



# **Guarantee throughput with QoS**

## **ONTAP 9**

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# Guarantee throughput with QoS

## Guarantee throughput with QoS overview

You can use storage quality of service (QoS) to guarantee that performance of critical workloads is not degraded by competing workloads. You can set a throughput *ceiling* on a competing workload to limit its impact on system resources, or set a throughput *floor* for a critical workload, ensuring that it meets minimum throughput targets, regardless of demand by competing workloads. You can even set a ceiling and floor for the same workload.

### About throughput ceilings (QoS Max)

A throughput ceiling limits throughput for a workload to a maximum number of IOPS or MBps, or IOPS and MBps. In the figure below, the throughput ceiling for workload 2 ensures that it does not "bully" workloads 1 and 3.

A *policy group* defines the throughput ceiling for one or more workloads. A workload represents the I/O operations for a *storage object*: a volume, file, qtree or LUN, or all the volumes, files, qtrees, or LUNs in an SVM. You can specify the ceiling when you create the policy group, or you can wait until after you monitor workloads to specify it.



Throughput to workloads might exceed the specified ceiling by up to 10%, especially if a workload experiences rapid changes in throughput. The ceiling might be exceeded by up to 50% to handle bursts. Bursts occur on single nodes when tokens accumulate up to 150%



### About throughput floors (QoS Min)

A throughput floor guarantees that throughput for a workload does not fall below a minimum number of IOPS or MBps, or IOPS and MBps. In the figure below, the throughput floors for workload 1 and workload 3 ensure that they meet minimum throughput targets, regardless of demand by workload 2.



As the examples suggest, a throughput ceiling throttles throughput directly. A throughput floor throttles throughput indirectly, by giving priority to the workloads for which the floor has been set.

A policy group that defines a throughput floor cannot be applied to an SVM. You can specify the floor when you create the policy group, or you can wait until after you monitor workloads to specify it.



In releases before ONTAP 9.7, throughput floors are guaranteed when there is sufficient performance capacity available. In ONTAP 9.7 and later, throughput floors can be guaranteed even when there is insufficient performance capacity available. This new floor behavior is called floors v2. To meet the guarantees, floors v2 can result in higher latency on workloads without a throughput floor or on work that exceeds the floor settings. Floors v2 applies to both QoS and adaptive QoS. The option of enabling/disabling the new behavior of floors v2 is available in ONTAP 9.7P6 and later. A workload might fall below the specified floor during critical operations like `volume move trigger-cutover`. Even when sufficient capacity is available and critical operations are not taking place, throughput to a workload might fall below the specified floor by up to 5%. If floors are overprovisioned and there is no performance capacity, some workloads might fall below the specified floor.



## About shared and non-shared QoS policy groups

Beginning with ONTAP 9.4, you can use a *non-shared* QoS policy group to specify that the defined throughput ceiling or floor applies to each member workload individually. Behavior of *shared* policy groups depends on the policy type:

- For throughput ceilings, the total throughput for the workloads assigned to the shared policy group cannot exceed the specified ceiling.
- For throughput floors, the shared policy group can be applied to a single workload only.

## About adaptive QoS

Ordinarily, the value of the policy group you assign to a storage object is fixed. You need to change the value manually when the size of the storage object changes. An increase in the amount of space used on a volume, for example, usually requires a corresponding increase in the throughput ceiling specified for the volume.

*Adaptive QoS* automatically scales the policy group value to workload size, maintaining the ratio of IOPS to TBs|GBs as the size of the workload changes. That is a significant advantage when you are managing hundreds or thousands of workloads in a large deployment.

You typically use adaptive QoS to adjust throughput ceilings, but you can also use it to manage throughput floors (when workload size increases). Workload size is expressed as either the allocated space for the storage object or the space used by the storage object.



Used space is available for throughput floors in ONTAP 9.5 and later. It is not supported for throughput floors in ONTAP 9.4 and earlier.

- An *allocated space* policy maintains the IOPS/TB|GB ratio according to the nominal size of the storage object. If the ratio is 100 IOPS/GB, a 150 GB volume will have a throughput ceiling of 15,000 IOPS for as long as the volume remains that size. If the volume is resized to 300 GB, adaptive QoS adjusts the throughput ceiling to 30,000 IOPS.
- A *used space* policy (the default) maintains the IOPS/TB|GB ratio according to the amount of actual data stored before storage efficiencies. If the ratio is 100 IOPS/GB, a 150 GB volume that has 100 GB of data stored would have a throughput ceiling of 10,000 IOPS. As the amount of used space changes, adaptive QoS adjusts the throughput ceiling according to the ratio.

Beginning with ONTAP 9.5, you can specify an I/O block size for your application that enables a throughput limit to be expressed in both IOPS and MBps. The MBps limit is calculated from the block size multiplied by the IOPS limit. For example, an I/O block size of 32K for an IOPS limit of 6144IOPS/TB yields an MBps limit of 192MBps.

You can expect the following behavior for both throughput ceilings and floors:

- When a workload is assigned to an adaptive QoS policy group, the ceiling or floor is updated immediately.
- When a workload in an adaptive QoS policy group is resized, the ceiling or floor is updated in approximately five minutes.

Throughput must increase by at least 10 IOPS before updates take place.

Adaptive QoS policy groups are always non-shared: the defined throughput ceiling or floor applies to each member workload individually.

Beginning with ONTAP 9.6, throughput floors is supported on ONTAP Select premium with SSD.

## General support

The following table shows the differences in support for throughput ceilings, throughput floors, and adaptive QoS.

| Resource or feature | Throughput ceiling | Throughput floor   | Throughput floor v2  | Adaptive QoS  |
|---------------------|--------------------|--|--|---------------|
| ONTAP 9 version     | All                | 9.2 and later  | 9.7 and later  | 9.3 and later |
| Platforms           | All                | <ul style="list-style-type: none"><li>• AFF</li><li>• C190 *</li><li>• ONTAP Select premium with SSD *</li></ul> | <ul style="list-style-type: none"><li>• AFF</li><li>• C190</li><li>• ONTAP Select premium with SSD</li></ul> | All           |
| Protocols           | All                | All  | All  | All           |

|                        |     |   |   |     |
|------------------------|-----|---|---|-----|
| FabricPool             | Yes | Yes, if the tiering policy is set to "none" and no blocks are in the cloud. | Yes, if the tiering policy is set to "none" and no blocks are in the cloud. | Yes |
| SnapMirror Synchronous | Yes | No  | No  | Yes |

\*C190 and ONTAP Select support started with the ONTAP 9.6 release.

## Supported workloads for throughput ceilings

The following table shows workload support for throughput ceilings by ONTAP 9 version. Root volumes, load-sharing mirrors, and data protection mirrors are not supported.

| Workload support - ceiling          | 9.0 | 9.1 | 9.2 | 9.3 | 9.4 and later | 9.8 and later |
|-------------------------------------|-----|-----|-----|-----|---------------|---------------|
| Volume                              | yes | yes | yes | yes | yes           | yes           |
| File                                | yes | yes | yes | yes | yes           | yes           |
| LUN                                 | yes | yes | yes | yes | yes           | yes           |
| SVM                                 | yes | yes | yes | yes | yes           | yes           |
| FlexGroup volume                    | no  | no  | no  | yes | yes           | yes           |
| qtrees*                             | no  | no  | no  | no  | no            | yes           |
| Multiple workloads per policy group | yes | yes | yes | yes | yes           | yes           |
| Non-shared policy groups            | no  | no  | no  | no  | yes           | yes           |

\*Beginning with ONTAP 9.8, NFS access is supported in qtrees in FlexVol and FlexGroup volumes with NFS enabled. Beginning with ONTAP 9.9.1, SMB access is also supported in qtrees in FlexVol and FlexGroup volumes with SMB enabled.

## Supported workloads for throughput floors

The following table shows workload support for throughput floors by ONTAP 9 version. Root volumes, load-sharing mirrors, and data protection mirrors are not supported.

| <b>Workload support - floor</b>     | <b>9.2</b> | <b>9.3</b> | <b>9.4 and later</b> | <b>9.8 and later</b> |
|-------------------------------------|------------|------------|----------------------|----------------------|
| Volume                              | yes        | yes        | yes                  | yes                  |
| File                                | no         | yes        | yes                  | yes                  |
| LUN                                 | yes        | yes        | yes                  | yes                  |
| SVM                                 | no         | no         | no                   | yes                  |
| FlexGroup volume                    | no         | no         | yes                  | yes                  |
| qtrees *                            | no         | no         | no                   | yes                  |
| Multiple workloads per policy group | no         | no         | yes                  | yes                  |
| Non-shared policy groups            | no         | no         | yes                  | yes                  |

\*Beginning with ONTAP 9.8, NFS access is supported in qtrees in FlexVol and FlexGroup volumes with NFS enabled. Beginning with ONTAP 9.9.1, SMB access is also supported in qtrees in FlexVol and FlexGroup volumes with SMB enabled.

## Supported workloads for adaptive QoS

The following table shows workload support for adaptive QoS by ONTAP 9 version. Root volumes, load-sharing mirrors, and data protection mirrors are not supported.

| <b>Workload support - adaptive QoS</b> | <b>9.3</b> | <b>9.4 and later</b> |
|--|------------|----------------------|
| Volume                                 | yes        | yes                  |
| File                                   | no         | yes                  |
| LUN                                    | no         | yes                  |
| SVM                                    | no         | no                   |
| FlexGroup volume                       | no         | yes                  |
| Multiple workloads per policy group    | yes        | yes                  |
| Non-shared policy groups               | yes        | yes                  |

## Maximum number of workloads and policy groups

The following table shows the maximum number of workloads and policy groups by ONTAP 9 version.

| Workload support              | 9.3 and earlier | 9.4 and later |
|-------------------------------|-----------------|---------------|
| Maximum workloads per cluster | 12,000          | 40,000        |
| Maximum workloads per node    | 12,000          | 40,000        |
| Maximum policy groups         | 12,000          | 12,000        |

## Enable or disable throughput floors v2

You can enable or disable throughput floors v2 on AFF. The default is enabled. With floors v2 enabled, throughput floors can be met when controllers are heavily used at the expense of higher latency on other workloads. Floors v2 applies to both QoS and Adaptive QoS.

### Steps

1. Change to advanced privilege level:

```
set -privilege advanced
```

2. Enter one of the following commands:

| If you want to... | Use this command:  |
|-------------------|--|
| Disable floors v2 | <pre>qos settings throughput-floors-v2<br/>-enable false</pre> |
| Enable floors v2  | <pre>qos settings throughput-floors-v2<br/>-enable true</pre>  |



To disable throughput floors v2 in an MetroCluster cluster, you must run the

```
qos settings throughput-floors-v2 -enable false
```

command on both the source and destination clusters.

```
cluster1::*> qos settings throughput-floors-v2 -enable false
```

## Storage QoS workflow

If you already know the performance requirements for the workloads you want to manage



with QoS, you can specify the throughput limit when you create the policy group. Otherwise, you can wait until after you monitor the workloads to specify the limit.

## Set a throughput ceiling with QoS

You can use the `max-throughput` field for a policy group to define a throughput ceiling for storage object workloads (QoS Max). You can apply the policy group when you create or modify the storage object.

### What you'll need

- You must be a cluster administrator to create a policy group.
- You must be a cluster administrator to apply a policy group to an SVM.

### About this task

- Beginning with ONTAP 9.4, you can use a *non-shared* QoS policy group to specify that the defined throughput ceiling applies to each member workload individually. Otherwise, the policy group is *shared*: the total throughput for the workloads assigned to the policy group cannot exceed the specified ceiling.

Set `-is-shared=false` for the `qos policy-group create` command to specify a non-shared policygroup.

- You can specify the throughput limit for the ceiling in IOPS, MB/s, or IOPS, MB/s. If you specify both IOPS and MB/s, whichever limit is reached first is enforced.



If you set a ceiling and a floor for the same workload, you can specify the throughput limit for the ceiling in IOPS only.

- A storage object that is subject to a QoS limit must be contained by the SVM to which the policy group belongs. Multiple policy groups can belong to the same SVM.
- You cannot assign a storage object to a policy group if its containing object or its child objects belong to the policy group.
- It is a QoS best practice to apply a policy group to the same type of storage objects.

### Steps

1. Create a policy group:

```
qos policy-group create -policy-group policy_group -vserver SVM -max-throughput number_of_iops|Mb/S|iops,Mb/S -is-shared true|false
```

For complete command syntax, see the man page. You can use the `qos policy-group modify` command to adjust throughput ceilings.

The following command creates the shared policy group `pg-vs1` with a maximum throughput of 5,000 IOPS:

```
cluster1::> qos policy-group create -policy-group pg-vs1 -vserver vs1 -max-throughput 5000iops -is-shared true
```

The following command creates the non-shared policy group `pg-vs3` with a maximum throughput of 100 IOPS and 400 Kb/S:

```
cluster1::> qos policy-group create -policy-group pg-vs3 -vserver vs3
-max-throughput 100iops,400KB/s -is-shared false
```

The following command creates the non-shared policy group `pg-vs4` without a throughput limit:

```
cluster1::> qos policy-group create -policy-group pg-vs4 -vserver vs4
-is-shared false
```

## 2. Apply a policy group to an SVM, file, volume, or LUN:

```
storage_object create -vserver SVM -qos-policy-group policy_group
```

For complete command syntax, see the man pages. You can use the `storage_object modify` command to apply a different policy group to the storage object.

The following command applies policy group `pg-vs1` to SVM `vs1`:

```
cluster1::> vserver create -vserver vs1 -qos-policy-group pg-vs1
```

The following commands apply policy group `pg-app` to the volumes `app1` and `app2`:

```
cluster1::> volume create -vserver vs2 -volume app1 -aggregate aggr1
-qos-policy-group pg-app
```

```
cluster1::> volume create -vserver vs2 -volume app2 -aggregate aggr1
-qos-policy-group pg-app
```

## 3. Monitor policy group performance:

```
qos statistics performance show
```

For complete command syntax, see the man page.



Monitor performance from the cluster. Do not use a tool on the host to monitor performance.

The following command shows policy group performance:

```
cluster1::> qos statistics performance show
```

| Policy Group        | IOPS  | Throughput | Latency   |
|---------------------|-------|------------|-----------|
| -total-             | 12316 | 47.76MB/s  | 1264.00us |
| pg_vs1              | 5008  | 19.56MB/s  | 2.45ms    |
| _System-Best-Effort | 62    | 13.36KB/s  | 4.13ms    |
| _System-Background  | 30    | 0KB/s      | 0ms       |

#### 4. Monitor workload performance:

```
qos statistics workload performance show
```

For complete command syntax, see the man page.



Monitor performance from the cluster. Do not use a tool on the host to monitor performance.

The following command shows workload performance:

```
cluster1::> qos statistics workload performance show
```

| Workload        | ID    | IOPS  | Throughput | Latency   |
|-----------------|-------|-------|------------|-----------|
| -total-         | -     | 12320 | 47.84MB/s  | 1215.00us |
| app1-wid7967    | 7967  | 7219  | 28.20MB/s  | 319.00us  |
| vs1-wid12279    | 12279 | 5026  | 19.63MB/s  | 2.52ms    |
| _USERSPACE_APPS | 14    | 55    | 10.92KB/s  | 236.00us  |
| _Scan_Backgro.. | 5688  | 20    | 0KB/s      | 0ms       |



You can use the `qos statistics workload latency show` command to view detailed latency statistics for QoS workloads.

## Set a throughput floor with QoS

You can use the `min-throughput` field for a policy group to define a throughput floor for storage object workloads (QoS Min). You can apply the policy group when you create or modify the storage object. Beginning with ONTAP 9.8, you can specify the throughput floor in IOPS or MBps, or IOPS and MBps.

#### What you'll need

- You must be running ONTAP 9.2 or later. Throughput floors are available beginning with ONTAP 9.2.
- You must be a cluster administrator to create a policy group.

#### About this task

- Beginning with ONTAP 9.4, you can use a *non-shared* QoS policy group to specify that the defined throughput floor be applied to each member workload individually. This is the only condition in which a

policy group for a throughput floor can be applied to multiple workloads.

Set `-is-shared=false` for the `qos policy-group create` command to specify a non-shared policy group.

- Throughput to a workload might fall below the specified floor if there is insufficient performance capacity (headroom) on the node or aggregate.
- A storage object that is subject to a QoS limit must be contained by the SVM to which the policy group belongs. Multiple policy groups can belong to the same SVM.
- It is a QoS best practice to apply a policy group to the same type of storage objects.
- A policy group that defines a throughput floor cannot be applied to an SVM.

## Steps

1. Check for adequate performance capacity on the node or aggregate, as described in [permalink :identify-remaining-performance-capacity-task.html](#)[Identifying remaining performance capacity].
2. Create a policy group:

```
qos policy-group create -policy group policy_group -vserver SVM -min  
-throughput qos_target -is-shared true|false
```

For complete command syntax, see the man page for your ONTAP release. You can use the `qos policy-group modify` command to adjust throughput floors.

The following command creates the shared policy group `pg-vs2` with a minimum throughput of 1,000 IOPS:

```
cluster1::> qos policy-group create -policy group pg-vs2 -vserver vs2  
-min-throughput 1000iops -is-shared true
```

The following command creates the non-shared policy group `pg-vs4` without a throughput limit:

```
cluster1::> qos policy-group create -policy group pg-vs4 -vserver vs4  
-is-shared false
```

3. Apply a policy group to a volume or LUN:

```
storage_object create -vserver SVM -qos-policy-group policy_group
```

For complete command syntax, see the man pages. You can use the `_storage_object_modify` command to apply a different policy group to the storage object.

The following command applies policy group `pg-app2` to the volume `app2`:

```
cluster1::> volume create -vserver vs2 -volume app2 -aggregate aggr1  
-qos-policy-group pg-app2
```

#### 4. Monitor policy group performance:

```
qos statistics performance show
```

For complete command syntax, see the man page.



Monitor performance from the cluster. Do not use a tool on the host to monitor performance.

The following command shows policy group performance:

```
cluster1::> qos statistics performance show
```

| Policy Group        | IOPS  | Throughput | Latency   |
|---------------------|-------|------------|-----------|
| -total-             | 12316 | 47.76MB/s  | 1264.00us |
| pg_app2             | 7216  | 28.19MB/s  | 420.00us  |
| _System-Best-Effort | 62    | 13.36KB/s  | 4.13ms    |
| _System-Background  | 30    | 0KB/s      | 0ms       |

#### 5. Monitor workload performance:

```
qos statistics workload performance show
```

For complete command syntax, see the man page.



Monitor performance from the cluster. Do not use a tool on the host to monitor performance.

The following command shows workload performance:

```
cluster1::> qos statistics workload performance show
```

| Workload        | ID    | IOPS  | Throughput | Latency   |
|-----------------|-------|-------|------------|-----------|
| -total-         | -     | 12320 | 47.84MB/s  | 1215.00us |
| app2-wid7967    | 7967  | 7219  | 28.20MB/s  | 319.00us  |
| vs1-wid12279    | 12279 | 5026  | 19.63MB/s  | 2.52ms    |
| _USERSPACE_APPS | 14    | 55    | 10.92KB/s  | 236.00us  |
| _Scan_Backgro.. | 5688  | 20    | 0KB/s      | 0ms       |



You can use the `qos statistics workload latency show` command to view detailed latency statistics for QoS workloads.

## Use adaptive QoS policy groups

You can use an *adaptive* QoS policy group to automatically scale a throughput ceiling or floor to volume size, maintaining the ratio of IOPS to TBs|GBs as the size of the volume changes. That is a significant advantage when you are managing hundreds or thousands

of workloads in a large deployment.

**What you'll need**

- You must be running ONTAP 9.3. Adaptive QoS policy groups are available beginning with ONTAP 9.3.
- You must be a cluster administrator to create a policy group.

**About this task**

A storage object can be a member of an adaptive policy group or a non-adaptive policy group, but not both. The SVM of the storage object and the policy must be the same. The storage object must be online.

Adaptive QoS policy groups are always non-shared: the defined throughput ceiling or floor applies to each member workload individually.

The ratio of throughput limits to storage object size is determined by the interaction of the following fields:

- `expected-iops` is the minimum expected IOPS per allocated TB|GB.



`expected-iops` is guaranteed on AFF platforms only. `expected-iops` is guaranteed for FabricPool only if the tiering policy is set to "none" and no blocks are in the cloud. `expected-iops` is guaranteed for volumes that are not in a SnapMirror Synchronous relationship.

- `peak-iops` is the maximum possible IOPS per allocated or used TB|GB.
- `expected-iops-allocation` specifies whether allocated space (the default) or used space is used for `expected-iops`.



`expected-iops-allocation` is available in ONTAP 9.5 and later. It is not supported in ONTAP 9.4 and earlier.

- `peak-iops-allocation` specifies whether allocated space or used space (the default) is used for `peak-iops`.
- `absolute-min-iops` is the absolute minimum number of IOPS. You can use this field with very small storage objects. It overrides both `peak-iops` and/or `expected-iops` when `absolute-min-iops` is greater than the calculated `expected-iops`.

For example, if you set `expected-iops` to 1,000 IOPS/TB, and the volume size is less than 1 GB, the calculated `expected-iops` will be a fractional IOP. The calculated `peak-iops` will be an even smaller fraction. You can avoid this by setting `absolute-min-iops` to a realistic value.

- `block-size` specifies the application I/O block size. The default is 32K. Valid values are 8K, 16K, 32K, 64K, ANY. ANY means that the block size is not enforced.

Three default adaptive QoS policy groups are available, as shown in the following table. You can apply these policy groups directly to a volume.

| Default policy group | Expected IOPS/TB | Peak IOPS/TB | Absolute Min IOPS |
|----------------------|------------------|--------------|-------------------|
| extreme              | 6,144            | 12,288       | 1000              |

|             |       |       |     |
|-------------|-------|-------|-----|
| performance | 2,048 | 4,096 | 500 |
| value       | 128   | 512   | 75  |

You cannot assign a storage object to a policy group if its containing object or its child objects belong to a policy group. The following table lists the restrictions.

| If you assign the...     | Then you cannot assign...                                       |
|--------------------------|---|
| SVM to a policy group    | Any storage objects contained by the SVM to a policy group      |
| Volume to a policy group | The volume's containing SVM or any child LUNs to a policy group |
| LUN to a policy group    | The LUN's containing volume or SVM to a policy group            |
| File to a policy group   | The file's containing volume or SVM to a policy group           |

## Steps

1. Create an adaptive QoS policy group:

```
qos adaptive-policy-group create -policy group policy_group -vserver SVM
-expected-iops number_of_iops/TB|GB -peak-iops number_of_iops/TB|GB -expected
-iops-allocation-space|used-space -peak-iops-allocation allocated-space|used-
space -absolute-min-iops number_of_iops -block-size 8K|16K|32K|64K|ANY
```

For complete command syntax, see the man page.



-expected-iops-allocation and -block-size is available in ONTAP 9.5 and later. These options are not supported in ONTAP 9.4 and earlier.

The following command creates adaptive QoS policy group `adpg-app1` with `-expected-iops` set to 300 IOPS/TB, `-peak-iops` set to 1,000 IOPS/TB, `-peak-iops-allocation` set to `used-space`, and `-absolute-min-iops` set to 50 IOPS:

```
cluster1::> qos adaptive-policy-group create -policy group adpg-app1
-vserver vs2 -expected-iops 300iops/tb -peak-iops 1000iops/TB -peak-iops
-allocation used-space -absolute-min-iops 50iops
```

2. Apply an adaptive QoS policy group to a volume:

```
volume create -vserver SVM -volume volume -aggregate aggregate -size number_of
TB|GB -qos-adaptive-policy-group policy_group
```

For complete command syntax, see the man pages.

The following command applies adaptive QoS policy group `adpg-app1` to volume `app1`:

```
cluster1::> volume create -vserver vs1 -volume app1 -aggregate aggr1  
-size 2TB -qos-adaptive-policy-group adpg-app1
```

The following commands apply the default adaptive QoS policy group `extreme` to the new volume `app4` and to the existing volume `app5`. The throughput ceiling defined for the policy group applies to volumes `app4` and `app5` individually:

```
cluster1::> volume create -vserver vs4 -volume app4 -aggregate aggr4  
-size 2TB -qos-adaptive-policy-group extreme
```

```
cluster1::> volume modify -vserver vs5 -volume app5 -qos-adaptive-policy  
-group extreme
```



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