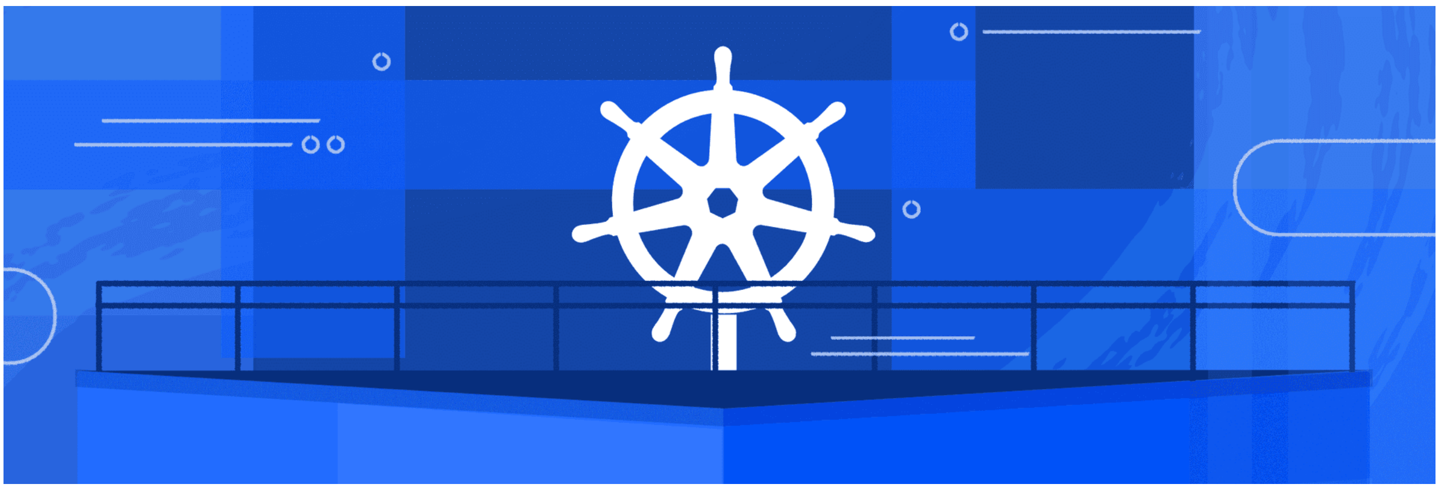
Container orchestration is the automated process of coordinating and organizing all aspects of individual containers, their functions, and their dynamic environments.

Using container orchestration, one can

- manage when and how containers start and stop,
- schedule and coordinate components' activities,
- monitor health,
- institute failover and recovery processes.

4. What is Kubernetes

> Kubernetes aka. k8s (pronounced /kates/)



Kubernetes is a portable, extensible, open-source platform for managing containerized workloads and services, that facilitates both declarative configuration and automation.

- Open source container orchestration tool
- Orignially developed by Google
- First graduated CNCF project
- Open source version of Borg
- Helps manages containerized applictions in different environments

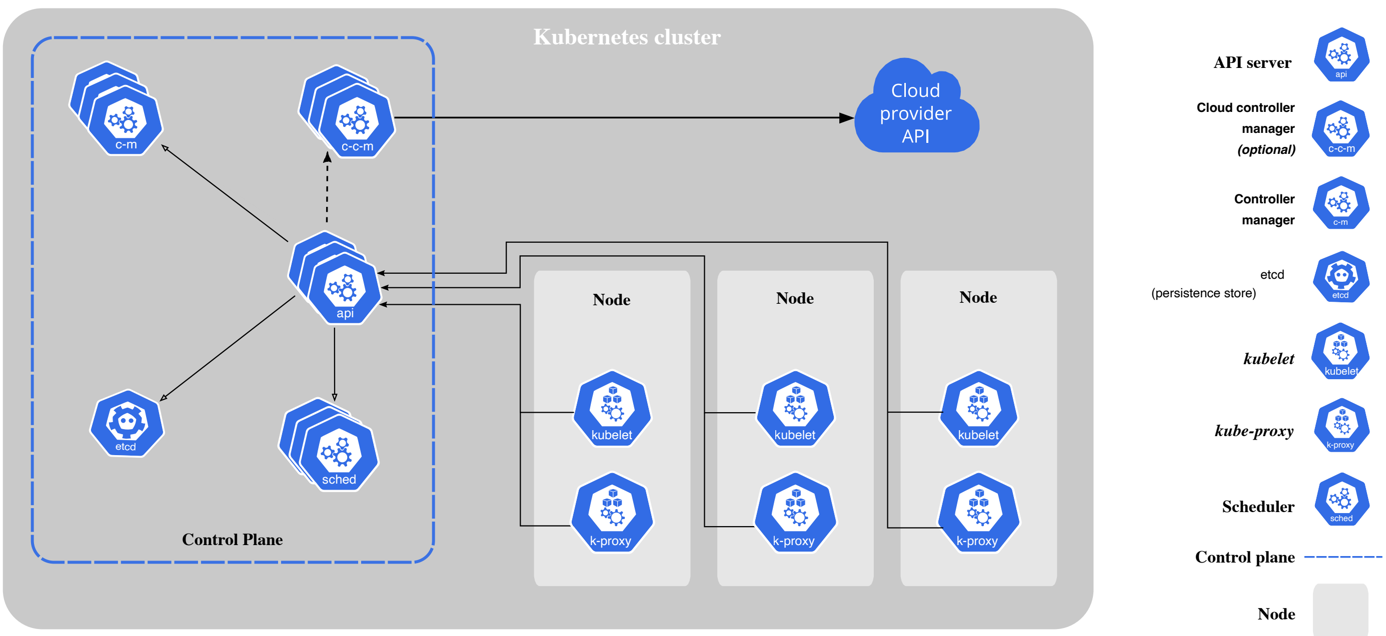
Features provided by Kubernetes

- **High Availability**
    - Application High Availability building on ReplicaSet, StatefulSet
    - Kubernetes Components are high available
- **Security**
    - Services are running on TLS
    - Provide ServiceAccount and User Account
    - Isolation by Namespace
    - Secret

- Secret
- Taints, PSP, Network Policy
- **Portability**
  - multi host os
  - Multi cloud and hybrid cloud
- **Extensibility**
  - CRD
  - Plugins (Addons)

5. Kubernetes Architecture

You can visiualize a Kubernetes cluster as two parts: the **control plane** and **the worker machines, or nodes**.



Components of the control plane

Control plane is the nerve center of our Kubernetes cluster.

- Control the cluster, along with data about the cluster's state and configuration.
- Handle the important work of making sure your containers are running in sufficient numbers and with the necessary resources.

kube-apiserver

- The Kubernetes API is the front end of the Kubernetes control plane, **handling internal and external requests**.
- You can access the API through **REST** calls, through the **kubectl** command-line interface, or through other command-line tools such as kubeadm.

kube-scheduler

kube-scheduler

- Control plane component that **watches for newly created Pods** with no assigned node, and selects a node for them to run on.
- The scheduler considers the r**esource needs of a pod**, such as CPU or memory, along with the **health** of the cluster.
- It is only responsible for deciding which pod goes on which node. **It doesn't actually place the pod on the nodes**. The **kubelet** or the captain on the ship is who creates the pod on the ships.

kube-controller-manager

- Controllers take care of actually running the cluster
- Kubernetes controller-manager contains several controller functions in one.
  - **Node-Controller**
  - **Replication-Controller**: It is responsible for monitoring the status of replicasets and ensuring that the desired number of PODs are available at all times within the set.
  - PV-Binder-Controller
  - Service-Account-Controller
  - StatefulSet
  - ReplicaSet
  - CronJob
  - Job-Controller
  - PV-Protection-Controller
  - Deployment-Controller
  - Namespace-Controller
  - Endpoint-Controller
- All of these controllers are packaged into a single process called `Kube-Controller-Manager`.

etcd

- A key value datebase for Cluster Data Store
- Configuration data and information about the state of the cluster.

Components of the worker nodes

Node components run on every node, maintaining running pods and providing the Kubernetes runtime environment.

Nodes

It is an abstraction for the compute node. Every cluster has at least one worker node to run containerized applications.

Pods

Pods

The ultimate aim is to **deploy** our application in the form of **containers** on a set of machines that are **configured as worker nodes** in a cluster.

However, **Kubernetes does not deploy containers directly on the worker nodes**.

- A pod is **the smallest and simplest unit** in the Kubernetes object model.
- It represents **a single instance of an application**.
- Each pod is made up of a container or a series of tightly coupled containers

kubelet

- An agent that runs on each node in the cluster. It makes sure that containers are running in a Pod
- It communicates with the control plane
- It will not maintain containers not created by Kubernetes
- Jobs performed by kubelet: Register Node, Create Pods, Monitor Node and Pod

kube-proxy

- A **Pod network** is a virtual network that **spans across all the nodes in the cluster** to which all the Pods connect to.
- Each compute node also contains kube-proxy, a network proxy for facilitating Kubernetes networking services.
- kube-proxy maintains network rules on nodes.
- Works on the Level 4 TCP/IP stack
- Underhood is iptables or ipvs
    - Creates an IP table rule on each node in the cluster.
    - Forwarding traffic heading to the IP of the service to the IP of the actual Pod.
- It's job is to **look for new services** and every time a new service is created it creates the appropriate rules on each node to **farword traffic to those services to the backend pods**.

Container runtime

To run the containers, each compute node has a container runtime engine. For example, Docker.

Addons

- kube-dns: provide DNS Service for the cluster
- Ingress Controller: provide external access for service
- Metrics Server: provide resource monitoring
- Dashboard: provide web-based UI

```
# View component definition files in kubeadm
ls /etc/kubernetes/manifests
```

6. Basic commands in `kubectl`

When running a `kubectl` command,

- The kubectl utility is in fact reaching to the kube-api server.
- The kube-api server first authenticates the request and validates it.
- It then retrieves the inforamtion from the etcd cluster and reponse back to the user.

The worflow when a change is requested

```
curl -X POST /api/v1/namespaces/default/pods ...
```

1. Authenticate user
2. Validate request
3. Retrieve data
4. Update ETCD
5. Scheduler
6. Kubelet

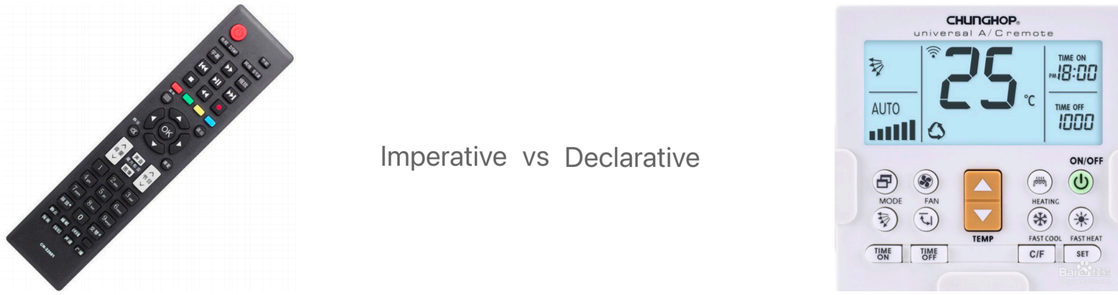
- The scheduler continuously monitors the API server and realizes that there is a new pod with no node assigned.
- The scheduler identifies the right noed to place the new POD on and communicates that back to the kube-api server.
- The API server then updates the information in the ETCD cluster.
- The API server then passes that information to the kubelet in appropriate worker node.
- The kubelet then creates the POD on the node and instructs the container runtime engine to deploy the application image.
- Once done, the kubelet updates the status back to the API server and the API server then updates the data back in the ETCD cluster.

```
kubectl get po —oyaml -w

kubectl describe po xxx

kubectl exec

kubectl logs
```

7. Kubernetes Objects

Imperative vs Declartive

Imperative vs Declartive



- Everything in Kubernetes is abstracted as an object.
- Idempotency
- API Standardization

Kubernetes Objects

- Kubernetes objects are **persistent entities** in the Kubernetes system.
    - Kubernetes uses these entities to **represent the state of your cluster**.
    - By creating an object, you are specifing the cluster's **desired state**.
    - Kubernetes provides **Kubernetes API** to manage these objects.
- The API object is the **base unit** to manage a Kubernetes Cluster.
- New API objects will be introduced when new features are added to Kubernetes Cluster

> kubectl api-resources
>
> kubecl explain

How to Describe a Kubernetes object

Every kubernetes object has below four types of properties

TypeMeta

The most fundamental definition of an object, uses **GKV(Group, Kind, Version)** to define the type of an object.

- **Group**: The kubernetes API is grouped into multiple such groups based on their purposes, `/metrics`, `/healthz`, `/version`, `/api`, `/apis`, `/logs`.
    - Core: `/api`: namespaces, pods, replication controllers, events, endpoints, nodes, bindings, persistent volumes, persistent volume claims, configmaps, secrets, services, etc.
    - Named: `/apis`: apps, extensions, networking, storage, authentication certificates etc.
- **Kind**: Defines the type of the object, for example, Node, Pod, Deployment, Service, etc.
- **Version**: Different API versions indicate different levels of stability and support.

Metadata

Metadata

- **Namespace** and **Name** are the most important two properties of Metadata type. They uniquely identifies an instance of an object.
- **Label** defines whether the object can be recognized. An object can have any number of labels in key-value format. Supports filters.
- **Annotation** is also in key-value format, but serve different purposes: for example, assist deploying application, security policy and scheduling policy. Rolling update information in deployment.
- **Finalizer**: a resource lock. When deleting an object and the resource lock is not null, then it's an logical delete.
- **ResourceVersion**: Every object has an resource object at any time.

Spec

- providing a description of the characteristics you want the resource to have, i.e. the **desired state**.
- different objects may have different specs.
- Defined by the client

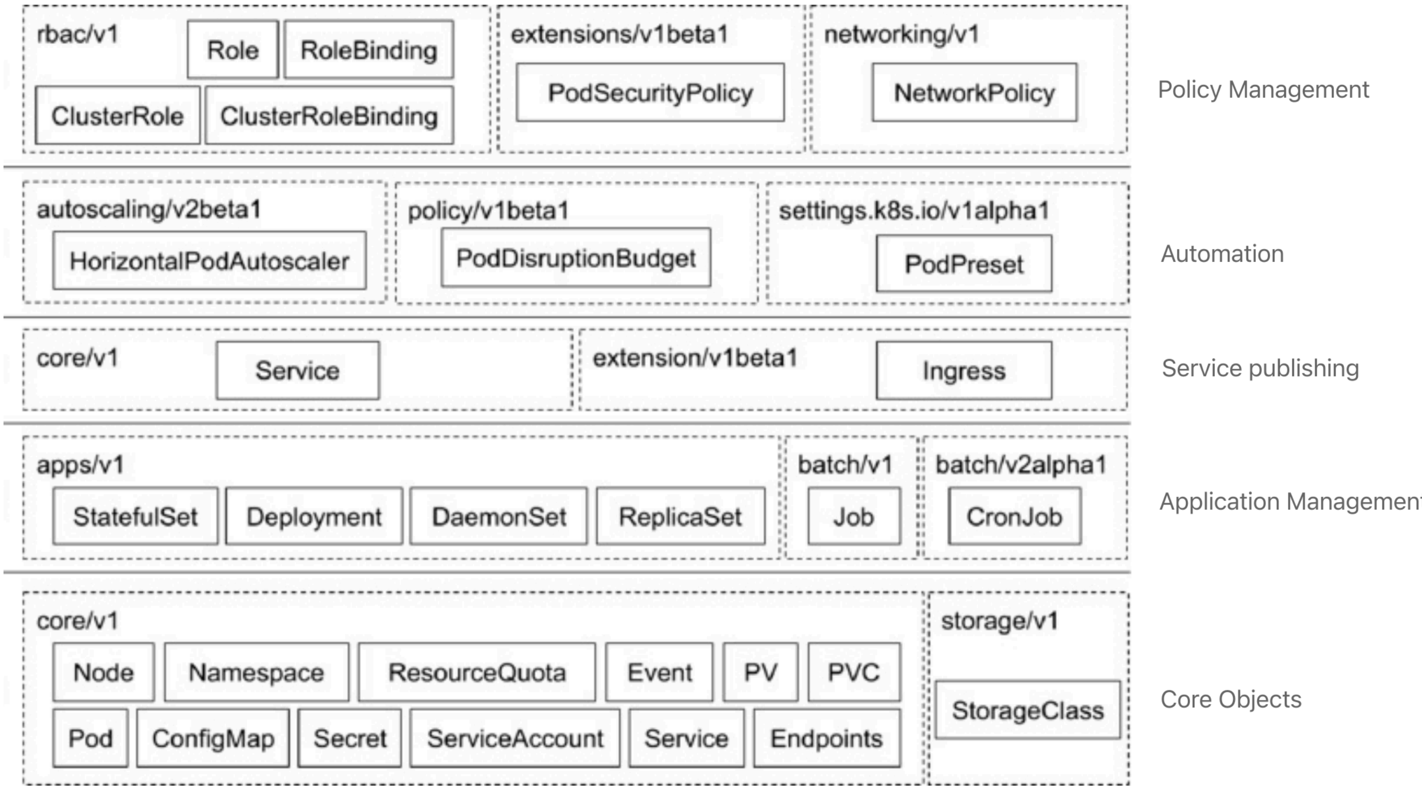
Status

- describes the ***current state*** of the object
- It's updated by the controllers.
- The **control plane** continually and actively **manages every object's actual state** to match the desired state

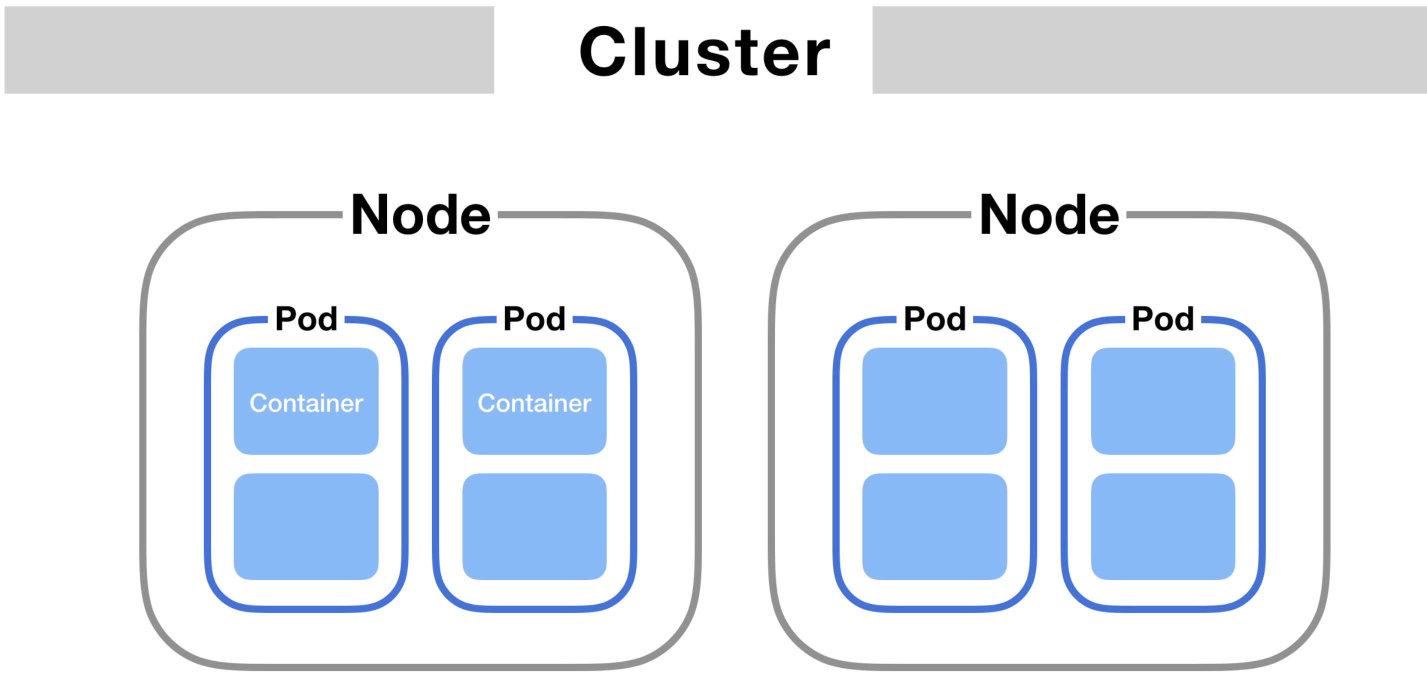
Demo: An exmaple of object definition file

```yaml
apiVersion: apps/v1
kind: Deployment
metadata:
  name: nginx-deployment
spec:
  selector:
    matchLabels:
      app: nginx
  replicas: 2
  template:
    metadata:
      labels:
        app: nginx
    spec:
      containers:
      - name: nginx
        image: nginx:1.14.2
        ports:
        - containerPort: 80
```

An overview of Kubernetes objects by groups



8. Deploying applications using Kubernetes



Node

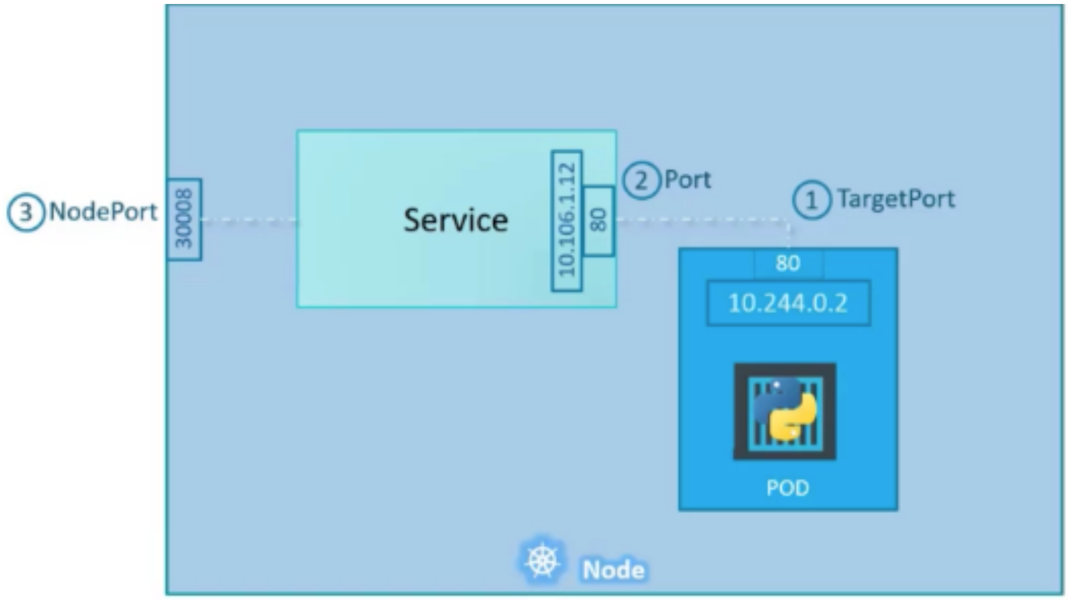
- host machine, can be physical machine or virtual machine

Pod

- Smallest unit in kubernetes for scheduling
- An abstraction over container
- Contains a group of containers, normally one application per pod
- Sharing PID, IPC, Network, File System etc.
- Each Pod gets its own IP address
- Pods are ephermeral, each time new Pod are created, they are assigned a new IP.

Service

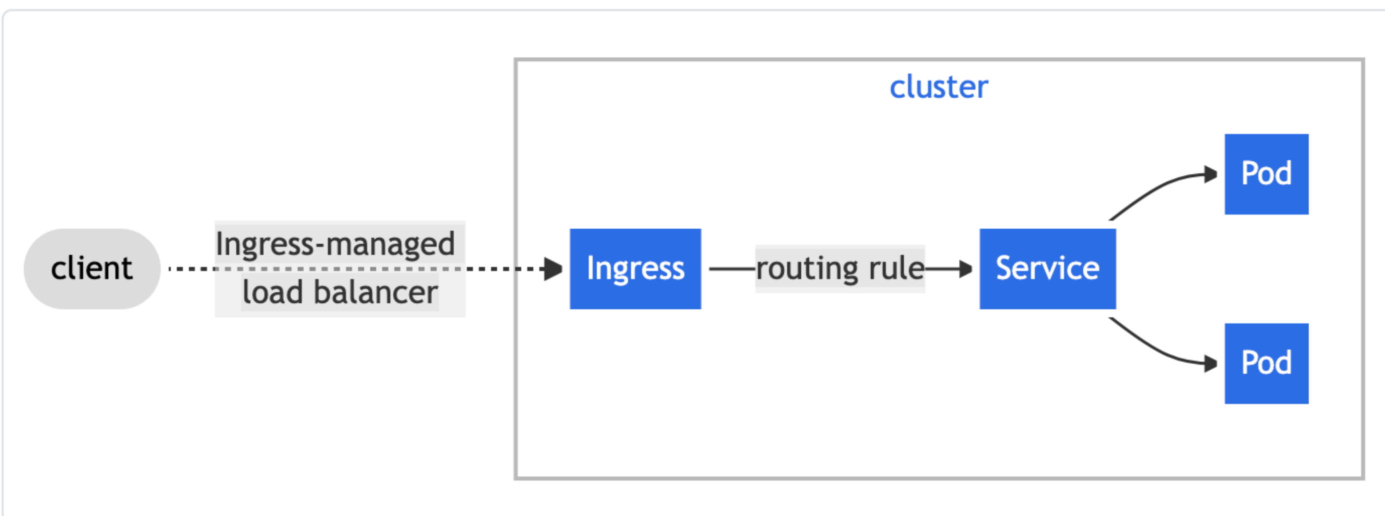
- Service is static or perment IP address.
- Services enable communication between variaous components within and outside of the application.
- Every Pod can be attached to a service. Different lifecyle compared to Pod.
- By default, The service is in fact like **a virtual server inside the node**. the service has its own IP address and that IP address is called **the cluster IP of the service**. (DB Service)
- Expose **external service** (Web App Service)
  - NodePort: **makes an internal Pod accessiable** on a Port on the Node.

- 

- Load Balancing

Ingress

- manages external access to the services in a cluster
- exposes HTTP and HTTPS routes from outside the cluster to services within the cluster.



- Works on level 7 HTTP stack

ConfigMap & Secret

- **ConfigMaps** are used to **pass configuration data in the form of key value pairs** in Kubernetes.e.g. service url
    - Create ConfigMap
    - Inject into Pod
- **Secrets** are used to **store sensitive information** like passwords or keys.

  They are similiar to ConfigMap except that they're **stored in n encoded or hashed format.**

Volume

- Mount external volume to Pod
- Volume: define the source of volume
- VolumeMounts: define how the volume mount to Pod

Deployment

The deployment provides us with the capability to **upgrade the underlying instances** seamlessly using rolling updates, undo changes, and pause and resume changes as required.

- Provides declarative updates to applications.
- Scale up and down by specifying replicas
- The Kubernetes deployment object lets you:
  - Deploy a replica set or pod
  - Update pods and replica sets
  - Rollback to previous deployment versions
  - Scale a deployment
  - Pause or continue a deployment

9. Demo

```
# 1. Pod
# Create nginx yaml
kubectl run webapp --image=nginx --dry-run=client -o yaml > web-pod.yaml



# 2. Service
# Create nginx svc yaml
kubectl expose pod webapp --name=webappsvc --port=80 --target-port=80 --dry-run=client -o yaml > web-svc.yaml
kubectl delete svc webappsvc

# 3. Deploy
# Create Objects
kubectl create deployment --image=nginx webappdeploy --dry-run=client -o yaml > web-deploy.yaml

# Update Objects
kubectl edit deployment webappdeploy
kubectl scale deployment webappdeploy --replicas=3
kubectl set image deployment nginx nginx=nginx:1.18
```

Create Config Maps Imperative

Create Config Maps Imperative

```
# cm short for configmap
kubectl create cm

# simple ones using --from-literal option
kubectl crete configmap \
    <config-name> --from-literal=<key>=<value>

kubectl create configmap app-config --from-literal=APP_COLOR=blue --from-
literal=APP_MOD=prod

# complicate ones using --from-file option
kubectl crete configmap
    <config-name> --from-file=<path-to-file>

kubectl create configmap app-config --from-file=app_config.properties
```

Create Config Maps Imperative

Create a `config-map.yaml`

```
apiVersion: v1
kind: ConfigMap
metadata:
  name: app-config
data:
  APP_COLOR: blue
  APP_MODE: prod
```

```
kubectl create -f config-map.yaml
```

Use ConfigMaps in Pods

Add the `envFrom` option in `pod-definition.yaml`.

`envFrom` is a list

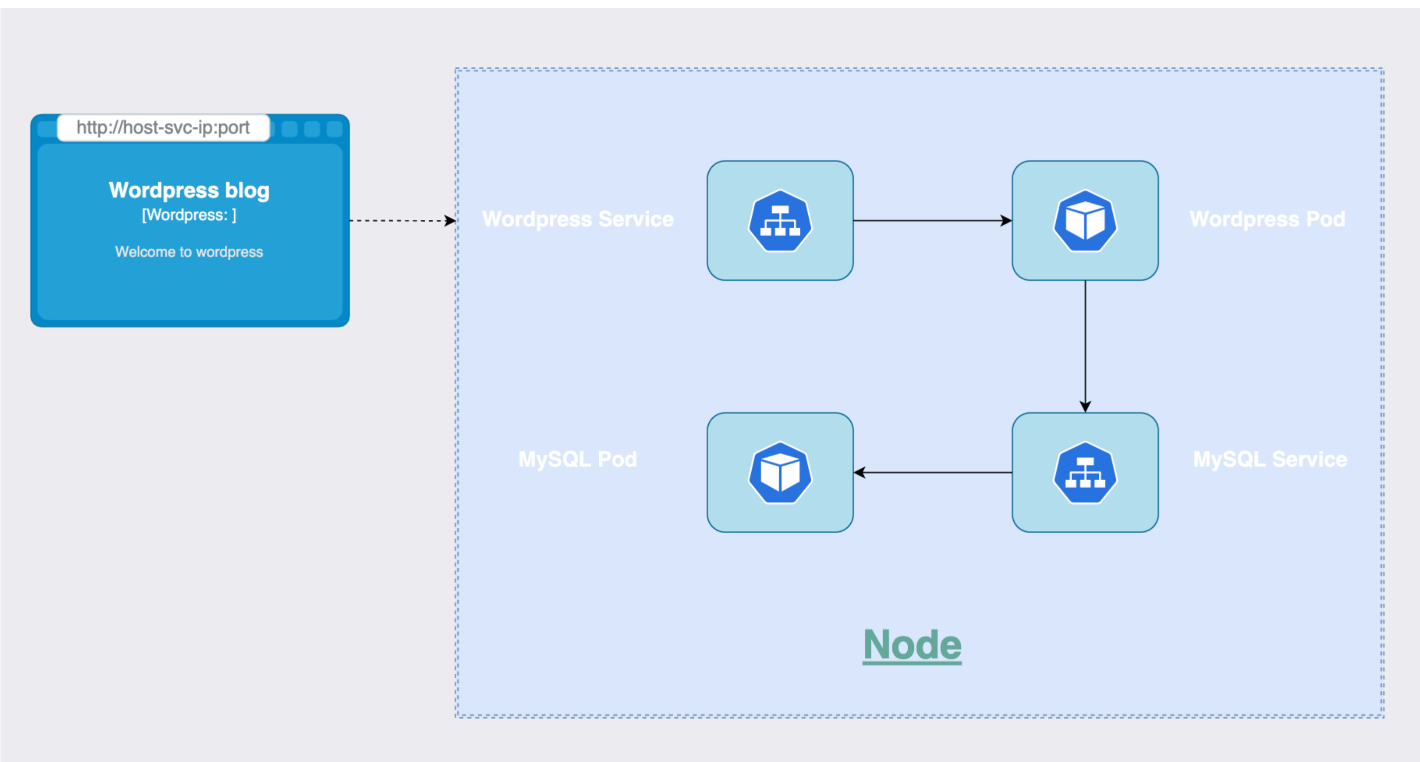
```
apiVersion: v1
```

```
apiVersion: v1
kind: Pod
metadata:
  name: simple-webapp-color
spec:
  containers:
  - name: simple-webapp
    image: nginx
    ports:
    - containerPort: 8080
    envFrom:
    - configMapRef:
        name: app-config
```

To check the usage of envFrom:

```
kubectl explain pods --recursive | grep envFrom -A3
```

Deploying Wordpress and MySQL



Steps to do this deployment

```
# Create mysql-secret for mysql Pod
kubectl create secret generic mysql-secret \
--from-literal=MYSQL_DATABASE=blog \
--from-literal=MYSQL_USER=admin \
```

```
--from-literal=MYSQL_PASSWORD=admin \
--from-literal=MYSQL_ROOT_PASSWORD=admin

# Create wordpress-secret for wordpress pod
kubectl create secret generic wordpress-secret \
--from-literal=WORDPRESS_DB_USER=root \
--from-literal=WORDPRESS_DB_PASSWORD=admin \
--from-literal=WORDPRESS_DB_NAME=blog \
--from-literal=WORDPRESS_DB_HOST=dbsvc

# create mysql pod
kubectl apply -f mysql-pod.yaml

# mysql svc
kubectl expose pod mysql --name=dbsvc --port=3306

# create wordpress pod
kubectl apply -f wordpress-pod.yaml

# wordpress nodeport svc
kubectl expose pod wordpress --name=myblog --port=80 --type=NodePort

# Users can visit wordpres
# Check the port of myblog service,
kubectl get svc myblog
# Then user can visit from the browser using VM host ip, 192.168.56.11:port,
192.168.56.12:port
```

References

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