



OpenShift Container Platform 4.1

Scalability and performance

Scaling your Red Hat OpenShift Container Platform 4.1 cluster and tuning performance in production environments

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Abstract

This document provides instruction on scaling your cluster and optimizing the performance of your Red Hat OpenShift Container Platform environment.

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CHAPTER 1. RECOMMENDED HOST PRACTICES

This topic provides recommended host practices for OpenShift Container Platform.

1.1. RECOMMENDED NODE HOST PRACTICES

The OpenShift Container Platform node configuration file contains important options. For example, two parameters control the maximum number of pods that can be scheduled to a node: **podsPerCore** and **maxPods**.

When both options are in use, the lower of the two values limits the number of pods on a node. Exceeding these values can result in:

- Increased CPU utilization.
- Slow pod scheduling.
- Potential out-of-memory scenarios, depending on the amount of memory in the node.
- Exhausting the pool of IP addresses.
- Resource overcommitting, leading to poor user application performance.



IMPORTANT

In Kubernetes, a pod that is holding a single container actually uses two containers. The second container is used to set up networking prior to the actual container starting. Therefore, a system running 10 pods will actually have 20 containers running.

podsPerCore sets the number of pods the node can run based on the number of processor cores on the node. For example, if **podsPerCore** is set to **10** on a node with 4 processor cores, the maximum number of pods allowed on the node will be **40**.

```
kubeletConfig:
  podsPerCore: 10
```

Setting **podsPerCore** to **0** disables this limit. The default is **0**. **podsPerCore** cannot exceed **maxPods**.

maxPods sets the number of pods the node can run to a fixed value, regardless of the properties of the node.

```
kubeletConfig:
  maxPods: 250
```

1.2. MASTER NODE SIZING

The master node resource requirements depend on the number of nodes in the cluster. The following master node size recommendations are based on the results of control plane density focused testing.

Number of worker nodes	CPU cores	Memory (GB)
25	4	16

Number of worker nodes	CPU cores	Memory (GB)
100	8	32
250	16	64



IMPORTANT

Because you cannot modify the master node size in a running OpenShift Container Platform 4.1 cluster, you must estimate your total node count and use the suggested master size during installation.



NOTE

In OpenShift Container Platform 4.1, half of a CPU core (500 millicore) is now reserved by the system by default compared to OpenShift Container Platform 3.11 and previous versions. The sizes are determined taking that into consideration.

1.3. CREATE A KUBELETCONFIG CRD TO EDIT KUBELET PARAMETERS

The kubelet configuration is currently serialized as an ignition configuration, so it can be directly edited. However, there is also a new kubelet-config-controller added to the Machine Config Controller (MCC). This allows you to create a KubeletConfig custom resource (CR) to edit the kubelet parameters.

Procedure

1. Run:

```
$ oc get machineconfig
```

This provides a list of the available machine configuration objects you can select. By default, the two kubelet-related configs are **01-master-kubelet** and **01-worker-kubelet**.

2. To check the current value of max Pods per node, run:

```
# oc describe node <node-ip> | grep Allocatable -A6
```

Look for **value: pods: <value>**.

For example:

```
# oc describe node ip-172-31-128-158.us-east-2.compute.internal | grep Allocatable -A6
Allocatable:
attachable-volumes-aws-ebs: 25
cpu:                        3500m
hugepages-1Gi:             0
hugepages-2Mi:             0
memory:                    15341844Ki
pods:                      250
```


3. To set the max Pods per node on the worker nodes, create a YAML file that contains the kubelet configuration. For example, **max-worker-pods.yaml**:

```
apiVersion: machineconfiguration.openshift.io/v1
kind: KubeletConfig
metadata:
  name: set-max-pods
spec:
  machineConfigSelector: 01-worker-kubelet
  kubeletConfig:
    maxPods: 250
```

4. Apply the file by running:

```
$ oc apply -f max-worker-pods.yaml
```

5. Verify the change by running:

```
$ oc get kubeletconfigs set-max-pods -o yaml
```

By default, only one machine is allowed to be unavailable when applying the kubelet-related configuration to the available worker nodes. For a large cluster, it can take a long time for the configuration change to be reflected. At any time, you can adjust the number of machines that are updating to speed up the process.

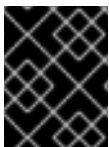
Procedure

1. Run:

```
$ oc edit machineconfigpool worker
```

2. Set **maxUnavailable** to the desired value.

```
spec:
  maxUnavailable: <node_count>
```



IMPORTANT

When setting the value, consider the number of worker nodes that can be unavailable without affecting the applications running on the cluster.

1.4. RECOMMENDED ETCD PRACTICES

For large and dense clusters, etcd can suffer from poor performance if the keyspace grows excessively large and exceeds the space quota. Periodic maintenance of etcd including defragmentation needs to be done to free up space in the data store. It is highly recommended that you monitor Prometheus for etcd metrics and defragment it when needed before etcd raises a cluster-wide alarm that puts the cluster into a maintenance mode, which only accepts key reads and deletes. Some of the key metrics to monitor are **etcd_server_quota_backend_bytes** which is the current quota limit, **etcd_mvcc_db_total_size_in_use_in_bytes** which indicates the actual database usage after a history compaction, and **etcd_debugging_mvcc_db_total_size_in_bytes** which shows the database size including free space waiting for defragmentation.

1.5. ADDITIONAL RESOURCES

- [OpenShift Container Platform cluster limits](#)

CHAPTER 2. USING THE NODE TUNING OPERATOR

Learn about the Node Tuning Operator and how you can use it to manage node-level tuning by orchestrating the tuned daemon.

2.1. ABOUT THE NODE TUNING OPERATOR

The Node Tuning Operator helps you manage node-level tuning by orchestrating the tuned daemon. The majority of high-performance applications require some level of kernel tuning. The Node Tuning Operator provides a unified management interface to users of node-level sysctls and more flexibility to add custom tuning, which is currently a Technology Preview feature, specified by user needs. The Operator manages the containerized tuned daemon for OpenShift Container Platform as a Kubernetes DaemonSet. It ensures the custom tuning specification is passed to all containerized tuned daemons running in the cluster in the format that the daemons understand. The daemons run on all nodes in the cluster, one per node.

The Node Tuning Operator is part of a standard OpenShift Container Platform installation in version 4.1 and later.

2.2. ACCESSING AN EXAMPLE NODE TUNING OPERATOR SPECIFICATION

Use this process to access an example Node Tuning Operator specification.

Procedure

1. Run:

```
$ oc get Tuned/default -o yaml -n openshift-cluster-node-tuning-operator
```

2.3. DEFAULT PROFILES SET ON A CLUSTER

The following are the default profiles set on a cluster.

```
apiVersion: tuned.openshift.io/v1alpha1
kind: Tuned
metadata:
  name: default
  namespace: openshift-cluster-node-tuning-operator
spec:
  profile:
    - name: "openshift"
    data: |
      [main]
      summary=Optimize systems running OpenShift (parent profile)
      include=${f:virt_check:virtual-guest:throughput-performance}
      [selinux]
      avc_cache_threshold=8192
      [net]
      nf_conntrack_hashsize=131072
      [sysctl]
      net.ipv4.ip_forward=1
      kernel.pid_max=>131072
```

```

net.netfilter.nf_conntrack_max=1048576
net.ipv4.neigh.default.gc_thresh1=8192
net.ipv4.neigh.default.gc_thresh2=32768
net.ipv4.neigh.default.gc_thresh3=65536
net.ipv6.neigh.default.gc_thresh1=8192
net.ipv6.neigh.default.gc_thresh2=32768
net.ipv6.neigh.default.gc_thresh3=65536
[sysfs]
/sys/module/nvme_core/parameters/io_timeout=4294967295
/sys/module/nvme_core/parameters/max_retries=10
- name: "openshift-control-plane"
data: |
[main]
summary=Optimize systems running OpenShift control plane
include=openshift
[sysctl]
# ktune sysctl settings, maximizing i/o throughput
#
# Minimal preemption granularity for CPU-bound tasks:
# (default: 1 msec# (1 + ilog(ncpus)), units: nanoseconds)
kernel.sched_min_granularity_ns=10000000
# The total time the scheduler will consider a migrated process
# "cache hot" and thus less likely to be re-migrated
# (system default is 500000, i.e. 0.5 ms)
kernel.sched_migration_cost_ns=5000000
# SCHED_OTHER wake-up granularity.
#
# Preemption granularity when tasks wake up. Lower the value to
# improve wake-up latency and throughput for latency critical tasks.
kernel.sched_wakeup_granularity_ns=4000000
- name: "openshift-node"
data: |
[main]
summary=Optimize systems running OpenShift nodes
include=openshift
[sysctl]
net.ipv4.tcp_fastopen=3
fs.inotify.max_user_watches=65536
- name: "openshift-control-plane-es"
data: |
[main]
summary=Optimize systems running ES on OpenShift control-plane
include=openshift-control-plane
[sysctl]
vm.max_map_count=262144
- name: "openshift-node-es"
data: |
[main]
summary=Optimize systems running ES on OpenShift nodes
include=openshift-node
[sysctl]
vm.max_map_count=262144
recommend:
- profile: "openshift-control-plane-es"
priority: 10
match:

```

```

- label: "tuned.openshift.io/elasticsearch"
  type: "pod"
  match:
- label: "node-role.kubernetes.io/master"
- label: "node-role.kubernetes.io/infra"

- profile: "openshift-node-es"
  priority: 20
  match:
- label: "tuned.openshift.io/elasticsearch"
  type: "pod"

- profile: "openshift-control-plane"
  priority: 30
  match:
- label: "node-role.kubernetes.io/master"
- label: "node-role.kubernetes.io/infra"

- profile: "openshift-node"
  priority: 40

```



IMPORTANT

Custom profiles for custom tuning specification is a Technology Preview feature only. Technology Preview features are not supported with Red Hat production service level agreements (SLAs) and might not be functionally complete. Red Hat does not recommend using them in production. These features provide early access to upcoming product features, enabling customers to test functionality and provide feedback during the development process.

For more information about the support scope of Red Hat Technology Preview features, see <https://access.redhat.com/support/offerings/techpreview/>.

2.4. CUSTOM TUNING SPECIFICATION

The custom resource (CR) for the operator has two major sections. The first section, **profile:**, is a list of tuned profiles and their names. The second, **recommend:**, defines the profile selection logic.

Multiple custom tuning specifications can co-exist as multiple CRs in the operator's namespace. The existence of new CRs or the deletion of old CRs is detected by the Operator. All existing custom tuning specifications are merged and appropriate objects for the containerized tuned daemons are updated.

Profile data

The **profile:** section lists tuned profiles and their names.

```

profile:
- name: tuned_profile_1
  data: |
    # Tuned profile specification
    [main]
    summary=Description of tuned_profile_1 profile

    [sysctl]
    net.ipv4.ip_forward=1

```

```
# ... other sysctl's or other tuned daemon plugins supported by the containerized tuned

# ...

- name: tuned_profile_n
  data: |
    # Tuned profile specification
    [main]
    summary=Description of tuned_profile_n profile

    # tuned_profile_n profile settings
```

Recommended profiles

The **profile:** selection logic is defined by the **recommend:** section of the CR:

```
recommend:
- match:                # optional; if omitted, profile match is assumed unless a profile with a
  higher matches first
  <match>                # an optional array
  priority: <priority>    # profile ordering priority, lower numbers mean higher priority (0 is the
  highest priority)
  profile: <tuned_profile_name> # e.g. tuned_profile_1

# ...

- match:
  <match>
  priority: <priority>
  profile: <tuned_profile_name> # e.g. tuned_profile_n
```

If **<match>** is omitted, a profile match (for example, **true**) is assumed.

<match> is an optional array recursively defined as follows:

```
- label: <label_name>    # node or pod label name
  value: <label_value>   # optional node or pod label value; if omitted, the presence of <label_name>
  is enough to match
  type: <label_type>     # optional node or pod type ("node" or "pod"); if omitted, "node" is assumed
  <match>                # an optional <match> array
```

If **<match>** is not omitted, all nested **<match>** sections must also evaluate to **true**. Otherwise, **false** is assumed and the profile with the respective **<match>** section will not be applied or recommended. Therefore, the nesting (child **<match>** sections) works as logical AND operator. Conversely, if any item of the **<match>** array matches, the entire **<match>** array evaluates to **true**. Therefore, the array acts as logical OR operator.

Example

```
- match:
- label: tuned.openshift.io/elasticsearch
  match:
- label: node-role.kubernetes.io/master
- label: node-role.kubernetes.io/infra
  type: pod
```

```

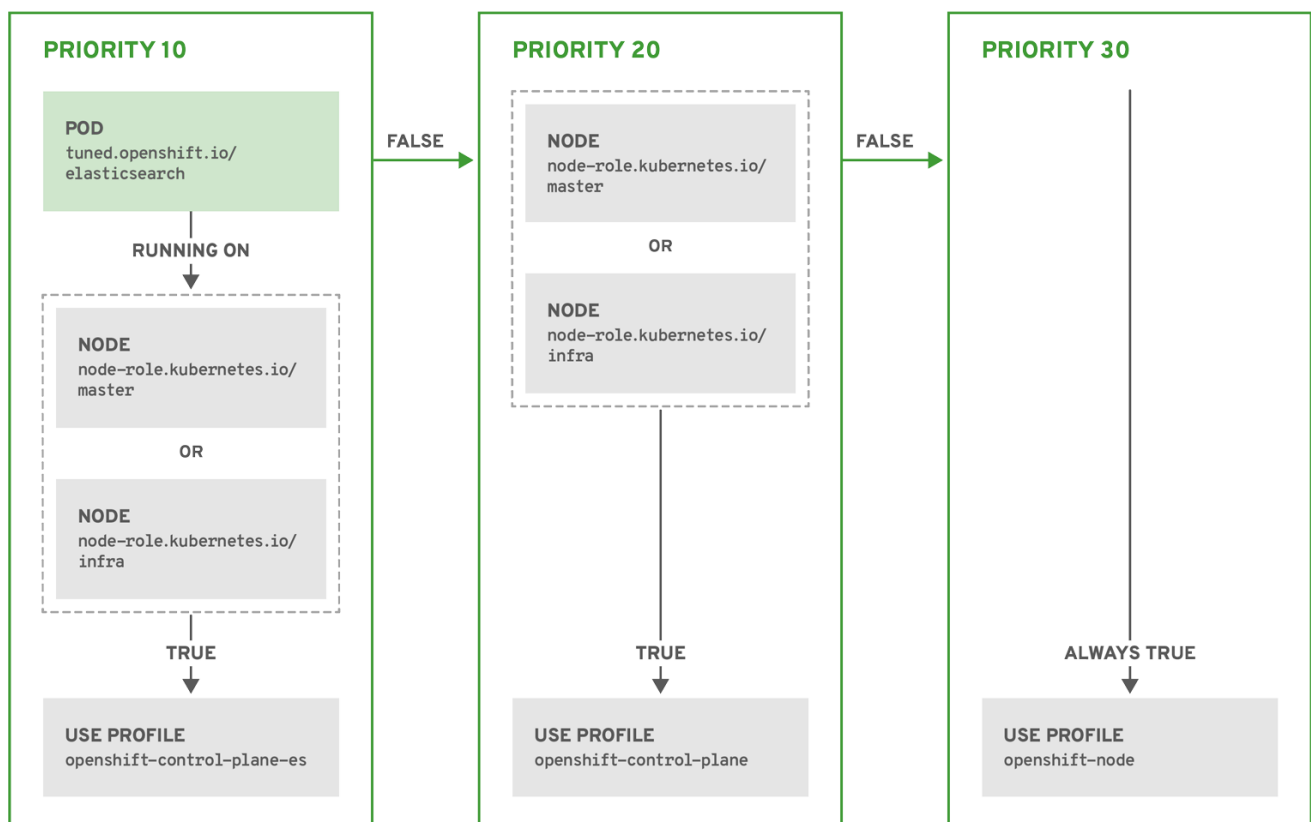
priority: 10
profile: openshift-control-plane-es
- match:
  - label: node-role.kubernetes.io/master
  - label: node-role.kubernetes.io/infra
priority: 20
profile: openshift-control-plane
- priority: 30
  profile: openshift-node

```

The CR above is translated for the containerized tuned daemon into its **recommend.conf** file based on the profile priorities. The profile with the highest priority (**10**) is **openshift-control-plane-es** and, therefore, it is considered first. The containerized tuned daemon running on a given node looks to see if there is a pod running on the same node with the **tuned.openshift.io/elasticsearch** label set. If not, the entire **<match>** section evaluates as **false**. If there is such a pod with the label, in order for the **<match>** section to evaluate to **true**, the node label also needs to be **node-role.kubernetes.io/master** or **node-role.kubernetes.io/infra**.

If the labels for the profile with priority **10** matched, **openshift-control-plane-es** profile is applied and no other profile is considered. If the node/pod label combination did not match, the second highest priority profile (**openshift-control-plane**) is considered. This profile is applied if the containerized tuned pod runs on a node with labels **node-role.kubernetes.io/master** or **node-role.kubernetes.io/infra**.

Finally, the profile **openshift-node** has the lowest priority of **30**. It lacks the **<match>** section and, therefore, will always match. It acts as a profile catch-all to set **openshift-node** profile, if no other profile with higher priority matches on a given node.



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2.5. SUPPORTED TUNED DAEMON PLUG-INS

Excluding the **[main]** section, the following Tuned plug-ins are supported when using custom profiles defined in the **profile:** section of the Tuned CR:

- audio
- cpu
- disk
- eeepc_she
- modules
- mounts
- net
- scheduler
- scsi_host
- selinux
- sysctl
- sysfs
- usb
- video
- vm

There is some dynamic tuning functionality provided by some of these plug-ins that is not supported. The following Tuned plug-ins are currently not supported:

- bootloader
- script
- systemd

See [Available Tuned Plug-ins](#) and [Getting Started with Tuned](#) for more information.

CHAPTER 3. USING CLUSTER LOADER

Cluster Loader is a tool that deploys large numbers of various objects to a cluster, which creates user-defined cluster objects. Build, configure, and run Cluster Loader to measure performance metrics of your OpenShift Container Platform deployment at various cluster states.

3.1. INSTALLING CLUSTER LOADER

Cluster Loader is included in the **origin-tests** container image.

Procedure

1. To pull the **origin-tests** container image, run:

```
$ sudo podman pull quay.io/openshift/origin-tests:4.1
```

3.2. RUNNING CLUSTER LOADER

Procedure

1. Execute Cluster Loader using the built-in test configuration, which deploys five template builds and waits for them to complete:

```
$ sudo podman run -v ${LOCAL_KUBECONFIG}:/root/.kube/config -i
quay.io/openshift/origin-tests:4.1 /bin/bash -c 'export KUBECONFIG=/root/.kube/config && \
openshift-tests run-test "[Feature:Performance][Serial][Slow] Load cluster should load the \
cluster [Suite:openshift]'"
```

Alternatively, execute Cluster Loader with a user-defined configuration by setting the environment variable for **VIPERCONFIG**:

```
$ sudo podman run -v ${LOCAL_KUBECONFIG}:/root/.kube/config -i
quay.io/openshift/origin-tests:4.1 /bin/bash -c 'export KUBECONFIG=/root/.kube/config && \
export VIPERCONFIG=config/test && \
openshift-tests run-test "[Feature:Performance][Serial][Slow] Load cluster should load the \
cluster [Suite:openshift]'"
```

In this example, there is a subdirectory called **config/** with a configuration file called **test.yml**. In the command line, exclude the extension of the configuration file, as the tool will automatically determine the file type and extension.

3.3. CONFIGURING CLUSTER LOADER

The tool creates multiple namespaces (projects), which contain multiple templates or pods.

Locate the configuration files for Cluster Loader in the **config/** subdirectory. The pod files and template files referenced in these configuration examples are found in the **content/** subdirectory.

3.3.1. Example Cluster Loader configuration file

Cluster Loader's configuration file is a basic YAML file:

```

provider: local 1
ClusterLoader:
  cleanup: true
  projects:
    - num: 1
      basename: clusterloader-cakephp-mysql
      tuning: default
      ifexists: reuse
      templates:
        - num: 1
          file: ./examples/quickstarts/cakephp-mysql.json

    - num: 1
      basename: clusterloader-dancer-mysql
      tuning: default
      ifexists: reuse
      templates:
        - num: 1
          file: ./examples/quickstarts/dancer-mysql.json

    - num: 1
      basename: clusterloader-django-postgresql
      tuning: default
      ifexists: reuse
      templates:
        - num: 1
          file: ./examples/quickstarts/django-postgresql.json

    - num: 1
      basename: clusterloader-nodejs-mongodb
      tuning: default
      ifexists: reuse
      templates:
        - num: 1
          file: ./examples/quickstarts/nodejs-mongodb.json

    - num: 1
      basename: clusterloader-rails-postgresql
      tuning: default
      templates:
        - num: 1
          file: ./examples/quickstarts/rails-postgresql.json

  tuningset: 2
    - name: default
      pods:
        stepping: 3
          stepsize: 5
          pause: 0 s
        rate_limit: 4
          delay: 0 ms

```

1 Optional setting for end-to-end tests. Set to **local** to avoid extra log messages.

2 The tuning sets allow rate limiting and stepping, the ability to create several batches of pods while pausing in between sets. Cluster Loader monitors completion of the previous step before

padding in between each Cluster Loader instance completion of the previous step before continuing.

- 3 Stepping will pause for **M** seconds after each **N** objects are created.
- 4 Rate limiting will wait **M** milliseconds between the creation of objects.

3.3.2. Configuration fields

Table 3.1. Top-level Cluster Loader Fields

Field	Description
cleanup	Set to true or false . One definition per configuration. If set to true , cleanup deletes all namespaces (projects) created by Cluster Loader at the end of the test.
projects	A sub-object with one or many definition(s). Under projects , each namespace to create is defined and projects has several mandatory subheadings.
tuningset	A sub-object with one definition per configuration. tuningset allows the user to define a tuning set to add configurable timing to project or object creation (pods, templates, and so on).
sync	An optional sub-object with one definition per configuration. Adds synchronization possibilities during object creation.

Table 3.2. Fields under **projects**

Field	Description
num	An integer. One definition of the count of how many projects to create.
basename	A string. One definition of the base name for the project. The count of identical namespaces will be appended to Basename to prevent collisions.
tuning	A string. One definition of what tuning set you want to apply to the objects, which you deploy inside this namespace.
ifexists	A string containing either reuse or delete . Defines what the tool does if it finds a project or namespace that has the same name of the project or namespace it creates during execution.

Field	Description
configmaps	A list of key-value pairs. The key is the ConfigMap name and the value is a path to a file from which you create the ConfigMap.
secrets	A list of key-value pairs. The key is the secret name and the value is a path to a file from which you create the secret.
Pods	A sub-object with one or many definition(s) of pods to deploy.
templates	A sub-object with one or many definition(s) of templates to deploy.

Table 3.3. Fields under **pods** and **templates**

Field	Description
num	An integer. The number of pods or templates to deploy.
image	A string. The docker image URL to a repository where it can be pulled.
basename	A string. One definition of the base name for the template (or pod) that you want to create.
file	A string. The path to a local file, which is either a PodSpec or template to be created.
parameters	Key-value pairs. Under parameters , you can specify a list of values to override in the pod or template.

Table 3.4. Fields under **tuningset**

Field	Description
name	A string. The name of the tuning set which will match the name specified when defining a tuning in a project.
pods	A sub-object identifying the tuningset that will apply to pods.
templates	A sub-object identifying the tuningset that will apply to templates.

Table 3.5. Fields under **tuningset pods** or **tuningset templates**

Field	Description
stepping	A sub-object. A stepping configuration used if you want to create an object in a step creation pattern.
rate_limit	A sub-object. A rate-limiting tuning set configuration to limit the object creation rate.

Table 3.6. Fields under **tuningset pods** or **tuningset templates, stepping**

Field	Description
stepsize	An integer. How many objects to create before pausing object creation.
pause	An integer. How many seconds to pause after creating the number of objects defined in stepsize .
timeout	An integer. How many seconds to wait before failure if the object creation is not successful.
delay	An integer. How many milliseconds (ms) to wait between creation requests.

Table 3.7. Fields under **sync**

Field	Description
server	A sub-object with enabled and port fields. The boolean enabled defines whether to start a HTTP server for pod synchronization. The integer port defines the HTTP server port to listen on (9090 by default).
running	A boolean. Wait for pods with labels matching selectors to go into Running state.
succeeded	A boolean. Wait for pods with labels matching selectors to go into Completed state.
selectors	A list of selectors to match pods in Running or Completed states.
timeout	A string. The synchronization timeout period to wait for pods in Running or Completed states. For values that are not 0 , use units: [ns us ms s m h].

3.4. KNOWN ISSUES

If the **IDENTIFIER** parameter is not defined in user templates, template creation fails with **error: unknown parameter name "IDENTIFIER"**. If you deploy templates, add this parameter to your template to avoid this error:

```
{  
  "name": "IDENTIFIER",  
  "description": "Number to append to the name of resources",  
  "value": "1"  
}
```

If you deploy pods, adding the parameter is unnecessary.

CHAPTER 4. USING CPU MANAGER

CPU Manager manages groups of CPUs and constrains workloads to specific CPUs.

CPU Manager is useful for workloads that have some of these attributes:

- Require as much CPU time as possible.
- Are sensitive to processor cache misses.
- Are low-latency network applications.
- Coordinate with other processes and benefit from sharing a single processor cache.

4.1. SETTING UP CPU MANAGER

Procedure

1. Optional: Label a node:

```
# oc label node perf-node.example.com cpumanager=true
```

2. Edit the **MachineConfigPool** of the nodes where CPU Manager should be enabled. In this example, all workers have CPU Manager enabled:

```
# oc edit machineconfigpool worker
```

3. Add a label to the worker **MachineConfigPool**:

```
metadata:
  creationTimestamp: 2019-xx-xxx
  generation: 3
  labels:
    custom-kubelet: cpumanager-enabled
```

4. Create a **KubeletConfig**, **cpumanager-kubeletconfig.yaml**, custom resource (CR). Refer to the label created in the previous step to have the correct nodes updated with the new **KubeletConfig**. See the **machineConfigPoolSelector** section:

```
apiVersion: machineconfiguration.openshift.io/v1
kind: KubeletConfig
metadata:
  name: cpumanager-enabled
spec:
  machineConfigPoolSelector:
    matchLabels:
      custom-kubelet: cpumanager-enabled
  kubeletConfig:
    cpuManagerPolicy: static
    cpuManagerReconcilePeriod: 5s
```

5. Create the dynamic **KubeletConfig**:

```
# oc create -f cpumanager-kubeletconfig.yaml
```

This adds the CPU Manager feature to the **KubeletConfig** and, if needed, the Machine Config Operator (MCO) reboots the node. To enable CPU Manager, a reboot is not needed.

6. Check for the merged **KubeletConfig**:

```
# oc get machineconfig 99-worker-XXXXXX-XXXXX-XXXX-XXXXX-kubelet -o json | grep
ownerReference -A7

  "ownerReferences": [
    {
      "apiVersion": "machineconfiguration.openshift.io/v1",
      "kind": "KubeletConfig",
      "name": "cpumanager-enabled",
      "uid": "7ed5616d-6b72-11e9-aae1-021e1ce18878"
    }
  ],
```

7. Check the worker for the updated **kubelet.conf**:

```
# oc debug node/perf-node.example.com
sh-4.4# cat /host/etc/kubernetes/kubelet.conf | grep cpuManager
cpuManagerPolicy: static 1
cpuManagerReconcilePeriod: 5s 2
```

1 2 These settings were defined when you created the **KubeletConfig** CR.

8. Create a Pod that requests a core or multiple cores. Both limits and requests must have their CPU value set to a whole integer. That is the number of cores that will be dedicated to this Pod:

```
# cat cpumanager-pod.yaml
apiVersion: v1
kind: Pod
metadata:
  generateName: cpumanager-
spec:
  containers:
  - name: cpumanager
    image: gcr.io/google_containers/pause-amd64:3.0
    resources:
      requests:
        cpu: 1
        memory: "1G"
      limits:
        cpu: 1
        memory: "1G"
    nodeSelector:
      cpumanager: "true"
```

9. Create the Pod:

```
# oc create -f cpumanager-pod.yaml
```


10. Verify that the Pod is scheduled to the node that you labeled:

```
# oc describe pod cpumanager
Name:          cpumanager-6cqz7
Namespace:     default
Priority:       0
PriorityClassName: <none>
Node: perf-node.example.com/xxx.xx.xx.xxx
...
Limits:
  cpu:  1
  memory: 1G
Requests:
  cpu:    1
  memory: 1G
...
QoS Class:   Guaranteed
Node-Selectors: cpumanager=true
```

11. Verify that the **cgroups** are set up correctly. Get the process ID (PID) of the **pause** process:

```
# └─init.scope
|   └─1 /usr/lib/systemd/systemd --switched-root --system --deserialize 17
└─kubepods.slice
    └─kubepods-pod69c01f8e_6b74_11e9_ac0f_0a2b62178a22.slice
        └─crio-b5437308f1a574c542bdf08563b865c0345c8f8c0b0a655612c.scope
            └─32706 /pause
```

Pods of quality of service (QoS) tier **Guaranteed** are placed within the **kubepods.slice**. Pods of other QoS tiers end up in child **cgroups** of **kubepods**:

```
# cd /sys/fs/cgroup/cpuset/kubepods.slice/kubepods-
pod69c01f8e_6b74_11e9_ac0f_0a2b62178a22.slice/crio-
b5437308f1ad1a7db0574c542bdf08563b865c0345c86e9585f8c0b0a655612c.scope
# for i in `ls cpuset.cpus tasks` ; do echo -n "$i "; cat $i ; done
cpuset.cpus 1
tasks 32706
```

12. Check the allowed CPU list for the task:

```
# grep ^Cpus_allowed_list /proc/32706/status
Cpus_allowed_list:  1
```

13. Verify that another pod (in this case, the pod in the **burstable** QoS tier) on the system cannot run on the core allocated for the **Guaranteed** pod:

```
# cat /sys/fs/cgroup/cpuset/kubepods.slice/kubepods-besteffort.slice/kubepods-besteffort-
podc494a073_6b77_11e9_98c0_06bba5c387ea.slice/crio-
c56982f57b75a2420947f0afc6cafe7534c5734efc34157525fa9abbf99e3849.scope/cpuset.cpus
```

```
0
```

```
# oc describe node perf-node.example.com
```

```

...
Capacity:
  attachable-volumes-aws-ebs: 39
  cpu: 2
  ephemeral-storage: 124768236Ki
  hugepages-1Gi: 0
  hugepages-2Mi: 0
  memory: 8162900Ki
  pods: 250
Allocatable:
  attachable-volumes-aws-ebs: 39
  cpu: 1500m
  ephemeral-storage: 124768236Ki
  hugepages-1Gi: 0
  hugepages-2Mi: 0
  memory: 7548500Ki
  pods: 250
-----
-
  default          cpumanager-6cqz7      1 (66%)    1 (66%)    1G (12%)
  1G (12%)        29m

```

Allocated resources:

(Total limits may be over 100 percent, i.e., overcommitted.)

Resource	Requests	Limits
-----	-----	-----
cpu	1440m (96%)	1 (66%)

This VM has two CPU cores. You set **kube-reserved** to 500 millicores, meaning half of one core is subtracted from the total capacity of the node to arrive at the **Node Allocatable** amount. You can see that **Allocatable CPU** is 1500 millicores. This means you can run one of the CPU Manager pods since each will take one whole core. A whole core is equivalent to 1000 millicores. If you try to schedule a second pod, the system will accept the pod, but it will never be scheduled:

NAME	READY	STATUS	RESTARTS	AGE
cpumanager-6cqz7	1/1	Running	0	33m
cpumanager-7qc2t	0/1	Pending	0	11s

CHAPTER 5. SCALING THE CLUSTER MONITORING OPERATOR

OpenShift Container Platform exposes metrics that the Cluster Monitoring Operator collects and stores in the Prometheus-based monitoring stack. As an OpenShift Container Platform administrator, you can view system resources, containers and components metrics in one dashboard interface, Grafana.

5.1. PROMETHEUS DATABASE STORAGE REQUIREMENTS

Red Hat performed various tests for different scale sizes.

Table 5.1. Prometheus Database storage requirements based on number of nodes/pods in the cluster

Number of Nodes	Number of Pods	Prometheus storage growth per day	Prometheus storage growth per 15 days	RAM Space (per scale size)	Network (per tsdb chunk)
50	1800	6.3 GB	94 GB	6 GB	16 MB
100	3600	13 GB	195 GB	10 GB	26 MB
150	5400	19 GB	283 GB	12 GB	36 MB
200	7200	25 GB	375 GB	14 GB	46 MB

Approximately 20 percent of the expected size was added as overhead to ensure that the storage requirements do not exceed the calculated value.

The above calculation is for the default OpenShift Container Platform Cluster Monitoring Operator.



NOTE

CPU utilization has minor impact. The ratio is approximately 1 core out of 40 per 50 nodes and 1800 pods.

Lab environment

In a previous release, all experiments were performed in an OpenShift Container Platform on OpenStack environment:

- Infra nodes (VMs) - 40 cores, 157 GB RAM.
- CNS nodes (VMs) - 16 cores, 62 GB RAM, NVMe drives.

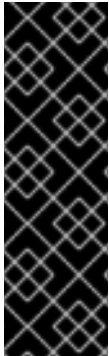


IMPORTANT

Currently, OpenStack environments are not supported for OpenShift Container Platform 4.1.

Recommendations for OpenShift Container Platform

- Use at least three infrastructure (infra) nodes.
- Use at least three **openshift-container-storage** nodes with non-volatile memory express (NVMe) drives.



IMPORTANT

OpenShift Container Storage (OCS) is currently a Technology Preview feature. Technology Preview features are not supported with Red Hat production service level agreements (SLAs), might not be functionally complete, and Red Hat does not recommend to use them for production. These features provide early access to upcoming product features, enabling customers to test functionality and provide feedback during the development process.

See the [Red Hat Technology Preview features support scope](#) for more information.

5.2. CONFIGURING CLUSTER MONITORING

Procedure

To increase the storage capacity for Prometheus:

1. Create a YAML configuration file, `cluster-monitoring-config.yml`. For example:

```
apiVersion: v1
kind: ConfigMap
data:
  config.yaml: |
    prometheusOperator:
      baseImage: quay.io/coreos/prometheus-operator
      prometheusConfigReloaderBaseImage: quay.io/coreos/prometheus-config-reloader
      configReloaderBaseImage: quay.io/coreos/configmap-reload
      nodeSelector:
        node-role.kubernetes.io/infra: ""
    prometheusK8s:
      retention: {{PROMETHEUS_RETENTION_PERIOD}} 1
      baseImage: openshift/prometheus
      nodeSelector:
        node-role.kubernetes.io/infra: ""
      volumeClaimTemplate:
        spec:
          storageClassName: gp2
          resources:
            requests:
              storage: {{PROMETHEUS_STORAGE_SIZE}} 2
    alertmanagerMain:
      baseImage: openshift/prometheus-alertmanager
      nodeSelector:
        node-role.kubernetes.io/infra: ""
      volumeClaimTemplate:
        spec:
          storageClassName: gp2
          resources:
```

```

    requests:
      storage: {{ALERTMANAGER_STORAGE_SIZE}} 3
nodeExporter:
  baseImage: openshift/prometheus-node-exporter
kubeRbacProxy:
  baseImage: quay.io/coreos/kube-rbac-proxy
kubeStateMetrics:
  baseImage: quay.io/coreos/kube-state-metrics
nodeSelector:
  node-role.kubernetes.io/infra: ""
grafana:
  baseImage: grafana/grafana
nodeSelector:
  node-role.kubernetes.io/infra: ""
auth:
  baseImage: openshift/oauth-proxy
k8sPrometheusAdapter:
  nodeSelector:
    node-role.kubernetes.io/infra: ""
metadata:
  name: cluster-monitoring-config
namespace: openshift-monitoring

```

- 1** A typical value is **PROMETHEUS_RETENTION_PERIOD=15d**. Units are measured in time using one of these suffixes: s, m, h, d.
- 2** A typical value is **PROMETHEUS_STORAGE_SIZE=2000Gi**. Storage values can be a plain integer or as a fixed-point integer using one of these suffixes: E, P, T, G, M, K. You can also use the power-of-two equivalents: Ei, Pi, Ti, Gi, Mi, Ki.
- 3** A typical value is **ALERTMANAGER_STORAGE_SIZE=20Gi**. Storage values can be a plain integer or as a fixed-point integer using one of these suffixes: E, P, T, G, M, K. You can also use the power-of-two equivalents: Ei, Pi, Ti, Gi, Mi, Ki.

2. Set the values like the retention period and storage sizes.
3. Apply the changes by running:

```
$ oc create -f cluster-monitoring-config.yml
```

CHAPTER 6. PLANNING YOUR ENVIRONMENT ACCORDING TO OBJECT LIMITS

Consider the following object limits when you plan your OpenShift Container Platform cluster.

These limits are based on the largest possible cluster. For smaller clusters, the limits are proportionally lower. There are many factors that influence the stated thresholds, including the etcd version or storage data format.

In most cases, exceeding these limits results in lower overall performance. It does not necessarily mean that the cluster will fail.

6.1. OPENSIFT CONTAINER PLATFORM CLUSTER LIMITS

Limit type	3.9 limit	3.10 limit	3.11 limit	4.1 limit
Number of nodes [a]	2,000	2,000	2,000	2,000
Number of pods [b]	120,000	150,000	150,000	150,000
Number of pods per node	250	250	250	250
Number of pods per core	10 is the default value. The maximum supported value is the number of pods per node.	There is no default value. The maximum supported value is the number of pods per node.	There is no default value. The maximum supported value is the number of pods per node.	There is no default value. The maximum supported value is the number of pods per node.
Number of namespaces [c]	10,000	10,000	10,000	10,000
Number of builds: Pipeline Strategy	10,000 (Default pod RAM 512 Mi)	10,000 (Default pod RAM 512 Mi)	10,000 (Default pod RAM 512 Mi)	10,000 (Default pod RAM 512 Mi)
Number of pods per namespace [d]	3,000	3,000	25,000	25,000
Number of services [e]	10,000	10,000	10,000	10,000
Number of services per namespace	N/A	5,000	5,000	5,000

Limit type	3.9 limit	3.10 limit	3.11 limit	4.1 limit
Number of back-ends per service	5,000	5,000	5,000	5,000
Number of deployments per namespace ^[d]	2,000	2,000	2,000	2,000

[a] Clusters with more than the stated limit are not supported. Consider splitting into multiple clusters.

[b] The pod count displayed here is the number of test pods. The actual number of pods depends on the application's memory, CPU, and storage requirements.

[c] When there are a large number of active projects, etcd may suffer from poor performance if the key space grows excessively large and exceeds the space quota. Periodic maintenance of etcd, including defragmentation, is highly recommended to free etcd storage.

[d] There are a number of control loops in the system that must iterate over all objects in a given namespace as a reaction to some changes in state. Having a large number of objects of a given type in a single namespace can make those loops expensive and slow down processing given state changes. The limit assumes that the system has enough CPU, memory, and disk to satisfy the application requirements.

[e] Each service port and each service back-end has a corresponding entry in iptables. The number of back-ends of a given service impact the size of the endpoints objects, which impacts the size of data that is being sent all over the system.

In OpenShift Container Platform 4.1, half of a CPU core (500 millicore) is now reserved by the system compared to OpenShift Container Platform 3.11 and previous versions.

In OpenShift Container Platform 4.1, the tested node limit has been lowered until scale tests can be run at a higher node count.

6.2. HOW TO PLAN YOUR ENVIRONMENT ACCORDING TO CLUSTER LIMITS



IMPORTANT

Oversubscribing the physical resources on a node affects resource guarantees the Kubernetes scheduler makes during pod placement. Learn what measures you can take to avoid memory swapping.



IMPORTANT

Some of the limits are stretched only in a single dimension. They will vary when many objects are running on the cluster.

While planning your environment, determine how many pods are expected to fit per node:

$$\text{Maximum Pods per Cluster} / \text{Expected Pods per Node} = \text{Total Number of Nodes}$$

The number of pods expected to fit on a node is dependent on the application itself. Consider the application's memory, CPU, and storage requirements.

Example scenario

If you want to scope your cluster for 2200 pods per cluster, you would need at least nine nodes, assuming that there are 250 maximum pods per node:

$$2200 / 250 = 8.8$$

If you increase the number of nodes to 20, then the pod distribution changes to 110 pods per node:

$$2200 / 20 = 110$$

6.3. HOW TO PLAN YOUR ENVIRONMENT ACCORDING TO APPLICATION REQUIREMENTS

Consider an example application environment:

Pod type	Pod quantity	Max memory	CPU cores	Persistent storage
apache	100	500 MB	0.5	1 GB
node.js	200	1 GB	1	1 GB
postgresql	100	1 GB	2	10 GB
JBoss EAP	100	1 GB	1	1 GB

Extrapolated requirements: 550 CPU cores, 450GB RAM, and 1.4TB storage.

Instance size for nodes can be modulated up or down, depending on your preference. Nodes are often resource overcommitted. In this deployment scenario, you can choose to run additional smaller nodes or fewer larger nodes to provide the same amount of resources. Factors such as operational agility and cost-per-instance should be considered.

Node type	Quantity	CPUs	RAM (GB)
Nodes (option 1)	100	4	16
Nodes (option 2)	50	8	32
Nodes (option 3)	25	16	64

Some applications lend themselves well to overcommitted environments, and some do not. Most Java applications and applications that use huge pages are examples of applications that would not allow for overcommitment. That memory can not be used for other applications. In the example above, the environment would be roughly 30 percent overcommitted, a common ratio.

CHAPTER 7. OPTIMIZING STORAGE

Optimizing storage helps to minimize storage use across all resources. By optimizing storage, administrators help ensure that existing storage resources are working in an efficient manner.

7.1. AVAILABLE PERSISTENT STORAGE OPTIONS

Understand your persistent storage options so that you can optimize your OpenShift Container Platform environment.

Table 7.1. Available storage options

Storage type	Description	Examples
Block	<ul style="list-style-type: none"> Presented to the operating system (OS) as a block device Suitable for applications that need full control of storage and operate at a low level on files bypassing the file system Also referred to as a Storage Area Network (SAN) Non-shareable, which means that only one client at a time can mount an endpoint of this type 	Ceph RBD, OpenStack Cinder, AWS EBS, Azure Disk, GCE persistent disk, and VMware vSphere support dynamic persistent volume (PV) provisioning natively in OpenShift Container Platform.
File	<ul style="list-style-type: none"> Presented to the OS as a file system export to be mounted Also referred to as Network Attached Storage (NAS) Concurrency, latency, file locking mechanisms, and other capabilities vary widely between protocols, implementations, vendors, and scales. 	RHEL NFS, NetApp NFS ^[a] , Azure File, Vendor NFS, AWS EFS
Object	<ul style="list-style-type: none"> Accessible through a REST API endpoint Configurable for use in the OpenShift Container Platform Registry Applications must build their drivers into the application and/or container. 	Ceph Object Storage (RADOS Gateway), OpenStack Swift, Aliyun OSS, AWS S3, Google Cloud Storage, Azure Blob Storage
[a] NetApp NFS supports dynamic PV provisioning when using the Trident plug-in.		

**IMPORTANT**

Currently, CNS is not supported in OpenShift Container Platform 4.1.

7.2. RECOMMENDED CONFIGURABLE STORAGE TECHNOLOGY

The following table summarizes the recommended and configurable storage technologies for the given OpenShift Container Platform cluster application.

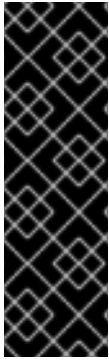
Table 7.2. Recommended and configurable storage technology

Storage type	ROX [a]	RWX [b]	Registry	Scaled registry	Metrics [c]	Logging	Apps
Block	Yes [d]	No	Configurable	Not configurable	Recommended	Recommended	Recommended
File	Yes [d]	Yes	Configurable	Configurable	Configurable [e]	Configurable [f]	Recommended
Object	Yes	Yes	Recommended	Recommended	Not configurable	Not configurable	Not configurable [g]
<p>[a] ReadOnlyMany</p> <p>[b] ReadWriteMany</p> <p>[c] Prometheus is the underlying technology used for metrics.</p> <p>[d] This does not apply to physical disk, VM physical disk, VMDK, loopback over NFS, AWS EBS, and Azure Disk.</p> <p>[e] For metrics, using file storage with the ReadWriteMany (RWX) access mode is unreliable. If you use file storage, do not configure the RWX access mode on any PersistentVolumeClaims that are configured for use with metrics.</p> <p>[f] For logging, using any shared storage would be an anti-pattern. One volume per elasticsearch is required.</p> <p>[g] Object storage is not consumed through OpenShift Container Platform's PVs/persistent volume claims (PVCs). Apps must integrate with the object storage REST API.</p>							

**NOTE**

A scaled registry is an OpenShift Container Platform registry where three or more pod replicas are running.

7.2.1. Specific application storage recommendations



IMPORTANT

Testing shows issues with using the NFS server on RHEL as storage backend for the container image registry. This includes the OpenShift Container Registry and Quay, Cassandra for metrics storage, and Elasticsearch for logging storage. Therefore, using 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 core components.

7.2.1.1. Registry

In a non-scaled/high-availability (HA) OpenShift Container Platform registry cluster deployment:

- The preferred storage technology is object storage followed by block storage. The storage technology does not have to support RWX access mode.
- The storage technology must ensure read-after-write consistency. All NAS storage are not recommended for OpenShift Container Platform Registry cluster deployment with production workloads.
- While **hostPath** volumes are configurable for a non-scaled/HA OpenShift Container Platform Registry, they are not recommended for cluster deployment.

7.2.1.2. Scaled registry

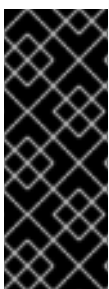
In a scaled/HA OpenShift Container Platform registry cluster deployment:

- The preferred storage technology is object storage. The storage technology must support RWX access mode and must ensure read-after-write consistency.
- File storage and block storage are not recommended for a scaled/HA OpenShift Container Platform registry cluster deployment with production workloads.
- All NAS storage are not recommended for OpenShift Container Platform Registry cluster deployment with production workloads.

7.2.1.3. Metrics

In an OpenShift Container Platform hosted metrics cluster deployment:

- The preferred storage technology is block storage.



IMPORTANT

Testing shows significant unrecoverable corruptions using file storage and, therefore, file storage is not recommended for use with metrics.

There are file storage implementations in the marketplace that might not have these issues. Contact the individual storage vendor for more information on any testing that was possibly completed against these OpenShift core components.

7.2.1.4. Logging

In an OpenShift Container Platform hosted logging cluster deployment:

- The preferred storage technology is block storage.
- It is not recommended to use NAS storage for a hosted metrics cluster deployment with production workloads.



IMPORTANT

Testing shows issues with using the NFS server on RHEL as storage backend for the container image registry. This includes Elasticsearch for logging storage. Therefore, using 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 core components.

7.2.1.5. Applications

Application use cases vary from application to application, as described in the following examples:

- Storage technologies that support dynamic PV provisioning have low mount time latencies, and are not tied to nodes to support a healthy cluster.
- Application developers are responsible for knowing and understanding the storage requirements for their application, and how it works with the provided storage to ensure that issues do not occur when an application scales or interacts with the storage layer.

7.2.2. Other specific application storage recommendations

- OpenShift Container Platform Internal **etcd**: For the best etcd reliability, the lowest consistent latency storage technology is preferable.
- OpenStack Cinder: OpenStack Cinder tends to be adept in ROX access mode use cases.
- Databases: Databases (RDBMSs, NoSQL DBs, etc.) tend to perform best with dedicated block storage.

CHAPTER 8. OPTIMIZING ROUTING

The OpenShift Container Platform HAProxy router scales to optimize performance.

8.1. BASELINE ROUTER PERFORMANCE

The OpenShift Container Platform router is the Ingress point for all external traffic destined for OpenShift Container Platform services.

When evaluating a single HAProxy router performance in terms of HTTP requests handled per second, the performance varies depending on many factors. In particular:

- HTTP keep-alive/close mode
- route type
- TLS session resumption client support
- number of concurrent connections per target route
- number of target routes
- back end server page size
- underlying infrastructure (network/SDN solution, CPU, and so on)

While performance in your specific environment will vary, Red Hat lab tests on a public cloud instance of size 4 vCPU/16GB RAM, a single HAProxy router handling 100 routes terminated by backends serving 1kB static pages is able to handle the following number of transactions per second.

In HTTP keep-alive mode scenarios:

Encryption	LoadBalancerService	HostNetwork
none	21515	29622
edge	16743	22913
passthrough	36786	53295
re-encrypt	21583	25198

In HTTP close (no keep-alive) scenarios:

Encryption	LoadBalancerService	HostNetwork
none	5719	8273
edge	2729	4069
passthrough	4121	5344

Encryption	LoadBalancerService	HostNetwork
re-encrypt	2320	2941

Default router configuration with **ROUTER_THREADS=4** was used and two different endpoint publishing strategies (LoadBalancerService/HostNetwork) tested. TLS session resumption was used for encrypted routes. With HTTP keep-alive, a single HAProxy router is capable of saturating 1 Gbit NIC at page sizes as small as 8 kB.

When running on bare metal with modern processors, you can expect roughly twice the performance of the public cloud instance above. This overhead is introduced by the virtualization layer in place on public clouds and holds mostly true for private cloud-based virtualization as well. The following table is a guide on how many applications to use behind the router:

Number of applications	Application type
5-10	static file/web server or caching proxy
100-1000	applications generating dynamic content

In general, HAProxy can support routes for 5 to 1000 applications, depending on the technology in use. Router performance might be limited by the capabilities and performance of the applications behind it, such as language or static versus dynamic content.

Router sharding should be used to serve more routes towards applications and help horizontally scale the routing tier.

8.2. ROUTER PERFORMANCE OPTIMIZATIONS

Setting the maximum number of connections

One of the most important tunable parameters for HAProxy scalability is the **maxconn** parameter, which sets the maximum per-process number of concurrent connections to a given number. Adjust this parameter by editing the **ROUTER_MAX_CONNECTIONS** environment variable in the OpenShift Container Platform HAProxy router's deployment configuration file.



NOTE

A connection includes the front end and internal back end. This counts as two connections. Be sure to set **ROUTER_MAX_CONNECTIONS** to double than the number of connections you intend to create.

CPU and interrupt affinity

In OpenShift Container Platform, the HAProxy router runs as a single process. The OpenShift Container Platform HAProxy router typically performs better on a system with fewer but high frequency cores, rather than on an symmetric multiprocessing (SMP) system with a high number of lower frequency cores.

Pinning the HAProxy process to one CPU core and the network interrupts to another CPU core tends to increase network performance. Having processes and interrupts on the same non-uniform memory

access (NUMA) node helps avoid memory accesses by ensuring a shared L3 cache. However, this level of control is generally not possible on a public cloud environment.

CPU pinning is performed either by **taskset** or by using HAProxy's **cpu-map** parameter. This directive takes two arguments: the process ID and the CPU core ID. For example, to pin HAProxy process **1** onto CPU core **0**, add the following line to the global section of HAProxy's configuration file:

```
cpu-map 1 0
```

Increasing the number of threads

The HAProxy router comes with support for multithreading in OpenShift Container Platform. On a multiple CPU core system, increasing the number of threads can help the performance, especially when terminating SSL on the router.

Impacts of buffer increases

The OpenShift Container Platform HAProxy router request buffer configuration limits the size of headers in incoming requests and responses from applications. The HAProxy parameter **tune.bufsize** can be increased to allow processing of larger headers and to allow applications with very large cookies to work, such as those accepted by load balancers provided by many public cloud providers. However, this affects the total memory use, especially when large numbers of connections are open. With very large numbers of open connections, the memory usage will be nearly proportionate to the increase of this tunable parameter.

Optimizations for HAProxy reloads

Long-lasting connections, such as WebSocket connections, combined with long client/server HAProxy timeouts and short HAProxy reload intervals, can cause instantiation of many HAProxy processes. These processes must handle old connections, which were started before the HAProxy configuration reload. A large number of these processes is undesirable, as it will exert unnecessary load on the system and can lead to issues, such as out of memory conditions.

Router environment variables affecting this behavior are **ROUTER_DEFAULT_TUNNEL_TIMEOUT**, **ROUTER_DEFAULT_CLIENT_TIMEOUT**, **ROUTER_DEFAULT_SERVER_TIMEOUT**, and **RELOAD_INTERVAL** in particular.

CHAPTER 9. WHAT HUGE PAGES DO AND HOW THEY ARE CONSUMED BY APPLICATIONS

9.1. WHAT HUGE PAGES DO

Memory is managed in blocks known as pages. On most systems, a page is 4Ki. 1Mi of memory is equal to 256 pages; 1Gi of memory is 256,000 pages, and so on. CPUs have a built-in memory management unit that manages a list of these pages in hardware. The Translation Lookaside Buffer (TLB) is a small hardware cache of virtual-to-physical page mappings. If the virtual address passed in a hardware instruction can be found in the TLB, the mapping can be determined quickly. If not, a TLB miss occurs, and the system falls back to slower, software-based address translation, resulting in performance issues. Since the size of the TLB is fixed, the only way to reduce the chance of a TLB miss is to increase the page size.

A huge page is a memory page that is larger than 4Ki. On x86_64 architectures, there are two common huge page sizes: 2Mi and 1Gi. Sizes vary on other architectures. In order to use huge pages, code must be written so that applications are aware of them. Transparent Huge Pages (THP) attempt to automate the management of huge pages without application knowledge, but they have limitations. In particular, they are limited to 2Mi page sizes. THP can lead to performance degradation on nodes with high memory utilization or fragmentation due to defragmenting efforts of THP, which can lock memory pages. For this reason, some applications may be designed to (or recommend) usage of pre-allocated huge pages instead of THP.

In OpenShift Container Platform, applications in a pod can allocate and consume pre-allocated huge pages.

9.2. HOW HUGE PAGES ARE CONSUMED BY APPS

Nodes must pre-allocate huge pages in order for the node to report its huge page capacity. A node can only pre-allocate huge pages for a single size.

Huge pages can be consumed through container-level resource requirements using the resource name **hugepages-<size>**, where size is the most compact binary notation using integer values supported on a particular node. For example, if a node supports 2048KiB page sizes, it exposes a schedulable resource **hugepages-2Mi**. Unlike CPU or memory, huge pages do not support over-commitment.

```
apiVersion: v1
kind: Pod
metadata:
  generateName: hugepages-volume-
spec:
  containers:
  - securityContext:
      privileged: true
    image: rhel7:latest
    command:
    - sleep
    - inf
    name: example
    volumeMounts:
    - mountPath: /dev/hugepages
      name: hugepage
  resources:
    limits:
```



```

hugepages-2Mi: 100Mi 1
memory: "1Gi"
cpu: "1"
volumes:
- name: hugepage
  emptyDir:
    medium: HugePages

```

- 1** Specify the amount of memory for **hugepages** as the exact amount to be allocated. Do not specify this value as the amount of memory for **hugepages** multiplied by the size of the page. For example, given a huge page size of 2MB, if you want to use 100MB of huge-page-backed RAM for your application, then you would allocate 50 huge pages. OpenShift Container Platform handles the math for you. As in the above example, you can specify **100MB** directly.

Allocating huge pages of a specific size

Some platforms support multiple huge page sizes. To allocate huge pages of a specific size, precede the huge pages boot command parameters with a huge page size selection parameter **hugepagesz=<size>**. The **<size>** value must be specified in bytes with an optional scale suffix [**kKmMgG**]. The default huge page size can be defined with the **default_hugepagesz=<size>** boot parameter.

Huge page requirements

- Huge page requests must equal the limits. This is the default if limits are specified, but requests are not.
- Huge pages are isolated at a pod scope. Container isolation is planned in a future iteration.
- **EmptyDir** volumes backed by huge pages must not consume more huge page memory than the pod request.
- Applications that consume huge pages via **shmget()** with **SHM_HUGETLB** must run with a supplemental group that matches *proc/sys/vm/hugetlb_shm_group*.

Additional resources

- [Configuring Transparent Huge Pages](#)

9.3. CONFIGURING HUGE PAGES

Nodes must pre-allocate huge pages used in an OpenShift Container Platform cluster. Use the Node Tuning Operator to allocate huge pages on a specific node.

Procedure

1. Label the node so that the Node Tuning Operator knows on which node to apply the tuned profile, which describes how many huge pages should be allocated:

```
$ oc label node <node_using_hugepages> hugepages=true
```

2. Create a file with the following content and name it **hugepages_tuning.yaml**:

```

apiVersion: tuned.openshift.io/v1
kind: Tuned

```

```

metadata:
  name: hugepages ❶
  namespace: openshift-cluster-node-tuning-operator
spec:
  profile: ❷
  - data: |
      [main]
      summary=Configuration for hugepages
      include=openshift-node

      [vm]
      transparent_hugepages=never

      [sysctl]
      vm.nr_hugepages=1024
      name: node-hugepages
  recommend:
  - match: ❸
    - label: hugepages
    priority: 30
    profile: node-hugepages

```

- ❶ Set the **name** parameter value to **hugepages**.
- ❷ Set the **profile** section to allocate huge pages.
- ❸ Set the **match** section to associate the profile to nodes with the **hugepages** label.

3. Create the custom **hugepages** tuned profile by using the **hugepages_tuning.yaml** file:

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

4. After creating the profile, the Operator applies the new profile to the correct node and allocates huge pages. Check the logs of a tuned pod on a node using huge pages to verify:

```
$ oc logs <tuned_pod_on_node_using_hugepages> \
  -n openshift-cluster-node-tuning-operator | grep 'applied$' | tail -n1
```

```
2019-08-08 07:20:41,286 INFO    tuned.daemon.daemon: static tuning from profile 'node-
hugepages' applied
```