Kubernetes, often abbreviated as K8s, is a powerful open-source platform for automating the deployment, scaling, and management of containerized applications. Developed originally by Google, Kubernetes is now maintained by the Cloud Native Computing Foundation (CNCF). Below is a comprehensive guide covering the key concepts, architecture, and best practices for Kubernetes.

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1. Introduction to Kubernetes

What is Kubernetes?

Kubernetes is a container orchestration platform that automates the deployment, scaling, and operations of application containers across clusters of machines. It abstracts the underlying infrastructure and provides a unified API for managing containerized applications.

1.1 Key Features of Kubernetes

- **Automated Deployment and Scaling:** Automatically deploy, manage, and scale applications.
- **Self-Healing:** Automatically replaces failed containers and restarts applications.
- **Load Balancing:** Distributes traffic across containers.
- **Storage Orchestration:** Manages storage resources for applications.
- **Service Discovery:** Provides DNS names for services and load balances across them.
- **Configuration Management:** Manages configuration and secrets for applications.
- **Rolling Updates:** Performs rolling updates to applications with zero downtime.

1.2 Basic Terminology

Term	**Description**
Cluster	A set of nodes (physical or virtual machines) running Kubernetes components.
Node	A machine (VM or physical) that runs Kubernetes components like the Kubelet and Docker.

| **Pod** | The smallest deployable unit that can contain one or more containers.
|
| **Deployment** | A higher-level abstraction for managing and scaling a set of Pods.
|
| **Service** | Defines how to access Pods, providing load balancing and service discovery.
|
| **Namespace** | Virtual clusters within a Kubernetes cluster to organize resources.
|
| **ReplicaSet** | Ensures a specified number of pod replicas are running at any given time.
|
| **StatefulSet** | Manages stateful applications, maintaining unique identities for Pods.
|
| **DaemonSet** | Ensures a copy of a Pod runs on all (or some) Nodes.
|
| **Job** | Manages the execution of one-time tasks and ensures completion.
|
CronJob	Creates Jobs on a scheduled time basis.
ConfigMap	Manages configuration data for applications.
Secret	Stores sensitive data, such as passwords or tokens.
Ingress	Manages external access to services, typically via HTTP/HTTPS.
PersistentVolume (PV)	A piece of storage in the cluster provisioned by an administrator.
PersistentVolumeClaim (PVC)	A request for storage by a user.
Helm	A package manager for Kubernetes applications.

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2. Kubernetes Architecture

2.1 Kubernetes Components

Component	**Description**

| **Master Node** | Manages the Kubernetes cluster. Contains components like API server, controller manager, and scheduler. |

| **Kubelet** | An agent that runs on each worker node, ensuring that containers are running in Pods. |

| **Kube-Proxy** | Maintains network rules for Pod communication and load balancing. |

| **API Server** | The entry point for all REST commands used to control the cluster. |

| **Controller Manager** | Ensures that the desired state of the cluster is maintained. |

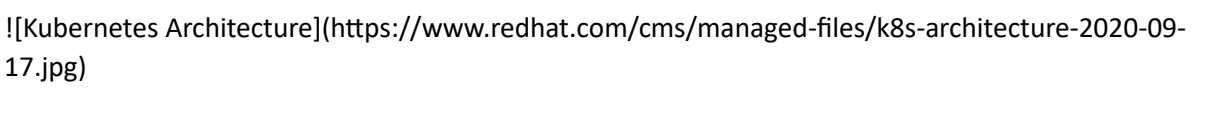
| **Scheduler** | Assigns Pods to Nodes based on resource availability and constraints. |

| **etcd** | A distributed key-value store used for storing all Kubernetes cluster data. |

2.2 Kubernetes Object Lifecycle

Lifecycle Stage	**Description**
Creation	Define objects using YAML or JSON manifests and apply them using `kubectl apply`.
Update	Modify the configuration and apply changes using `kubectl apply`.
Scaling	Adjust the number of Pods using `kubectl scale`.
Deletion	Remove objects using `kubectl delete`.

Diagram of Kubernetes Architecture:



Source: Red Hat

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3. Core Kubernetes Concepts

3.1 Pods

- **What is a Pod?**
  - A Pod is the smallest and simplest Kubernetes object. A Pod encapsulates one or more containers.
  - **Example YAML for a Pod:**

    ```yaml
    apiVersion: v1
    kind: Pod
    metadata:
      name: my-pod
    spec:
      containers:
      - name: my-container
        image: nginx:latest
        ports:
        - containerPort: 80
    ```

3.2 Deployments

- **What is a Deployment?**
  - A higher-level abstraction for managing a set of Pods. It ensures the desired state is maintained.
  - **Example YAML for a Deployment:**

    ```yaml
    apiVersion: apps/v1
    kind: Deployment
    ```

```
  metadata:
    name: my-deployment
  spec:
    replicas: 3
    selector:
      matchLabels:
        app: my-app
    template:
      metadata:
        labels:
          app: my-app
      spec:
        containers:
        - name: my-container
          image: nginx:latest
          ports:
          - containerPort: 80
```

3.3 Services

- **What is a Service?**
  - Provides a stable IP address and DNS name for a set of Pods.
  - **Example YAML for a Service:**

```yaml
  apiVersion: v1
  kind: Service
  metadata:
    name: my-service
  spec:
```

```
  selector:
    app: my-app
  ports:
    - protocol: TCP
      port: 80
      targetPort: 80
```

3.4 ConfigMaps and Secrets

- **ConfigMaps**: Manage configuration data for applications.
- **Secrets**: Store sensitive data such as passwords and tokens.
- **Example YAML for a ConfigMap:**

  ```yaml
  apiVersion: v1
  kind: ConfigMap
  metadata:
    name: my-config
  data:
    key1: value1
    key2: value2
  ```

- **Example YAML for a Secret:**

  ```yaml
  apiVersion: v1
  kind: Secret
  metadata:
    name: my-secret
  ```

```
type: Opaque
data:
  username: dXNlcg==  # Base64 encoded username
  password: cGFzc3dvcmQ=  # Base64 encoded password
```

3.5 Persistent Storage

- **PersistentVolume (PV)**: A storage resource in the cluster.
- **PersistentVolumeClaim (PVC)**: A request for storage.
- **Example YAML for a PV:**

```yaml
apiVersion: v1
kind: PersistentVolume
metadata:
  name: my-pv
spec:
  accessModes:
    - ReadWriteOnce
  resources:
    requests:
      storage: 1Gi
  hostPath:
    path: "/mnt/data"
```

- **Example YAML for a PVC:**

```yaml
apiVersion: v1
```

```
kind: PersistentVolumeClaim
metadata:
  name: my-pvc
spec:
  accessModes:
    - ReadWriteOnce
  resources:
    requests:
      storage: 1Gi
```

3.6 Ingress

- **What is Ingress?**
  - Manages external access to services, typically HTTP/HTTPS.
  - **Example YAML for an Ingress:**

```yaml
apiVersion: networking.k8s.io/v1
kind: Ingress
metadata:
  name: my-ingress
spec:
  rules:
  - host: myapp.example.com
    http:
      paths:
      - path: /
        pathType: Prefix
        backend:
          service:
```

```
            name: my-service
            port:
              number: 80
```

3.7 Helm Charts

- **What is Helm?**
  - A package manager for Kubernetes, similar to apt for Debian-based systems or yum for Red Hat-based systems.
- **Basic Commands:**
  - **Install a Chart:**
    ```bash
    helm install my-release stable/nginx
    ```
  - **Upgrade a Release:**
    ```bash
    helm upgrade my-release stable/nginx
    ```
  - **Uninstall a Release:**
    ```bash
    helm uninstall my-release
    ```

Helm Chart Example:

```yaml
apiVersion: v2
name: mychart
description: A Helm chart for Kubernetes
version: 0.1.0
```

```
dependencies:
  - name: nginx
    version: 1.16.0
    repository: https://charts.bitnami.com/bitnami

templates:
  - name: deployment.yaml
    apiVersion: apps/v1
    kind: Deployment
    spec:
      replicas: 3
      selector:
        matchLabels:
          app: my-app
      template:
        metadata:
          labels:
            app: my-app
        spec:
          containers:
```