OpenShift Container Platform 4.4

Installing on vSphere

Installing OpenShift Container Platform vSphere clusters

Last Updated: 2021-02-15

OpenShift Container Platform 4.4 Installing on vSphere

Installing OpenShift Container Platform vSphere clusters

Legal Notice

Abstract

This document provides instructions for installing OpenShift Container Platform clusters on VMware vSphere.

Table of Contents

CHAPTER 1. INSTALLING ON VSPHERE

1.1. INSTALLING A CLUSTER ON VSPHERE

In OpenShift Container Platform version 4.4, you can install a cluster on VMware vSphere infrastructure that you provision.

1.1.1. Prerequisites

- Provision persistent storage for your cluster. To deploy a private image registry, your storage must provide **ReadWriteMany** access modes.
- Review details about the OpenShift Container Platform installation and update processes.
- If you use a firewall, you must configure it to allow the sites that your cluster requires access to.

NOTE

Be sure to also review this site list if you are configuring a proxy.

1.1.2. Internet and Telemetry access for OpenShift Container Platform

In OpenShift Container Platform 4.4, you require access to the Internet to install your cluster. The Telemetry service, which runs by default to provide metrics about cluster health and the success of updates, also requires Internet access. If your cluster is connected to the Internet, Telemetry runs automatically, and your cluster is registered to the Red Hat OpenShift Cluster Manager (OCM) .

Once you confirm that your Red Hat OpenShift Cluster Manager inventory is correct, either maintained automatically by Telemetry or manually using OCM, use subscription watch to track your OpenShift Container Platform subscriptions at the account or multi-cluster level.

You must have Internet access to:

- Access the Red Hat OpenShift Cluster Manager page to download the installation program and perform subscription management. If the cluster has Internet access and you do not disable Telemetry, that service automatically entitles your cluster.
- Access Quay.io to obtain the packages that are required to install your cluster.
- Obtain the packages that are required to perform cluster updates.

IMPORTANT

If your cluster cannot have direct Internet access, you can perform a restricted network installation on some types of infrastructure that you provision. During that process, you download the content that is required and use it to populate a mirror registry with the packages that you need to install a cluster and generate the installation program. With some installation types, the environment that you install your cluster in will not require Internet access. Before you update the cluster, you update the content of the mirror registry.

1.1.3. VMware vSphere infrastructure requirements

You must install the OpenShift Container Platform cluster on a VMware vSphere version 6 instance that meets the requirements for the components that you use.

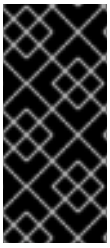
Table 1.1. Minimum supported vSphere version for VMware components

Component	Minimum supported versions	Description
Hypervisor	vSphere 6.5 with HW version 13	This version is the minimum version that Red Hat Enterprise Linux CoreOS (RHCOS) supports. See the Red Hat Enterprise Linux 8 supported hypervisors list.
Networking (NSX-T)	vSphere 6.5U3 or vSphere 6.7U2 and later	vSphere 6.5U3 or vSphere 6.7U2+ are required for OpenShift Container Platform. VMware's NSX Container Plug-in (NCP) 3.0.2 is certified with OpenShift Container Platform 4.4 and NSX-T 3.x+.
Storage with in-tree drivers	vSphere 6.5 or vSphere 6.7	This plug-in creates vSphere storage by using the in-tree storage drivers for vSphere included in OpenShift Container Platform and can be used when vSphere CSI drivers are not available.
Storage with vSphere CSI driver	vSphere 6.7U3 and later	This plug-in creates vSphere storage by using the standard Container Storage Interface. The vSphere CSI driver is provided and supported by VMware.

If you use a vSphere version 6.5 instance, consider upgrading to 6.7U2 before you install OpenShift Container Platform.

IMPORTANT

You must ensure that the time on your ESXi hosts is synchronized before you install OpenShift Container Platform. See Edit Time Configuration for a Host in the VMware documentation.



IMPORTANT

A limitation of using VPC is that the Storage Distributed Resource Scheduler (SDRS) is not supported. See link:https://vmware.github.io/vsphere-storage-for-kubernetes/documentation/faqs.html[vSphere Storage for Kubernetes FAQs] in the VMware documentation.

1.1.4. Required vCenter account privileges

To install an OpenShift Container Platform cluster in vCenter, the cluster requires access to an account with privileges to read and create the required resources. Using an account that has administrative privileges is the simplest way to access all of the necessary permissions.

A user requires the following privileges to install an OpenShift Container Platform cluster:

- Datastore
  - **Allocate space**
- Folder
  - **Create folder**
  - **Delete folder**
- vSphere Tagging
  - All privileges
- Network
  - **Assign network**
- Resource
  - **Assign virtual machine to resource pool**
- Profile-driven storage
  - All privileges
- vApp
  - All privileges
- Virtual machine
  - All privileges

For more information about creating an account with only the required privileges, see vSphere Permissions and User Management Tasks in the vSphere documentation.

1.1.5. Machine requirements for a cluster with user-provisioned infrastructure

For a cluster that contains user-provisioned infrastructure, you must deploy all of the required machines.

1.1.5.1. Required machines

The smallest OpenShift Container Platform clusters require the following hosts:

- One temporary bootstrap machine
- Three control plane, or master, machines
- At least two compute machines, which are also known as worker machines

NOTE

The cluster requires the bootstrap machine to deploy the OpenShift Container Platform cluster on the three control plane machines. You can remove the bootstrap machine after you install the cluster.

IMPORTANT

To maintain high availability of your cluster, use separate physical hosts for these cluster machines.

The bootstrap, control plane, and compute machines must use the Red Hat Enterprise Linux CoreOS (RHCOS) as the operating system.

Note that RHCOS is based on Red Hat Enterprise Linux 8 and inherits all of its hardware certifications and requirements. See Red Hat Enterprise Linux technology capabilities and limits .

1.1.5.2. Network connectivity requirements

All the Red Hat Enterprise Linux CoreOS (RHCOS) machines require network in **initramfs** during boot to fetch Ignition config files from the Machine Config Server. During the initial boot, the machines require either a DHCP server or that static IP addresses be set in order to establish a network connection to download their Ignition config files.

1.1.5.3. Minimum resource requirements

Each cluster machine must meet the following minimum requirements:

Machine	Operating System	vCPU[1]	Virtual RAM	Storage
Bootstrap	RHCOS	4	16 GB	120 GB
Control plane	RHCOS	4	16 GB	120 GB
Compute	RHCOS or RHEL 7.6	2	8 GB	120 GB

[1] 1 physical core provides 2 vCPUs when hyper-threading is enabled. 1 physical core provides 1 vCPU when hyper-threading is not enabled.

1.1.5.4. Certificate signing requests management

Because your cluster has limited access to automatic machine management when you use infrastructure that you provision, you must provide a mechanism for approving cluster certificate signing requests (CSRs) after installation. The **kube-controller-manager** only approves the kubelet client CSRs. The **machine-approver** cannot guarantee the validity of a serving certificate that is requested by using kubelet credentials because it cannot confirm that the correct machine issued the request. You must determine and implement a method of verifying the validity of the kubelet serving certificate requests and approving them.

1.1.6. Creating the user-provisioned infrastructure

Before you deploy an OpenShift Container Platform cluster that uses user-provisioned infrastructure, you must create the underlying infrastructure.

Prerequisites

- Review the OpenShift Container Platform 4.x Tested Integrations page before you create the supporting infrastructure for your cluster.

Procedure

1. Configure DHCP or set static IP addresses on each node.
2. Provision the required load balancers.
3. Configure the ports for your machines.
4. Configure DNS.
5. Ensure network connectivity.

1.1.6.1. Networking requirements for user-provisioned infrastructure

All the Red Hat Enterprise Linux CoreOS (RHCOS) machines require network in **initramfs** during boot to fetch Ignition config from the machine config server.

During the initial boot, the machines require either a DHCP server or that static IP addresses be set on each host in the cluster in order to establish a network connection, which allows them to download their Ignition config files.

It is recommended to use the DHCP server to manage the machines for the cluster long-term. Ensure that the DHCP server is configured to provide persistent IP addresses and host names to the cluster machines.

The Kubernetes API server, which runs on each master node after a successful cluster installation, must be able to resolve the node names of the cluster machines. If the API servers and worker nodes are in different zones, you can configure a default DNS search zone to allow the API server to resolve the node names. Another supported approach is to always refer to hosts by their fully-qualified domain names in both the node objects and all DNS requests.

You must configure the network connectivity between machines to allow cluster components to communicate. Each machine must be able to resolve the host names of all other machines in the cluster.

Table 1.2. All machines to all machines

Protocol	Port	Description
ICMP	N/A	Network reachability tests
TCP	**9000**-**9999**	Host level services, including the node exporter on ports **9100**-**9101** and the Cluster Version Operator on port**9099**.
	10250-**10259**	The default ports that Kubernetes reserves
	10256	openshift-sdn

Protocol	Port	Description
UDP	**4789**	VXLAN and Geneve
	6081	VXLAN and Geneve
	9000-**9999**	Host level services, including the node exporter on ports **9100**-**9101**.
TCP/UDP	**30000**-**32767**	Kubernetes node port

Table 1.3. All machines to control plane

Protocol	Port	Description
TCP	**2379**-**2380**	etcd server, peer, and metrics ports
	6443	Kubernetes API

Network topology requirements

The infrastructure that you provision for your cluster must meet the following network topology requirements.

IMPORTANT

OpenShift Container Platform requires all nodes to have internet access to pull images for platform containers and provide telemetry data to Red Hat.

Load balancers

Before you install OpenShift Container Platform, you must provision two load balancers that meet the following requirements:

1. **API load balancer**: Provides a common endpoint for users, both human and machine, to interact with and configure the platform. Configure the following conditions:

   - Layer 4 load balancing only. This can be referred to as Raw TCP, SSL Passthrough, or SSL Bridge mode. If you use SSL Bridge mode, you must enable Server Name Indication (SNI) for the API routes.
   - A stateless load balancing algorithm. The options vary based on the load balancer implementation.

   NOTE

   Session persistence is not required for the API load balancer to function properly.

   Configure the following ports on both the front and back of the load balancers:

   Table 1.4. API load balancer

Port	Back-end machines (pool members)	Internal	External	Description
6443	Bootstrap and control plane. You remove the bootstrap machine from the load balancer after the bootstrap machine initializes the cluster control plane. You must configure the **/readyz** endpoint for the API server health check probe.	X	X	Kubernetes API server
22623	Bootstrap and control plane. You remove the bootstrap machine from the load balancer after the bootstrap machine initializes the cluster control plane.	X		Machine config server

NOTE

The load balancer must be configured to take a maximum of 30 seconds from the time the API server turns off the **/readyz** endpoint to the removal of the API server instance from the pool. Within the time frame after **/readyz** returns an error or becomes healthy, the endpoint must have been removed or added. Probing every 5 or 10 seconds, with two successful requests to become healthy and three to become unhealthy, are well-tested values.

2. **Application Ingress load balancer**: Provides an Ingress point for application traffic flowing in from outside the cluster. Configure the following conditions:

   - Layer 4 load balancing only. This can be referred to as Raw TCP, SSL Passthrough, or SSL Bridge mode. If you use SSL Bridge mode, you must enable Server Name Indication (SNI) for the Ingress routes.
   - A connection-based or session-based persistence is recommended, based on the options available and types of applications that will be hosted on the platform.

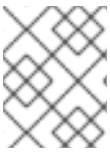
   Configure the following ports on both the front and back of the load balancers:

Table 1.5. Application Ingress load balancer

Port	Back-end machines (pool members)	Internal	External	Description
443	The machines that run the Ingress router pods, compute, or worker, by default.	X	X	HTTPS traffic
80	The machines that run the Ingress router pods, compute, or worker, by default.	X	X	HTTP traffic

TIP

If the true IP address of the client can be seen by the load balancer, enabling source IP-based session persistence can improve performance for applications that use end-to-end TLS encryption.



NOTE

A working configuration for the Ingress router is required for an OpenShift Container Platform cluster. You must configure the Ingress router after the control plane initializes.

Ethernet adaptor hardware address requirements
When provisioning VMs for the cluster, the ethernet interfaces configured for each VM must use a MAC address from the VMware Organizationally Unique Identifier (OUI) allocation ranges:

- **00:05:69:00:00:00** to **00:05:69:FF:FF:FF**
- **00:0c:29:00:00:00** to **00:0c:29:FF:FF:FF**
- **00:1c:14:00:00:00** to **00:1c:14:FF:FF:FF**
- **00:50:56:00:00:00** to **00:50:56:FF:FF:FF**

If a MAC address outside the VMware OUI is used, the cluster installation will not succeed.

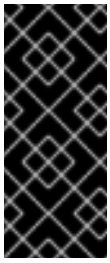
1.1.6.2. User-provisioned DNS requirements

DNS is used for name resolution and reverse name resolution. DNS A/AAAA or CNAME records are used for name resolution and PTR records are used for reverse name resolution. The reverse records are important because Red Hat Enterprise Linux CoreOS (RHCOS) uses the reverse records to set the host name for all the nodes. Additionally, the reverse records are used to generate the certificate signing requests (CSR) that OpenShift Container Platform needs to operate.

The following DNS records are required for an OpenShift Container Platform cluster that uses user-provisioned infrastructure. In each record, **<cluster_name>** is the cluster name and **<base_domain>** is the cluster base domain that you specify in the **install-config.yaml** file. A complete DNS record takes the form: **<component>.<cluster_name>.<base_domain>.**.

Table 1.6. Required DNS records

Component	Record	Description
Kubernetes API	**api.<cluster_name>.<base_domain>.**	Add a DNS A/AAAA or CNAME record, and a DNS PTR record, to identify the load balancer for the control plane machines. These records must be resolvable by both clients external to the cluster and from all the nodes within the cluster.

Component	Record	Description
	api-int.<cluster_name>. <base_domain>.	Add a DNS A/AAAA or CNAME record, and a DNS PTR record, to identify the load balancer for the control plane machines. These records must be resolvable from all the nodes within the cluster.  **IMPORTANT** The API server must be able to resolve the worker nodes by the host names that are recorded in Kubernetes. If the API server cannot resolve the node names, then proxied API calls can fail, and you cannot retrieve logs from pods.
Routes	***.apps.<cluster_name>. <base_domain>.**	Add a wildcard DNS A/AAAA or CNAME record that refers to the load balancer that targets the machines that run the Ingress router pods, which are the worker nodes by default. These records must be resolvable by both clients external to the cluster and from all the nodes within the cluster.
Bootstrap	**bootstrap.<cluster_name>. <base_domain>.**	Add a DNS A/AAAA or CNAME record, and a DNS PTR record, to identify the bootstrap machine. These records must be resolvable by the nodes within the cluster.
Master hosts	**<master><n>. <cluster_name>. <base_domain>.**	Add DNS A/AAAA or CNAME records and DNS PTR records to identify each machine for the master nodes. These records must be resolvable by the nodes within the cluster.
Worker hosts	**<worker><n>. <cluster_name>. <base_domain>.**	Add DNS A/AAAA or CNAME records and DNS PTR records to identify each machine for the worker nodes. These records must be resolvable by the nodes within the cluster.

TIP

You can use the **nslookup <hostname>** command to verify name resolution. You can use the **dig -x <ip_address>** command to verify reverse name resolution for the PTR records.

The following example of a BIND zone file shows sample A records for name resolution. The purpose of the example is to show the records that are needed. The example is not meant to provide advice for choosing one name resolution service over another.

Example 1.1. Sample DNS zone database

```
$TTL 1W
@ IN SOA ns1.example.com. root (
  2019070700 ; serial
```

```
    3H  ; refresh (3 hours)
    30M  ; retry (30 minutes)
    2W  ; expiry (2 weeks)
    1W )  ; minimum (1 week)
  IN NS ns1.example.com.
  IN MX 10 smtp.example.com.
;
;
ns1 IN A 192.168.1.5
smtp IN A 192.168.1.5
;
helper IN A 192.168.1.5
helper.ocp4 IN A 192.168.1.5
;
; The api identifies the IP of your load balancer.
api.ocp4  IN A 192.168.1.5
api-int.ocp4  IN A 192.168.1.5
;
; The wildcard also identifies the load balancer.
*.apps.ocp4  IN A 192.168.1.5
;
; Create an entry for the bootstrap host.
bootstrap.ocp4 IN A 192.168.1.96
;
; Create entries for the master hosts.
master0.ocp4  IN A 192.168.1.97
master1.ocp4  IN A 192.168.1.98
master2.ocp4  IN A 192.168.1.99
;
; Create entries for the worker hosts.
worker0.ocp4  IN A 192.168.1.11
worker1.ocp4  IN A 192.168.1.7
;
;EOF
```

The following example BIND zone file shows sample PTR records for reverse name resolution.

Example 1.2. Sample DNS zone database for reverse records

```
$TTL 1W
@ IN SOA ns1.example.com. root (
    2019070700 ; serial
    3H  ; refresh (3 hours)
    30M  ; retry (30 minutes)
    2W  ; expiry (2 weeks)
    1W )  ; minimum (1 week)
  IN NS ns1.example.com.
;
; The syntax is "last octet" and the host must have an FQDN
; with a trailing dot.
97 IN PTR master0.ocp4.example.com.
98 IN PTR master1.ocp4.example.com.
99 IN PTR master2.ocp4.example.com.
;
```

```
96 IN PTR bootstrap.ocp4.example.com.
;
5 IN PTR api.ocp4.ocp4.example.com.
5 IN PTR api-int.ocp4.ocp4.example.com.
;
11 IN PTR worker0.ocp4.example.com.
7 IN PTR worker1.ocp4.example.com.
;
;EOF
```

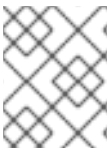
1.1.7. Generating an SSH private key and adding it to the agent

If you want to perform installation debugging or disaster recovery on your cluster, you must provide an SSH key to both your **ssh-agent** and the installation program. You can use this key to access the bootstrap machine in a public cluster to troubleshoot installation issues.

NOTE

In a production environment, you require disaster recovery and debugging.

You can use this key to SSH into the master nodes as the user **core**. When you deploy the cluster, the key is added to the **core** user's **~/.ssh/authorized_keys** list.



NOTE

You must use a local key, not one that you configured with platform-specific approaches such as AWS key pairs.

Procedure

1. If you do not have an SSH key that is configured for password-less authentication on your computer, create one. For example, on a computer that uses a Linux operating system, run the following command:

```
$ ssh-keygen -t ed25519 -N '' \
  -f <path>/<file_name> 1
```

1 Specify the path and file name, such as **~/.ssh/id_rsa**, of the SSH key. Do not specify an existing SSH key, as it will be overwritten.

   Running this command generates an SSH key that does not require a password in the location that you specified.

2. Start the **ssh-agent** process as a background task:

```
$ eval "$(ssh-agent -s)"

Agent pid 31874
```

3. Add your SSH private key to the **ssh-agent**:

```
$ ssh-add <path>/<file_name> (1)

Identity added: /home/<you>/<path>/<file_name> (<computer_name>)
```

(1) Specify the path and file name for your SSH private key, such as **~/.ssh/id_rsa**

Next steps

- When you install OpenShift Container Platform, provide the SSH public key to the installation program. If you install a cluster on infrastructure that you provision, you must provide this key to your cluster's machines.

1.1.8. Obtaining the installation program

Before you install OpenShift Container Platform, download the installation file on a local computer.

Prerequisites

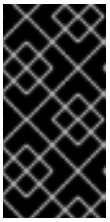
- You must install the cluster from a computer that uses Linux or macOS.
- You need 500 MB of local disk space to download the installation program.

Procedure

1. Access the Infrastructure Provider page on the Red Hat OpenShift Cluster Manager site. If you have a Red Hat account, log in with your credentials. If you do not, create an account.
2. Navigate to the page for your installation type, download the installation program for your operating system, and place the file in the directory where you will store the installation configuration files.

IMPORTANT

The installation program creates several files on the computer that you use to install your cluster. You must keep both the installation program and the files that the installation program creates after you finish installing the cluster.



IMPORTANT

Deleting the files created by the installation program does not remove your cluster, even if the cluster failed during installation. You must complete the OpenShift Container Platform uninstallation procedures outlined for your specific cloud provider to remove your cluster entirely.

3. Extract the installation program. For example, on a computer that uses a Linux operating system, run the following command:

```
$ tar xvf <installation_program>.tar.gz
```

4. From the Pull Secret page on the Red Hat OpenShift Cluster Manager site, download your installation pull secret as a **.txt** file. This pull secret allows you to authenticate with the services that are provided by the included authorities, including Quay.io, which serves the container

images for OpenShift Container Platform components.

1.1.9. Manually creating the installation configuration file

For installations of OpenShift Container Platform that use user-provisioned infrastructure, you must manually generate your installation configuration file.

Prerequisites

- Obtain the OpenShift Container Platform installation program and the access token for your cluster.

Procedure

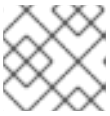
1. Create an installation directory to store your required installation assets in:

```
$ mkdir <installation_directory>
```

IMPORTANT

You must create a directory. Some installation assets, like bootstrap X.509 certificates have short expiration intervals, so you must not reuse an installation directory. If you want to reuse individual files from another cluster installation, you can copy them into your directory. However, the file names for the installation assets might change between releases. Use caution when copying installation files from an earlier OpenShift Container Platform version.

2. Customize the following **install-config.yaml** file template and save it in the **<installation_directory>**.



NOTE

You must name this configuration file **install-config.yaml**.

3. Back up the **install-config.yaml** file so that you can use it to install multiple clusters.

IMPORTANT

The **install-config.yaml** file is consumed during the next step of the installation process. You must back it up now.

1.1.9.1. Sample install-config.yaml file for VMware vSphere

You can customize the **install-config.yaml** file to specify more details about your OpenShift Container Platform cluster's platform or modify the values of the required parameters.

```
apiVersion: v1
baseDomain: example.com (1)
compute:
- hyperthreading: Enabled (2) (3)
  name: worker
  replicas: 0 (4)
```

```
controlPlane:
  hyperthreading: Enabled 5 6
  name: master
  replicas: 3 7
metadata:
  name: test 8
platform:
  vsphere:
    vcenter: your.vcenter.server 9
    username: username 10
    password: password 11
    datacenter: datacenter 12
    defaultDatastore: datastore 13
fips: false 14
pullSecret: '{"auths": ...}' 15
sshKey: 'ssh-ed25519 AAAA...' 16
```

1 The base domain of the cluster. All DNS records must be sub-domains of this base and include the cluster name.

2 5 The **controlPlane** section is a single mapping, but the compute section is a sequence of mappings. To meet the requirements of the different data structures, the first line of the **compute** section must begin with a hyphen, **-**, and the first line of the **controlPlane** section must not. Although both sections currently define a single machine pool, it is possible that future versions of OpenShift Container Platform will support defining multiple compute pools during installation. Only one control plane pool is used.

3 6 Whether to enable or disable simultaneous multithreading, or **hyperthreading**. By default, simultaneous multithreading is enabled to increase the performance of your machines' cores. You can disable it by setting the parameter value to **Disabled**. If you disable simultaneous multithreading in some cluster machines, you must disable it in all cluster machines.

IMPORTANT

If you disable simultaneous multithreading, ensure that your capacity planning accounts for the dramatically decreased machine performance. Your machines must use at least 8 CPUs and 32 GB of RAM if you disable simultaneous multithreading.

4 You must set the value of the **replicas** parameter to **0**. This parameter controls the number of workers that the cluster creates and manages for you, which are functions that the cluster does not perform when you use user-provisioned infrastructure. You must manually deploy worker machines for the cluster to use before you finish installing OpenShift Container Platform.

7 The number of control plane machines that you add to the cluster. Because the cluster uses this values as the number of etcd endpoints in the cluster, the value must match the number of control plane machines that you deploy.

8 The cluster name that you specified in your DNS records.

9 The fully-qualified host name or IP address of the vCenter server.

10 The name of the user for accessing the server. This user must have at least the roles and privileges that are required for static or dynamic persistent volume provisioning in vSphere.

11 The password associated with the vSphere user.

12 The vSphere datacenter.

13 The default vSphere datastore to use.

14 Whether to enable or disable FIPS mode. By default, FIPS mode is not enabled. If FIPS mode is enabled, the Red Hat Enterprise Linux CoreOS (RHCOS) machines that OpenShift Container Platform runs on bypass the default Kubernetes cryptography suite and use the cryptography modules that are provided with RHCOS instead.

15 The pull secret that you obtained from the Pull Secret page on the Red Hat OpenShift Cluster Manager site. This pull secret allows you to authenticate with the services that are provided by the included authorities, including Quay.io, which serves the container images for OpenShift Container Platform components.

16 The public portion of the default SSH key for the **core** user in Red Hat Enterprise Linux CoreOS (RHCOS).

NOTE

For production OpenShift Container Platform clusters on which you want to perform installation debugging or disaster recovery, specify an SSH key that your **ssh-agent** process uses.

1.1.9.2. Configuring the cluster-wide proxy during installation

Production environments can deny direct access to the Internet and instead have an HTTP or HTTPS proxy available. You can configure a new OpenShift Container Platform cluster to use a proxy by configuring the proxy settings in the **install-config.yaml** file.

Prerequisites

- An existing **install-config.yaml** file.
- Review the sites that your cluster requires access to and determine whether any need to bypass the proxy. By default, all cluster egress traffic is proxied, including calls to hosting cloud provider APIs. Add sites to the **Proxy** object's **spec.noProxy** field to bypass the proxy if necessary.

NOTE

The **Proxy** object **status.noProxy** field is populated with the values of the **networking.machineNetwork[].cidr**, **networking.clusterNetwork[].cidr**, and **networking.serviceNetwork[]** fields from your installation configuration.

For installations on Amazon Web Services (AWS), Google Cloud Platform (GCP), Microsoft Azure, and Red Hat OpenStack Platform (RHOSP), the **Proxy** object **status.noProxy** field is also populated with the instance metadata endpoint (**169.254.169.254**).

Procedure

1. Edit your **install-config.yaml** file and add the proxy settings. For example:

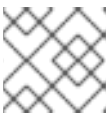
```
apiVersion: v1
baseDomain: my.domain.com
proxy:
  httpProxy: http://<username>:<pswd>@<ip>:<port> 1
  httpsProxy: http://<username>:<pswd>@<ip>:<port> 2
  noProxy: example.com 3
additionalTrustBundle: | 4
    -----BEGIN CERTIFICATE-----
    <MY_TRUSTED_CA_CERT>
    -----END CERTIFICATE-----
...
```

1. A proxy URL to use for creating HTTP connections outside the cluster. The URL scheme must be **http**. If you use an MITM transparent proxy network that does not require additional proxy configuration but requires additional CAs, you must not specify an **httpProxy** value.

2. A proxy URL to use for creating HTTPS connections outside the cluster. If this field is not specified, then **httpProxy** is used for both HTTP and HTTPS connections. If you use an MITM transparent proxy network that does not require additional proxy configuration but requires additional CAs, you must not specify an **httpsProxy** value.

3. A comma-separated list of destination domain names, domains, IP addresses, or other network CIDRs to exclude proxying. Preface a domain with **.** to include all subdomains of that domain. Use ***** to bypass proxy for all destinations. You must include vCenter's IP address and the IP range that you use for its machines.

4. If provided, the installation program generates a config map that is named **user-ca-bundle** in the **openshift-config** namespace that contains one or more additional CA certificates that are required for proxying HTTPS connections. The Cluster Network Operator then creates a **trusted-ca-bundle** config map that merges these contents with the Red Hat Enterprise Linux CoreOS (RHCOS) trust bundle, and this config map is referenced in the **Proxy** object's **trustedCA** field. The **additionalTrustBundle** field is required unless the proxy's identity certificate is signed by an authority from the RHCOS trust bundle. If you use an MITM transparent proxy network that does not require additional proxy configuration but requires additional CAs, you must provide the MITM CA certificate.



NOTE

The installation program does not support the proxy **readinessEndpoints** field.

2. Save the file and reference it when installing OpenShift Container Platform.

The installation program creates a cluster-wide proxy that is named **cluster** that uses the proxy settings in the provided **install-config.yaml** file. If no proxy settings are provided, a **cluster Proxy** object is still created, but it will have a nil **spec**.

NOTE

Only the **Proxy** object named **cluster** is supported, and no additional proxies can be created.

1.1.10. Creating the Kubernetes manifest and Ignition config files

Because you must modify some cluster definition files and manually start the cluster machines, you must generate the Kubernetes manifest and Ignition config files that the cluster needs to make its machines.

IMPORTANT

The Ignition config files that the installation program generates contain certificates that expire after 24 hours, which are then renewed at that time. If the cluster is shut down before renewing the certificates and the cluster is later restarted after the 24 hours have elapsed, the cluster automatically recovers the expired certificates. The exception is that you must manually approve the pending **node-bootstrapper** certificate signing requests (CSRs) to recover kubelet certificates. See the documentation for *Recovering from expired control plane certificates* for more information.

Prerequisites

- Obtain the OpenShift Container Platform installation program.
- Create the **install-config.yaml** installation configuration file.

Procedure

1. Generate the Kubernetes manifests for the cluster:

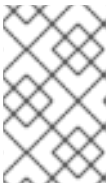
```
$ ./openshift-install create manifests --dir=<installation_directory> 1

INFO Consuming Install Config from target directory
WARNING Making control-plane schedulable by setting MastersSchedulable to true for
Scheduler cluster settings
```

1 For **<installation_directory>**, specify the installation directory that contains the **install-config.yaml** file you created.

   Because you create your own compute machines later in the installation process, you can safely ignore this warning.

2. Modify the **<installation_directory>/manifests/cluster-scheduler-02-config.yml** Kubernetes manifest file to prevent pods from being scheduled on the control plane machines:
   a. Open the **<installation_directory>/manifests/cluster-scheduler-02-config.yml** file.
   b. Locate the **mastersSchedulable** parameter and set its value to **False**.
   c. Save and exit the file.



NOTE

Currently, due to a Kubernetes limitation, router Pods running on control plane machines will not be reachable by the ingress load balancer. This step might not be required in a future minor version of OpenShift Container Platform.

3. Obtain the Ignition config files:

```
$ ./openshift-install create ignition-configs --dir=<installation_directory> 1
```

1 For **<installation_directory>**, specify the same installation directory.

The following files are generated in the directory:

```
.
├── auth
│   ├── kubeadmin-password
│   └── kubeconfig
├── bootstrap.ign
├── master.ign
├── metadata.json
└── worker.ign
```

1.1.11. Creating Red Hat Enterprise Linux CoreOS (RHCOS) machines in vSphere

Before you install a cluster that contains user-provisioned infrastructure on VMware vSphere, you must create RHCOS machines on vSphere hosts for it to use.

Prerequisites

- Obtain the Ignition config files for your cluster.
- Have access to an HTTP server that you can access from your computer and that the machines that you create can access.
- Create a vSphere cluster.

Procedure

1. Upload the bootstrap Ignition config file, which is named **<installation_directory>/bootstrap.ign**, that the installation program created to your HTTP server. Note the URL of this file.
   You must host the bootstrap Ignition config file because it is too large to fit in a vApp property.
2. Save the following secondary Ignition config file for your bootstrap node to your computer as **<installation_directory>/append-bootstrap.ign**.

```
{
  "ignition": {
    "config": {
      "append": [
        {
          "source": "<bootstrap_ignition_config_url>", 1
          "verification": {}
        }
      ]
    },
    "timeouts": {},
    "version": "2.2.0"
  },
  "networkd": {},
  "passwd": {},
```

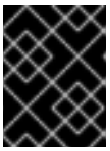
```
  "storage": {},
  "systemd": {}
}
```

1 Specify the URL of the bootstrap Ignition config file that you hosted.

When you create the virtual machine (VM) for the bootstrap machine, you use this Ignition config file.

3. Convert the master, worker, and secondary bootstrap Ignition config files to base64 encoding. For example, if you use a Linux operating system, you can use the **base64** command to encode the files.

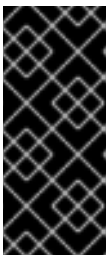
```
$ base64 -w0 <installation_directory>/master.ign > <installation_directory>/master.64
$ base64 -w0 <installation_directory>/worker.ign > <installation_directory>/worker.64
$ base64 -w0 <installation_directory>/append-bootstrap.ign >
<installation_directory>/append-bootstrap.64
```



IMPORTANT

If you plan to add more compute machines to your cluster after you finish installation, do not delete these files.

4. Obtain the RHCOS OVA image from the Product Downloads page on the Red Hat customer portal or the RHCOS image mirror page.

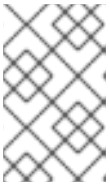


IMPORTANT

The RHCOS images might not change with every release of OpenShift Container Platform. You must download an image with the highest version that is less than or equal to the OpenShift Container Platform version that you install. Use the image version that matches your OpenShift Container Platform version if it is available.

The file name contains the OpenShift Container Platform version number in the format **rhcos-<version>-vmware.<architecture>.ova**.

5. In the vSphere Client, create a folder in your datacenter to store your VMs.
   a. Click the **VMs and Templates** view.
   b. Right-click the name of your datacenter.
   c. Click **New Folder → New VM and Template Folder**.
   d. In the window that is displayed, enter the folder name. The folder name must match the cluster name that you specified in the **install-config.yaml** file.
6. In the vSphere Client, create a template for the OVA image.



NOTE

In the following steps, you use the same template for all of your cluster machines and provide the location for the Ignition config file for that machine type when you provision the VMs.

a. From the **Hosts and Clusters** tab, right-click your cluster's name and click **Deploy OVF Template**.

b. On the **Select an OVF** tab, specify the name of the RHCOS OVA file that you downloaded.

c. On the **Select a name and folder** tab, set a **Virtual machine name**, such as RHCOS, click the name of your vSphere cluster, and select the folder you created in the previous step.

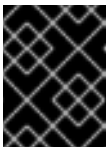
d. On the **Select a compute resource** tab, click the name of your vSphere cluster.

e. On the **Select storage** tab, configure the storage options for your VM.

- Select **Thin Provision** or **Thick Provision**, based on your storage preferences.
- Select the datastore that you specified in your **install-config.yaml** file.

f. On the **Select network** tab, specify the network that you configured for the cluster, if available.

g. If you plan to use the same template for all cluster machine types, do not specify values on the **Customize template** tab.



IMPORTANT

If you plan to add more compute machines to your cluster after you finish installation, do not delete this template.

7. After the template deploys, deploy a VM for a machine in the cluster.

a. Right-click the template's name and click **Clone → Clone to Virtual Machine**

b. On the **Select a name and folder** tab, specify a name for the VM. You might include the machine type in the name, such as **control-plane-0** or **compute-1**.

c. On the **Select a name and folder** tab, select the name of the folder that you created for the cluster.

d. On the **Select a compute resource** tab, select the name of a host in your datacenter.

e. Optional: On the **Select storage** tab, customize the storage options.

f. On the **Select clone options**, select **Customize this virtual machine's hardware**.

g. On the **Customize hardware** tab, click **VM Options → Advanced**.

- Optional: In the event of cluster performance issues, from the **Latency Sensitivity** list, select **High**.
- Click **Edit Configuration**, and on the **Configuration Parameters** window, click **Add Configuration Params**. Define the following parameter names and values:

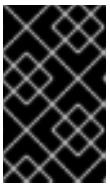
- **guestinfo.ignition.config.data**: Paste the contents of the base64-encoded Ignition config file for this machine type.
- **guestinfo.ignition.config.data.encoding**: Specify **base64**.
- **disk.EnableUUID**: Specify **TRUE**.

- Alternatively, prior to powering on the virtual machine add via vApp properties:
  - Navigate to a virtual machine from the vCenter Server inventory.
  - On the **Configure** tab, expand **Settings** and select **vApp options.**
  - Scroll down and under **Properties** apply the configurations from above.

h. In the **Virtual Hardware** panel of the **Customize hardware** tab, modify the specified values as required. Ensure that the amount of RAM, CPU, and disk storage meets the minimum requirements for the machine type.

i. Complete the configuration and power on the VM.

8. Create the rest of the machines for your cluster by following the preceding steps for each machine.



IMPORTANT

You must create the bootstrap and control plane machines at this time. Because some pods are deployed on compute machines by default, also create at least two compute machine before you install the cluster.

1.1.12. Creating more Red Hat Enterprise Linux CoreOS (RHCOS) machines in vSphere

You can create more compute machines for your cluster that uses user-provisioned infrastructure on VMware vSphere.

Prerequisites

- Obtain the base64-encoded Ignition file for your compute machines.
- You have access to the vSphere template that you created for your cluster.

Procedure

1. After the template deploys, deploy a VM for a machine in the cluster.
   a. Right-click the template's name and click **Clone → Clone to Virtual Machine**
   b. On the **Select a name and folder** tab, specify a name for the VM. You might include the machine type in the name, such as **compute-1**.
   c. On the **Select a name and folder** tab, select the name of the folder that you created for the cluster.
   d. On the **Select a compute resource** tab, select the name of a host in your datacenter.

e. Optional: On the **Select storage** tab, customize the storage options.

f. On the **Select clone options**, select **Customize this virtual machine's hardware**.

g. On the **Customize hardware** tab, click **VM Options → Advanced**.

- From the **Latency Sensitivity** list, select **High**.
- Click **Edit Configuration**, and on the **Configuration Parameters** window, click **Add Configuration Params**. Define the following parameter names and values:
  - **guestinfo.ignition.config.data**: Paste the contents of the base64-encoded compute Ignition config file for this machine type.
  - **guestinfo.ignition.config.data.encoding**: Specify **base64**.
  - **disk.EnableUUID**: Specify **TRUE**.

h. In the **Virtual Hardware** panel of the **Customize hardware** tab, modify the specified values as required. Ensure that the amount of RAM, CPU, and disk storage meets the minimum requirements for the machine type. Also, make sure to select the correct network under **Add network adapter** if there are multiple networks available.

i. Complete the configuration and power on the VM.

2. Continue to create more compute machines for your cluster.

1.1.13. Installing the CLI by downloading the binary

You can install the OpenShift CLI (**oc**) in order to interact with OpenShift Container Platform from a command-line interface. You can install **oc** on Linux, Windows, or macOS.

IMPORTANT

If you installed an earlier version of **oc**, you cannot use it to complete all of the commands in OpenShift Container Platform 4.4. Download and install the new version of **oc**.

1.1.13.1. Installing the CLI on Linux

You can install the OpenShift CLI (**oc**) binary on Linux by using the following procedure.

Procedure

1. Navigate to the Infrastructure Provider page on the Red Hat OpenShift Cluster Manager site.
2. Select your infrastructure provider, and, if applicable, your installation type.
3. In the **Command-line interface** section, select **Linux** from the drop-down menu and click **Download command-line tools**.
4. Unpack the archive:

```
$ tar xvzf <file>
```

5. Place the **oc** binary in a directory that is on your **PATH**.
   To check your **PATH**, execute the following command:

```
$ echo $PATH
```

After you install the CLI, it is available using the **oc** command:

```
$ oc <command>
```

1.1.13.2. Installing the CLI on Windows

You can install the OpenShift CLI (**oc**) binary on Windows by using the following procedure.

Procedure

1. Navigate to the Infrastructure Provider page on the Red Hat OpenShift Cluster Manager site.
2. Select your infrastructure provider, and, if applicable, your installation type.
3. In the **Command-line interface** section, select **Windows** from the drop-down menu and click **Download command-line tools**.
4. Unzip the archive with a ZIP program.
5. Move the **oc** binary to a directory that is on your **PATH**.
   To check your **PATH**, open the command prompt and execute the following command:

```
C:\> path
```

After you install the CLI, it is available using the **oc** command:

```
C:\> oc <command>
```

1.1.13.3. Installing the CLI on macOS

You can install the OpenShift CLI (**oc**) binary on macOS by using the following procedure.

Procedure

1. Navigate to the Infrastructure Provider page on the Red Hat OpenShift Cluster Manager site.
2. Select your infrastructure provider, and, if applicable, your installation type.
3. In the **Command-line interface** section, select **MacOS** from the drop-down menu and click **Download command-line tools**.
4. Unpack and unzip the archive.
5. Move the **oc** binary to a directory on your PATH.
   To check your **PATH**, open a terminal and execute the following command:

```
$ echo $PATH
```

After you install the CLI, it is available using the **oc** command:

```
$ oc <command>
```

1.1.14. Creating the cluster

To create the OpenShift Container Platform cluster, you wait for the bootstrap process to complete on the machines that you provisioned by using the Ignition config files that you generated with the installation program.

Prerequisites

- Create the required infrastructure for the cluster.
- You obtained the installation program and generated the Ignition config files for your cluster.
- You used the Ignition config files to create RHCOS machines for your cluster.
- Your machines have direct Internet access or have an HTTP or HTTPS proxy available.

Procedure

1. Monitor the bootstrap process:

```
$ ./openshift-install --dir=<installation_directory> wait-for bootstrap-complete \ 1
    --log-level=info 2
INFO Waiting up to 30m0s for the Kubernetes API at https://api.test.example.com...
INFO API v1.17.1 up
INFO Waiting up to 30m0s for bootstrapping to complete...
INFO It is now safe to remove the bootstrap resources
```

1 For **<installation_directory>**, specify the path to the directory that you stored the installation files in.

2 To view different installation details, specify **warn**, **debug**, or **error** instead of **info**.

The command succeeds when the Kubernetes API server signals that it has been bootstrapped on the control plane machines.

2. After bootstrap process is complete, remove the bootstrap machine from the load balancer.

IMPORTANT

You must remove the bootstrap machine from the load balancer at this point. You can also remove or reformat the machine itself.

1.1.15. Logging in to the cluster

You can log in to your cluster as a default system user by exporting the cluster **kubeconfig** file. The **kubeconfig** file contains information about the cluster that is used by the CLI to connect a client to the correct cluster and API server. The file is specific to a cluster and is created during OpenShift Container Platform installation.

Prerequisites

- Deploy an OpenShift Container Platform cluster.
- Install the **oc** CLI.

Procedure

1. Export the **kubeadmin** credentials:

```
$ export KUBECONFIG=<installation_directory>/auth/kubeconfig 1
```

1 For **<installation_directory>**, specify the path to the directory that you stored the installation files in.

2. Verify you can run **oc** commands successfully using the exported configuration:

```
$ oc whoami
system:admin
```

1.1.16. Approving the certificate signing requests for your machines

When you add machines to a cluster, two pending certificate signing requests (CSRs) are generated for each machine that you added. You must confirm that these CSRs are approved or, if necessary, approve them yourself. The client requests must be approved first, followed by the server requests.

Prerequisites

- You added machines to your cluster.

Procedure

1. Confirm that the cluster recognizes the machines:

```
# oc get nodes

NAME                 STATUS   ROLES    AGE   VERSION
master-01.example.com   Ready    master   40d   v1.17.1
master-02.example.com   Ready    master   40d   v1.17.1
master-03.example.com   Ready    master   40d   v1.17.1
worker-01.example.com   Ready    worker   40d   v1.17.1
worker-02.example.com   Ready    worker   40d   v1.17.1
```

The output lists all of the machines that you created.

2. Review the pending CSRs and ensure that you see the client requests with the **Pending** or **Approved** status for each machine that you added to the cluster:

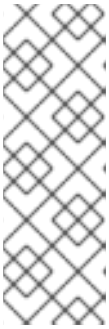
```
$ oc get csr

NAME        AGE     REQUESTOR                                                   CONDITION
csr-8b2br   15m     system:serviceaccount:openshift-machine-config-operator:node-
bootstrapper   Pending
```

```
csr-8vnps   15m     system:serviceaccount:openshift-machine-config-operator:node-
bootstrapper   Pending
...
```

In this example, two machines are joining the cluster. You might see more approved CSRs in the list.

3. If the CSRs were not approved, after all of the pending CSRs for the machines you added are in **Pending** status, approve the CSRs for your cluster machines:



NOTE

Because the CSRs rotate automatically, approve your CSRs within an hour of adding the machines to the cluster. If you do not approve them within an hour, the certificates will rotate, and more than two certificates will be present for each node. You must approve all of these certificates. After you approve the initial CSRs, the subsequent node client CSRs are automatically approved by the cluster **kube-controller-manager**. You must implement a method of automatically approving the kubelet serving certificate requests.

- To approve them individually, run the following command for each valid CSR:

```
$ oc adm certificate approve <csr_name> 1
```

1 **<csr_name>** is the name of a CSR from the list of current CSRs.

- To approve all pending CSRs, run the following command:

```
$ oc get csr -o go-template='{{range .items}}{{if not .status}}{{.metadata.name}}{{"\n"}}
{{end}}{{end}}' | xargs oc adm certificate approve
```

4. Now that your client requests are approved, you must review the server requests for each machine that you added to the cluster:

```
$ oc get csr
```

Example output

```
NAME        AGE     REQUESTOR                                                   CONDITION
csr-bfd72   5m26s   system:node:ip-10-0-50-126.us-east-2.compute.internal
Pending
csr-c57lv   5m26s   system:node:ip-10-0-95-157.us-east-2.compute.internal
Pending
...
```

5. If the remaining CSRs are not approved, and are in the **Pending** status, approve the CSRs for your cluster machines:

- To approve them individually, run the following command for each valid CSR:

```
$ oc adm certificate approve <csr_name> 1
```

1 **<csr_name>** is the name of a CSR from the list of current CSRs.

- To approve all pending CSRs, run the following command:

```
$ oc get csr -o go-template='{{range .items}}{{if not .status}}{{.metadata.name}}{{"\n"}}
{{end}}{{end}}' | xargs oc adm certificate approve
```

6. After all client and server CSRs have been approved, the machines have the **Ready** status. Verify this by running the following command:

```
$ oc get nodes
```

Example output

```
NAME      STATUS    ROLES   AGE  VERSION
master-0  Ready     master  73m  v1.20.0
master-1  Ready     master  73m  v1.20.0
master-2  Ready     master  74m  v1.20.0
worker-0  Ready     worker  11m  v1.20.0
worker-1  Ready     worker  11m  v1.20.0
```

NOTE

It can take a few minutes after approval of the server CSRs for the machines to transition to the **Ready** status.

Additional information

- For more information on CSRs, see Certificate Signing Requests.

1.1.17. Initial Operator configuration

After the control plane initializes, you must immediately configure some Operators so that they all become available.

Prerequisites

- Your control plane has initialized.

Procedure

1. Watch the cluster components come online:

```
$ watch -n5 oc get clusteroperators

NAME                       VERSION   AVAILABLE   PROGRESSING   DEGRADED
SINCE
authentication             4.4.0     True        False         False     69s
cloud-credential           4.4.0     True        False         False     12m
cluster-autoscaler         4.4.0     True        False         False     11m
console                    4.4.0     True        False         False     46s
dns                        4.4.0     True        False         False     11m
```

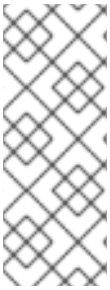
```
image-registry                  4.4.0     True        False         False      5m26s
ingress                         4.4.0     True        False         False      5m36s
kube-apiserver                  4.4.0     True        False         False      8m53s
kube-controller-manager         4.4.0     True        False         False      7m24s
kube-scheduler                  4.4.0     True        False         False      12m
machine-api                     4.4.0     True        False         False      12m
machine-config                  4.4.0     True        False         False      7m36s
marketplace                     4.4.0     True        False         False      7m54m
monitoring                      4.4.0     True        False         False      7h54s
network                         4.4.0     True        False         False      5m9s
node-tuning                     4.4.0     True        False         False      11m
openshift-apiserver             4.4.0     True        False         False      11m
openshift-controller-manager    4.4.0     True        False         False      5m943s
openshift-samples               4.4.0     True        False         False      3m55s
operator-lifecycle-manager      4.4.0     True        False         False      11m
operator-lifecycle-manager-catalog   4.4.0     True        False         False      11m
service-ca                      4.4.0     True        False         False      11m
service-catalog-apiserver       4.4.0     True        False         False      5m26s
service-catalog-controller-manager   4.4.0     True        False         False      5m25s
storage                         4.4.0     True        False         False      5m30s
```

2. Configure the Operators that are not available.

1.1.17.1. Image registry removed during installation

On platforms that do not provide shareable object storage, the OpenShift Image Registry Operator bootstraps itself as **Removed**. This allows **openshift-installer** to complete installations on these platform types.

After installation, you must edit the Image Registry Operator configuration to switch the **managementState** from **Removed** to **Managed**.



NOTE

The Prometheus console provides an **ImageRegistryRemoved** alert, for example:

"Image Registry has been removed. **ImageStreamTags**, **BuildConfigs** and **DeploymentConfigs** which reference **ImageStreamTags** may not work as expected. Please configure storage and update the config to **Managed** state by editing configs.imageregistry.operator.openshift.io."

1.1.17.2. Image registry storage configuration

The Image Registry Operator is not initially available for platforms that do not provide default storage. After installation, you must configure your registry to use storage so the Registry Operator is made available.

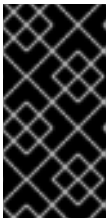
Instructions for both configuring a persistent volume, which is required for production clusters, and for configuring an empty directory as the storage location, which is available for only non-production clusters, are shown.

1.1.17.2.1. Configuring registry storage for VMware vSphere

As a cluster administrator, following installation you must configure your registry to use storage.

Prerequisites

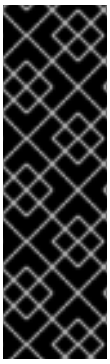
- Cluster administrator permissions.
- A cluster on VMware vSphere.
- Persistent storage provisioned for your cluster, such as Red Hat OpenShift Container Storage.



IMPORTANT

OpenShift Container Platform supports **ReadWriteOnce** access for image registry storage when you have only one replica. To deploy an image registry that supports high availability with two or more replicas, **ReadWriteMany** access is required.

- Must have "100Gi" capacity.



IMPORTANT

Testing shows issues with using the NFS server on RHEL as storage backend for core services. This includes the OpenShift Container Registry and Quay, Prometheus for monitoring storage, and Elasticsearch for logging storage. Therefore, using RHEL NFS to back PVs used by core services is not recommended.

Other NFS implementations on the marketplace might not have these issues. Contact the individual NFS implementation vendor for more information on any testing that was possibly completed against these OpenShift Container Platform core components.

Procedure

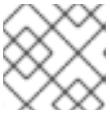
1. To configure your registry to use storage, change the **spec.storage.pvc** in the **configs.imageregistry/cluster** resource.

NOTE

When using shared storage, review your security settings to prevent outside access.

2. Verify that you do not have a registry pod:

```
$ oc get pod -n openshift-image-registry
```



NOTE

If the storage type is **emptyDIR**, the replica number cannot be greater than **1**.

3. Check the registry configuration:

```
$ oc edit configs.imageregistry.operator.openshift.io
```

Example output

```
storage:
  pvc:
    claim: 1
```

1 Leave the **claim** field blank to allow the automatic creation of an **image-registry-storage** PVC.

4. Check the **clusteroperator** status:

```
$ oc get clusteroperator image-registry
```

1.1.17.2.2. Configuring storage for the image registry in non-production clusters

You must configure storage for the Image Registry Operator. For non-production clusters, you can set the image registry to an empty directory. If you do so, all images are lost if you restart the registry.

Procedure

- To set the image registry storage to an empty directory:

```
$ oc patch configs.imageregistry.operator.openshift.io cluster --type merge --patch '{"spec":{"storage":{"emptyDir":{}}}}'
```

WARNING

Configure this option for only non-production clusters.

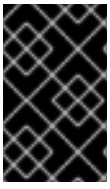
If you run this command before the Image Registry Operator initializes its components, the **oc patch** command fails with the following error:

```
Error from server (NotFound): configs.imageregistry.operator.openshift.io "cluster" not found
```

Wait a few minutes and run the command again.

1.1.17.2.3. Configuring block registry storage for VMware vSphere

To allow the image registry to use block storage types such as vSphere Virtual Machine Disk (VMDK) during upgrades as a cluster administrator, you can use the **Recreate** rollout strategy.



IMPORTANT

Block storage volumes are supported but not recommended for use with image registry on production clusters. An installation where the registry is configured on block storage is not highly available because the registry cannot have more than one replica.

Procedure

1. To set the image registry storage as a block storage type, patch the registry so that it uses the **Recreate** rollout strategy and runs with only **1** replica:

```
$ oc patch config.imageregistry.operator.openshift.io/cluster --type=merge -p '{"spec":
{"rolloutStrategy":"Recreate","replicas":1}}'
```

2. Provision the PV for the block storage device, and create a PVC for that volume. The requested block volume uses the ReadWriteOnce (RWO) access mode.

   a. Create a **pvc.yaml** file with the following contents to define a VMware vSphere **PersistentVolumeClaim** object:

```
kind: PersistentVolumeClaim
apiVersion: v1
metadata:
  name: image-registry-storage (1)
spec:
  accessModes:
  - ReadWriteOnce (2)
  resources:
    requests:
      storage: 100Gi (3)
```

   (1) A unique name that represents the **PersistentVolumeClaim** object.

   (2) The access mode of the PersistentVolumeClaim. With **ReadWriteOnce**, the volume can be mounted with read and write permissions by a single node.

   (3) The size of the PersistentVolumeClaim.

   b. Create the **PersistentVolumeClaim** object from the file:

```
$ oc create -f pvc.yaml
```

3. Edit the registry configuration so that it references the correct PVC:

```
$ oc edit config.imageregistry.operator.openshift.io -o yaml
```

Example output

```
storage:
  pvc:
    claim: (1)
```

(1) Creating a custom PVC allows you to leave the **claim** field blank for the default automatic creation of an **image-registry-storage** PVC.

For instructions about configuring registry storage so that it references the correct PVC, see Configuring the registry for vSphere.

1.1.18. Completing installation on user-provisioned infrastructure

After you complete the Operator configuration, you can finish installing the cluster on infrastructure that you provide.

Prerequisites

- Your control plane has initialized.
- You have completed the initial Operator configuration.

Procedure

1. Confirm that all the cluster components are online:

```
$ watch -n5 oc get clusteroperators

NAME                                       VERSION   AVAILABLE   PROGRESSING   DEGRADED
SINCE
authentication                             4.4.3     True        False         False      7m56s
cloud-credential                           4.4.3     True        False         False      31m
cluster-autoscaler                         4.4.3     True        False         False      16m
console                                    4.4.3     True        False         False      10m
csi-snapshot-controller                    4.4.3     True        False         False      16m
dns                                        4.4.3     True        False         False      22m
etcd                                       4.4.3     False       False         False      25s
image-registry                             4.4.3     True        False         False      16m
ingress                                    4.4.3     True        False         False      16m
insights                                   4.4.3     True        False         False      17m
kube-apiserver                             4.4.3     True        False         False      19m
kube-controller-manager                    4.4.3     True        False         False      20m
kube-scheduler                             4.4.3     True        False         False      20m
kube-storage-version-migrator              4.4.3     True        False         False      16m
machine-api                                4.4.3     True        False         False      22m
machine-config                             4.4.3     True        False         False      22m
marketplace                                4.4.3     True        False         False      16m
monitoring                                 4.4.3     True        False         False      10m
network                                    4.4.3     True        False         False      23m
node-tuning                                4.4.3     True        False         False      23m
openshift-apiserver                        4.4.3     True        False         False      17m
openshift-controller-manager               4.4.3     True        False         False      15m
openshift-samples                          4.4.3     True        False         False      16m
operator-lifecycle-manager                 4.4.3     True        False         False      22m
operator-lifecycle-manager-catalog         4.4.3     True        False         False      22m
operator-lifecycle-manager-packageserver   4.4.3     True        False         False      18m
service-ca                                 4.4.3     True        False         False      23m
service-catalog-apiserver                  4.4.3     True        False         False      23m
service-catalog-controller-manager         4.4.3     True        False         False      23m
storage                                    4.4.3     True        False         False      17m
```

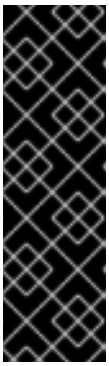
When all of the cluster Operators are **AVAILABLE**, you can complete the installation.

2. Monitor for cluster completion:

```
$ ./openshift-install --dir=<installation_directory> wait-for install-complete 1
INFO Waiting up to 30m0s for the cluster to initialize...
```

1 For **<installation_directory>**, specify the path to the directory that you stored the installation files in.

The command succeeds when the Cluster Version Operator finishes deploying the OpenShift Container Platform cluster from Kubernetes API server.



IMPORTANT

The Ignition config files that the installation program generates contain certificates that expire after 24 hours, which are then renewed at that time. If the cluster is shut down before renewing the certificates and the cluster is later restarted after the 24 hours have elapsed, the cluster automatically recovers the expired certificates. The exception is that you must manually approve the pending **node-bootstrapper** certificate signing requests (CSRs) to recover kubelet certificates. See the documentation for *Recovering from expired control plane certificates* for more information.

3. Confirm that the Kubernetes API server is communicating with the pods.

   a. To view a list of all pods, use the following command:

```
$ oc get pods --all-namespaces

NAMESPACE                       NAME                                        READY   STATUS
RESTARTS   AGE
openshift-apiserver-operator    openshift-apiserver-operator-85cb746d55-zqhs8   1/1
Running    1          9m
openshift-apiserver             apiserver-67b9g                               1/1     Running     0
3m
openshift-apiserver             apiserver-ljcmx                               1/1     Running     0
1m
openshift-apiserver             apiserver-z25h4                               1/1     Running     0
2m
openshift-authentication-operator authentication-operator-69d5d8bf84-vh2n8        1/1
Running    0          5m
...
```

   b. View the logs for a pod that is listed in the output of the previous command by using the following command:

```
$ oc logs <pod_name> -n <namespace> 1
```

   1 Specify the pod name and namespace, as shown in the output of the previous command.

   If the pod logs display, the Kubernetes API server can communicate with the cluster machines.

You can add extra compute machines after the cluster installation is completed by following Adding compute machines to vSphere.

1.1.19. Backing up VMware vSphere volumes

OpenShift Container Platform provisions new volumes as independent persistent disks to freely attach and detach the volume on any node in the cluster. As a consequence, it is not possible to back up volumes that use snapshots, or to restore volumes from snapshots. See Snapshot Limitations for more information.

Procedure

To create a backup of persistent volumes:

1. Stop the application that is using the persistent volume.
2. Clone the persistent volume.
3. Restart the application.
4. Create a backup of the cloned volume.
5. Delete the cloned volume.

1.1.20. Next steps

- Customize your cluster.
- If necessary, you can opt out of remote health reporting .
- Set up your registry and configure registry storage .

1.2. INSTALLING A CLUSTER ON VSPHERE WITH NETWORK CUSTOMIZATIONS

In OpenShift Container Platform version 4.4, you can install a cluster on VMware vSphere infrastructure that you provision with customized network configuration options. By customizing your network configuration, your cluster can coexist with existing IP address allocations in your environment and integrate with existing MTU and VXLAN configurations.

You must set most of the network configuration parameters during installation, and you can modify only **kubeProxy** configuration parameters in a running cluster.

1.2.1. Prerequisites

- Review details about the OpenShift Container Platform installation and update processes.
- If you use a firewall, you must configure it to access Red Hat Insights .

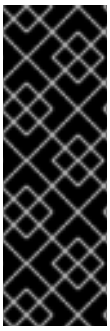
1.2.2. Internet and Telemetry access for OpenShift Container Platform

In OpenShift Container Platform 4.4, you require access to the Internet to install your cluster. The Telemetry service, which runs by default to provide metrics about cluster health and the success of updates, also requires Internet access. If your cluster is connected to the Internet, Telemetry runs automatically, and your cluster is registered to the Red Hat OpenShift Cluster Manager (OCM) .

Once you confirm that your Red Hat OpenShift Cluster Manager inventory is correct, either maintained automatically by Telemetry or manually using OCM, use subscription watch to track your OpenShift Container Platform subscriptions at the account or multi-cluster level.

You must have Internet access to:

- Access the Red Hat OpenShift Cluster Manager page to download the installation program and perform subscription management. If the cluster has Internet access and you do not disable Telemetry, that service automatically entitles your cluster.
- Access Quay.io to obtain the packages that are required to install your cluster.
- Obtain the packages that are required to perform cluster updates.



IMPORTANT

If your cluster cannot have direct Internet access, you can perform a restricted network installation on some types of infrastructure that you provision. During that process, you download the content that is required and use it to populate a mirror registry with the packages that you need to install a cluster and generate the installation program. With some installation types, the environment that you install your cluster in will not require Internet access. Before you update the cluster, you update the content of the mirror registry.

1.2.3. VMware vSphere infrastructure requirements

You must install the OpenShift Container Platform cluster on a VMware vSphere version 6 instance that meets the requirements for the components that you use.

Table 1.7. Minimum supported vSphere version for VMware components

Component	Minimum supported versions	Description
Hypervisor	vSphere 6.5 with HW version 13	This version is the minimum version that Red Hat Enterprise Linux CoreOS (RHCOS) supports. See the Red Hat Enterprise Linux 8 supported hypervisors list.
Networking (NSX-T)	vSphere 6.5U3 or vSphere 6.7U2 and later	vSphere 6.5U3 or vSphere 6.7U2+ are required for OpenShift Container Platform. VMware's NSX Container Plug-in (NCP) 3.0.2 is certified with OpenShift Container Platform 4.4 and NSX-T 3.x+.
Storage with in-tree drivers	vSphere 6.5 or vSphere 6.7	This plug-in creates vSphere storage by using the in-tree storage drivers for vSphere included in OpenShift Container Platform and can be used when vSphere CSI drivers are not available.

Component	Minimum supported versions	Description
Storage with vSphere CSI driver	vSphere 6.7U3 and later	This plug-in creates vSphere storage by using the standard Container Storage Interface. The vSphere CSI driver is provided and supported by VMware.

If you use a vSphere version 6.5 instance, consider upgrading to 6.7U2 before you install OpenShift Container Platform.

IMPORTANT

You must ensure that the time on your ESXi hosts is synchronized before you install OpenShift Container Platform. See Edit Time Configuration for a Host in the VMware documentation.

IMPORTANT

> A limitation of using VPC is that the Storage Distributed Resource Scheduler (SDRS) is not supported. See link:https://vmware.github.io/vsphere-storage-for-kubernetes/documentation/faqs.html[vSphere Storage for Kubernetes FAQs] in the VMware documentation.

1.2.4. Required vCenter account privileges

To install an OpenShift Container Platform cluster in vCenter, the cluster requires access to an account with privileges to read and create the required resources. Using an account that has administrative privileges is the simplest way to access all of the necessary permissions.

A user requires the following privileges to install an OpenShift Container Platform cluster:

- Datastore
  - **Allocate space**
- Folder
  - **Create folder**
  - **Delete folder**
- vSphere Tagging
  - All privileges
- Network
  - **Assign network**
- Resource
  - **Assign virtual machine to resource pool**

- Profile-driven storage
  - All privileges
- vApp
  - All privileges
- Virtual machine
  - All privileges

For more information about creating an account with only the required privileges, see vSphere Permissions and User Management Tasks in the vSphere documentation.

1.2.5. Machine requirements for a cluster with user-provisioned infrastructure

For a cluster that contains user-provisioned infrastructure, you must deploy all of the required machines.

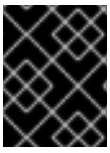
1.2.5.1. Required machines

The smallest OpenShift Container Platform clusters require the following hosts:

- One temporary bootstrap machine
- Three control plane, or master, machines
- At least two compute machines, which are also known as worker machines

NOTE

The cluster requires the bootstrap machine to deploy the OpenShift Container Platform cluster on the three control plane machines. You can remove the bootstrap machine after you install the cluster.



IMPORTANT

To maintain high availability of your cluster, use separate physical hosts for these cluster machines.

The bootstrap, control plane, and compute machines must use the Red Hat Enterprise Linux CoreOS (RHCOS) as the operating system.

Note that RHCOS is based on Red Hat Enterprise Linux 8 and inherits all of its hardware certifications and requirements. See Red Hat Enterprise Linux technology capabilities and limits .

1.2.5.2. Network connectivity requirements

All the Red Hat Enterprise Linux CoreOS (RHCOS) machines require network in **initramfs** during boot to fetch Ignition config files from the Machine Config Server. During the initial boot, the machines require either a DHCP server or that static IP addresses be set in order to establish a network connection to download their Ignition config files.

1.2.5.3. Minimum resource requirements

Each cluster machine must meet the following minimum requirements:

Machine	Operating System	vCPU[1]	Virtual RAM	Storage
Bootstrap	RHCOS	4	16 GB	120 GB
Control plane	RHCOS	4	16 GB	120 GB
Compute	RHCOS or RHEL 7.6	2	8 GB	120 GB

[1] 1 physical core provides 2 vCPUs when hyper-threading is enabled. 1 physical core provides 1 vCPU when hyper-threading is not enabled.

1.2.5.4. Certificate signing requests management

Because your cluster has limited access to automatic machine management when you use infrastructure that you provision, you must provide a mechanism for approving cluster certificate signing requests (CSRs) after installation. The **kube-controller-manager** only approves the kubelet client CSRs. The **machine-approver** cannot guarantee the validity of a serving certificate that is requested by using kubelet credentials because it cannot confirm that the correct machine issued the request. You must determine and implement a method of verifying the validity of the kubelet serving certificate requests and approving them.

1.2.6. Creating the user-provisioned infrastructure

Before you deploy an OpenShift Container Platform cluster that uses user-provisioned infrastructure, you must create the underlying infrastructure.

Prerequisites

- Review the OpenShift Container Platform 4.x Tested Integrations page before you create the supporting infrastructure for your cluster.

Procedure

1. Configure DHCP or set static IP addresses on each node.
2. Provision the required load balancers.
3. Configure the ports for your machines.
4. Configure DNS.
5. Ensure network connectivity.

1.2.6.1. Networking requirements for user-provisioned infrastructure

All the Red Hat Enterprise Linux CoreOS (RHCOS) machines require network in **initramfs** during boot to fetch Ignition config from the machine config server.

During the initial boot, the machines require either a DHCP server or that static IP addresses be set on each host in the cluster in order to establish a network connection, which allows them to download their Ignition config files.

It is recommended to use the DHCP server to manage the machines for the cluster long-term. Ensure that the DHCP server is configured to provide persistent IP addresses and host names to the cluster machines.

The Kubernetes API server, which runs on each master node after a successful cluster installation, must be able to resolve the node names of the cluster machines. If the API servers and worker nodes are in different zones, you can configure a default DNS search zone to allow the API server to resolve the node names. Another supported approach is to always refer to hosts by their fully-qualified domain names in both the node objects and all DNS requests.

You must configure the network connectivity between machines to allow cluster components to communicate. Each machine must be able to resolve the host names of all other machines in the cluster.

Table 1.8. All machines to all machines

Protocol	Port	Description
ICMP	N/A	Network reachability tests
TCP	**9000**-**9999**	Host level services, including the node exporter on ports **9100**-**9101** and the Cluster Version Operator on port**9099**.
	10250-**10259**	The default ports that Kubernetes reserves
	10256	openshift-sdn
UDP	**4789**	VXLAN and Geneve
	6081	VXLAN and Geneve
	9000-**9999**	Host level services, including the node exporter on ports **9100**-**9101**.
TCP/UDP	**30000**-**32767**	Kubernetes node port

Table 1.9. All machines to control plane

Protocol	Port	Description
TCP	**2379**-**2380**	etcd server, peer, and metrics ports
	6443	Kubernetes API

Network topology requirements

The infrastructure that you provision for your cluster must meet the following network topology requirements.

IMPORTANT

OpenShift Container Platform requires all nodes to have internet access to pull images for platform containers and provide telemetry data to Red Hat.

Load balancers

Before you install OpenShift Container Platform, you must provision two load balancers that meet the following requirements:

1. **API load balancer**: Provides a common endpoint for users, both human and machine, to interact with and configure the platform. Configure the following conditions:

   - Layer 4 load balancing only. This can be referred to as Raw TCP, SSL Passthrough, or SSL Bridge mode. If you use SSL Bridge mode, you must enable Server Name Indication (SNI) for the API routes.
   - A stateless load balancing algorithm. The options vary based on the load balancer implementation.

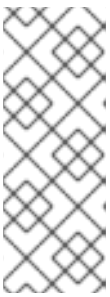
   NOTE

   Session persistence is not required for the API load balancer to function properly.

   Configure the following ports on both the front and back of the load balancers:

   Table 1.10. API load balancer

Port	Back-end machines (pool members)	Internal	External	Description
6443	Bootstrap and control plane. You remove the bootstrap machine from the load balancer after the bootstrap machine initializes the cluster control plane. You must configure the **/readyz** endpoint for the API server health check probe.	X	X	Kubernetes API server
22623	Bootstrap and control plane. You remove the bootstrap machine from the load balancer after the bootstrap machine initializes the cluster control plane.	X		Machine config server

   NOTE

   The load balancer must be configured to take a maximum of 30 seconds from the time the API server turns off the **/readyz** endpoint to the removal of the API server instance from the pool. Within the time frame after **/readyz** returns an error or becomes healthy, the endpoint must have been removed or added. Probing every 5 or 10 seconds, with two successful requests to become healthy and three to become unhealthy, are well-tested values.

2. **Application Ingress load balancer**: Provides an Ingress point for application traffic flowing in from outside the cluster. Configure the following conditions:

   - Layer 4 load balancing only. This can be referred to as Raw TCP, SSL Passthrough, or SSL Bridge mode. If you use SSL Bridge mode, you must enable Server Name Indication (SNI) for the Ingress routes.
   - A connection-based or session-based persistence is recommended, based on the options available and types of applications that will be hosted on the platform.

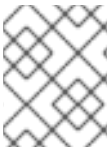
   Configure the following ports on both the front and back of the load balancers:

Table 1.11. Application Ingress load balancer

Port	Back-end machines (pool members)	Internal	External	Description
443	The machines that run the Ingress router pods, compute, or worker, by default.	X	X	HTTPS traffic
80	The machines that run the Ingress router pods, compute, or worker, by default.	X	X	HTTP traffic

TIP

If the true IP address of the client can be seen by the load balancer, enabling source IP-based session persistence can improve performance for applications that use end-to-end TLS encryption.



NOTE

A working configuration for the Ingress router is required for an OpenShift Container Platform cluster. You must configure the Ingress router after the control plane initializes.

Ethernet adaptor hardware address requirements
When provisioning VMs for the cluster, the ethernet interfaces configured for each VM must use a MAC address from the VMware Organizationally Unique Identifier (OUI) allocation ranges:

- **00:05:69:00:00:00** to **00:05:69:FF:FF:FF**
- **00:0c:29:00:00:00** to **00:0c:29:FF:FF:FF**
- **00:1c:14:00:00:00** to **00:1c:14:FF:FF:FF**
- **00:50:56:00:00:00** to **00:50:56:FF:FF:FF**

If a MAC address outside the VMware OUI is used, the cluster installation will not succeed.

1.2.6.2. User-provisioned DNS requirements

DNS is used for name resolution and reverse name resolution. DNS A/AAAA or CNAME records are used for name resolution and PTR records are used for reverse name resolution. The reverse records are important because Red Hat Enterprise Linux CoreOS (RHCOS) uses the reverse records to set the

host name for all the nodes. Additionally, the reverse records are used to generate the certificate signing requests (CSR) that OpenShift Container Platform needs to operate.

The following DNS records are required for an OpenShift Container Platform cluster that uses user-provisioned infrastructure. In each record, **<cluster_name>** is the cluster name and **<base_domain>** is the cluster base domain that you specify in the **install-config.yaml** file. A complete DNS record takes the form: **<component>.<cluster_name>.<base_domain>.**.

Table 1.12. Required DNS records

Component	Record	Description
Kubernetes API	**api.<cluster_name>. <base_domain>.**	Add a DNS A/AAAA or CNAME record, and a DNS PTR record, to identify the load balancer for the control plane machines. These records must be resolvable by both clients external to the cluster and from all the nodes within the cluster.
	api-int.<cluster_name>. <base_domain>.	Add a DNS A/AAAA or CNAME record, and a DNS PTR record, to identify the load balancer for the control plane machines. These records must be resolvable from all the nodes within the cluster.  **IMPORTANT** The API server must be able to resolve the worker nodes by the host names that are recorded in Kubernetes. If the API server cannot resolve the node names, then proxied API calls can fail, and you cannot retrieve logs from pods.
Routes	***.apps.<cluster_name>. <base_domain>.**	Add a wildcard DNS A/AAAA or CNAME record that refers to the load balancer that targets the machines that run the Ingress router pods, which are the worker nodes by default. These records must be resolvable by both clients external to the cluster and from all the nodes within the cluster.
Bootstrap	**bootstrap.<cluster_name>. <base_domain>.**	Add a DNS A/AAAA or CNAME record, and a DNS PTR record, to identify the bootstrap machine. These records must be resolvable by the nodes within the cluster.
Master hosts	**<master><n>. <cluster_name>. <base_domain>.**	Add DNS A/AAAA or CNAME records and DNS PTR records to identify each machine for the master nodes. These records must be resolvable by the nodes within the cluster.
Worker hosts	**<worker><n>. <cluster_name>. <base_domain>.**	Add DNS A/AAAA or CNAME records and DNS PTR records to identify each machine for the worker nodes. These records must be resolvable by the nodes within the cluster.

TIP

You can use the **nslookup <hostname>** command to verify name resolution. You can use the **dig -x <ip_address>** command to verify reverse name resolution for the PTR records.

The following example of a BIND zone file shows sample A records for name resolution. The purpose of the example is to show the records that are needed. The example is not meant to provide advice for choosing one name resolution service over another.

Example 1.3. Sample DNS zone database

```
$TTL 1W
@ IN SOA ns1.example.com. root (
   2019070700 ; serial
   3H  ; refresh (3 hours)
   30M  ; retry (30 minutes)
   2W  ; expiry (2 weeks)
   1W )  ; minimum (1 week)
 IN NS ns1.example.com.
 IN MX 10 smtp.example.com.
;
;
ns1 IN A 192.168.1.5
smtp IN A 192.168.1.5
;
helper IN A 192.168.1.5
helper.ocp4 IN A 192.168.1.5
;
; The api identifies the IP of your load balancer.
api.ocp4  IN A 192.168.1.5
api-int.ocp4  IN A 192.168.1.5
;
; The wildcard also identifies the load balancer.
*.apps.ocp4  IN A 192.168.1.5
;
; Create an entry for the bootstrap host.
bootstrap.ocp4 IN A 192.168.1.96
;
; Create entries for the master hosts.
master0.ocp4  IN A 192.168.1.97
master1.ocp4  IN A 192.168.1.98
master2.ocp4  IN A 192.168.1.99
;
; Create entries for the worker hosts.
worker0.ocp4  IN A 192.168.1.11
worker1.ocp4  IN A 192.168.1.7
;
;EOF
```

The following example BIND zone file shows sample PTR records for reverse name resolution.

Example 1.4. Sample DNS zone database for reverse records

```
$TTL 1W
@ IN SOA ns1.example.com. root (
   2019070700 ; serial
   3H  ; refresh (3 hours)
   30M  ; retry (30 minutes)
   2W  ; expiry (2 weeks)
   1W )  ; minimum (1 week)
 IN NS ns1.example.com.
;
; The syntax is "last octet" and the host must have an FQDN
; with a trailing dot.
97 IN PTR master0.ocp4.example.com.
98 IN PTR master1.ocp4.example.com.
99 IN PTR master2.ocp4.example.com.
;
96 IN PTR bootstrap.ocp4.example.com.
;
5 IN PTR api.ocp4.ocp4.example.com.
5 IN PTR api-int.ocp4.ocp4.example.com.
;
11 IN PTR worker0.ocp4.example.com.
7 IN PTR worker1.ocp4.example.com.
;
;EOF
```

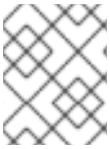
1.2.7. Generating an SSH private key and adding it to the agent

If you want to perform installation debugging or disaster recovery on your cluster, you must provide an SSH key to both your **ssh-agent** and the installation program. You can use this key to access the bootstrap machine in a public cluster to troubleshoot installation issues.

NOTE

In a production environment, you require disaster recovery and debugging.

You can use this key to SSH into the master nodes as the user **core**. When you deploy the cluster, the key is added to the **core** user's **~/.ssh/authorized_keys** list.



NOTE

You must use a local key, not one that you configured with platform-specific approaches such as AWS key pairs.

Procedure

1. If you do not have an SSH key that is configured for password-less authentication on your computer, create one. For example, on a computer that uses a Linux operating system, run the following command:

```
$ ssh-keygen -t ed25519 -N '' \
    -f <path>/<file_name> (1)
```

1 Specify the path and file name, such as ~/**.ssh/id_rsa**, of the SSH key. Do not specify an existing SSH key, as it will be overwritten.

Running this command generates an SSH key that does not require a password in the location that you specified.

2. Start the **ssh-agent** process as a background task:

```
$ eval "$(ssh-agent -s)"

Agent pid 31874
```

3. Add your SSH private key to the **ssh-agent**:

```
$ ssh-add <path>/<file_name> 1

Identity added: /home/<you>/<path>/<file_name> (<computer_name>)
```

1 Specify the path and file name for your SSH private key, such as ~/**.ssh/id_rsa**

Next steps

- When you install OpenShift Container Platform, provide the SSH public key to the installation program.

1.2.8. Obtaining the installation program

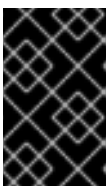
Before you install OpenShift Container Platform, download the installation file on a local computer.

Prerequisites

- You must install the cluster from a computer that uses Linux or macOS.
- You need 500 MB of local disk space to download the installation program.

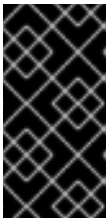
Procedure

1. Access the Infrastructure Provider page on the Red Hat OpenShift Cluster Manager site. If you have a Red Hat account, log in with your credentials. If you do not, create an account.
2. Navigate to the page for your installation type, download the installation program for your operating system, and place the file in the directory where you will store the installation configuration files.



IMPORTANT

The installation program creates several files on the computer that you use to install your cluster. You must keep both the installation program and the files that the installation program creates after you finish installing the cluster.



IMPORTANT

Deleting the files created by the installation program does not remove your cluster, even if the cluster failed during installation. You must complete the OpenShift Container Platform uninstallation procedures outlined for your specific cloud provider to remove your cluster entirely.

3. Extract the installation program. For example, on a computer that uses a Linux operating system, run the following command:

```
$ tar xvf <installation_program>.tar.gz
```

4. From the Pull Secret page on the Red Hat OpenShift Cluster Manager site, download your installation pull secret as a **.txt** file. This pull secret allows you to authenticate with the services that are provided by the included authorities, including Quay.io, which serves the container images for OpenShift Container Platform components.

1.2.9. Manually creating the installation configuration file

For installations of OpenShift Container Platform that use user-provisioned infrastructure, you must manually generate your installation configuration file.

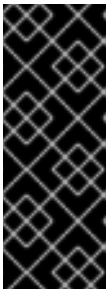
Prerequisites

- Obtain the OpenShift Container Platform installation program and the access token for your cluster.

Procedure

1. Create an installation directory to store your required installation assets in:

```
$ mkdir <installation_directory>
```



IMPORTANT

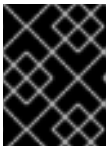
You must create a directory. Some installation assets, like bootstrap X.509 certificates have short expiration intervals, so you must not reuse an installation directory. If you want to reuse individual files from another cluster installation, you can copy them into your directory. However, the file names for the installation assets might change between releases. Use caution when copying installation files from an earlier OpenShift Container Platform version.

2. Customize the following **install-config.yaml** file template and save it in the **<installation_directory>**.

NOTE

You must name this configuration file **install-config.yaml**.

3. Back up the **install-config.yaml** file so that you can use it to install multiple clusters.



IMPORTANT

The **install-config.yaml** file is consumed during the next step of the installation process. You must back it up now.

1.2.9.1. Sample install-config.yaml file for VMware vSphere

You can customize the **install-config.yaml** file to specify more details about your OpenShift Container Platform cluster's platform or modify the values of the required parameters.

```
apiVersion: v1
baseDomain: example.com (1)
compute:
- hyperthreading: Enabled (2) (3)
  name: worker
  replicas: 0 (4)
controlPlane:
  hyperthreading: Enabled (5) (6)
  name: master
  replicas: 3 (7)
metadata:
  name: test (8)
platform:
  vsphere:
    vcenter: your.vcenter.server (9)
    username: username (10)
    password: password (11)
    datacenter: datacenter (12)
    defaultDatastore: datastore (13)
fips: false (14)
pullSecret: '{"auths": ...}' (15)
sshKey: 'ssh-ed25519 AAAA...' (16)
```

(1) The base domain of the cluster. All DNS records must be sub-domains of this base and include the cluster name.

(2) (5) The **controlPlane** section is a single mapping, but the compute section is a sequence of mappings. To meet the requirements of the different data structures, the first line of the **compute** section must begin with a hyphen, **-**, and the first line of the **controlPlane** section must not. Although both sections currently define a single machine pool, it is possible that future versions of OpenShift Container Platform will support defining multiple compute pools during installation. Only one control plane pool is used.

(3) (6) Whether to enable or disable simultaneous multithreading, or **hyperthreading**. By default, simultaneous multithreading is enabled to increase the performance of your machines' cores. You can disable it by setting the parameter value to **Disabled**. If you disable simultaneous multithreading in some cluster machines, you must disable it in all cluster machines.

IMPORTANT

If you disable simultaneous multithreading, ensure that your capacity planning accounts for the dramatically decreased machine performance. Your machines must use at least 8 CPUs and 32 GB of RAM if you disable simultaneous multithreading.

4 You must set the value of the **replicas** parameter to **0**. This parameter controls the number of workers that the cluster creates and manages for you, which are functions that the cluster does not

7 The number of control plane machines that you add to the cluster. Because the cluster uses this values as the number of etcd endpoints in the cluster, the value must match the number of control plane machines that you deploy.

8 The cluster name that you specified in your DNS records.

9 The fully-qualified host name or IP address of the vCenter server.

10 The name of the user for accessing the server. This user must have at least the roles and privileges that are required for static or dynamic persistent volume provisioning in vSphere.

11 The password associated with the vSphere user.

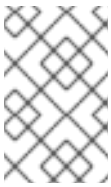
12 The vSphere datacenter.

13 The default vSphere datastore to use.

14 Whether to enable or disable FIPS mode. By default, FIPS mode is not enabled. If FIPS mode is enabled, the Red Hat Enterprise Linux CoreOS (RHCOS) machines that OpenShift Container Platform runs on bypass the default Kubernetes cryptography suite and use the cryptography modules that are provided with RHCOS instead.

15 The pull secret that you obtained from the Pull Secret page on the Red Hat OpenShift Cluster Manager site. This pull secret allows you to authenticate with the services that are provided by the included authorities, including Quay.io, which serves the container images for OpenShift Container Platform components.

16 The public portion of the default SSH key for the **core** user in Red Hat Enterprise Linux CoreOS (RHCOS).

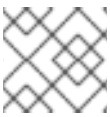


NOTE

For production OpenShift Container Platform clusters on which you want to perform installation debugging or disaster recovery, specify an SSH key that your **ssh-agent** process uses.

1.2.9.2. Network configuration parameters

You can modify your cluster network configuration parameters in the **install-config.yaml** configuration file. The following table describes the parameters.



NOTE

You cannot modify these parameters in the **install-config.yaml** file after installation.

Table 1.13. Required network parameters

Parameter	Description	Value
networking.networkType	The default Container Network Interface (CNI) network provider plug-in to deploy. The **OpenShiftSDN** plug-in is the only plug-in supported in OpenShift Container Platform 4.4.	The default value is **OpenShiftSDN**.
networking.clusterNetwork[].cidr	A block of IP addresses from which pod IP addresses are allocated. The **OpenShiftSDN** network plug-in supports multiple cluster networks. The address blocks for multiple cluster networks must not overlap. Select address pools large enough to fit your anticipated workload.	An IP address allocation in CIDR format. The default value is **10.128.0.0/14**.
networking.clusterNetwork[].hostPrefix	The subnet prefix length to assign to each individual node. For example, if **hostPrefix** is set to **23**, then each node is assigned a /**23** subnet out of the given **cidr**, allowing for 510 (2^(32 - 23) - 2) pod IP addresses.	A subnet prefix. The default value is **23**.
networking.serviceNetwork[]	A block of IP addresses for services. **OpenShiftSDN** allows only one **serviceNetwork** block. The address block must not overlap with any other network block.	An IP address allocation in CIDR format. The default value is **172.30.0.0/16**.
networking.machineNetwork[].cidr	A block of IP addresses assigned to nodes created by the OpenShift Container Platform installation program while installing the cluster. The address block must not overlap with any other network block. Multiple CIDR ranges may be specified.	An IP address allocation in CIDR format. The default value is **10.0.0.0/16**.

1.2.10. Modifying advanced network configuration parameters

You can modify the advanced network configuration parameters only before you install the cluster. Advanced configuration customization lets you integrate your cluster into your existing network environment by specifying an MTU or VXLAN port, by allowing customization of kube-proxy settings, and by specifying a different **mode** for the **openshiftSDNConfig** parameter.

IMPORTANT

Modifying the OpenShift Container Platform manifest files directly is not supported.

Prerequisites

- Create the **install-config.yaml** file and complete any modifications to it.
- Create the Ignition config files for your cluster.

Procedure

1. Use the following command to create manifests:

```
$ ./openshift-install create manifests --dir=<installation_directory> 1
```

1 For **<installation_directory>**, specify the name of the directory that contains the **install-config.yaml** file for your cluster.

2. Create a file that is named **cluster-network-03-config.yml** in the **<installation_directory>/manifests/** directory:

```
$ touch <installation_directory>/manifests/cluster-network-03-config.yml 1
```

1 For **<installation_directory>**, specify the directory name that contains the **manifests/** directory for your cluster.

After creating the file, several network configuration files are in the **manifests/** directory, as shown:

```
$ ls <installation_directory>/manifests/cluster-network-*
```

Example output

```
cluster-network-01-crd.yml
cluster-network-02-config.yml
cluster-network-03-config.yml
```

3. Open the **cluster-network-03-config.yml** file in an editor and enter a CR that describes the Operator configuration you want:

```
apiVersion: operator.openshift.io/v1
kind: Network
metadata:
  name: cluster
spec: 1
  clusterNetwork:
  - cidr: 10.128.0.0/14
    hostPrefix: 23
  serviceNetwork:
  - 172.30.0.0/16
  defaultNetwork:
    type: OpenShiftSDN
    openshiftSDNConfig:
      mode: NetworkPolicy
      mtu: 1450
      vxlanPort: 4789
```

1 The parameters for the **spec** parameter are only an example. Specify your configuration for the Cluster Network Operator in the CR.

The CNO provides default values for the parameters in the CR, so you must specify only the parameters that you want to change.

4. Save the **cluster-network-03-config.yml** file and quit the text editor.

5. Optional: Back up the **manifests/cluster-network-03-config.yml** file. The installation program deletes the **manifests/** directory when creating the cluster.

1.2.11. Cluster Network Operator configuration

The configuration for the cluster network is specified as part of the Cluster Network Operator (CNO) configuration and stored in a CR object that is named **cluster**. The CR specifies the parameters for the **Network** API in the **operator.openshift.io** API group.

You can specify the cluster network configuration for your OpenShift Container Platform cluster by setting the parameter values for the **defaultNetwork** parameter in the CNO CR. The following CR displays the default configuration for the CNO and explains both the parameters you can configure and the valid parameter values:

Cluster Network Operator CR

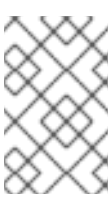
```
apiVersion: operator.openshift.io/v1
kind: Network
metadata:
  name: cluster
spec:
  clusterNetwork: 1
  - cidr: 10.128.0.0/14
    hostPrefix: 23
  serviceNetwork: 2
  - 172.30.0.0/16
  defaultNetwork: 3
    ...
  kubeProxyConfig: 4
    iptablesSyncPeriod: 30s 5
    proxyArguments:
      iptables-min-sync-period: 6
      - 0s
```

1 2 Specified in the **install-config.yaml** file.

3 Configures the default Container Network Interface (CNI) network provider for the cluster network.

4 The parameters for this object specify the **kube-proxy** configuration. If you do not specify the parameter values, the Cluster Network Operator applies the displayed default parameter values. If you are using the OVN-Kubernetes default CNI network provider, the kube-proxy configuration has no effect.

5 The refresh period for **iptables** rules. The default value is **30s**. Valid suffixes include **s**, **m**, and **h** and are described in the Go time package documentation.



NOTE

Because of performance improvements introduced in OpenShift Container Platform 4.3 and greater, adjusting the **iptablesSyncPeriod** parameter is no longer necessary.

6 The minimum duration before refreshing **iptables** rules. This parameter ensures that the refresh does not happen too frequently. Valid suffixes include **s**, **m**, and **h** and are described in the Go time

1.2.11.1. Configuration parameters for the OpenShift SDN default CNI network provider

The following YAML object describes the configuration parameters for the OpenShift SDN default Container Network Interface (CNI) network provider.

```
defaultNetwork:
  type: OpenShiftSDN (1)
  openshiftSDNConfig: (2)
    mode: NetworkPolicy (3)
    mtu: 1450 (4)
    vxlanPort: 4789 (5)
```

1 Specified in the **install-config.yaml** file.

2 Specify only if you want to override part of the OpenShift SDN configuration.

3 Configures the network isolation mode for OpenShift SDN. The allowed values are **Multitenant**, **Subnet**, or **NetworkPolicy**. The default value is **NetworkPolicy**.

4 The maximum transmission unit (MTU) for the VXLAN overlay network. This value is normally configured automatically, but if the nodes in your cluster do not all use the same MTU, then you must set this explicitly to 50 less than the smallest node MTU value.

5 The port to use for all VXLAN packets. The default value is **4789**. If you are running in a virtualized environment with existing nodes that are part of another VXLAN network, then you might be required to change this. For example, when running an OpenShift SDN overlay on top of VMware NSX-T, you must select an alternate port for VXLAN, since both SDNs use the same default VXLAN port number.

On Amazon Web Services (AWS), you can select an alternate port for the VXLAN between port **9000** and port **9999**.

1.2.11.2. Cluster Network Operator example configuration

A complete CR object for the CNO is displayed in the following example:

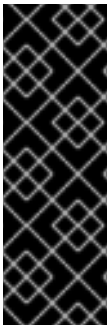
Cluster Network Operator example CR

```
apiVersion: operator.openshift.io/v1
kind: Network
metadata:
  name: cluster
spec:
  clusterNetwork:
  - cidr: 10.128.0.0/14
    hostPrefix: 23
  serviceNetwork:
  - 172.30.0.0/16
  defaultNetwork:
    type: OpenShiftSDN
```

```
    openshiftSDNConfig:
      mode: NetworkPolicy
      mtu: 1450
      vxlanPort: 4789
  kubeProxyConfig:
    iptablesSyncPeriod: 30s
    proxyArguments:
      iptables-min-sync-period:
      - 0s
```

1.2.12. Creating the Ignition config files

Because you must manually start the cluster machines, you must generate the Ignition config files that the cluster needs to make its machines.



IMPORTANT

The Ignition config files that the installation program generates contain certificates that expire after 24 hours, which are then renewed at that time. If the cluster is shut down before renewing the certificates and the cluster is later restarted after the 24 hours have elapsed, the cluster automatically recovers the expired certificates. The exception is that you must manually approve the pending **node-bootstrapper** certificate signing requests (CSRs) to recover kubelet certificates. See the documentation for *Recovering from expired control plane certificates* for more information.

Prerequisites

- Obtain the OpenShift Container Platform installation program and the pull secret for your cluster.

Procedure

1. Obtain the Ignition config files:

```
$ ./openshift-install create ignition-configs --dir=<installation_directory> 1
```

1 For **<installation_directory>**, specify the directory name to store the files that the installation program creates.

IMPORTANT

If you created an **install-config.yaml** file, specify the directory that contains it. Otherwise, specify an empty directory. Some installation assets, like bootstrap X.509 certificates have short expiration intervals, so you must not reuse an installation directory. If you want to reuse individual files from another cluster installation, you can copy them into your directory. However, the file names for the installation assets might change between releases. Use caution when copying installation files from an earlier OpenShift Container Platform version.

The following files are generated in the directory:

```
.
```

```
├── auth
│   ├── kubeadmin-password
│   └── kubeconfig
├── bootstrap.ign
├── master.ign
├── metadata.json
└── worker.ign
```

1.2.13. Creating Red Hat Enterprise Linux CoreOS (RHCOS) machines in vSphere

Before you install a cluster that contains user-provisioned infrastructure on VMware vSphere, you must create RHCOS machines on vSphere hosts for it to use.

Prerequisites

- Obtain the Ignition config files for your cluster.
- Have access to an HTTP server that you can access from your computer and that the machines that you create can access.
- Create a vSphere cluster.

Procedure

1. Upload the bootstrap Ignition config file, which is named **<installation_directory>/bootstrap.ign**, that the installation program created to your HTTP server. Note the URL of this file.
   You must host the bootstrap Ignition config file because it is too large to fit in a vApp property.
2. Save the following secondary Ignition config file for your bootstrap node to your computer as **<installation_directory>/append-bootstrap.ign**.

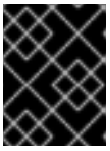
```
{
  "ignition": {
    "config": {
      "append": [
        {
          "source": "<bootstrap_ignition_config_url>", 1
          "verification": {}
        }
      ]
    },
    "timeouts": {},
    "version": "2.2.0"
  },
  "networkd": {},
  "passwd": {},
  "storage": {},
  "systemd": {}
}
```

1 Specify the URL of the bootstrap Ignition config file that you hosted.

When you create the virtual machine (VM) for the bootstrap machine, you use this Ignition config file.

3. Convert the master, worker, and secondary bootstrap Ignition config files to base64 encoding. For example, if you use a Linux operating system, you can use the **base64** command to encode the files.

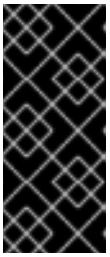
```
$ base64 -w0 <installation_directory>/master.ign > <installation_directory>/master.64
$ base64 -w0 <installation_directory>/worker.ign > <installation_directory>/worker.64
$ base64 -w0 <installation_directory>/append-bootstrap.ign >
<installation_directory>/append-bootstrap.64
```



IMPORTANT

If you plan to add more compute machines to your cluster after you finish installation, do not delete these files.

4. Obtain the RHCOS OVA image from the Product Downloads page on the Red Hat customer portal or the RHCOS image mirror page.



IMPORTANT

The RHCOS images might not change with every release of OpenShift Container Platform. You must download an image with the highest version that is less than or equal to the OpenShift Container Platform version that you install. Use the image version that matches your OpenShift Container Platform version if it is available.

The file name contains the OpenShift Container Platform version number in the format **rhcos-<version>-vmware.<architecture>.ova**.

5. In the vSphere Client, create a folder in your datacenter to store your VMs.

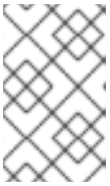
   a. Click the **VMs and Templates** view.

   b. Right-click the name of your datacenter.

   c. Click **New Folder → New VM and Template Folder**.

   d. In the window that is displayed, enter the folder name. The folder name must match the cluster name that you specified in the **install-config.yaml** file.

6. In the vSphere Client, create a template for the OVA image.



NOTE

In the following steps, you use the same template for all of your cluster machines and provide the location for the Ignition config file for that machine type when you provision the VMs.

   a. From the **Hosts and Clusters** tab, right-click your cluster's name and click **Deploy OVF Template**.

   b. On the **Select an OVF** tab, specify the name of the RHCOS OVA file that you downloaded.

c. On the **Select a name and folder** tab, set a **Virtual machine name**, such as RHCOS, click the name of your vSphere cluster, and select the folder you created in the previous step.

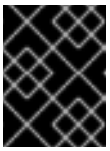
d. On the **Select a compute resource** tab, click the name of your vSphere cluster.

e. On the **Select storage** tab, configure the storage options for your VM.

- Select **Thin Provision** or **Thick Provision**, based on your storage preferences.
- Select the datastore that you specified in your **install-config.yaml** file.

f. On the **Select network** tab, specify the network that you configured for the cluster, if available.

g. If you plan to use the same template for all cluster machine types, do not specify values on the **Customize template** tab.



IMPORTANT

If you plan to add more compute machines to your cluster after you finish installation, do not delete this template.

7. After the template deploys, deploy a VM for a machine in the cluster.

a. Right-click the template's name and click **Clone → Clone to Virtual Machine**

b. On the **Select a name and folder** tab, specify a name for the VM. You might include the machine type in the name, such as **control-plane-0** or **compute-1**.

c. On the **Select a name and folder** tab, select the name of the folder that you created for the cluster.

d. On the **Select a compute resource** tab, select the name of a host in your datacenter.

e. Optional: On the **Select storage** tab, customize the storage options.

f. On the **Select clone options**, select **Customize this virtual machine's hardware**.

g. On the **Customize hardware** tab, click **VM Options → Advanced**.

- Optional: In the event of cluster performance issues, from the **Latency Sensitivity** list, select **High**.
- Click **Edit Configuration**, and on the **Configuration Parameters** window, click **Add Configuration Params**. Define the following parameter names and values:
  - **guestinfo.ignition.config.data**: Paste the contents of the base64-encoded Ignition config file for this machine type.
  - **guestinfo.ignition.config.data.encoding**: Specify **base64**.
  - **disk.EnableUUID**: Specify **TRUE**.
- Alternatively, prior to powering on the virtual machine add via vApp properties:
  - Navigate to a virtual machine from the vCenter Server inventory.
  - On the **Configure** tab, expand **Settings** and select **vApp options.**

- Scroll down and under **Properties** apply the configurations from above.

h. In the **Virtual Hardware** panel of the **Customize hardware** tab, modify the specified values as required. Ensure that the amount of RAM, CPU, and disk storage meets the minimum requirements for the machine type.

i. Complete the configuration and power on the VM.

8. Create the rest of the machines for your cluster by following the preceding steps for each machine.

IMPORTANT

You must create the bootstrap and control plane machines at this time. Because some pods are deployed on compute machines by default, also create at least two compute machine before you install the cluster.

1.2.14. Creating more Red Hat Enterprise Linux CoreOS (RHCOS) machines in vSphere

You can create more compute machines for your cluster that uses user-provisioned infrastructure on VMware vSphere.

Prerequisites

- Obtain the base64-encoded Ignition file for your compute machines.
- You have access to the vSphere template that you created for your cluster.

Procedure

1. After the template deploys, deploy a VM for a machine in the cluster.
   a. Right-click the template's name and click **Clone → Clone to Virtual Machine**
   b. On the **Select a name and folder** tab, specify a name for the VM. You might include the machine type in the name, such as **compute-1**.
   c. On the **Select a name and folder** tab, select the name of the folder that you created for the cluster.
   d. On the **Select a compute resource** tab, select the name of a host in your datacenter.
   e. Optional: On the **Select storage** tab, customize the storage options.
   f. On the **Select clone options**, select **Customize this virtual machine's hardware**.
   g. On the **Customize hardware** tab, click **VM Options → Advanced**.
      - From the **Latency Sensitivity** list, select **High**.
      - Click **Edit Configuration**, and on the **Configuration Parameters** window, click **Add Configuration Params**. Define the following parameter names and values:
        - **guestinfo.ignition.config.data**: Paste the contents of the base64-encoded compute Ignition config file for this machine type.

- **guestinfo.ignition.config.data.encoding**: Specify **base64**.
- **disk.EnableUUID**: Specify **TRUE**.

h. In the **Virtual Hardware** panel of the **Customize hardware** tab, modify the specified values as required. Ensure that the amount of RAM, CPU, and disk storage meets the minimum requirements for the machine type. Also, make sure to select the correct network under **Add network adapter** if there are multiple networks available.

i. Complete the configuration and power on the VM.

2. Continue to create more compute machines for your cluster.

1.2.15. Installing the CLI by downloading the binary

You can install the OpenShift CLI (**oc**) in order to interact with OpenShift Container Platform from a command-line interface. You can install **oc** on Linux, Windows, or macOS.

IMPORTANT

If you installed an earlier version of **oc**, you cannot use it to complete all of the commands in OpenShift Container Platform 4.4. Download and install the new version of **oc**.

1.2.15.1. Installing the CLI on Linux

You can install the OpenShift CLI (**oc**) binary on Linux by using the following procedure.

Procedure

1. Navigate to the Infrastructure Provider page on the Red Hat OpenShift Cluster Manager site.
2. Select your infrastructure provider, and, if applicable, your installation type.
3. In the **Command-line interface** section, select **Linux** from the drop-down menu and click **Download command-line tools**.
4. Unpack the archive:

```
$ tar xvzf <file>
```

5. Place the **oc** binary in a directory that is on your **PATH**.
   To check your **PATH**, execute the following command:

```
$ echo $PATH
```

After you install the CLI, it is available using the **oc** command:

```
$ oc <command>
```

1.2.15.2. Installing the CLI on Windows

You can install the OpenShift CLI (**oc**) binary on Windows by using the following procedure.

Procedure

1. Navigate to the Infrastructure Provider page on the Red Hat OpenShift Cluster Manager site.
2. Select your infrastructure provider, and, if applicable, your installation type.
3. In the **Command-line interface** section, select **Windows** from the drop-down menu and click **Download command-line tools**.
4. Unzip the archive with a ZIP program.
5. Move the **oc** binary to a directory that is on your **PATH**.
   To check your **PATH**, open the command prompt and execute the following command:

```
C:\> path
```

After you install the CLI, it is available using the **oc** command:

```
C:\> oc <command>
```

1.2.15.3. Installing the CLI on macOS

You can install the OpenShift CLI (**oc**) binary on macOS by using the following procedure.

Procedure

1. Navigate to the Infrastructure Provider page on the Red Hat OpenShift Cluster Manager site.
2. Select your infrastructure provider, and, if applicable, your installation type.
3. In the **Command-line interface** section, select **MacOS** from the drop-down menu and click **Download command-line tools**.
4. Unpack and unzip the archive.
5. Move the **oc** binary to a directory on your PATH.
   To check your **PATH**, open a terminal and execute the following command:

```
$ echo $PATH
```

After you install the CLI, it is available using the **oc** command:

```
$ oc <command>
```

1.2.16. Creating the cluster

To create the OpenShift Container Platform cluster, you wait for the bootstrap process to complete on the machines that you provisioned by using the Ignition config files that you generated with the installation program.

Prerequisites

- Create the required infrastructure for the cluster.

- You obtained the installation program and generated the Ignition config files for your cluster.
- You used the Ignition config files to create RHCOS machines for your cluster.
- Your machines have direct Internet access or have an HTTP or HTTPS proxy available.

Procedure

1. Monitor the bootstrap process:

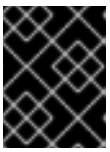
```
$ ./openshift-install --dir=<installation_directory> wait-for bootstrap-complete \ 1
    --log-level=info 2
INFO Waiting up to 30m0s for the Kubernetes API at https://api.test.example.com...
INFO API v1.17.1 up
INFO Waiting up to 30m0s for bootstrapping to complete...
INFO It is now safe to remove the bootstrap resources
```

1 For **<installation_directory>**, specify the path to the directory that you stored the installation files in.

2 To view different installation details, specify **warn**, **debug**, or **error** instead of **info**.

The command succeeds when the Kubernetes API server signals that it has been bootstrapped on the control plane machines.

2. After bootstrap process is complete, remove the bootstrap machine from the load balancer.



IMPORTANT

You must remove the bootstrap machine from the load balancer at this point. You can also remove or reformat the machine itself.

1.2.17. Logging in to the cluster

You can log in to your cluster as a default system user by exporting the cluster **kubeconfig** file. The **kubeconfig** file contains information about the cluster that is used by the CLI to connect a client to the correct cluster and API server. The file is specific to a cluster and is created during OpenShift Container Platform installation.

Prerequisites

- Deploy an OpenShift Container Platform cluster.
- Install the **oc** CLI.

Procedure

1. Export the **kubeadmin** credentials:

```
$ export KUBECONFIG=<installation_directory>/auth/kubeconfig 1
```

1 For **<installation_directory>**, specify the path to the directory that you stored the installation files in.

2. Verify you can run **oc** commands successfully using the exported configuration:

```
$ oc whoami
system:admin
```

1.2.18. Approving the certificate signing requests for your machines

When you add machines to a cluster, two pending certificate signing requests (CSRs) are generated for each machine that you added. You must confirm that these CSRs are approved or, if necessary, approve them yourself. The client requests must be approved first, followed by the server requests.

Prerequisites

- You added machines to your cluster.

Procedure

1. Confirm that the cluster recognizes the machines:

```
# oc get nodes

NAME                 STATUS   ROLES    AGE   VERSION
master-01.example.com   Ready    master   40d   v1.17.1
master-02.example.com   Ready    master   40d   v1.17.1
master-03.example.com   Ready    master   40d   v1.17.1
worker-01.example.com   Ready    worker   40d   v1.17.1
worker-02.example.com   Ready    worker   40d   v1.17.1
```

   The output lists all of the machines that you created.

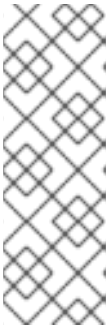
2. Review the pending CSRs and ensure that you see the client requests with the **Pending** or **Approved** status for each machine that you added to the cluster:

```
$ oc get csr

NAME        AGE     REQUESTOR                                                   CONDITION
csr-8b2br   15m     system:serviceaccount:openshift-machine-config-operator:node-
bootstrapper   Pending
csr-8vnps   15m     system:serviceaccount:openshift-machine-config-operator:node-
bootstrapper   Pending
...
```

   In this example, two machines are joining the cluster. You might see more approved CSRs in the list.

3. If the CSRs were not approved, after all of the pending CSRs for the machines you added are in **Pending** status, approve the CSRs for your cluster machines:



NOTE

Because the CSRs rotate automatically, approve your CSRs within an hour of adding the machines to the cluster. If you do not approve them within an hour, the certificates will rotate, and more than two certificates will be present for each node. You must approve all of these certificates. After you approve the initial CSRs, the subsequent node client CSRs are automatically approved by the cluster **kube-controller-manager**. You must implement a method of automatically approving the kubelet serving certificate requests.

- To approve them individually, run the following command for each valid CSR:

```
$ oc adm certificate approve <csr_name> 1
```

1 **<csr_name>** is the name of a CSR from the list of current CSRs.

- To approve all pending CSRs, run the following command:

```
$ oc get csr -o go-template='{{range .items}}{{if not .status}}{{.metadata.name}}{{"\n"}}
{{end}}{{end}}' | xargs oc adm certificate approve
```

4. Now that your client requests are approved, you must review the server requests for each machine that you added to the cluster:

```
$ oc get csr
```

Example output

```
NAME        AGE    REQUESTOR                                                   CONDITION
csr-bfd72   5m26s  system:node:ip-10-0-50-126.us-east-2.compute.internal
Pending
csr-c57lv   5m26s  system:node:ip-10-0-95-157.us-east-2.compute.internal
Pending
...
```

5. If the remaining CSRs are not approved, and are in the **Pending** status, approve the CSRs for your cluster machines:

- To approve them individually, run the following command for each valid CSR:

```
$ oc adm certificate approve <csr_name> 1
```

1 **<csr_name>** is the name of a CSR from the list of current CSRs.

- To approve all pending CSRs, run the following command:

```
$ oc get csr -o go-template='{{range .items}}{{if not .status}}{{.metadata.name}}{{"\n"}}
{{end}}{{end}}' | xargs oc adm certificate approve
```

6. After all client and server CSRs have been approved, the machines have the **Ready** status. Verify this by running the following command:

```
$ oc get nodes
```

Example output

```
NAME      STATUS    ROLES   AGE  VERSION
master-0  Ready     master  73m  v1.20.0
master-1  Ready     master  73m  v1.20.0
master-2  Ready     master  74m  v1.20.0
worker-0  Ready     worker  11m  v1.20.0
worker-1  Ready     worker  11m  v1.20.0
```

NOTE

It can take a few minutes after approval of the server CSRs for the machines to transition to the **Ready** status.

Additional information

- For more information on CSRs, see Certificate Signing Requests.

1.2.19. Initial Operator configuration

After the control plane initializes, you must immediately configure some Operators so that they all become available.

Prerequisites

- Your control plane has initialized.

Procedure

1. Watch the cluster components come online:

```
$ watch -n5 oc get clusteroperators

NAME                                       VERSION   AVAILABLE   PROGRESSING   DEGRADED
SINCE
authentication                             4.4.0     True        False         False      69s
cloud-credential                           4.4.0     True        False         False      12m
cluster-autoscaler                         4.4.0     True        False         False      11m
console                                    4.4.0     True        False         False      46s
dns                                        4.4.0     True        False         False      11m
image-registry                             4.4.0     True        False         False      5m26s
ingress                                    4.4.0     True        False         False      5m36s
kube-apiserver                             4.4.0     True        False         False      8m53s
kube-controller-manager                    4.4.0     True        False         False      7m24s
kube-scheduler                             4.4.0     True        False         False      12m
machine-api                                4.4.0     True        False         False      12m
machine-config                             4.4.0     True        False         False      7m36s
marketplace                                4.4.0     True        False         False      7m54m
monitoring                                 4.4.0     True        False         False      7h54s
network                                    4.4.0     True        False         False      5m9s
node-tuning                                4.4.0     True        False         False      11m
openshift-apiserver                        4.4.0     True        False         False      11m
```

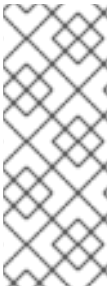
```
openshift-controller-manager       4.4.0     True        False         False      5m943s
openshift-samples                  4.4.0     True        False         False      3m55s
operator-lifecycle-manager         4.4.0     True        False         False      11m
operator-lifecycle-manager-catalog 4.4.0     True        False         False      11m
service-ca                         4.4.0     True        False         False      11m
service-catalog-apiserver          4.4.0     True        False         False      5m26s
service-catalog-controller-manager 4.4.0     True        False         False      5m25s
storage                            4.4.0     True        False         False      5m30s
```

2. Configure the Operators that are not available.

1.2.19.1. Image registry removed during installation

On platforms that do not provide shareable object storage, the OpenShift Image Registry Operator bootstraps itself as **Removed**. This allows **openshift-installer** to complete installations on these platform types.

After installation, you must edit the Image Registry Operator configuration to switch the **managementState** from **Removed** to **Managed**.



NOTE

The Prometheus console provides an **ImageRegistryRemoved** alert, for example:

"Image Registry has been removed. **ImageStreamTags**, **BuildConfigs** and **DeploymentConfigs** which reference **ImageStreamTags** may not work as expected. Please configure storage and update the config to **Managed** state by editing configs.imageregistry.operator.openshift.io."

1.2.19.2. Image registry storage configuration

The Image Registry Operator is not initially available for platforms that do not provide default storage. After installation, you must configure your registry to use storage so the Registry Operator is made available.

Instructions for both configuring a persistent volume, which is required for production clusters, and for configuring an empty directory as the storage location, which is available for only non-production clusters, are shown.

For instructions about configuring registry storage so that it references the correct PVC, see Configuring the registry for vSphere.

1.2.20. Completing installation on user-provisioned infrastructure

After you complete the Operator configuration, you can finish installing the cluster on infrastructure that you provide.

Prerequisites

- Your control plane has initialized.
- You have completed the initial Operator configuration.

Procedure

1. Confirm that all the cluster components are online:

```
$ watch -n5 oc get clusteroperators

NAME                                       VERSION   AVAILABLE   PROGRESSING   DEGRADED
SINCE
authentication                             4.4.3     True        False         False      7m56s
cloud-credential                           4.4.3     True        False         False      31m
cluster-autoscaler                         4.4.3     True        False         False      16m
console                                    4.4.3     True        False         False      10m
csi-snapshot-controller                    4.4.3     True        False         False      16m
dns                                        4.4.3     True        False         False      22m
etcd                                       4.4.3     False       False         False      25s
image-registry                             4.4.3     True        False         False      16m
ingress                                    4.4.3     True        False         False      16m
insights                                   4.4.3     True        False         False      17m
kube-apiserver                             4.4.3     True        False         False      19m
kube-controller-manager                    4.4.3     True        False         False      20m
kube-scheduler                             4.4.3     True        False         False      20m
kube-storage-version-migrator              4.4.3     True        False         False      16m
machine-api                                4.4.3     True        False         False      22m
machine-config                             4.4.3     True        False         False      22m
marketplace                                4.4.3     True        False         False      16m
monitoring                                 4.4.3     True        False         False      10m
network                                    4.4.3     True        False         False      23m
node-tuning                                4.4.3     True        False         False      23m
openshift-apiserver                        4.4.3     True        False         False      17m
openshift-controller-manager               4.4.3     True        False         False      15m
openshift-samples                          4.4.3     True        False         False      16m
operator-lifecycle-manager                 4.4.3     True        False         False      22m
operator-lifecycle-manager-catalog         4.4.3     True        False         False      22m
operator-lifecycle-manager-packageserver   4.4.3     True        False         False      18m
service-ca                                 4.4.3     True        False         False      23m
service-catalog-apiserver                  4.4.3     True        False         False      23m
service-catalog-controller-manager         4.4.3     True        False         False      23m
storage                                    4.4.3     True        False         False      17m
```

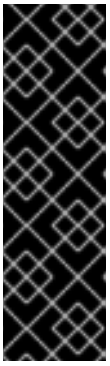
When all of the cluster Operators are **AVAILABLE**, you can complete the installation.

2. Monitor for cluster completion:

```
$ ./openshift-install --dir=<installation_directory> wait-for install-complete 1
INFO Waiting up to 30m0s for the cluster to initialize...
```

1 For **<installation_directory>**, specify the path to the directory that you stored the installation files in.

The command succeeds when the Cluster Version Operator finishes deploying the OpenShift Container Platform cluster from Kubernetes API server.



IMPORTANT

The Ignition config files that the installation program generates contain certificates that expire after 24 hours, which are then renewed at that time. If the cluster is shut down before renewing the certificates and the cluster is later restarted after the 24 hours have elapsed, the cluster automatically recovers the expired certificates. The exception is that you must manually approve the pending **node-bootstrapper** certificate signing requests (CSRs) to recover kubelet certificates. See the documentation for *Recovering from expired control plane certificates* for more information.

3. Confirm that the Kubernetes API server is communicating with the pods.

   a. To view a list of all pods, use the following command:

```
$ oc get pods --all-namespaces

NAMESPACE                       NAME                                         READY   STATUS
RESTARTS   AGE
openshift-apiserver-operator    openshift-apiserver-operator-85cb746d55-zqhs8   1/1
Running    1          9m
openshift-apiserver             apiserver-67b9g                               1/1     Running     0
3m
openshift-apiserver             apiserver-ljcmx                               1/1     Running     0
1m
openshift-apiserver             apiserver-z25h4                               1/1     Running     0
2m
openshift-authentication-operator authentication-operator-69d5d8bf84-vh2n8       1/1
Running    0          5m
...
```

   b. View the logs for a pod that is listed in the output of the previous command by using the following command:

```
$ oc logs <pod_name> -n <namespace> 1
```

   1 Specify the pod name and namespace, as shown in the output of the previous command.

   If the pod logs display, the Kubernetes API server can communicate with the cluster machines.

You can add extra compute machines after the cluster installation is completed by following Adding compute machines to vSphere.

1.2.21. Backing up VMware vSphere volumes

OpenShift Container Platform provisions new volumes as independent persistent disks to freely attach and detach the volume on any node in the cluster. As a consequence, it is not possible to back up volumes that use snapshots, or to restore volumes from snapshots. See Snapshot Limitations for more information.

Procedure

To create a backup of persistent volumes:

1. Stop the application that is using the persistent volume.
2. Clone the persistent volume.
3. Restart the application.
4. Create a backup of the cloned volume.
5. Delete the cloned volume.

1.2.22. Next steps

- Customize your cluster.
- If necessary, you can opt out of remote health reporting .
- Set up your registry and configure registry storage .

1.3. INSTALLING A CLUSTER ON VSPHERE IN A RESTRICTED NETWORK

In OpenShift Container Platform version 4.4, you can install a cluster on VMware vSphere infrastructure that you provision in a restricted network.

1.3.1. Prerequisites

- Create a registry on your mirror host and obtain the **imageContentSources** data for your version of OpenShift Container Platform.

IMPORTANT

Because the installation media is on the mirror host, you can use that computer to complete all installation steps.

- Provision persistent storage for your cluster. To deploy a private image registry, your storage must provide **ReadWriteMany** access modes.
- Review details about the OpenShift Container Platform installation and update processes.
- If you use a firewall and plan to use telemetry, you must configure the firewall to allow the sites that your cluster requires access to.

NOTE

Be sure to also review this site list if you are configuring a proxy.

1.3.2. About installations in restricted networks

In OpenShift Container Platform 4.4, you can perform an installation that does not require an active connection to the Internet to obtain software components. You complete an installation in a restricted network on only infrastructure that you provision, not infrastructure that the installation program provisions, so your platform selection is limited.

If you choose to perform a restricted network installation on a cloud platform, you still require access to

its cloud APIs. Some cloud functions, like Amazon Web Service's IAM service, require Internet access, so you might still require Internet access. Depending on your network, you might require less Internet access for an installation on bare metal hardware or on VMware vSphere.

To complete a restricted network installation, you must create a registry that mirrors the contents of the OpenShift Container Platform registry and contains the installation media. You can create this registry on a mirror host, which can access both the Internet and your closed network, or by using other methods that meet your restrictions.

IMPORTANT

Restricted network installations always use user-provisioned infrastructure. Because of the complexity of the configuration for user-provisioned installations, consider completing a standard user-provisioned infrastructure installation before you attempt a restricted network installation. Completing this test installation might make it easier to isolate and troubleshoot any issues that might arise during your installation in a restricted network.

1.3.2.1. Additional limits

Clusters in restricted networks have the following additional limitations and restrictions:

- The **ClusterVersion** status includes an **Unable to retrieve available updates** error.
- By default, you cannot use the contents of the Developer Catalog because you cannot access the required image stream tags.

1.3.3. Internet and Telemetry access for OpenShift Container Platform

In OpenShift Container Platform 4.4, you require access to the Internet to obtain the images that are necessary to install your cluster. The Telemetry service, which runs by default to provide metrics about cluster health and the success of updates, also requires Internet access. If your cluster is connected to the Internet, Telemetry runs automatically, and your cluster is registered to the Red Hat OpenShift Cluster Manager (OCM).

Once you confirm that your Red Hat OpenShift Cluster Manager inventory is correct, either maintained automatically by Telemetry or manually using OCM, use subscription watch to track your OpenShift Container Platform subscriptions at the account or multi-cluster level.

You must have Internet access to:

- Access the Red Hat OpenShift Cluster Manager page to download the installation program and perform subscription management. If the cluster has Internet access and you do not disable Telemetry, that service automatically entitles your cluster.
- Access Quay.io to obtain the packages that are required to install your cluster.
- Obtain the packages that are required to perform cluster updates.

IMPORTANT

If your cluster cannot have direct Internet access, you can perform a restricted network installation on some types of infrastructure that you provision. During that process, you download the content that is required and use it to populate a mirror registry with the packages that you need to install a cluster and generate the installation program. With some installation types, the environment that you install your cluster in will not require Internet access. Before you update the cluster, you update the content of the mirror registry.

1.3.4. VMware vSphere infrastructure requirements

You must install the OpenShift Container Platform cluster on a VMware vSphere version 6 instance that meets the requirements for the components that you use.

Table 1.14. Minimum supported vSphere version for VMware components

Component	Minimum supported versions	Description
Hypervisor	vSphere 6.5 with HW version 13	This version is the minimum version that Red Hat Enterprise Linux CoreOS (RHCOS) supports. See the Red Hat Enterprise Linux 8 supported hypervisors list.
Networking (NSX-T)	vSphere 6.5U3 or vSphere 6.7U2 and later	vSphere 6.5U3 or vSphere 6.7U2+ are required for OpenShift Container Platform. VMware's NSX Container Plug-in (NCP) 3.0.2 is certified with OpenShift Container Platform 4.4 and NSX-T 3.x+.
Storage with in-tree drivers	vSphere 6.5 or vSphere 6.7	This plug-in creates vSphere storage by using the in-tree storage drivers for vSphere included in OpenShift Container Platform and can be used when vSphere CSI drivers are not available.
Storage with vSphere CSI driver	vSphere 6.7U3 and later	This plug-in creates vSphere storage by using the standard Container Storage Interface. The vSphere CSI driver is provided and supported by VMware.

If you use a vSphere version 6.5 instance, consider upgrading to 6.7U2 before you install OpenShift Container Platform.

IMPORTANT

You must ensure that the time on your ESXi hosts is synchronized before you install OpenShift Container Platform. See Edit Time Configuration for a Host in the VMware documentation.

IMPORTANT

> A limitation of using VPC is that the Storage Distributed Resource Scheduler (SDRS) is not supported. See link:https://vmware.github.io/vsphere-storage-for-kubernetes/documentation/faqs.html[vSphere Storage for Kubernetes FAQs] in the VMware documentation.

1.3.5. Required vCenter account privileges

To install an OpenShift Container Platform cluster in vCenter, the cluster requires access to an account with privileges to read and create the required resources. Using an account that has administrative privileges is the simplest way to access all of the necessary permissions.

A user requires the following privileges to install an OpenShift Container Platform cluster:

- Datastore
  - **Allocate space**
- Folder
  - **Create folder**
  - **Delete folder**
- vSphere Tagging
  - All privileges
- Network
  - **Assign network**
- Resource
  - **Assign virtual machine to resource pool**
- Profile-driven storage
  - All privileges
- vApp
  - All privileges
- Virtual machine
  - All privileges

For more information about creating an account with only the required privileges, see vSphere Permissions and User Management Tasks in the vSphere documentation.

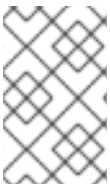
1.3.6. Machine requirements for a cluster with user-provisioned infrastructure

For a cluster that contains user-provisioned infrastructure, you must deploy all of the required machines.

1.3.6.1. Required machines

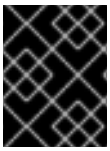
The smallest OpenShift Container Platform clusters require the following hosts:

- One temporary bootstrap machine
- Three control plane, or master, machines
- At least two compute machines, which are also known as worker machines



NOTE

The cluster requires the bootstrap machine to deploy the OpenShift Container Platform cluster on the three control plane machines. You can remove the bootstrap machine after you install the cluster.



IMPORTANT

To maintain high availability of your cluster, use separate physical hosts for these cluster machines.

The bootstrap, control plane, and compute machines must use the Red Hat Enterprise Linux CoreOS (RHCOS) as the operating system.

Note that RHCOS is based on Red Hat Enterprise Linux 8 and inherits all of its hardware certifications and requirements. See Red Hat Enterprise Linux technology capabilities and limits .

1.3.6.2. Network connectivity requirements

All the Red Hat Enterprise Linux CoreOS (RHCOS) machines require network in **initramfs** during boot to fetch Ignition config files from the Machine Config Server. During the initial boot, the machines require either a DHCP server or that static IP addresses be set in order to establish a network connection to download their Ignition config files.

1.3.6.3. Minimum resource requirements

Each cluster machine must meet the following minimum requirements:

Machine	Operating System	vCPU[1]	Virtual RAM	Storage
Bootstrap	RHCOS	4	16 GB	120 GB
Control plane	RHCOS	4	16 GB	120 GB
Compute	RHCOS or RHEL 7.6	2	8 GB	120 GB

Machine	Operating System	vCPU[1]	Virtual RAM	Storage

[1] 1 physical core provides 2 vCPUs when hyper-threading is enabled. 1 physical core provides 1 vCPU when hyper-threading is not enabled.

1.3.6.4. Certificate signing requests management

Because your cluster has limited access to automatic machine management when you use infrastructure that you provision, you must provide a mechanism for approving cluster certificate signing requests (CSRs) after installation. The **kube-controller-manager** only approves the kubelet client CSRs. The **machine-approver** cannot guarantee the validity of a serving certificate that is requested by using kubelet credentials because it cannot confirm that the correct machine issued the request. You must determine and implement a method of verifying the validity of the kubelet serving certificate requests and approving them.

1.3.7. Creating the user-provisioned infrastructure

Before you deploy an OpenShift Container Platform cluster that uses user-provisioned infrastructure, you must create the underlying infrastructure.

Prerequisites

- Review the OpenShift Container Platform 4.x Tested Integrations page before you create the supporting infrastructure for your cluster.

Procedure

1. Configure DHCP or set static IP addresses on each node.
2. Provision the required load balancers.
3. Configure the ports for your machines.
4. Configure DNS.
5. Ensure network connectivity.

1.3.7.1. Networking requirements for user-provisioned infrastructure

All the Red Hat Enterprise Linux CoreOS (RHCOS) machines require network in **initramfs** during boot to fetch Ignition config from the machine config server.

During the initial boot, the machines require either a DHCP server or that static IP addresses be set on each host in the cluster in order to establish a network connection, which allows them to download their Ignition config files.

It is recommended to use the DHCP server to manage the machines for the cluster long-term. Ensure that the DHCP server is configured to provide persistent IP addresses and host names to the cluster machines.

The Kubernetes API server, which runs on each master node after a successful cluster installation, must be able to resolve the node names of the cluster machines. If the API servers and worker nodes are in different zones, you can configure a default DNS search zone to allow the API server to resolve the

node names. Another supported approach is to always refer to hosts by their fully-qualified domain names in both the node objects and all DNS requests.

You must configure the network connectivity between machines to allow cluster components to communicate. Each machine must be able to resolve the host names of all other machines in the cluster.

Table 1.15. All machines to all machines

Protocol	Port	Description
ICMP	N/A	Network reachability tests
TCP	**9000**-**9999**	Host level services, including the node exporter on ports **9100**-**9101** and the Cluster Version Operator on port**9099**.
	10250-**10259**	The default ports that Kubernetes reserves
	10256	openshift-sdn
UDP	**4789**	VXLAN and Geneve
	6081	VXLAN and Geneve
	9000-**9999**	Host level services, including the node exporter on ports **9100**-**9101**.
TCP/UDP	**30000**-**32767**	Kubernetes node port

Table 1.16. All machines to control plane

Protocol	Port	Description
TCP	**2379**-**2380**	etcd server, peer, and metrics ports
	6443	Kubernetes API

Network topology requirements
The infrastructure that you provision for your cluster must meet the following network topology requirements.

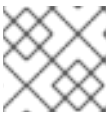
IMPORTANT

OpenShift Container Platform requires all nodes to have internet access to pull images for platform containers and provide telemetry data to Red Hat.

Load balancers
Before you install OpenShift Container Platform, you must provision two load balancers that meet the following requirements:

1. **API load balancer**: Provides a common endpoint for users, both human and machine, to interact with and configure the platform. Configure the following conditions:

   - Layer 4 load balancing only. This can be referred to as Raw TCP, SSL Passthrough, or SSL Bridge mode. If you use SSL Bridge mode, you must enable Server Name Indication (SNI) for the API routes.
   - A stateless load balancing algorithm. The options vary based on the load balancer implementation.



NOTE

Session persistence is not required for the API load balancer to function properly.

Configure the following ports on both the front and back of the load balancers:

Table 1.17. API load balancer

Port	Back-end machines (pool members)	Internal	External	Description
6443	Bootstrap and control plane. You remove the bootstrap machine from the load balancer after the bootstrap machine initializes the cluster control plane. You must configure the **/readyz** endpoint for the API server health check probe.	X	X	Kubernetes API server
22623	Bootstrap and control plane. You remove the bootstrap machine from the load balancer after the bootstrap machine initializes the cluster control plane.	X		Machine config server

NOTE

The load balancer must be configured to take a maximum of 30 seconds from the time the API server turns off the **/readyz** endpoint to the removal of the API server instance from the pool. Within the time frame after **/readyz** returns an error or becomes healthy, the endpoint must have been removed or added. Probing every 5 or 10 seconds, with two successful requests to become healthy and three to become unhealthy, are well-tested values.

2. **Application Ingress load balancer**: Provides an Ingress point for application traffic flowing in from outside the cluster. Configure the following conditions:

   - Layer 4 load balancing only. This can be referred to as Raw TCP, SSL Passthrough, or SSL Bridge mode. If you use SSL Bridge mode, you must enable Server Name Indication (SNI) for the Ingress routes.
   - A connection-based or session-based persistence is recommended, based on the options available and types of applications that will be hosted on the platform.

Configure the following ports on both the front and back of the load balancers:

Table 1.18. Application Ingress load balancer

Port	Back-end machines (pool members)	Internal	External	Description
443	The machines that run the Ingress router pods, compute, or worker, by default.	X	X	HTTPS traffic
80	The machines that run the Ingress router pods, compute, or worker, by default.	X	X	HTTP traffic

TIP

If the true IP address of the client can be seen by the load balancer, enabling source IP-based session persistence can improve performance for applications that use end-to-end TLS encryption.

NOTE

A working configuration for the Ingress router is required for an OpenShift Container Platform cluster. You must configure the Ingress router after the control plane initializes.

Ethernet adaptor hardware address requirements
When provisioning VMs for the cluster, the ethernet interfaces configured for each VM must use a MAC address from the VMware Organizationally Unique Identifier (OUI) allocation ranges:

- **00:05:69:00:00:00** to **00:05:69:FF:FF:FF**
- **00:0c:29:00:00:00** to **00:0c:29:FF:FF:FF**
- **00:1c:14:00:00:00** to **00:1c:14:FF:FF:FF**
- **00:50:56:00:00:00** to **00:50:56:FF:FF:FF**

If a MAC address outside the VMware OUI is used, the cluster installation will not succeed.

1.3.7.2. User-provisioned DNS requirements

DNS is used for name resolution and reverse name resolution. DNS A/AAAA or CNAME records are used for name resolution and PTR records are used for reverse name resolution. The reverse records are important because Red Hat Enterprise Linux CoreOS (RHCOS) uses the reverse records to set the host name for all the nodes. Additionally, the reverse records are used to generate the certificate signing requests (CSR) that OpenShift Container Platform needs to operate.

The following DNS records are required for an OpenShift Container Platform cluster that uses user-provisioned infrastructure. In each record, **<cluster_name>** is the cluster name and **<base_domain>** is the cluster base domain that you specify in the **install-config.yaml** file. A complete DNS record takes the form: **<component>.<cluster_name>.<base_domain>.**.

Table 1.19. Required DNS records

Component	Record	Description
Kubernetes API	**api.<cluster_name>.<base_domain>.**	Add a DNS A/AAAA or CNAME record, and a DNS PTR record, to identify the load balancer for the control plane machines. These records must be resolvable by both clients external to the cluster and from all the nodes within the cluster.
	api-int.<cluster_name>.<base_domain>.	Add a DNS A/AAAA or CNAME record, and a DNS PTR record, to identify the load balancer for the control plane machines. These records must be resolvable from all the nodes within the cluster.  **IMPORTANT** The API server must be able to resolve the worker nodes by the host names that are recorded in Kubernetes. If the API server cannot resolve the node names, then proxied API calls can fail, and you cannot retrieve logs from pods.
Routes	***.apps.<cluster_name>.<base_domain>.**	Add a wildcard DNS A/AAAA or CNAME record that refers to the load balancer that targets the machines that run the Ingress router pods, which are the worker nodes by default. These records must be resolvable by both clients external to the cluster and from all the nodes within the cluster.
Bootstrap	**bootstrap.<cluster_name>.<base_domain>.**	Add a DNS A/AAAA or CNAME record, and a DNS PTR record, to identify the bootstrap machine. These records must be resolvable by the nodes within the cluster.
Master hosts	**<master><n>.<cluster_name>.<base_domain>.**	Add DNS A/AAAA or CNAME records and DNS PTR records to identify each machine for the master nodes. These records must be resolvable by the nodes within the cluster.
Worker hosts	**<worker><n>.<cluster_name>.<base_domain>.**	Add DNS A/AAAA or CNAME records and DNS PTR records to identify each machine for the worker nodes. These records must be resolvable by the nodes within the cluster.

TIP

You can use the **nslookup <hostname>** command to verify name resolution. You can use the **dig -x <ip_address>** command to verify reverse name resolution for the PTR records.

The following example of a BIND zone file shows sample A records for name resolution. The purpose of the example is to show the records that are needed. The example is not meant to provide advice for choosing one name resolution service over another.

Example 1.5. Sample DNS zone database

```
$TTL 1W
@ IN SOA ns1.example.com. root (
   2019070700 ; serial
   3H  ; refresh (3 hours)
   30M  ; retry (30 minutes)
   2W  ; expiry (2 weeks)
   1W )  ; minimum (1 week)
 IN NS ns1.example.com.
 IN MX 10 smtp.example.com.
;
;
ns1 IN A 192.168.1.5
smtp IN A 192.168.1.5
;
helper IN A 192.168.1.5
helper.ocp4 IN A 192.168.1.5
;
; The api identifies the IP of your load balancer.
api.ocp4  IN A 192.168.1.5
api-int.ocp4  IN A 192.168.1.5
;
; The wildcard also identifies the load balancer.
*.apps.ocp4  IN A 192.168.1.5
;
; Create an entry for the bootstrap host.
bootstrap.ocp4 IN A 192.168.1.96
;
; Create entries for the master hosts.
master0.ocp4  IN A 192.168.1.97
master1.ocp4  IN A 192.168.1.98
master2.ocp4  IN A 192.168.1.99
;
; Create entries for the worker hosts.
worker0.ocp4  IN A 192.168.1.11
worker1.ocp4  IN A 192.168.1.7
;
;EOF
```

The following example BIND zone file shows sample PTR records for reverse name resolution.

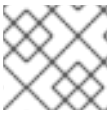
Example 1.6. Sample DNS zone database for reverse records

```
$TTL 1W
@ IN SOA ns1.example.com. root (
   2019070700 ; serial
   3H  ; refresh (3 hours)
   30M  ; retry (30 minutes)
   2W  ; expiry (2 weeks)
   1W )  ; minimum (1 week)
 IN NS ns1.example.com.
;
; The syntax is "last octet" and the host must have an FQDN
; with a trailing dot.
97 IN PTR master0.ocp4.example.com.
```

```
98 IN PTR master1.ocp4.example.com.
99 IN PTR master2.ocp4.example.com.
;
96 IN PTR bootstrap.ocp4.example.com.
;
5 IN PTR api.ocp4.ocp4.example.com.
5 IN PTR api-int.ocp4.ocp4.example.com.
;
11 IN PTR worker0.ocp4.example.com.
7 IN PTR worker1.ocp4.example.com.
;
;EOF
```

1.3.8. Generating an SSH private key and adding it to the agent

If you want to perform installation debugging or disaster recovery on your cluster, you must provide an SSH key to both your **ssh-agent** and the installation program. You can use this key to access the bootstrap machine in a public cluster to troubleshoot installation issues.



NOTE

In a production environment, you require disaster recovery and debugging.

You can use this key to SSH into the master nodes as the user **core**. When you deploy the cluster, the key is added to the **core** user's ~/**.ssh/authorized_keys** list.

NOTE

You must use a local key, not one that you configured with platform-specific approaches such as AWS key pairs.

Procedure

1. If you do not have an SSH key that is configured for password-less authentication on your computer, create one. For example, on a computer that uses a Linux operating system, run the following command:

```
$ ssh-keygen -t ed25519 -N '' \
    -f <path>/<file_name> 1
```

1 Specify the path and file name, such as ~/**.ssh/id_rsa**, of the SSH key. Do not specify an existing SSH key, as it will be overwritten.

   Running this command generates an SSH key that does not require a password in the location that you specified.

2. Start the **ssh-agent** process as a background task:

```
$ eval "$(ssh-agent -s)"

Agent pid 31874
```

3. Add your SSH private key to the **ssh-agent**:

```
$ ssh-add <path>/<file_name> (1)

Identity added: /home/<you>/<path>/<file_name> (<computer_name>)
```

(1) Specify the path and file name for your SSH private key, such as **~/.ssh/id_rsa**

Next steps

- When you install OpenShift Container Platform, provide the SSH public key to the installation program. If you install a cluster on infrastructure that you provision, you must provide this key to your cluster's machines.

1.3.9. Manually creating the installation configuration file

For installations of OpenShift Container Platform that use user-provisioned infrastructure, you must manually generate your installation configuration file.

Prerequisites

- Obtain the OpenShift Container Platform installation program and the access token for your cluster.
- Obtain the **imageContentSources** section from the output of the command to mirror the repository.
- Obtain the contents of the certificate for your mirror registry.

Procedure

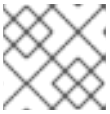
1. Create an installation directory to store your required installation assets in:

```
$ mkdir <installation_directory>
```

IMPORTANT

You must create a directory. Some installation assets, like bootstrap X.509 certificates have short expiration intervals, so you must not reuse an installation directory. If you want to reuse individual files from another cluster installation, you can copy them into your directory. However, the file names for the installation assets might change between releases. Use caution when copying installation files from an earlier OpenShift Container Platform version.

2. Customize the following **install-config.yaml** file template and save it in the **<installation_directory>**.



NOTE

You must name this configuration file **install-config.yaml**.

- Unless you use a registry that RHCOS trusts by default, such as **docker.io**, you must provide the contents of the certificate for your mirror repository in the **additionalTrustBundle** section. In most cases, you must provide the certificate for your mirror.
- You must include the **imageContentSources** section from the output of the command to mirror the repository.

3. Back up the **install-config.yaml** file so that you can use it to install multiple clusters.

IMPORTANT

The **install-config.yaml** file is consumed during the next step of the installation process. You must back it up now.

1.3.9.1. Sample install-config.yaml file for VMware vSphere

You can customize the **install-config.yaml** file to specify more details about your OpenShift Container Platform cluster's platform or modify the values of the required parameters.

```
apiVersion: v1
baseDomain: example.com (1)
compute:
- hyperthreading: Enabled (2) (3)
  name: worker
  replicas: 0 (4)
controlPlane:
  hyperthreading: Enabled (5) (6)
  name: master
  replicas: 3 (7)
metadata:
  name: test (8)
platform:
  vsphere:
    vcenter: your.vcenter.server (9)
    username: username (10)
    password: password (11)
    datacenter: datacenter (12)
    defaultDatastore: datastore (13)
fips: false (14)
pullSecret: '{"auths":{"<local_registry>": {"auth": "<credentials>","email": "you@example.com"}}}' (15)
sshKey: 'ssh-ed25519 AAAA...' (16)
additionalTrustBundle: | (17)
  -----BEGIN CERTIFICATE-----
  ZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZ
  -----END CERTIFICATE-----
imageContentSources: (18)
- mirrors:
  - <local_registry>/<local_repository_name>/release
  source: quay.io/openshift-release-dev/ocp-release
- mirrors:
  - <local_registry>/<local_repository_name>/release
  source: registry.svc.ci.openshift.org/ocp/release
```

1. The base domain of the cluster. All DNS records must be sub-domains of this base and include the cluster name.

2 5. The **controlPlane** section is a single mapping, but the compute section is a sequence of mappings. To meet the requirements of the different data structures, the first line of the **compute** section must begin with a hyphen, **-**, and the first line of the **controlPlane** section must not. Although both sections currently define a single machine pool, it is possible that future versions of OpenShift Container Platform will support defining multiple compute pools during installation. Only one control plane pool is used.

3 6. Whether to enable or disable simultaneous multithreading, or **hyperthreading**. By default, simultaneous multithreading is enabled to increase the performance of your machines' cores. You can disable it by setting the parameter value to **Disabled**. If you disable simultaneous multithreading in some cluster machines, you must disable it in all cluster machines.

IMPORTANT

If you disable simultaneous multithreading, ensure that your capacity planning accounts for the dramatically decreased machine performance. Your machines must use at least 8 CPUs and 32 GB of RAM if you disable simultaneous multithreading.

4. You must set the value of the **replicas** parameter to **0**. This parameter controls the number of workers that the cluster creates and manages for you, which are functions that the cluster does not perform when you use user-provisioned infrastructure. You must manually deploy worker machines for the cluster to use before you finish installing OpenShift Container Platform.

7. The number of control plane machines that you add to the cluster. Because the cluster uses this values as the number of etcd endpoints in the cluster, the value must match the number of control plane machines that you deploy.

8. The cluster name that you specified in your DNS records.

9. The fully-qualified host name or IP address of the vCenter server.

10. The name of the user for accessing the server. This user must have at least the roles and privileges that are required for static or dynamic persistent volume provisioning in vSphere.

11. The password associated with the vSphere user.

12. The vSphere datacenter.

13. The default vSphere datastore to use.

14. Whether to enable or disable FIPS mode. By default, FIPS mode is not enabled. If FIPS mode is enabled, the Red Hat Enterprise Linux CoreOS (RHCOS) machines that OpenShift Container Platform runs on bypass the default Kubernetes cryptography suite and use the cryptography modules that are provided with RHCOS instead.

15. For **<local_registry>**, specify the registry domain name, and optionally the port, that your mirror registry uses to serve content. For example **registry.example.com** or **registry.example.com:5000**. For **<credentials>**, specify the base64-encoded user name and password for your mirror registry.

16. The public portion of the default SSH key for the **core** user in Red Hat Enterprise Linux CoreOS (RHCOS).

NOTE

For production OpenShift Container Platform clusters on which you want to perform installation debugging or disaster recovery, specify an SSH key that your **ssh-agent** process uses.

17 Provide the contents of the certificate file that you used for your mirror registry.

18 Provide the **imageContentSources** section from the output of the command to mirror the repository.

1.3.9.2. Configuring the cluster-wide proxy during installation

Production environments can deny direct access to the Internet and instead have an HTTP or HTTPS proxy available. You can configure a new OpenShift Container Platform cluster to use a proxy by configuring the proxy settings in the **install-config.yaml** file.

Prerequisites

- An existing **install-config.yaml** file.
- Review the sites that your cluster requires access to and determine whether any need to bypass the proxy. By default, all cluster egress traffic is proxied, including calls to hosting cloud provider APIs. Add sites to the **Proxy** object's **spec.noProxy** field to bypass the proxy if necessary.

NOTE

The **Proxy** object **status.noProxy** field is populated with the values of the **networking.machineNetwork[].cidr**, **networking.clusterNetwork[].cidr**, and **networking.serviceNetwork[]** fields from your installation configuration.

For installations on Amazon Web Services (AWS), Google Cloud Platform (GCP), Microsoft Azure, and Red Hat OpenStack Platform (RHOSP), the **Proxy** object **status.noProxy** field is also populated with the instance metadata endpoint (**169.254.169.254**).

Procedure

1. Edit your **install-config.yaml** file and add the proxy settings. For example:

```
apiVersion: v1
baseDomain: my.domain.com
proxy:
  httpProxy: http://<username>:<pswd>@<ip>:<port> 1
  httpsProxy: http://<username>:<pswd>@<ip>:<port> 2
  noProxy: example.com 3
additionalTrustBundle: | 4
    -----BEGIN CERTIFICATE-----
    <MY_TRUSTED_CA_CERT>
    -----END CERTIFICATE-----
...
```

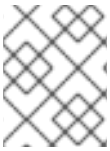
1. A proxy URL to use for creating HTTP connections outside the cluster. The URL scheme must be **http**. If you use an MITM transparent proxy network that does not require additional proxy configuration but requires additional CAs, you must not specify an **httpProxy** value.
2. A proxy URL to use for creating HTTPS connections outside the cluster. If this field is not specified, then **httpProxy** is used for both HTTP and HTTPS connections. If you use an MITM transparent proxy network that does not require additional proxy configuration but requires additional CAs, you must not specify an **httpsProxy** value.
3. A comma-separated list of destination domain names, domains, IP addresses, or other network CIDRs to exclude proxying. Preface a domain with **.** to include all subdomains of that domain. Use ***** to bypass proxy for all destinations.
4. If provided, the installation program generates a config map that is named **user-ca-bundle** in the **openshift-config** namespace that contains one or more additional CA certificates that are required for proxying HTTPS connections. The Cluster Network Operator then creates a **trusted-ca-bundle** config map that merges these contents with the Red Hat Enterprise Linux CoreOS (RHCOS) trust bundle, and this config map is referenced in the **Proxy** object's **trustedCA** field. The **additionalTrustBundle** field is required unless the proxy's identity certificate is signed by an authority from the RHCOS trust bundle. If you use an MITM transparent proxy network that does not require additional proxy configuration but requires additional CAs, you must provide the MITM CA certificate.

NOTE

The installation program does not support the proxy **readinessEndpoints** field.

2. Save the file and reference it when installing OpenShift Container Platform.

The installation program creates a cluster-wide proxy that is named **cluster** that uses the proxy settings in the provided **install-config.yaml** file. If no proxy settings are provided, a **cluster Proxy** object is still created, but it will have a nil **spec**.



NOTE

Only the **Proxy** object named **cluster** is supported, and no additional proxies can be created.

1.3.10. Creating the Kubernetes manifest and Ignition config files

Because you must modify some cluster definition files and manually start the cluster machines, you must generate the Kubernetes manifest and Ignition config files that the cluster needs to make its machines.

IMPORTANT

The Ignition config files that the installation program generates contain certificates that expire after 24 hours, which are then renewed at that time. If the cluster is shut down before renewing the certificates and the cluster is later restarted after the 24 hours have elapsed, the cluster automatically recovers the expired certificates. The exception is that you must manually approve the pending **node-bootstrapper** certificate signing requests (CSRs) to recover kubelet certificates. See the documentation for *Recovering from expired control plane certificates* for more information.

Prerequisites

- Obtain the OpenShift Container Platform installation program. For a restricted network installation, these files are on your mirror host.
- Create the **install-config.yaml** installation configuration file.

Procedure

1. Generate the Kubernetes manifests for the cluster:

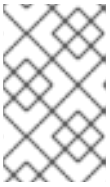
```
$ ./openshift-install create manifests --dir=<installation_directory> 1

INFO Consuming Install Config from target directory
WARNING Making control-plane schedulable by setting MastersSchedulable to true for
Scheduler cluster settings
```

1 For **<installation_directory>**, specify the installation directory that contains the **install-config.yaml** file you created.

Because you create your own compute machines later in the installation process, you can safely ignore this warning.

2. Modify the **<installation_directory>/manifests/cluster-scheduler-02-config.yml** Kubernetes manifest file to prevent pods from being scheduled on the control plane machines:
   a. Open the **<installation_directory>/manifests/cluster-scheduler-02-config.yml** file.
   b. Locate the **mastersSchedulable** parameter and set its value to **False**.
   c. Save and exit the file.



NOTE

Currently, due to a Kubernetes limitation, router Pods running on control plane machines will not be reachable by the ingress load balancer. This step might not be required in a future minor version of OpenShift Container Platform.

3. Obtain the Ignition config files:

```
$ ./openshift-install create ignition-configs --dir=<installation_directory> 1
```

1 For **<installation_directory>**, specify the same installation directory.

The following files are generated in the directory:

```
.
├── auth
│   ├── kubeadmin-password
│   └── kubeconfig
├── bootstrap.ign
```

```
├── master.ign
├── metadata.json
└── worker.ign
```

1.3.11. Creating Red Hat Enterprise Linux CoreOS (RHCOS) machines in vSphere

Before you install a cluster that contains user-provisioned infrastructure on VMware vSphere, you must create RHCOS machines on vSphere hosts for it to use.

Prerequisites

- Obtain the Ignition config files for your cluster.
- Have access to an HTTP server that you can access from your computer and that the machines that you create can access.
- Create a vSphere cluster.

Procedure

1. Upload the bootstrap Ignition config file, which is named **<installation_directory>/bootstrap.ign**, that the installation program created to your HTTP server. Note the URL of this file.
   You must host the bootstrap Ignition config file because it is too large to fit in a vApp property.
2. Save the following secondary Ignition config file for your bootstrap node to your computer as **<installation_directory>/append-bootstrap.ign**.

```
{
  "ignition": {
    "config": {
      "append": [
        {
          "source": "<bootstrap_ignition_config_url>", 1
          "verification": {}
        }
      ]
    },
    "timeouts": {},
    "version": "2.2.0"
  },
  "networkd": {},
  "passwd": {},
  "storage": {},
  "systemd": {}
}
```

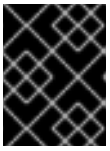
1 Specify the URL of the bootstrap Ignition config file that you hosted.

   When you create the virtual machine (VM) for the bootstrap machine, you use this Ignition config file.

3. Convert the master, worker, and secondary bootstrap Ignition config files to base64 encoding.

For example, if you use a Linux operating system, you can use the **base64** command to encode the files.

```
$ base64 -w0 <installation_directory>/master.ign > <installation_directory>/master.64
$ base64 -w0 <installation_directory>/worker.ign > <installation_directory>/worker.64
$ base64 -w0 <installation_directory>/append-bootstrap.ign >
<installation_directory>/append-bootstrap.64
```



IMPORTANT

If you plan to add more compute machines to your cluster after you finish installation, do not delete these files.

4. Obtain the RHCOS OVA image from the Product Downloads page on the Red Hat customer portal or the RHCOS image mirror page.

IMPORTANT

The RHCOS images might not change with every release of OpenShift Container Platform. You must download an image with the highest version that is less than or equal to the OpenShift Container Platform version that you install. Use the image version that matches your OpenShift Container Platform version if it is available.

The file name contains the OpenShift Container Platform version number in the format **rhcos-<version>-vmware.<architecture>.ova**.

5. In the vSphere Client, create a folder in your datacenter to store your VMs.
   a. Click the **VMs and Templates** view.
   b. Right-click the name of your datacenter.
   c. Click **New Folder → New VM and Template Folder**.
   d. In the window that is displayed, enter the folder name. The folder name must match the cluster name that you specified in the **install-config.yaml** file.
6. In the vSphere Client, create a template for the OVA image.

NOTE

In the following steps, you use the same template for all of your cluster machines and provide the location for the Ignition config file for that machine type when you provision the VMs.

   a. From the **Hosts and Clusters** tab, right-click your cluster's name and click **Deploy OVF Template**.
   b. On the **Select an OVF** tab, specify the name of the RHCOS OVA file that you downloaded.
   c. On the **Select a name and folder** tab, set a **Virtual machine name**, such as RHCOS, click the name of your vSphere cluster, and select the folder you created in the previous step.

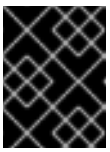
d. On the **Select a compute resource** tab, click the name of your vSphere cluster.

e. On the **Select storage** tab, configure the storage options for your VM.

- Select **Thin Provision** or **Thick Provision**, based on your storage preferences.
- Select the datastore that you specified in your **install-config.yaml** file.

f. On the **Select network** tab, specify the network that you configured for the cluster, if available.

g. If you plan to use the same template for all cluster machine types, do not specify values on the **Customize template** tab.



IMPORTANT

If you plan to add more compute machines to your cluster after you finish installation, do not delete this template.

7. After the template deploys, deploy a VM for a machine in the cluster.

a. Right-click the template's name and click **Clone → Clone to Virtual Machine**

b. On the **Select a name and folder** tab, specify a name for the VM. You might include the machine type in the name, such as **control-plane-0** or **compute-1**.

c. On the **Select a name and folder** tab, select the name of the folder that you created for the cluster.

d. On the **Select a compute resource** tab, select the name of a host in your datacenter.

e. Optional: On the **Select storage** tab, customize the storage options.

f. On the **Select clone options**, select **Customize this virtual machine's hardware**.

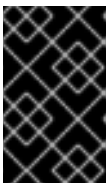
g. On the **Customize hardware** tab, click **VM Options → Advanced**.

- Optional: In the event of cluster performance issues, from the **Latency Sensitivity** list, select **High**.
- Click **Edit Configuration**, and on the **Configuration Parameters** window, click **Add Configuration Params**. Define the following parameter names and values:
  - **guestinfo.ignition.config.data**: Paste the contents of the base64-encoded Ignition config file for this machine type.
  - **guestinfo.ignition.config.data.encoding**: Specify **base64**.
  - **disk.EnableUUID**: Specify **TRUE**.
- Alternatively, prior to powering on the virtual machine add via vApp properties:
  - Navigate to a virtual machine from the vCenter Server inventory.
  - On the **Configure** tab, expand **Settings** and select **vApp options.**
  - Scroll down and under **Properties** apply the configurations from above.

h. In the **Virtual Hardware** panel of the **Customize hardware** tab, modify the specified values as required. Ensure that the amount of RAM, CPU, and disk storage meets the minimum requirements for the machine type.

i. Complete the configuration and power on the VM.

8. Create the rest of the machines for your cluster by following the preceding steps for each machine.



IMPORTANT

You must create the bootstrap and control plane machines at this time. Because some pods are deployed on compute machines by default, also create at least two compute machine before you install the cluster.

1.3.12. Creating more Red Hat Enterprise Linux CoreOS (RHCOS) machines in vSphere

You can create more compute machines for your cluster that uses user-provisioned infrastructure on VMware vSphere.

Prerequisites

- Obtain the base64-encoded Ignition file for your compute machines.
- You have access to the vSphere template that you created for your cluster.

Procedure

1. After the template deploys, deploy a VM for a machine in the cluster.
   a. Right-click the template's name and click **Clone → Clone to Virtual Machine**
   b. On the **Select a name and folder** tab, specify a name for the VM. You might include the machine type in the name, such as **compute-1**.
   c. On the **Select a name and folder** tab, select the name of the folder that you created for the cluster.
   d. On the **Select a compute resource** tab, select the name of a host in your datacenter.
   e. Optional: On the **Select storage** tab, customize the storage options.
   f. On the **Select clone options**, select **Customize this virtual machine's hardware**.
   g. On the **Customize hardware** tab, click **VM Options → Advanced**.
      - From the **Latency Sensitivity** list, select **High**.
      - Click **Edit Configuration**, and on the **Configuration Parameters** window, click **Add Configuration Params**. Define the following parameter names and values:
        - **guestinfo.ignition.config.data**: Paste the contents of the base64-encoded compute Ignition config file for this machine type.
        - **guestinfo.ignition.config.data.encoding**: Specify **base64**.

- **disk.EnableUUID**: Specify **TRUE**.

h. In the **Virtual Hardware** panel of the **Customize hardware** tab, modify the specified values as required. Ensure that the amount of RAM, CPU, and disk storage meets the minimum requirements for the machine type. Also, make sure to select the correct network under **Add network adapter** if there are multiple networks available.

i. Complete the configuration and power on the VM.

2. Continue to create more compute machines for your cluster.

1.3.13. Creating the cluster

To create the OpenShift Container Platform cluster, you wait for the bootstrap process to complete on the machines that you provisioned by using the Ignition config files that you generated with the installation program.

Prerequisites

- Create the required infrastructure for the cluster.
- You obtained the installation program and generated the Ignition config files for your cluster.
- You used the Ignition config files to create RHCOS machines for your cluster.

Procedure

1. Monitor the bootstrap process:

```
$ ./openshift-install --dir=<installation_directory> wait-for bootstrap-complete \ 1
    --log-level=info 2
INFO Waiting up to 30m0s for the Kubernetes API at https://api.test.example.com...
INFO API v1.17.1 up
INFO Waiting up to 30m0s for bootstrapping to complete...
INFO It is now safe to remove the bootstrap resources
```

1 For **<installation_directory>**, specify the path to the directory that you stored the installation files in.

2 To view different installation details, specify **warn**, **debug**, or **error** instead of **info**.

The command succeeds when the Kubernetes API server signals that it has been bootstrapped on the control plane machines.

2. After bootstrap process is complete, remove the bootstrap machine from the load balancer.

IMPORTANT

You must remove the bootstrap machine from the load balancer at this point. You can also remove or reformat the machine itself.

1.3.14. Logging in to the cluster

You can log in to your cluster as a default system user by exporting the cluster **kubeconfig** file. The

kubeconfig file contains information about the cluster that is used by the CLI to connect a client to the correct cluster and API server. The file is specific to a cluster and is created during OpenShift Container Platform installation.

Prerequisites

- Deploy an OpenShift Container Platform cluster.
- Install the **oc** CLI.

Procedure

1. Export the **kubeadmin** credentials:

```
$ export KUBECONFIG=<installation_directory>/auth/kubeconfig 1
```

1 For **<installation_directory>**, specify the path to the directory that you stored the installation files in.

2. Verify you can run **oc** commands successfully using the exported configuration:

```
$ oc whoami
system:admin
```

1.3.15. Approving the certificate signing requests for your machines

When you add machines to a cluster, two pending certificate signing requests (CSRs) are generated for each machine that you added. You must confirm that these CSRs are approved or, if necessary, approve them yourself. The client requests must be approved first, followed by the server requests.

Prerequisites

- You added machines to your cluster.

Procedure

1. Confirm that the cluster recognizes the machines:

```
# oc get nodes

NAME                 STATUS   ROLES    AGE   VERSION
master-01.example.com   Ready    master   40d   v1.17.1
master-02.example.com   Ready    master   40d   v1.17.1
master-03.example.com   Ready    master   40d   v1.17.1
worker-01.example.com   Ready    worker   40d   v1.17.1
worker-02.example.com   Ready    worker   40d   v1.17.1
```

The output lists all of the machines that you created.

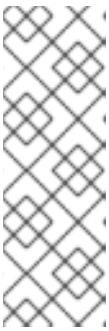
2. Review the pending CSRs and ensure that you see the client requests with the **Pending** or **Approved** status for each machine that you added to the cluster:

```
$ oc get csr
```

```
NAME        AGE     REQUESTOR                                                   CONDITION
csr-8b2br   15m     system:serviceaccount:openshift-machine-config-operator:node-bootstrapper   Pending
csr-8vnps   15m     system:serviceaccount:openshift-machine-config-operator:node-bootstrapper   Pending
...
```

In this example, two machines are joining the cluster. You might see more approved CSRs in the list.

3. If the CSRs were not approved, after all of the pending CSRs for the machines you added are in **Pending** status, approve the CSRs for your cluster machines:



NOTE

Because the CSRs rotate automatically, approve your CSRs within an hour of adding the machines to the cluster. If you do not approve them within an hour, the certificates will rotate, and more than two certificates will be present for each node. You must approve all of these certificates. After you approve the initial CSRs, the subsequent node client CSRs are automatically approved by the cluster **kube-controller-manager**. You must implement a method of automatically approving the kubelet serving certificate requests.

- To approve them individually, run the following command for each valid CSR:

```
$ oc adm certificate approve <csr_name> 1
```

1 **<csr_name>** is the name of a CSR from the list of current CSRs.

- To approve all pending CSRs, run the following command:

```
$ oc get csr -o go-template='{{range .items}}{{if not .status}}{{.metadata.name}}{{"\n"}}{{end}}{{end}}' | xargs oc adm certificate approve
```

4. Now that your client requests are approved, you must review the server requests for each machine that you added to the cluster:

```
$ oc get csr
```

Example output

```
NAME        AGE     REQUESTOR                                                   CONDITION
csr-bfd72   5m26s   system:node:ip-10-0-50-126.us-east-2.compute.internal       Pending
csr-c57lv   5m26s   system:node:ip-10-0-95-157.us-east-2.compute.internal       Pending
...
```

5. If the remaining CSRs are not approved, and are in the **Pending** status, approve the CSRs for your cluster machines:

- To approve them individually, run the following command for each valid CSR:

```
$ oc adm certificate approve <csr_name> 1
```

1 **<csr_name>** is the name of a CSR from the list of current CSRs.

- To approve all pending CSRs, run the following command:

```
$ oc get csr -o go-template='{{range .items}}{{if not .status}}{{.metadata.name}}{{"\n"}}
{{end}}{{end}}' | xargs oc adm certificate approve
```

6. After all client and server CSRs have been approved, the machines have the **Ready** status. Verify this by running the following command:

```
$ oc get nodes
```

Example output

```
NAME      STATUS    ROLES   AGE  VERSION
master-0  Ready     master  73m  v1.20.0
master-1  Ready     master  73m  v1.20.0
master-2  Ready     master  74m  v1.20.0
worker-0  Ready     worker  11m  v1.20.0
worker-1  Ready     worker  11m  v1.20.0
```

NOTE

It can take a few minutes after approval of the server CSRs for the machines to transition to the **Ready** status.

Additional information

- For more information on CSRs, see Certificate Signing Requests.

1.3.16. Initial Operator configuration

After the control plane initializes, you must immediately configure some Operators so that they all become available.

Prerequisites

- Your control plane has initialized.

Procedure

1. Watch the cluster components come online:

```
$ watch -n5 oc get clusteroperators

NAME                      VERSION   AVAILABLE   PROGRESSING   DEGRADED
SINCE
authentication            4.4.0     True        False         False     69s
cloud-credential          4.4.0     True        False         False     12m
cluster-autoscaler        4.4.0     True        False         False     11m
```

```
console                                    4.4.0     True        False         False      46s
dns                                        4.4.0     True        False         False      11m
image-registry                             4.4.0     True        False         False      5m26s
ingress                                    4.4.0     True        False         False      5m36s
kube-apiserver                             4.4.0     True        False         False      8m53s
kube-controller-manager                    4.4.0     True        False         False      7m24s
kube-scheduler                             4.4.0     True        False         False      12m
machine-api                                4.4.0     True        False         False      12m
machine-config                             4.4.0     True        False         False      7m36s
marketplace                                4.4.0     True        False         False      7m54m
monitoring                                 4.4.0     True        False         False      7h54s
network                                    4.4.0     True        False         False      5m9s
node-tuning                                4.4.0     True        False         False      11m
openshift-apiserver                        4.4.0     True        False         False      11m
openshift-controller-manager               4.4.0     True        False         False      5m943s
openshift-samples                          4.4.0     True        False         False      3m55s
operator-lifecycle-manager                 4.4.0     True        False         False      11m
operator-lifecycle-manager-catalog         4.4.0     True        False         False      11m
service-ca                                 4.4.0     True        False         False      11m
service-catalog-apiserver                  4.4.0     True        False         False      5m26s
service-catalog-controller-manager         4.4.0     True        False         False      5m25s
storage                                    4.4.0     True        False         False      5m30s
```

2. Configure the Operators that are not available.

1.3.16.1. Image registry storage configuration

The Image Registry Operator is not initially available for platforms that do not provide default storage. After installation, you must configure your registry to use storage so the Registry Operator is made available.

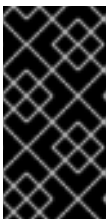
Instructions for both configuring a persistent volume, which is required for production clusters, and for configuring an empty directory as the storage location, which is available for only non-production clusters, are shown.

1.3.16.1.1. Configuring registry storage for VMware vSphere

As a cluster administrator, following installation you must configure your registry to use storage.

Prerequisites

- Cluster administrator permissions.
- A cluster on VMware vSphere.
- Persistent storage provisioned for your cluster, such as Red Hat OpenShift Container Storage.



IMPORTANT

OpenShift Container Platform supports **ReadWriteOnce** access for image registry storage when you have only one replica. To deploy an image registry that supports high availability with two or more replicas, **ReadWriteMany** access is required.

- Must have "100Gi" capacity.

IMPORTANT

Testing shows issues with using the NFS server on RHEL as storage backend for core services. This includes the OpenShift Container Registry and Quay, Prometheus for monitoring storage, and Elasticsearch for logging storage. Therefore, using RHEL NFS to back PVs used by core services is not recommended.

Other NFS implementations on the marketplace might not have these issues. Contact the individual NFS implementation vendor for more information on any testing that was possibly completed against these OpenShift Container Platform core components.

Procedure

1. To configure your registry to use storage, change the **spec.storage.pvc** in the **configs.imageregistry/cluster** resource.

NOTE

When using shared storage, review your security settings to prevent outside access.

2. Verify that you do not have a registry pod:

```
$ oc get pod -n openshift-image-registry
```

NOTE

If the storage type is **emptyDIR**, the replica number cannot be greater than **1**.

3. Check the registry configuration:

```
$ oc edit configs.imageregistry.operator.openshift.io
```

Example output

```
storage:
  pvc:
    claim: 1
```

1 Leave the **claim** field blank to allow the automatic creation of an **image-registry-storage** PVC.

4. Check the **clusteroperator** status:

```
$ oc get clusteroperator image-registry
```

1.3.16.1.2. Configuring storage for the image registry in non-production clusters

You must configure storage for the Image Registry Operator. For non-production clusters, you can set the image registry to an empty directory. If you do so, all images are lost if you restart the registry.

Procedure

Procedure

- To set the image registry storage to an empty directory:

```
$ oc patch configs.imageregistry.operator.openshift.io cluster --type merge --patch '{"spec":{"storage":{"emptyDir":{}}}}'
```

WARNING

Configure this option for only non-production clusters.

If you run this command before the Image Registry Operator initializes its components, the **oc patch** command fails with the following error:

```
Error from server (NotFound): configs.imageregistry.operator.openshift.io "cluster" not found
```

Wait a few minutes and run the command again.

For instructions about configuring registry storage so that it references the correct PVC, see Configuring the registry for vSphere.

1.3.17. Completing installation on user-provisioned infrastructure

After you complete the Operator configuration, you can finish installing the cluster on infrastructure that you provide.

Prerequisites

- Your control plane has initialized.
- You have completed the initial Operator configuration.

Procedure

1. Confirm that all the cluster components are online:

```
$ watch -n5 oc get clusteroperators

NAME                       VERSION   AVAILABLE   PROGRESSING   DEGRADED
SINCE
authentication             4.4.3     True        False         False      7m56s
cloud-credential           4.4.3     True        False         False      31m
cluster-autoscaler         4.4.3     True        False         False      16m
console                    4.4.3     True        False         False      10m
csi-snapshot-controller    4.4.3     True        False         False      16m
dns                        4.4.3     True        False         False      22m
etcd                       4.4.3     False       False         False      25s
image-registry             4.4.3     True        False         False      16m
ingress                    4.4.3     True        False         False      16m
insights                   4.4.3     True        False         False      17m
```

```
kube-apiserver                             4.4.3     True        False         False      19m
kube-controller-manager                    4.4.3     True        False         False      20m
kube-scheduler                             4.4.3     True        False         False      20m
kube-storage-version-migrator              4.4.3     True        False         False      16m
machine-api                                4.4.3     True        False         False      22m
machine-config                             4.4.3     True        False         False      22m
marketplace                                4.4.3     True        False         False      16m
monitoring                                 4.4.3     True        False         False      10m
network                                    4.4.3     True        False         False      23m
node-tuning                                4.4.3     True        False         False      23m
openshift-apiserver                        4.4.3     True        False         False      17m
openshift-controller-manager               4.4.3     True        False         False      15m
openshift-samples                          4.4.3     True        False         False      16m
operator-lifecycle-manager                 4.4.3     True        False         False      22m
operator-lifecycle-manager-catalog         4.4.3     True        False         False      22m
operator-lifecycle-manager-packageserver   4.4.3     True        False         False      18m
service-ca                                 4.4.3     True        False         False      23m
service-catalog-apiserver                  4.4.3     True        False         False      23m
service-catalog-controller-manager         4.4.3     True        False         False      23m
storage                                    4.4.3     True        False         False      17m
```

When all of the cluster Operators are **AVAILABLE**, you can complete the installation.

2. Monitor for cluster completion:

```
$ ./openshift-install --dir=<installation_directory> wait-for install-complete 1
INFO Waiting up to 30m0s for the cluster to initialize...
```

1 For **<installation_directory>**, specify the path to the directory that you stored the installation files in.

The command succeeds when the Cluster Version Operator finishes deploying the OpenShift Container Platform cluster from Kubernetes API server.

IMPORTANT

The Ignition config files that the installation program generates contain certificates that expire after 24 hours, which are then renewed at that time. If the cluster is shut down before renewing the certificates and the cluster is later restarted after the 24 hours have elapsed, the cluster automatically recovers the expired certificates. The exception is that you must manually approve the pending **node-bootstrapper** certificate signing requests (CSRs) to recover kubelet certificates. See the documentation for *Recovering from expired control plane certificates* for more information.

3. Confirm that the Kubernetes API server is communicating with the pods.

   a. To view a list of all pods, use the following command:

```
$ oc get pods --all-namespaces

NAMESPACE                       NAME                                         READY   STATUS
RESTARTS   AGE
openshift-apiserver-operator    openshift-apiserver-operator-85cb746d55-zqhs8   1/1
```

```
Running     1          9m
openshift-apiserver             apiserver-67b9g                          1/1     Running     0
3m
openshift-apiserver             apiserver-ljcmx                          1/1     Running     0
1m
openshift-apiserver             apiserver-z25h4                          1/1     Running     0
2m
openshift-authentication-operator authentication-operator-69d5d8bf84-vh2n8        1/1
Running     0          5m
...
```

b. View the logs for a pod that is listed in the output of the previous command by using the following command:

```
$ oc logs <pod_name> -n <namespace> 1
```

1 Specify the pod name and namespace, as shown in the output of the previous command.

If the pod logs display, the Kubernetes API server can communicate with the cluster machines.

4. Register your cluster on the Cluster registration page.

You can add extra compute machines after the cluster installation is completed by following Adding compute machines to vSphere.

1.3.18. Backing up VMware vSphere volumes

OpenShift Container Platform provisions new volumes as independent persistent disks to freely attach and detach the volume on any node in the cluster. As a consequence, it is not possible to back up volumes that use snapshots, or to restore volumes from snapshots. See Snapshot Limitations for more information.

Procedure

To create a backup of persistent volumes:

1. Stop the application that is using the persistent volume.
2. Clone the persistent volume.
3. Restart the application.
4. Create a backup of the cloned volume.
5. Delete the cloned volume.

1.3.19. Next steps

- Customize your cluster.
- If necessary, you can opt out of remote health reporting .