



Performance management with the CLI

ONTAP 9

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Performance management with the CLI

Performance management overview

You can set up basic performance management tasks identify and resolve common performance issues.

You can use these procedures to monitor cluster performance if the following assumptions apply to your situation:

- You want to use best practices, not explore every available option.
- You do not want to read a lot of conceptual background.
- You want to display system status and alerts, monitor cluster performance, and perform root-cause analysis by using Active IQ Unified Manager (formerly OnCommand Unified Manager), in addition to the ONTAP command-line interface.
- You are using the ONTAP command-line interface to configure storage quality of service (QoS).

QoS is also available in System Manager, NSLM, WFA, VSC (VMware Plug-in), and APIs.

- You want to install Unified Manager by using a virtual appliance, instead of a Linux or Windows-based installation.
- You're willing to use a static configuration rather than DHCP to install the software.
- You can access ONTAP commands at the advanced privilege level.
- You are a cluster administrator with the "admin" role.

Related information

If these assumptions are not correct for your situation, you should see the following resources:

- [Active IQ Unified Manager 9.8 Installation](#)
- [System administration](#)
- [Performance monitoring setup](#)

Monitor performance

Performance monitoring workflow overview

Monitoring cluster performance involves installing Active IQ Unified Manager software, setting up basic monitoring tasks, and identifying performance issues.



Verify that your VMware environment is supported

For successful installation of Active IQ Unified Manager, you must verify that your VMware environment meets the necessary requirements.

Steps

1. Verify that your VMware infrastructure meets the sizing requirements for the installation of Unified Manager.
2. Go to the [Interoperability Matrix](#) to verify that you have a supported combination of the following components:

- ONTAP version
- ESXi operating system version
- VMware vCenter Server version
- VMware Tools version
- Browser type and version



The [Interoperability Matrix](#) lists the supported configurations for Unified Manager.

3. Click the configuration name for the selected configuration.

Details for that configuration are displayed in the Configuration Details window.

4. Review the information in the following tabs:

- Notes

Lists important alerts and information that are specific to your configuration.

- Policies and Guidelines

Provides general guidelines for all configurations.

Active IQ Unified Manager worksheet

Before you install, configure, and connect Active IQ Unified Manager, you should have specific information about your environment readily available. You can record the information in the worksheet.

Unified Manager installation information

Virtual machine on which software is deployed	Your value
ESXi server IP address	
Host fully qualified domain name	
Host IP address	
Network mask	
Gateway IP address	
Primary DNS address	
Secondary DNS address	
Search domains	
Maintenance user name	
Maintenance user password	

Unified Manager configuration information

Setting	Your value
Maintenance user email address	
NTP server	

Setting	Your value
SMTP server host name or IP address	
SMTP user name	
SMTP password	
SMTP default port	25 (Default value)
Email from which alert notifications are sent	
LDAP bind distinguished name	
LDAP bind password	
Active Directory administrator name	
Active Directory password	
Authentication server base distinguished name	
Authentication server host name or IP address	

Cluster information

Capture the following information for each cluster on Unified Manager.

Cluster 1 of N	Your value
Host name or cluster-management IP address	
<div>  <p>The administrator must have been assigned the "admin" role.</p> </div> ONTAP administrator user name	
ONTAP administrator password	
Protocol (HTTP or HTTPS)	

Related information

[Administrator authentication and RBAC](#)

Install Active IQ Unified Manager

Download and deploy Active IQ Unified Manager

To install the software, you must download the virtual appliance (VA) installation file and then use a VMware vSphere Client to deploy the file to a VMware ESXi server. The VA is available in an OVA file.

Steps

1. Go to the **NetApp Support Site Software Download** page and locate Active IQ Unified Manager.

<https://mysupport.netapp.com/products/index.html>

2. Select **VMware vSphere** in the **Select Platform** drop-down menu and click **Go!**
3. Save the OVA file to a local or network location that is accessible to your VMware vSphere Client.
4. In VMware vSphere Client, click **File > Deploy OVF Template**.
5. Locate the OVA file and use the wizard to deploy the virtual appliance on the ESXi server.

You can use the **Properties** tab in the wizard to enter your static configuration information.

6. Power on the VM.
7. Click the **Console** tab to view the initial boot process.
8. Follow the prompt to install VMware Tools on the VM.
9. Configure the time zone.
10. Enter a maintenance user name and password.
11. Go to the URL displayed by the VM console.

Configure initial Active IQ Unified Manager settings

The Active IQ Unified Manager Initial Setup dialog box appears when you first access the web UI, which enables you to configure some initial settings and to add clusters.

Steps

1. Accept the default AutoSupport enabled setting.
2. Enter the NTP server details, the maintenance user email address, the SMTP server host name, and additional SMTP options, and then click **Save**.

After you finish

When the initial setup is complete, the Cluster Data Sources page is displayed where you can add the cluster details.

Specify the clusters to be monitored

You must add a cluster to an Active IQ Unified Manager server to monitor the cluster, view the cluster discovery status, and monitor its performance.

What you'll need

- You must have the following information:
 - Host name or cluster-management IP address

The host name is the fully qualified domain name (FQDN) or short name that Unified Manager uses to connect to the cluster. This host name must resolve to the cluster-management IP address.

The cluster-management IP address must be the cluster-management LIF of the administrative storage virtual machine (SVM). If you use a node-management LIF, the operation fails.

- ONTAP administrator user name and password
- Type of protocol (HTTP or HTTPS) that can be configured on the cluster and the port number of the cluster
- You must have the Application Administrator or Storage Administrator role.
- The ONTAP administrator must have the ONTAPI and SSH administrator roles.
- The Unified Manager FQDN must be able to ping ONTAP.

You can verify this by using the ONTAP command `ping -node node_name -destination Unified_Manager_FQDN`.

About this task

For a MetroCluster configuration, you must add both the local and remote clusters, and the clusters must be configured correctly.

Steps

1. Click **Configuration > Cluster Data Sources**.
2. From the Clusters page, click **Add**.
3. In the **Add Cluster** dialog box, specify the required values, such as the host name or IP address (IPv4 or IPv6) of the cluster, user name, password, protocol for communication, and port number.

By default, the HTTPS protocol is selected.

You can change the cluster-management IP address from IPv6 to IPv4 or from IPv4 to IPv6. The new IP address is reflected in the cluster grid and the cluster configuration page after the next monitoring cycle finishes.

4. Click **Add**.
5. If HTTPS is selected, perform the following steps:
 - a. In the **Authorize Host** dialog box, click **View Certificate** to view the certificate information about the cluster.
 - b. Click **Yes**.

Unified Manager checks the certificate only when the cluster is initially added, but does not check it for each API call to ONTAP.

If the certificate has expired, you cannot add the cluster. You must renew the SSL certificate and then add the cluster.

6. **Optional:** View the cluster discovery status:

- a. Review the cluster discovery status from the **Cluster Setup** page.

The cluster is added to the Unified Manager database after the default monitoring interval of approximately 15 minutes.

Set up basic monitoring tasks

Perform daily monitoring

You can perform daily monitoring to ensure that you do not have any immediate performance issues that require attention.

Steps

1. From the Active IQ Unified Manager UI, go to the **Event Inventory** page to view all current and obsolete events.
2. From the **View** option, select `Active Performance Events` and determine what action is required.

Use weekly and monthly performance trends to identify performance issues

Identifying performance trends can assist you in identifying whether the cluster is being overused or underused by analyzing volume latency. You can use similar steps to identify CPU, network, or other system bottlenecks.

Steps

1. Locate the volume that you suspect is being underused or overused.
2. On the **Volume Details** tab, click **30 d** to display the historical data.
3. In the "Break down data by" drop-down menu, select **Latency**, and then click **Submit**.
4. Deselect **Aggregate** in the cluster components comparison chart, and then compare the cluster latency with the volume latency chart.
5. Select **Aggregate** and deselect all other components in the cluster components comparison chart, and then compare the aggregate latency with the volume latency chart.
6. Compare the reads/writes latency chart to the volume latency chart.
7. Determine whether client application loads have caused a workload contention and rebalance workloads as needed.
8. Determine whether the aggregate is overused and causing contention and rebalance workloads as needed.

Use performance thresholds to generate event notifications

Events are notifications that the Active IQ Unified Manager generates automatically when a predefined condition occurs, or when a performance counter value crosses a threshold. Events help you identify performance issues in the clusters you are monitoring. You can configure alerts to send email notification automatically when events of certain severity types occur.

Set performance thresholds

You can set performance thresholds to monitor critical performance issues. User-defined thresholds trigger a warning or a critical event notification when the system approaches or exceeds the defined threshold.

Steps

1. Create the Warning and Critical event thresholds:
 - a. Select **Configuration > Performance Thresholds**.
 - b. Click **Create**.
 - c. Select the object type and specify a name and description of the policy.
 - d. Select the object counter condition and specify the limit values that define Warning and Critical events.
 - e. Select the duration of time that the limit values must be breached for an event to be sent, and then click **Save**.
2. Assign the threshold policy to the storage object.
 - a. Go to the Inventory page for the same cluster object type that you previously selected and choose the **Performance** from the View option.
 - b. Select the object to which you want to assign the threshold policy, and then click **Assign Threshold Policy**.
 - c. Select the policy you previously created, and then click **Assign Policy**.

Example

You can set user-defined thresholds to learn about critical performance issues. For example, if you have a Microsoft Exchange Server and you know that it crashes if volume latency exceeds 20 milliseconds, you can set a warning threshold at 12 milliseconds and a critical threshold at 15 milliseconds. With this threshold setting, you can receive notifications when the volume latency exceeds the limit.

	Warning		Critical	
Object Counter Condition*	Average Latency ms/op	12	ms/op	15 ms/op

Add alerts

You can configure alerts to notify you when a particular event is generated. You can configure alerts for a single resource, for a group of resources, or for events of a particular severity type. You can specify the frequency with which you want to be notified and associate a script to the alert.

What you'll need

- You must have configured notification settings such as the user email address, SMTP server, and SNMP trap host to enable the Active IQ Unified Manager server to use these settings to send notifications to users when an event is generated.
- You must know the resources and events for which you want to trigger the alert, and the user names or email addresses of the users that you want to notify.
- If you want to have a script execute based on the event, you must have added the script to Unified Manager by using the Scripts page.

- You must have the Application Administrator or Storage Administrator role.

About this task

You can create an alert directly from the Event details page after receiving an event in addition to creating an alert from the Alert Setup page, as described here.

Steps

1. In the left navigation pane, click **Storage Management > Alert Setup**.
2. In the **Alert Setup** page, click **Add**.
3. In the **Add Alert** dialog box, click **Name**, and enter a name and description for the alert.
4. Click **Resources**, and select the resources to be included in or excluded from the alert.

You can set a filter by specifying a text string in the **Name contains** field to select a group of resources. Based on the text string that you specify, the list of available resources displays only those resources that match the filter rule. The text string that you specify is case-sensitive.

If a resource conforms to both the include and exclude rules that you have specified, the exclude rule takes precedence over the include rule, and the alert is not generated for events related to the excluded resource.

5. Click **Events**, and select the events based on the event name or event severity type for which you want to trigger an alert.



To select more than one event, press the Ctrl key while you make your selections.

6. Click **Actions**, and select the users that you want to notify, choose the notification frequency, choose whether an SNMP trap will be sent to the trap receiver, and assign a script to be executed when an alert is generated.



If you modify the email address that is specified for the user and reopen the alert for editing, the Name field appears blank because the modified email address is no longer mapped to the user that was previously selected. Also, if you modified the email address of the selected user from the Users page, the modified email address is not updated for the selected user.

You can also choose to notify users through SNMP traps.

7. Click **Save**.

Example of adding an alert

This example shows how to create an alert that meets the following requirements:

- Alert name: HealthTest
- Resources: includes all volumes whose name contains "abc" and excludes all volumes whose name contains "xyz"
- Events: includes all critical health events
- Actions: includes "sample@domain.com", a "Test" script, and the user has to be notified every 15 minutes

Perform the following steps in the Add Alert dialog box:

1. Click **Name**, and enter HealthTest in the **Alert Name** field.

2. Click **Resources**, and in the Include tab, select **Volumes** from the drop-down list.
 - a. Enter `abc` in the **Name contains** field to display the volumes whose name contains "abc".
 - b. Select **<<All Volumes whose name contains 'abc'>>** from the Available Resources area, and move it to the Selected Resources area.
 - c. Click **Exclude**, and enter `xyz` in the **Name contains** field, and then click **Add**.
3. Click **Events**, and select **Critical** from the Event Severity field.
4. Select **All Critical Events** from the Matching Events area, and move it to the Selected Events area.
5. Click **Actions**, and enter `sample@domain.com` in the Alert these users field.
6. Select **Remind every 15 minutes** to notify the user every 15 minutes.

You can configure an alert to repeatedly send notifications to the recipients for a specified time. You should determine the time from which the event notification is active for the alert.

7. In the Select Script to Execute menu, select **Test** script.
8. Click **Save**.

Identify performance issues in Active IQ Unified Manager

If a performance event occurs, you can locate the source of the issue within Active IQ Unified Manager and use other tools to fix it. You might receive an email notification of an event or notice the event during daily monitoring.

Steps

1. Click the link in the email notification, which takes you directly to the storage object having a performance event.

If you...	Then...
Receive an email notification of an event	Click the link to go directly to the event details page.
Notice the event while analyzing the Event Inventory page	Select the event to go directly to the event details page.

2. If the event has crossed a system-defined threshold, follow the suggested actions in the UI to troubleshoot the issue.
3. If the event has crossed a user-defined threshold, analyze the event to determine if you need to take action.
4. If the issue persists, check the following settings:
 - Protocol settings on the storage system
 - Network settings on any Ethernet or fabric switches
 - Network settings on the storage system
 - Disk layout and aggregate metrics on the storage system
5. If the issue persists, contact technical support for assistance.

Use Active IQ Digital Advisor to view system performance

For any ONTAP system that sends AutoSupport telemetry to NetApp, you can view extensive performance and capacity data. Active IQ shows system performance over a longer period than you can see in System Manager.

You can view graphs of CPU utilization, latency, IOPS, IOPS by protocol, and network throughput. You can also download this data in .csv format for analysis in other tools.

In addition to this performance data, Active IQ can show you storage efficiency by workload and compare that efficiency to the expected efficiency for that type of workload. You can view capacity trends and see an estimate of how much additional storage you might need to add in a given timeframe



- Storage Efficiency is available at the customer, cluster, and node level on the left-hand-side of the main dashboard.
- Performance is available at the cluster and node level on the left-hand-side of the main dashboard.

Related information

[Active IQ Digital Advisor documentation](#)

[Active IQ Digital Advisor video playlist](#)

[Active IQ Web Portal](#)

Manage performance issues

Performance management workflow

Once you have identified a performance issue, you can conduct some basic diagnostic checks of your infrastructure to rule out obvious configuration errors. If those don't pinpoint the problem, you can start looking at workload management issues.



Perform basic infrastructure checks

Check protocol settings on the storage system

Check the NFS TCP maximum transfer size

For NFS, you can check whether the TCP maximum transfer size for reads and writes might be causing a performance issue. If you think the size is slowing performance, you can increase it.

What you'll need

- You must have cluster administrator privileges to perform this task.
- You must use advanced privilege level commands for this task.

Steps

1. Change to the advanced privilege level:

```
set -privilege advanced
```

2. Check the TCP maximum transfer size:

```
vserver nfs show -vserver vserver_name -instance
```

3. If the TCP maximum transfer size is too small, increase the size:

```
vserver nfs modify -vserver vserver_name -tcp-max-xfer-size integer
```

4. Return to the administrative privilege level:

```
set -privilege admin
```

Example

The following example changes the TCP maximum transfer size of SVM1 to 1048576:

```
cluster1::*> vserver nfs modify -vserver SVM1 -tcp-max-xfer-size 1048576
```

Check the iSCSI TCP read/write size

For iSCSI, you can check the TCP read/write size to determine if the size setting is creating a performance issue. If the size is the source of an issue, you can correct it.

What you'll need

Advanced privilege level commands are required for this task.

Steps

1. Change to advanced privilege level:

```
set -privilege advanced
```

2. Check the TCP window size setting:

```
vserver iscsi show -vserver vserver_name -instance
```

3. Modify the TCP window size setting:

```
vserver iscsi modify -vserver vserver_name -tcp-window-size integer
```

4. Return to administrative privilege:

```
set -privilege admin
```

Example

The following example changes the TCP window size of SVM1 to 131,400 bytes:

```
cluster1::*> vserver iscsi modify -vserver vs1 -tcp-window-size 131400
```

Check the CIFS multiplex settings

If slow CIFS network performance causes a performance issue, you can modify the multiplex settings to improve and correct it.

Steps

1. Check the CIFS multiplex setting:

```
vserver cifs options show -vserver -vserver_name -instance
```

2. Modify the CIFS multiplex setting:

```
vserver cifs options modify -vserver -vserver_name -max-mpx integer
```

Example

The following example changes the maximum multiplex count on SVM1 to 255:

```
cluster1::> vserver cifs options modify -vserver SVM1 -max-mpx 255
```

Check the FC adapter port speed

The adapter target port speed should match the speed of the device to which it connects, to optimize performance. If the port is set to autonegotiation, it can take longer to reconnect after a takeover and giveback or other interruption.

What you'll need

All LIFs that use this adapter as their home port must be offline.

Steps

1. Take the adapter offline:

```
network fcp adapter modify -node nodename -adapter adapter -state down
```

2. Check the maximum speed of the port adapter:

```
fcp adapter show -instance
```

3. Change the port speed, if necessary:

```
network fcp adapter modify -node nodename -adapter adapter -speed  
{1|2|4|8|10|16|auto}
```


4. Bring the adapter online:

```
network fcp adapter modify -node nodename -adapter adapter -state up
```

5. Bring all the LIFs on the adapter online:

```
network interface modify -vserver * -lif * { -home-node node1 -home-port e0c }  
-status-admin up
```

Example

The following example changes the port speed of adapter 0d on node1 to 2 Gbps:

```
cluster1::> network fcp adapter modify -node node1 -adapter 0d -speed 2
```

Check the network settings on the data switches

Although you must maintain the same MTU settings on your clients, servers and storage systems (that is, network endpoints), intermediate network devices such as NICs and switches should be set to their maximum MTU values to ensure that performance is not impacted.

For best performance, all components in the network must be able to forward jumbo frames (9000 bytes IP, 9022 bytes including Ethernet). Data switches should be set to at least 9022 bytes, but a typical value of 9216 is possible with most switches.

Procedure

For data switches, check that the MTU size is set to 9022 or higher.

For more information, see the switch vendor documentation.

Check the MTU network setting on the storage system

You can change the network settings on the storage system if they are not the same as on the client or other network endpoints. Whereas the management network MTU setting is set to 1500, the data network MTU size should be 9000.

About this task

All ports within a broadcast-domain have the same MTU size, with the exception of the e0M port handling management traffic. If the port is part of a broadcast-domain, use the `broadcast-domain modify` command to change the MTU for all ports within the modified broadcast-domain.

Note that intermediate network devices such as NICs and data switches can be set to higher MTU sizes than network endpoints. For more information, see [Check the network settings on the data switches](#).

Steps

1. Check the MTU port setting on the storage system:

```
network port show -instance
```

2. Change the MTU port setting to 9000:

```
network port modify -node nodename -port port -mtu 9000
```

Example

The following example changes the MTU port setting for e0a to 9000:

```
cluster1::*> network port modify -node node0 -port e0a -mtu 9000
```

Check disk throughput and latency

You can check the disk throughput and latency metrics for cluster nodes to assist you in troubleshooting.

About this task

Advanced privilege level commands are required for this task.

Steps

1. Change to advanced privilege level:

```
set -privilege advanced
```

2. Check the disk throughput and latency metrics:

```
statistics disk show -sort-key latency
```

Example

The following example displays the totals in each user read or write operation for node2 on cluster1:

```
::*> statistics disk show -sort-key latency
cluster1 : 8/24/2015 12:44:15
```

Disk	Node	Busy (%)	Total Ops	Read Ops	Write Ops	Read (Bps)	Write (Bps)	*Latency (us)
1.10.20	node2	4	5	3	2	95232	367616	23806
1.10.8	node2	4	5	3	2	138240	386048	22113
1.10.6	node2	3	4	2	2	48128	371712	19113
1.10.19	node2	4	6	3	2	102400	443392	19106
1.10.11	node2	4	4	2	2	122880	408576	17713

Check throughput and latency between nodes

You can use the `network test-path` command to identify network bottlenecks, or to

prequalify network paths between nodes. You can run the command between intercluster nodes or intracluster nodes.

What you'll need

- You must be a cluster administrator to perform this task.
- Advanced privilege level commands are required for this task.
- For an intercluster path, the source and destination clusters must be peered.

About this task

Occasionally, network performance between nodes may not meet expectations for your path configuration. A 1 Gbps transmission rate for the kind of large data transfers seen in SnapMirror replication operations, for example, would not be consistent with a 10 GbE link between the source and destination clusters.

You can use the `network test-path` command to measure throughput and latency between nodes. You can run the command between intercluster nodes or intracluster nodes.



The test saturates the network path with data, so you should run the command when the system is not busy and when network traffic between nodes is not excessive. The test times out after ten seconds. The command can be run only between ONTAP 9 nodes.

The `session-type` option identifies the type of operation you are running over the network path—for example, "AsyncMirrorRemote" for SnapMirror replication to a remote destination. The type dictates the amount of data used in the test. The following table defines the session types:

Session Type	Description
Default	SnapMirror replication between nodes in different clusters
AsyncMirrorLocal	SnapMirror replication between nodes in the same cluster
AsyncMirrorRemote	SnapMirror replication between nodes in different clusters
SyncMirrorRemote	SyncMirror replication between nodes in different clusters
RemoteDataTransfer	Data transfer between nodes in the same cluster (for example, an NFS request to a node for a file stored in a volume on a different node)

Steps

1. Change to advanced privilege level:

```
set -privilege advanced
```

2. Measure throughput and latency between nodes:

```
network test-path -source-node source_nodename |local -destination-cluster  
destination_clustername -destination-node destination_nodename -session-type  
Default|AsyncMirrorLocal|AsyncMirrorRemote|SyncMirrorRemote|RemoteDataTransfer
```

The source node must be in the local cluster. The destination node can be in the local cluster or in a peered cluster. A value of "local" for `-source-node` specifies the node on which you are running the command.

The following command measures throughput and latency for SnapMirror-type replication operations between node1 on the local cluster and node3 on cluster2:

```
cluster1::> network test-path -source-node node1 -destination-cluster  
cluster2 -destination-node node3 -session-type AsyncMirrorRemote  
Test Duration:          10.88 secs  
Send Throughput:        18.23 MB/sec  
Receive Throughput:     18.23 MB/sec  
MB sent:                198.31  
MB received:            198.31  
Avg latency in ms:      2301.47  
Min latency in ms:      61.14  
Max latency in ms:      3056.86
```

3. Return to administrative privilege:

```
set -privilege admin
```

After you finish

If performance does not meet expectations for the path configuration, you should check node performance statistics, use available tools to isolate the problem in the network, check switch settings, and so forth.

Manage workloads

Identify remaining performance capacity

Performance capacity, or *headroom*, measures how much work you can place on a node or an aggregate before performance of workloads on the resource begins to be affected by latency. Knowing the available performance capacity on the cluster helps you provision and balance workloads.

What you'll need

Advanced privilege level commands are required for this task.

About this task

You can use the following values for the `-object` option to collect and display headroom statistics:

- For CPUs, `resource_headroom_cpu`.
- For aggregates, `resource_headroom_aggr`.

You can also complete this task using System Manager and Active IQ Unified Manager.

Steps

1. Change to advanced privilege level:

```
set -privilege advanced
```

2. Start real-time headroom statistics collection:

```
statistics start -object resource_headroom_cpu|aggr
```

For complete command syntax, see the man page.

3. Display real-time headroom statistics information:

```
statistics show -object resource_headroom_cpu|aggr
```

For complete command syntax, see the man page.

4. Return to administrative privilege:

```
set -privilege admin
```

Example

The following example displays the average hourly headroom statistics for cluster nodes.

You can compute the available performance capacity for a node by subtracting the `current_utilization` counter from the `optimal_point_utilization` counter. In this example, the utilization capacity for CPU_sti2520-213 is -14% (72%-86%), which suggests that the CPU has been overutilized on average for the past hour.

You could have specified `ewma_daily`, `ewma_weekly`, or `ewma_monthly` to get the same information averaged over longer periods of time.

```
sti2520-2131454963690::*> statistics show -object resource_headroom_cpu
-raw -counter ewma_hourly
(statistics show)
```

```
Object: resource_headroom_cpu
Instance: CPU_sti2520-213
Start-time: 2/9/2016 16:06:27
End-time: 2/9/2016 16:06:27
Scope: sti2520-213
```

Counter	Value
-----	-----
ewma_hourly	-
current_ops	4376
current_latency	37719
current_utilization	86
optimal_point_ops	2573
optimal_point_latency	3589
optimal_point_utilization	72
optimal_point_confidence_factor	1

```
Object: resource_headroom_cpu
Instance: CPU_sti2520-214
Start-time: 2/9/2016 16:06:27
End-time: 2/9/2016 16:06:27
Scope: sti2520-214
```

Counter	Value
-----	-----
ewma_hourly	-
current_ops	0
current_latency	0
current_utilization	0
optimal_point_ops	0
optimal_point_latency	0
optimal_point_utilization	71
optimal_point_confidence_factor	1

```
2 entries were displayed.
```

Identify high-traffic clients or files

You can use ONTAP Active Objects technology to identify clients or files that are responsible for a disproportionately large amount of cluster traffic. Once you have identified these "top" clients or files, you can rebalance cluster workloads or take other steps to resolve the issue.

What you'll need

You must be a cluster administrator to perform this task.

Steps

1. View the top clients accessing the cluster:

```
statistics top client show -node node_name -sort-key sort_column -interval  
seconds_between_updates -iterations iterations -max number_of_instances
```

For complete command syntax, see the man page.

The following command displays the top clients accessing cluster1:

```
cluster1::> statistics top client show
```

```
cluster1 : 3/23/2016 17:59:10
```

Client	Vserver	Node	Protocol	*Total Ops
-----	-----	-----	-----	-----
172.17.180.170	vs4	siderop1-vs4	nfs	668
172.17.180.169	vs3	siderop1-vs3	nfs	337
172.17.180.171	vs3	siderop1-vs3	nfs	142
172.17.180.170	vs3	siderop1-vs3	nfs	137
172.17.180.123	vs3	siderop1-vs3	nfs	137
172.17.180.171	vs4	siderop1-vs4	nfs	95
172.17.180.169	vs4	siderop1-vs4	nfs	92
172.17.180.123	vs4	siderop1-vs4	nfs	92
172.17.180.153	vs3	siderop1-vs3	nfs	0

2. View the top files accessed on the cluster:

```
statistics top file show -node node_name -sort-key sort_column -interval  
seconds_between_updates -iterations iterations -max number_of_instances
```

For complete command syntax, see the man page.

The following command displays the top files accessed on cluster1:

```
cluster1::> statistics top file show
```

```
cluster1 : 3/23/2016 17:59:10
```

			*Total		
	File	Volume	Vserver	Node	Ops
/vol/vol1/vm170-read.dat		vol1	vs4	siderop1-vs4	22
/vol/vol1/vm69-write.dat		vol1	vs3	siderop1-vs3	6
/vol/vol2/vm171.dat		vol2	vs3	siderop1-vs3	2
/vol/vol2/vm169.dat		vol2	vs3	siderop1-vs3	2
/vol/vol2/p123.dat		vol2	vs4	siderop1-vs4	2
/vol/vol2/p123.dat		vol2	vs3	siderop1-vs3	2
/vol/vol1/vm171.dat		vol1	vs4	siderop1-vs4	2
/vol/vol1/vm169.dat		vol1	vs4	siderop1-vs4	2
/vol/vol1/vm169.dat		vol1	vs4	siderop1-vs3	2
/vol/vol1/p123.dat		vol1	vs4	siderop1-vs4	2

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">• AFF• C190 *• ONTAP Select premium with SSD *	<ul style="list-style-type: none">• AFF• C190• ONTAP Select premium with SSD	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.

Workload support - floor	9.2	9.3	9.4 and later	9.8 and later
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.

Workload support - adaptive QoS	9.3	9.4 and later
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	<code>qos settings throughput-floors-v2 -enable false</code>
Enable floors v2	<code>qos settings throughput-floors-v2 -enable true</code>



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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