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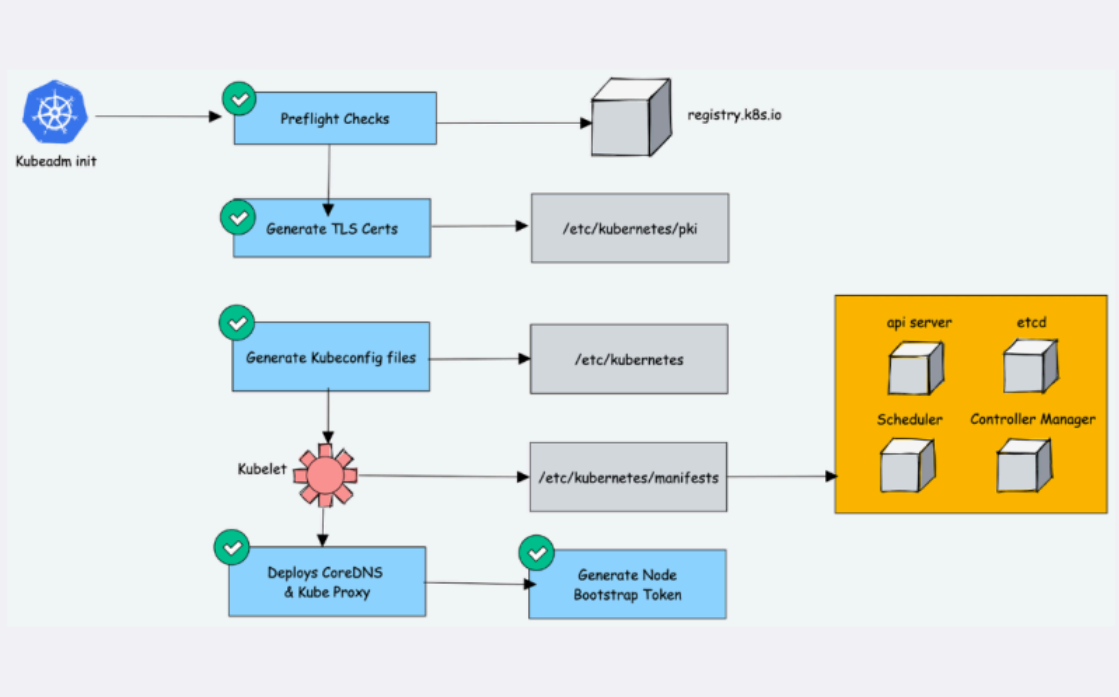
How To Setup Kubernetes Cluster Using Kubeadm

by **Bibin Wilson** · March 17, 2024



In this blog post, I have covered the **step-by-step guide to setting up a kubernetes cluster** using Kubeadm with one master and two worker nodes.

Kubeadm is an excellent tool to set up a working kubernetes cluster in less time. It does all the heavy lifting in terms of setting up all kubernetes cluster components. Also, It follows all the configuration best practices for a kubernetes cluster.

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What is Kubeadm?

Kubeadm is a tool to set up a minimum viable Kubernetes cluster without much complex configuration. Also, Kubeadm makes the whole process easy by running a series of prechecks to ensure that the server has all the essential components and configs to run Kubernetes.

It is developed and maintained by the official Kubernetes community. There are other options like minikube, kind, etc., that are pretty easy to set up. You can check out my minikube tutorial. Those are good options with minimum hardware requirements if you are deploying and testing applications on Kubernetes.

But if you want to play around with the cluster components or test utilities that are part of cluster administration, Kubeadm is the best option. Also, you can create a production-like cluster locally on a workstation for development and testing purposes.

Kubeadm Setup Prerequisites

Following are the prerequisites for **Kubeadm Kubernetes cluster setup**.

1. Minimum two **Ubuntu nodes** [One master and one worker node]. You can have more worker nodes as per your requirement.
2. The master node should have a minimum of **2 vCPU and 2GB RAM**.

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4. **10.X.X.X/X** network range with static IPs for master and worker nodes. We will be using the **192.x.x.x** series as the pod network range that will be used by the Calico network plugin. Make sure the Node IP range and pod IP range don't overlap.

Note: If you are setting up the cluster in the corporate network behind a proxy, ensure set the proxy variables and have access to the container registry and docker hub. Or talk to your network administrator to whitelist **registry.k8s.io** to pull the required images.

Kubeadm Port Requirements

Please refer to the following image and make sure all the ports are allowed for the control plane (master) and the worker nodes. If you are setting up the kubeadm cluster cloud servers, ensure you allow the ports in the firewall configuration.

Protocol	Direction	Port Range	Purpose	Used By
TCP	Inbound	6443*	Kubernetes API server	All
TCP	Inbound	2379-2380	etcd server client API	kube-apiserver, etcd
TCP	Inbound	10250	Kubelet API	Self, Control plane
TCP	Inbound	10251	kube-scheduler	Self
TCP	Inbound	10252	kube-controller-manager	Self

Worker node(s)

Protocol	Direction	Port Range	Purpose	Used By
TCP	Inbound	10250	Kubelet API	Self, Control plane
TCP	Inbound	30000-32767	NodePort Services**	All

If you are using vagrant-based Ubuntu VMs, the firewall will be disabled by default. So you don't have to do any firewall configurations.

Kubeadm for Kubernetes Certification Exams

If you are preparing for Kubernetes certifications like **CKA, CKAD, or CKS**, you can use the local kubeadm clusters to practice for the certification exam. In fact, kubeadm itself is part of the CKA and CKS exam. For CKA you might be asked to bootstrap a cluster using Kubeadm. For CKS, you have to upgrade the cluster using kubeadm.

If you use Vagrant-based VMs on your workstation, you can start and stop the cluster whenever you need. By having the local Kubeadm clusters, you can play around with all the cluster configurations and learn to troubleshoot different components in the cluster.

certification, make use of the CKA/CKAD/CKS coupon Codes before the price increases.

Vagrantfile, Kubeadm Scripts & Manifests

Also, all the commands used in this guide for master and worker nodes config are hosted in GitHub. You can clone the repository for reference.

```
git clone https://github.com/techiescamp/kubeadm-scripts
```

This guide intends to make you understand each config required for the Kubeadm setup. If you don't want to run the commands one by one, **you can run the script file directl**y.

If you are using Vagrant to set up the Kubernetes cluster, you can make use of my Vagrantfile. It launches 3 VMs. A self-explanatory basic Vagrantfile. If you are new to Vagrant, check the Vagrant tutorial.

If you are a Terraform and AWS user, you can make use of the Terraform script present under the Terraform folder to spin up ec2 instances.

Also, I have created a **video demo of the whole kubeadm setup. You can refer to** it during the setup.

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Kubernetes Cluster Setup Using Kubeadm

Following are the high-level steps involved in setting up a kubeadm-based Kubernetes cluster.

1. Install container runtime on all nodes- We will be using cri-o.
2. Install Kubeadm, Kubelet, and kubectl on all the nodes.
3. Initiate Kubeadm control plane configuration on the master node.
4. Save the node join command with the token.
5. Install the Calico network plugin (operator).
6. Join the worker node to the master node (control plane) using the join command.
7. Validate all cluster components and nodes.
8. Install Kubernetes Metrics Server
9. Deploy a sample app and validate the app

If you want to understand every cluster component in detail, refer to the comprehensive Kubernetes Architecture.

Now let's get started with the setup.

Step 1: Enable iptables Bridged Traffic on all the Nodes

Execute the following commands on **all the nodes** for IPtables to see bridged traffic. Here we are tweaking some kernel parameters and setting them using `sysctl` .

```
cat <<EOF | sudo tee /etc/modules-load.d/k8s.conf
overlay
br_netfilter
EOF

sudo modprobe overlay
sudo modprobe br_netfilter

# sysctl params required by setup, params persist across reboots
cat <<EOF | sudo tee /etc/sysctl.d/k8s.conf
net.bridge.bridge-nf-call-iptables  = 1
net.bridge.bridge-nf-call-ip6tables = 1
net.ipv4.ip_forward                 = 1
EOF

# Apply sysctl params without reboot
sudo sysctl --system
```

Step 2: Disable swap on all the Nodes

```
sudo swapoff -a
(crontab -l 2>/dev/null; echo "@reboot /sbin/swapoff -a") |
crontab - || true
```

The `fstab` entry will make sure the swap is off on system reboots.

You can also, control swap errors using the kubeadm parameter `--ignore-preflight-errors Swap` we will look at it in the latter part.

> **Note**: From 1.28 kubeadm has beta support for using swap with kubeadm clusters. Read this to understand more.

Step 3: Install CRI-O Runtime On All The Nodes

> **Note:** We are using cri-o instead if containerd because, in Kubernetes certification exams, cri-o is used as the container runtime in the exam clusters.

The basic requirement for a Kubernetes cluster is a container runtime. You can have any one of the following container runtimes.

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3 Docker Engine (using cri-dockerd)

We will be using CRI-O instead of Docker for this setup as Kubernetes deprecated Docker engine

Execute the following commands **on all the nodes** to install required dependencies and the latest version of CRIO.

```
sudo apt-get update -y
sudo apt-get install -y software-properties-common curl apt-
transport-https ca-certificates

curl -fsSL https://pkgs.k8s.io/addons:/cri-
o:/prerelease:/main/deb/Release.key |
    gpg --dearmor -o /etc/apt/keyrings/cri-o-apt-keyring.gpg
echo "deb [signed-by=/etc/apt/keyrings/cri-o-apt-keyring.gpg]
https://pkgs.k8s.io/addons:/cri-o:/prerelease:/main/deb/ /" |
    tee /etc/apt/sources.list.d/cri-o.list

sudo apt-get update -y
sudo apt-get install -y cri-o

sudo systemctl daemon-reload
sudo systemctl enable crio --now
sudo systemctl start crio.service
```

Install crictl.

```
VERSION="v1.28.0"
wget https://github.com/kubernetes-sigs/cri-
tools/releases/download/$VERSION/crictl-$VERSION-linux-
amd64.tar.gz
sudo tar zxvf crictl-$VERSION-linux-amd64.tar.gz -C /usr/local/bin
rm -f crictl-$VERSION-linux-amd64.tar.gz
```

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When you use container runtimes other than Docker, you can use the **crictl utility** to debug containers on the nodes. Also, it is useful in CKS certification where you need to debug containers.

Step 4: Install Kubeadm & Kubelet & Kubectl on all Nodes

Download the GPG key for the Kubernetes APT repository **on all the nodes.**

```
KUBERNETES_VERSION=1.29

sudo mkdir -p /etc/apt/keyrings
curl -fsSL
https://pkgs.k8s.io/core:/stable:/v$KUBERNETES_VERSION/deb/Release
.key | sudo gpg --dearmor -o /etc/apt/keyrings/kubernetes-apt-
keyring.gpg
echo "deb [signed-by=/etc/apt/keyrings/kubernetes-apt-keyring.gpg]
https://pkgs.k8s.io/core:/stable:/v$KUBERNETES_VERSION/deb/ /" |
sudo tee /etc/apt/sources.list.d/kubernetes.list
```

Update apt repo

```
sudo apt-get update -y
```

Note: If you are preparing for Kubernetes certification, install the specific version of kubernetes. For example,

You can use the following commands to find the latest versions. Install the first version in 1.29 so that you can practice cluster upgrade task.

```
apt-cache madison kubeadm | tac
```

Specify the version as shown below. Here I am using `1.29.0-1.1`

```
sudo apt-get install -y kubelet=1.29.0-1.1 kubectl=1.29.0-1.1
kubeadm=1.29.0-1.1
```

Or, to **install the latest version** from the repo use the following command without specifying any version.

```
sudo apt-get install -y kubelet kubeadm kubectl
```

Add hold to the packages to prevent upgrades.

```
sudo apt-mark hold kubelet kubeadm kubectl
```

Now we have all the required utilities and tools for configuring Kubernetes components using kubeadm.

Add the node IP to `KUBELET_EXTRA_ARGS` .

```
sudo apt-get install -y jq
local_ip="$(ip --json addr show eth0 | jq -r '.[0].addr_info[] |
```

```
EOF
```

Step 5: Initialize Kubeadm On Master Node To Setup Control Plane

Here you need to consider two options.

1. **Master Node with Private IP:** If you have nodes with only private IP addresses the API server would be accessed over the private IP of the master node.
2. **Master Node With Public IP:** If you are setting up a Kubeadm cluster on Cloud platforms and you need master Api server access over the Public IP of the master node server.

Only the Kubeadm initialization command **differs for Public and Private IPs.**

Execute the commands in this section only on the master node.

If you are using a **Private IP** for the **master Node**,

Set the following environment variables. Replace `10.0.0.10` with the IP of your master node.

```
IPADDR="10.0.0.10"
NODENAME=$(hostname -s)
POD_CIDR="192.168.0.0/16"
```

Set the following environment variables. The **IPADDR variable** will be automatically set to the server's public IP using `ifconfig.me` curl call. You can also replace it with a public IP address

```
IPADDR=$(curl ifconfig.me && echo "")
NODENAME=$(hostname -s)
POD_CIDR="192.168.0.0/16"
```

Now, initialize the master node control plane configurations using the kubeadm command.

For a **Private IP address-based setup** use the following init command.

```
sudo kubeadm init --apiserver-advertise-address=$IPADDR  --
apiserver-cert-extra-sans=$IPADDR  --pod-network-cidr=$POD_CIDR --
node-name $NODENAME --ignore-preflight-errors Swap
```

`--ignore-preflight-errors Swap` is actually not required as we disabled the swap initially.

For **Public IP address-based setup** use the following init command.

Here instead of `--apiserver-advertise-address` we use `--control-plane-endpoint` parameter for the API server endpoint.

```
sudo kubeadm init --control-plane-endpoint=$IPADDR  --apiserver-
cert-extra-sans=$IPADDR  --pod-network-cidr=$POD_CIDR --node-name
$NODENAME --ignore-preflight-errors Swap
```

On a successful kubeadm initialization, you should get an output with kubeconfig file location and the **join command with the token** as shown below. Copy that and save it to the file. we will need it for **joining the worker node to the master**.

Use the following **commands from the output** to create the `kubeconfig` in master so that you can use `kubectl` to interact with cluster API.

```
mkdir -p $HOME/.kube
sudo cp -i /etc/kubernetes/admin.conf $HOME/.kube/config
sudo chown $(id -u):$(id -g) $HOME/.kube/config
```

Now, verify the kubeconfig by executing the following kubectl command to list all the pods in the `kube-system` namespace.

```
kubectl get po -n kube-system
```

the network plugin, it will be in a running state.

You verify all the cluster component health statuses using the following command.

```
kubectl get --raw='/readyz?verbose'
```

You can get the cluster info using the following command.

```
kubectl cluster-info
```

By default, apps won't get scheduled on the master node. If you **want to use the master node for scheduling apps**, taint the master node.

```
kubectl taint nodes --all node-role.kubernetes.io/control-plane-
```

> **Note:** You can also pass the kubeadm configs as a file when initializing the cluster. See Kubeadm Init with config file

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Kubernetes Master Node

We have set up **cri-o, kubelet, and kubeadm** utilities on the worker nodes as well.

Now, let's join the worker node to the master node using the Kubeadm join command you have got in the output while setting up the master node.

If you missed copying the join command, execute the following command in the master node to recreate the token with the join command.

```
kubeadm token create --print-join-command
```

Here is what the command looks like. Use `sudo` if you running as a normal user. This command performs the TLS bootstrapping for the nodes.

```
sudo kubeadm join 10.128.0.37:6443 --token j4eice.33vgvgyf5cxw4u8i
\
    --discovery-token-ca-cert-hash
sha256:37f94469b58bcc8f26a4aa44441fb17196a585b37288f85e22475b00c36
f1c61
```

On successful execution, you will see the output saying, "This node has joined the cluster".

Now execute the **kubectl command from the master node** to check if the node is added to the master.

```
kubectl get nodes
```

Example output,

```
root@controlplane:~# kubectl get nodes

NAME           STATUS   ROLES           AGE     VERSION
controlplane   Ready    control-plane   8m42s   v1.29.0
node01         Ready    worker          2m6s    v1.29.0
```

In the above command, the ROLE is `<none>` for the worker nodes. You can add a label to the worker node using the following command. Replace `worker-node01` with the hostname of the worker node you want to label.

```
kubectl label node node01  node-role.kubernetes.io/worker=worker
```

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Step 7: Install Calico Network Plugin for Pod Networking

Kubeadm does not configure any network plugin. You need to install a network plugin of your choice for kubernetes pod networking and enable network policy.

I am using the Calico network plugin for this setup.

> **Note**: Make sure you execute the kubectl command from where you have configured the `kubeconfig` file. Either from the master of your workstation with the connectivity to the kubernetes API.

Execute the following commands to install the Calico network plugin operator on the cluster.

```
kubectl apply -f
https://docs.projectcalico.org/manifests/calico.yaml
```

After a couple of minutes, if you check the pods in `kube-system` namespace, you will see calico pods and running CoreDNS pods.

```
kubectl get po -n kube-system
```

Step 8: Setup Kubernetes Metrics Server

Kubeadm doesn't install metrics server component during its initialization. We have to install it separately.

To verify this, if you run the top command, you will see the `Metrics API not available` error.

```
root@controlplane:~# kubectl top nodes

error: Metrics API not available
```

To install the metrics server, execute the following metric server manifest file. It deploys metrics server version `v0.6.2`

```
kubectl apply -f
https://raw.githubusercontent.com/techiescamp/kubeadm-
scripts/main/manifests/metrics-server.yaml
```

work in the local setup and hosted it separately. Or else, you will get the following error.

```
because it doesn't contain any IP SANs" node=""
```

Once the metrics server objects are deployed, **it takes a minute** for you to see the node and pod metrics using the top command.

```
kubectl top nodes
```

You should be able to view the node metrics as shown below.

```
root@controlplane:~# kubectl top nodes

NAME           CPU(cores)   CPU%   MEMORY(bytes)   MEMORY%
controlplane   142m         7%     1317Mi          34%
node01         36m          1%     915Mi           23%
```

You can also view the pod CPU and memory metrics using the following command.

```
kubectl top pod -n kube-system
```

Step 9: Deploy A Sample Nginx Application

Now that we have all the components to make the cluster and applications work, let's deploy a sample Nginx application and see if

Create an Nginx deployment. Execute the following directly on the command line. It deploys the pod in the default namespace.

```
cat <<EOF | kubectl apply -f -
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:latest
        ports:
        - containerPort: 80
EOF
```

Expose the Nginx deployment on a **NodePort 32000**

```
cat <<EOF | kubectl apply -f -
apiVersion: v1
kind: Service
metadata:
  name: nginx-service
spec:
  selector:
    app: nginx
  type: NodePort
  ports:
    - port: 80
      targetPort: 80
```

Check the pod status using the following command.

```
kubectl get pods
```

Once the deployment is up, you should be able to access the Nginx home page on the allocated NodePort.

For example,

Step 10: Add Kubeadm Config to Workstation

If you prefer to connect the Kubeadm cluster using kubectl from your workstation, you can merge the kubeadm `admin.conf` with your existing kubeconfig file.

Follow the steps given below for the configuration.

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Step 2: Take a backup of the existing kubeconfig.

```
cp ~/.kube/config ~/.kube/config.bak
```

Step 3: Merge the default config with kubeadm-config.yaml and export it to KUBECONFIG variable

```
export KUBECONFIG=~/.kube/config:/path/to/kubeadm-config.yaml
```

Step 4: Merger the configs to a file

```
kubectl config view --flatten > ~/.kube/merged_config.yaml
```

Step 5: Replace the old config with the new config

```
mv ~/.kube/merged_config.yaml ~/.kube/config
```

Step 6: List all the contexts

```
kubectl config get-contexts -o name
```

Step 7: Set the current context to the kubeadm cluster.

```
kubectl config use-context <cluster-name-here>
```

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Possible Kubeadm Issues

Following are the possible issues you might encounter in the kubeadm setup.

1. **Pod Out of memory and CPU:** The master node should have a minimum of 2vCPU and 2 GB memory.
2. **Nodes cannot connect to Master:** Check the firewall between nodes and make sure all the nodes can talk to each other on the required kubernetes ports.
3. **Calico Pod Restarts:** Sometimes, if you use the same IP range for the node and pod network, Calico pods may not work as expected. So make sure the node and pod IP ranges don't overlap. Overlapping IP addresses could result in issues for other applications running on the cluster as well.

For other pod errors, check out the kubernetes pod troubleshooting guide.

If your server doesn't have a minimum of 2 vCPU, you will get the following error.

```
[ERROR NumCPU]: the number of available CPUs 1 is less than the
required 2
```

If you use a public IP with `--apiserver-advertise-address` parameter, you will have failed master node components with the following error.

```
kubelet-check] Initial timeout of 40s passed.


Unfortunately, an error has occurred:
        timed out waiting for the condition

This error is likely caused by:
        - The kubelet is not running
        - The kubelet is unhealthy due to a misconfiguration of
the node in some way (required cgroups disabled)

If you are on a systemd-powered system, you can try to
troubleshoot the error with the following commands:
        - 'systemctl status kubelet'
        - 'journalctl -xeu kubelet'
```

You will get the following error in worker nodes when you try to join a worker node with a new token after the master node reset. To rectify this error, reset the worker node using the command `kubeadm reset` .

```
[ERROR FileAvailable--etc-kubernetes-kubelet.conf]:
/etc/kubernetes/kubelet.conf already exists
        [ERROR Port-10250]: Port 10250 is in use
        [ERROR FileAvailable--etc-kubernetes-pki-ca.crt]:
/etc/kubernetes/pki/ca.crt already exists
```

Kubernetes Cluster Important Configurations

Following are the important Kubernetes cluster configurations you should know.

Static Pods Location (etcd, api-server, controller manager and scheduler)	/etc/kubernetes/manifests
TLS Certificates location (kubernetes-ca, etcd-ca and kubernetes-front-proxy-ca)	/etc/kubernetes/pki
Admin Kubeconfig File	/etc/kubernetes/admin.conf
Kubelet configuration	/var/lib/kubelet/config.yaml

There are configurations that are part of Kubernetes feature gates. If you want to use the features that are part of feature gates, you need to enable them during the Kubeadm initialization using a kubeadm configuration file.

You can refer to enabling feature gates in Kubeadm blog to understand more.

Upgrading Kubeadm Cluster

Using Kubeadm you can upgrade the kubernetes cluster for the same version patch or a new version.

Kubeadm upgrade doesn't introduce any downtime if you upgrade one node at a time.

To do hands-on, please refer to my step-by-step guide on Kubeadm cluster upgrade

etcd backup is one the key task in real world projects and for CKA certification.

You can follow the etcd backup guide to learn how to perform etcd backup and restore.

Setup Prometheus Monitoring

As a next step, you can try setting up the Prometheus monitoring stack on the Kubeadm cluster.

I have published a detailed guide for the setup. Refer to prometheus on Kubernetes guide for step-by-step guides. The stack contains, prometheus, alert manager, kube state metrics and Grafana.

How Does Kubeadm Work?

Here is how the Kubeadm setup works.

When you initialize a Kubernetes cluster using Kubeadm, it does the following.

1. When you initialize kubeadm, first it runs all the preflight checks to validate the system state and it downloads all the required cluster container images from the **registry.k8s.io** container registry.
2. It then generates required TLS certificates and stores them in the **/etc/kubernetes/pki** folder.

4. Then it starts the kubelet service generates the static pod manifests for all the cluster components and saves it in the **/etc/kubernetes/manifests** folder.
5. Next, it starts all the control plane components from the static pod manifests.
6. Then it installs core DNS and Kubeproxy components
7. Finally, it generates the node bootstrap token.
8. Worker nodes use this token to join the control plane.

As you can see all the key cluster configurations will be present under the /etc/kubernetes folder.

Kubeadm FAQs

How to use Custom CA Certificates With Kubeadm?

By default, kubeadm creates its own CA certificates. However, if you wish to use custom CA certificates, they should be placed in the

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How to generate the Kubeadm Join command?

You can use `kubeadm token create --print-join-command` command to generate the join command.

Conclusion

In this post, we learned to install Kubernetes step by step using kubeadm.

As a DevOps engineer, it is good to have an understanding of the Kubernetes cluster components. With companies using managed Kubernetes services, we miss learning the basic building blocks of kubernetes.

This Kubeadm setup is good for learning and playing around with kubernetes.

Also, there are many other Kubeadm configs that I did not cover in this guide as it is out of the scope of this guide. Please refer to the official Kubeadm documentation. By having the whole cluster setup in VMs, you can learn all the cluster components configs and troubleshoot the cluster on component failures.

Also, with Vagrant, you can create simple automation to bring up and tear down Kubernetes clusters on-demand in your local workstation. Check out my guide on automated kubernetes vagrant setup using kubeadm.

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Bibin Wilson is a cloud and DevOps consultant with over 10 years of IT experience. He has extensive hands-on experience with public cloud platforms, cloud hosting, Kubernetes and OpenShift deployments in production. He has authored over 300 tech tutorials, providing valuable insights to the DevOps community. His courses on techiescamp.com offer practical guidance and real-world examples for professionals aiming to excel in cloud, DevOps, and infrastructure automation.

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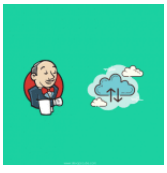

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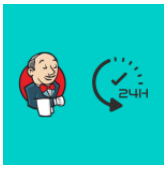

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