



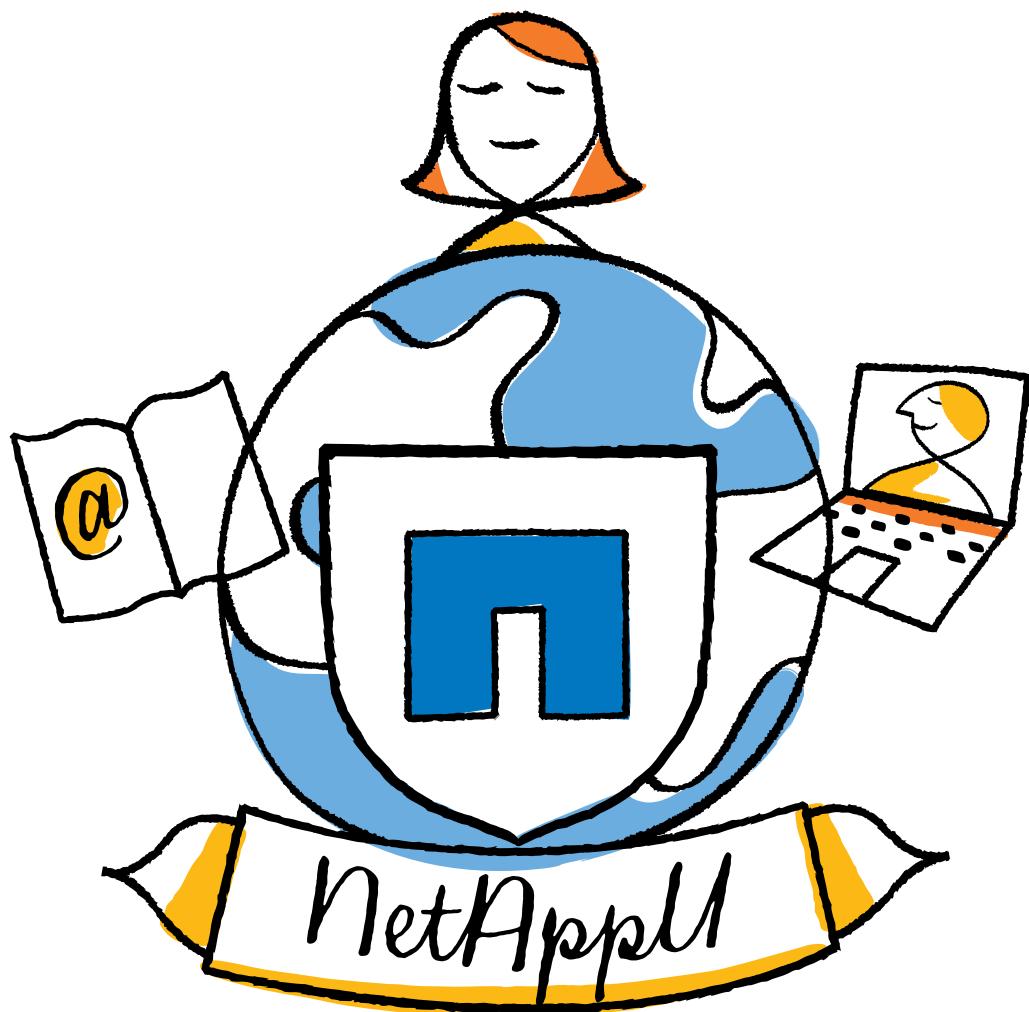
Go further, faster®

**NetApp®**

*NetApp University*

# Performance Analysis on Clustered Data ONTAP

Student Guide





NETAPP UNIVERSITY

## Performance Analysis on Clustered Data ONTAP

### Student Guide

Course ID: STRSW-ILT-PERFCDOT  
Catalog Number: STRSW-ILT-PERFCDOT-SG  
Content Version: 1.0

## **ATTENTION**

The information contained in this course is intended only for training. This course contains information and activities that, while beneficial for the purposes of training in a closed, non-production environment, can result in downtime or other severe consequences in a production environment. This course material is not a technical reference and should not, under any circumstances, be used in production environments. To obtain reference materials, refer to the NetApp product documentation that is located at <http://now.netapp.com/>.

## **COPYRIGHT**

© 2013 NetApp, Inc. All rights reserved. Printed in the U.S.A. Specifications subject to change without notice.

No part of this document covered by copyright may be reproduced in any form or by any means—graphic, electronic, or mechanical, including photocopying, recording, taping, or storage in an electronic retrieval system—without prior written permission of NetApp, Inc.

## **U.S. GOVERNMENT RIGHTS**

Commercial Computer Software. Government users are subject to the NetApp, Inc. standard license agreement and applicable provisions of the FAR and its supplements.

## **TRADEMARK INFORMATION**

NetApp, the NetApp logo, Go further, faster, AdminNODE, Akorri, ApplianceWatch, ASUP, AutoSupport, BalancePoint, BalancePoint Predictor, Bycast, Campaign Express, ChronoSpan, ComplianceClock, ControlNODE, Cryptainer, Data ONTAP, DataFabric, DataFort, Decru, Decru DataFort, DenseStak, Engenio, E-Stack, FAServer, FastStak, FilerView, FlexCache, FlexClone, FlexPod, FlexScale, FlexShare, FlexVol, FPolicy, GatewayNODE, gFiler, Imagine Virtually Anything, Infinivolt, Lifetime Key Management, LockVault, Manage ONTAP, MetroCluster, MultiStore, NearStore, NetApp Select, NetCache, NetCache, NOW (NetApp on the Web), OnCommand, ONTAPI, PerformanceStak, RAID DP, SANscreen, SANshare, SANtricity, SecureAdmin, SecureShare, Securitis, Service Builder, Simplicity, Simulate ONTAP, SnapCopy, SnapDirector, SnapDrive, SnapLock, SnapManager, SnapMirror, SnapMover, SnapProtect, SnapRestore, Snapshot, SnapValidator, SnapVault, StorageGRID, StorageNODE, StoreVault, SyncMirror, Tech OnTap, VelocityStak, vFiler, VFM, Virtual File Manager, WAFL, and XBB are trademarks or registered trademarks of NetApp, Inc. in the United States and/or other countries.

All other brands or products are either trademarks or registered trademarks of their respective holders and should be treated as such.

## TABLE OF CONTENTS

WELCOME .....	1
MODULE 1: HOW A NETAPP STORAGE SYSTEM WORKS.....	1-1
MODULE 2: PERFORMANCE OVERVIEW.....	2-1
MODULE 3: CLUSTERED STORAGE SYSTEM WORKLOADS AND BOTTLENECKS .....	3-1
MODULE 4: CLUSTER PERFORMANCE MONITORING AND ANALYSIS .....	4-1
MODULE 5: ONCOMMAND MANAGEMENT TOOLS.....	5-1
MODULE 6: STORAGE QOS.....	6-1
MODULE 7: SUMMARY .....	7-1



Go further, faster®

# Performance Analysis on Clustered Data ONTAP

Course ID:  
STRSW-ILT-PERFCDOT



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

1

## PERFORMANCE ANALYSIS ON CLUSTERED DATA ONTAP



# Classroom Logistics

## Schedule

- Start time
- Stop time
- Break times

## Safety

- Alarm signal
- Evacuation procedure
- Electrical safety guidelines

## Facilities

- Food and drinks
- Restrooms
- Phones

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

2

## CLASSROOM LOGISTICS



## Course Overview

- Collect and analyze system performance data from NetApp storage systems
- Interpret data and identify and implement changes that improve system efficiency
- Use system commands and features to monitor and enhance storage system performance

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

3

### COURSE OVERVIEW

This course provides you with the knowledge and skills that you need to collect and analyze system performance data from NetApp storage systems that are running clustered Data ONTAP. You learn how to interpret data and how to identify and implement changes that improve system efficiency. You also learn how to use system commands and features to monitor and enhance storage system performance using a combination of hands-on labs, case-studies, and technical discussion.



## Course Objectives

1 of 2

By the end of this course, you should be able to:

- Describe how data flows through the network and protocol layers of clustered Data ONTAP
- Define performance-related terms and describe basic methodologies
- Identify the methods that can be used to monitor and analyze storage system performance
- Use various methods and tools to collect performance data

### COURSE OBJECTIVES: 1 OF 2



## Course Objectives

### 2 of 2

By the end of this course, you should be able to:

- Use command output to analyze system performance and identify performance bottlenecks
- Use OnCommand management tools to view performance data
- Implement configurations that are based on recommended practices for resiliency and performance
- Locate resources and information that help you maximize system performance

## COURSE OBJECTIVES: 2 OF 2



## Course Agenda: Day 1

- Morning

- Module 1: How a NetApp Storage System Works
  - Module 2: Performance Overview

- Afternoon

Module 3: Clustered Storage System Workloads and Bottlenecks

## COURSE AGENDA: DAY 1



## Course Agenda: Day 2

- Morning

- Module 4: Cluster Performance Monitoring and Analysis

- Afternoon

- Module 5: OnCommand Management Tools
- Module 6: Storage QoS
- Module 7: Summary

## COURSE AGENDA: DAY 2



## NetApp University Information Sources

- NetApp Support Site  
<http://now.netapp.com>
  
- NetApp University  
<http://www.netapp.com/us/services/university/>
  
- NetApp University Support  
<http://netappusupport.custhelp.com>

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

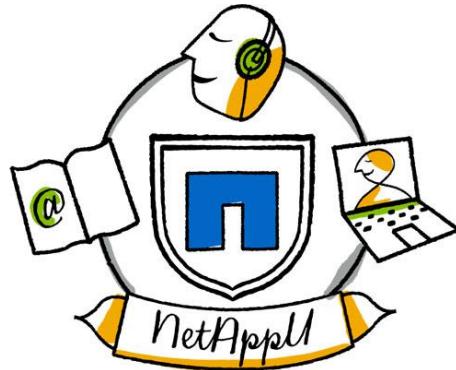
8

## NETAPP UNIVERSITY INFORMATION SOURCES



## Module 1

How a NetApp  
Storage System Works



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

1

### MODULE 1: HOW A NETAPP STORAGE SYSTEM WORKS



## Module Objectives

After this module, you should be able to:

- Describe the layers within the Data ONTAP architecture
- List the advantages that are provided by the ability of WAFL to optimize writes
- Explain the purpose of NVRAM
- Diagram the flow of read and write requests through the network and protocol layers of Data ONTAP
- Describe the benefits that RAID provides

## MODULE OBJECTIVES



## Lesson 1

### Architecture



© 2013 NetApp, Inc. All rights reserved.

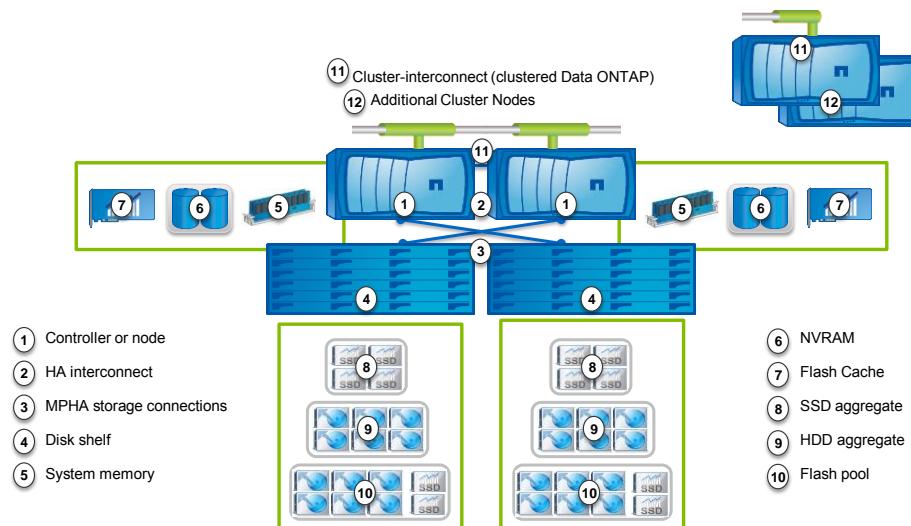
NetApp Confidential

3

## LESSON 1: ARCHITECTURE



# Storage System Architecture



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

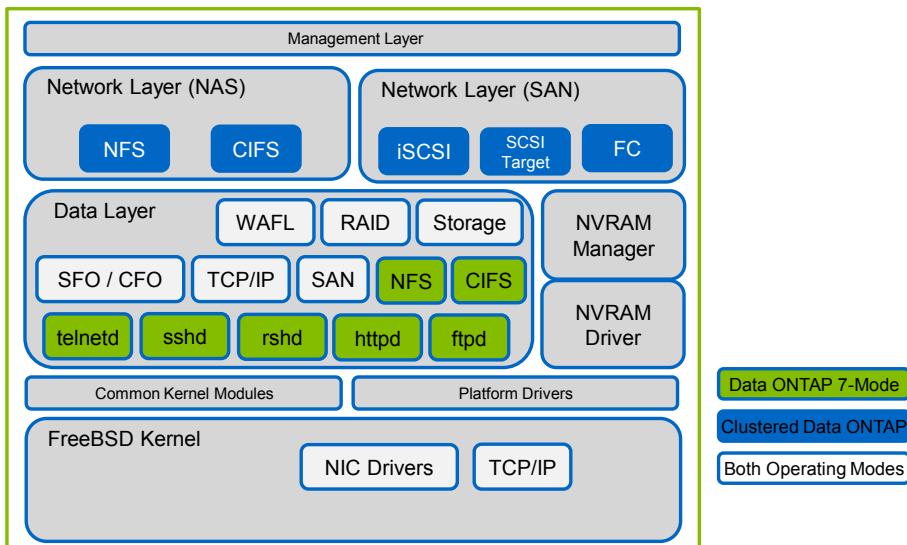
4

## STORAGE SYSTEM ARCHITECTURE

The NetApp storage system architecture includes multiple components: storage controllers, high-availability interconnect, multipath high-availability storage connections, disk shelves, system memory, NVRAM, Flash Cache modules, solid-state drive (SSD) aggregates, hard-disk-drive (HDD) aggregates, and flash pools. Storage systems that run the clustered Data ONTAP operating system also include cluster-interconnect and multiple cluster nodes.



# Data ONTAP Architecture



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

5

## DATA ONTAP ARCHITECTURE

The Data ONTAP architecture consists of multiple layers, which are built on top of the FreeBSD operating system. Above the FreeBSD kernel is the data layer that includes the WAFL (Write Anywhere File Layout) file system, RAID, storage, failover, and the protocols for Data ONTAP operating in 7-Mode. Also above the FreeBSD kernel is the NVRAM driver and manager. Above these layers is the NAS and SAN networking layer, which includes protocol support for clustered Data ONTAP. Above the networking layer is the Data ONTAP management layer.

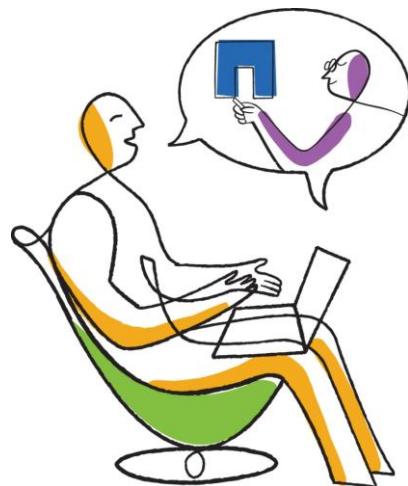
The data layer TCP/IP stack is used for all network layer protocols or, in other words, for all clustered Data ONTAP protocols. It is also used for all 7-Mode protocols. The TCP/IP stack in the FreeBSD kernel is used for traffic for ports for which the clustered Data ONTAP network layer does not have listeners.

**NOTE:** The clustered session manager (CSM) resides in the common kernel module.



## Lesson 2

### Read Data Access



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

6

## LESSON 2: READ DATA ACCESS



# Clustered Data ONTAP Data Access

## Direct Data Access

The target volume is **owned** by the controller that is hosting the logical interface (LIF).

## Indirect Data Access

The target volume is **not owned** by the controller that is hosting the LIF.

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

7

## CLUSTERED DATA ONTAP DATA ACCESS

Both clustered Data ONTAP and Data ONTAP operating in 7-Mode support direct data access; however, only clustered Data ONTAP supports indirect data access.



## Direct and Indirect Data Access

- Indirect data access: a key benefit of clustered Data ONTAP
- Latency between direct and indirect data access: negligible
- Throughput: affected by indirect data access

## DIRECT AND INDIRECT DATA ACCESS

Indirect data access enables you to scale workloads across multiple nodes. The latency between direct and indirect data access is negligible, provided that CPU headroom exists. Throughput can be affected by indirect data access, because additional processing might be required to move data over the cluster-interconnect.

**NOTE:** the terms latency and throughput will be fully covered in the next module.



## Data Access Type—Protocol Dependent

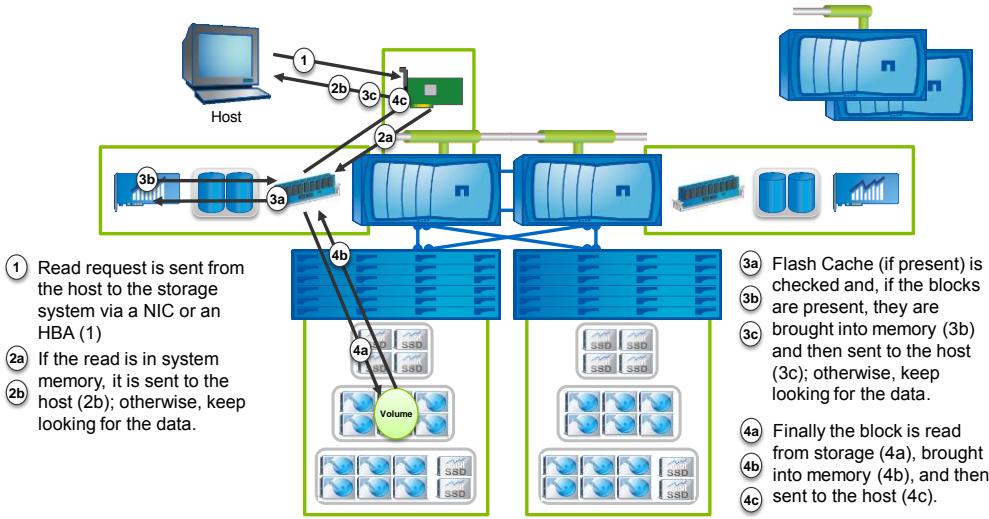
- SAN data access  
Direct or indirect (determined by optimized or non-optimized path)
- NFS data access  
Direct or indirect
- CIFS data access  
Direct or indirect

## DATA ACCESS TYPE—PROTOCOL DEPENDENT

The data access type is protocol dependent. SAN data access can be direct or indirect depending on path selected by Asymmetric Logical Unit Access (ALUA). NFS data access can be direct or indirect, except that pNFS is always direct. CIFS data access can be either direct or indirect.



# Read Operations (Direct Data Access)



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

10

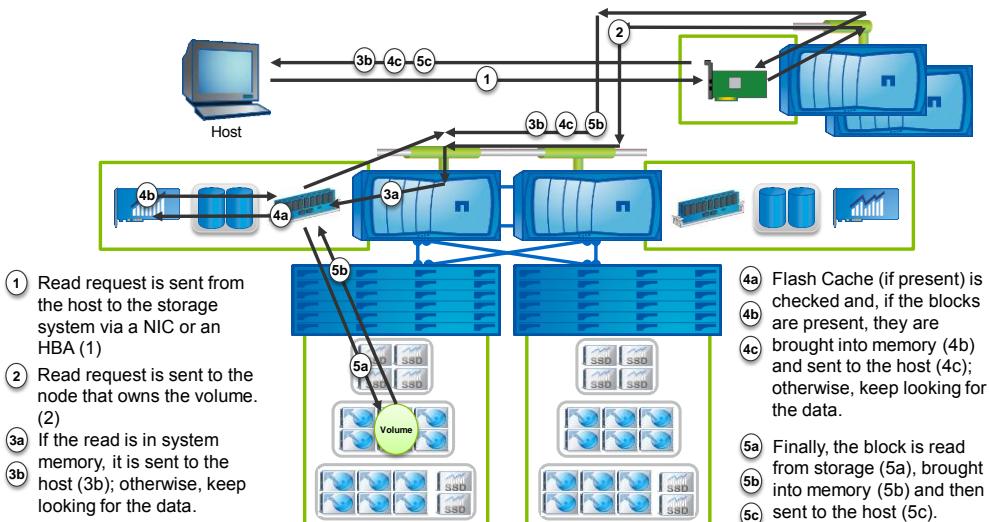
## READ OPERATIONS (DIRECT DATA ACCESS)

Read operations for direct access take the following path through the storage system:

1. The read request is sent from the host to the storage system via a network interface card (NIC) or a host bus adapter (HBA).
2. If the read is in system memory, it is sent to the host; otherwise, keep looking for the data.
3. Flash Cache is checked (if it is present) and, if the blocks are present, they are brought into memory and then sent to the host; otherwise, keep looking for the data.
4. The block is read from storage, brought into memory, and then sent to the host.



# Read Operations (Indirect Data Access)



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

11

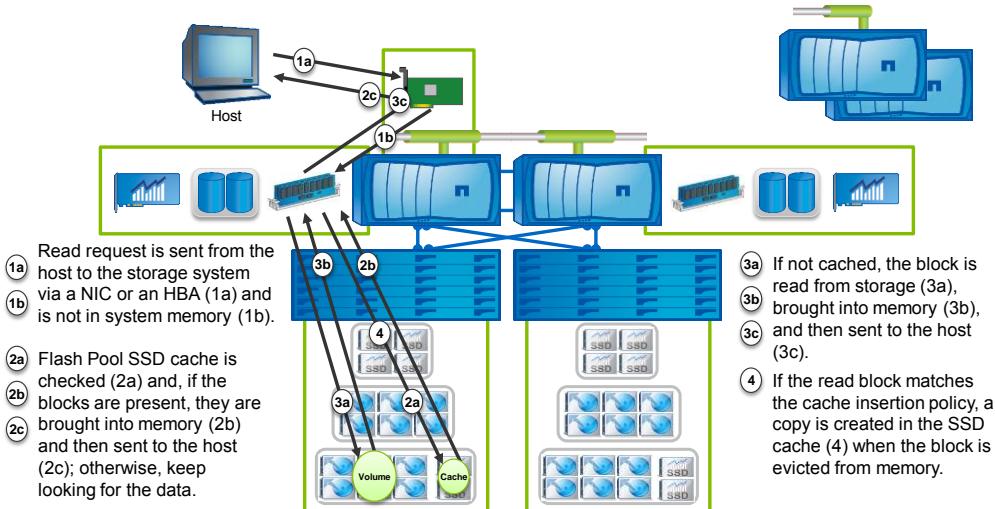
## READ OPERATIONS (INDIRECT DATA ACCESS)

Read operations for indirect data access take the following path through the storage system:

1. The read request is sent from the host to the storage system via a NIC or an HBA.
2. The read request is sent to the storage controller that owns the volume.
3. If the read is in system memory, it is sent to the host; otherwise, keep looking for the data.
4. Flash Cache (if it is present) is checked and, if the blocks are present, they are brought into memory and then sent to the host; otherwise, keep looking for the data.
5. The block is read from storage, brought into memory, and then sent to the host.



# Read Operations (Flash Pool SSD Cache)



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

12

## READ OPERATIONS (FLASH POOL SSD CACHE)

Read operations that involve Flash Pool SSD cache take the following path through the storage system:

1. The read request is sent from the host to the storage system via a NIC or an HBA and is not in system memory.
2. The Flash Pool SSD drive cache is checked and, if the blocks are present, they are brought into memory and then sent to the host; otherwise, keep looking for the data.
3. If not cached, the block is read from storage, brought into memory, and then sent to the host.
4. If the read block matches the cache insertion policy, a copy is created in the SSD cache when the block is evicted from memory.



## Readahead

- A proactive mechanism that enables Data ONTAP to detect read patterns  
When a pattern is detected, the system reads the pattern into memory in an effort to pre-empt future read requests.
- An additional layer of intelligence that Data ONTAP uses to keep the most relevant data in memory

## READAHEAD

Readahead enables Data ONTAP to detect read patterns (including long reads, strides, and backward reads). When a pattern is detected, the system reads the pattern into memory, reading more data than was requested in an effort to pre-empt future read requests.



## Lesson 3

### Write Data Access



© 2013 NetApp, Inc. All rights reserved.

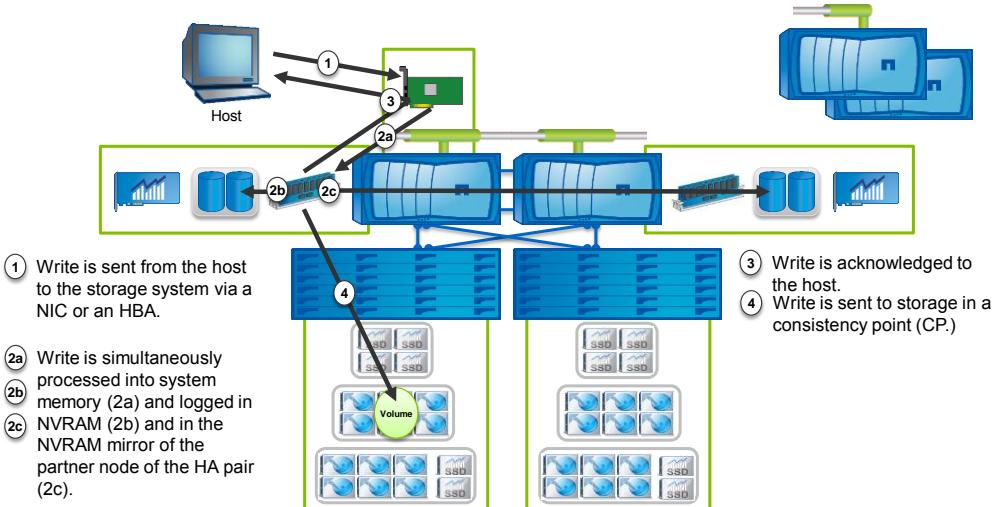
NetApp Confidential

14

## LESSON 3: WRITE DATA ACCESS



# Write Operations (Direct Data Access)



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

15

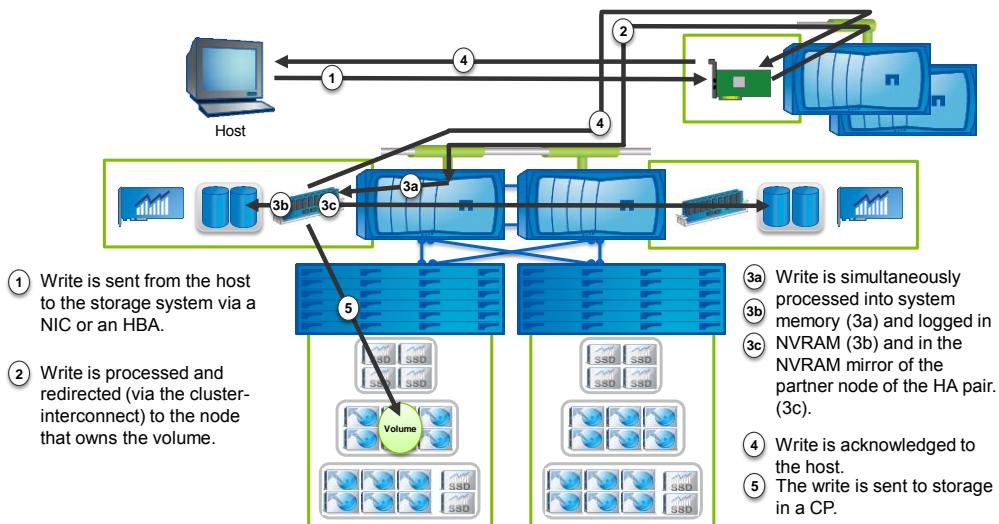
## WRITE OPERATIONS (DIRECT DATA ACCESS)

Write operations for direct access take the following path through the storage system:

1. The write request is sent from the host to the storage system via a NIC or an HBA.
2. The write is simultaneously processed into system memory and logged in NVRAM and in the NVRAM mirror of the partner node of the HA pair.
3. The write is acknowledged to the host.
4. The write is sent to storage in a consistency point (CP).



# Write Operations (Indirect Data Access)



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

16

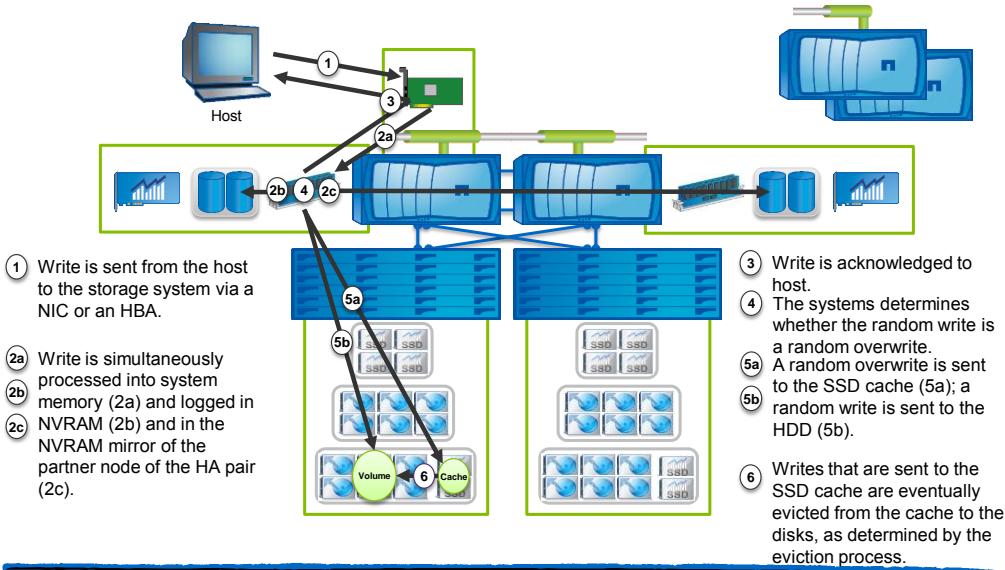
## WRITE OPERATIONS (INDIRECT DATA ACCESS)

Write operations for indirect data access take the following path through the storage system:

1. The write request is sent from the host to the storage system via a NIC or an HBA.
2. The write is processed and redirected (via the cluster-interconnect) to the storage controller that owns the volume.
3. The write is simultaneously processed into system memory and logged in NVRAM and in the NVRAM mirror of the partner node of the HA pair.
4. The write is acknowledged to the host.
5. The write is sent to storage in a CP.



# Write Operations (Flash Pool SSD Cache)



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

17

## WRITE OPERATIONS (FLASH POOL SSD CACHE)

Write operations that involve the SSD cache take the following path through the storage system:

1. The write request is sent from the host to the storage system via a NIC or an HBA.
2. The write is simultaneously processed into system memory and logged in NVRAM and in the NVRAM mirror of the partner node of the HA pair.
3. The write is acknowledged to the host.
4. The system determines whether the random write is a random overwrite.
5. A random overwrite is sent to the SSD cache; a random write is sent to the HDD.
6. Writes that are sent to the SSD cache are eventually evicted from the cache to the disks, as determined by the eviction process).

For detailed information, see TR-4070: *Flash Pool Design and Implementation Guide*.



## Lesson 4

### NVRAM and CPs



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

18

## LESSON 4: NVRAM AND CPS



# NVRAM and System Memory

- Write operations: sent to disk from memory (not NVRAM) in a CP
- NVRAM (and NVMEM) characteristics:
  - Battery-backed memory
  - Double-buffered journal of write operations
  - Mirrored between storage controllers in an HA pair
- Writes in memory that are logged in NVRAM (and mirrored): persistent.



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

19

## NVRAM AND SYSTEM MEMORY

With battery-backed memory, during a power outage, the battery maintains power and keeps the contents of the memory alive.



## NVRAM and System Memory: Details

- Main memory: the write cache
- NVRAM: not the write cache
  - Is used only for writes, never for reads
  - Is a redo log or short-term transaction log, typically less than 20 seconds
  - Provides a safety net, used in case of a system crash
  - After data is written, is not looked at again—unless a crash occurs
  - Enables rapid acknowledgment of client-write requests

### NVRAM AND SYSTEM MEMORY: DETAILS

NVRAM is not the write cache; NVRAM is a redo log.

NVRAM provides a safety net for the time between the acknowledgement of a client-write request and the commitment of the data to disk. After data is written to NVRAM, it is not looked at again, unless a crash occurs before a CP is complete. If a crash occurs, the operations in the NVRAM log are repeated; that is, the operations in the log are replayed into system memory.



## NVRAM Myths

- “NVRAM limits performance.”
- “NVRAM is a bottleneck.”

Write throughput is limited by the disks or the storage controller.

## NVRAM MYTHS



## CPs

Certain circumstances trigger a CP:

- One of the NVRAM buffers fills up, and it is time to flush the writes to disk (type = F or B).
- A ten-second timer runs out (type = T).
- A resource is exhausted or hits a predefined scenario, and it is time to flush the writes to disk (all other CP types).



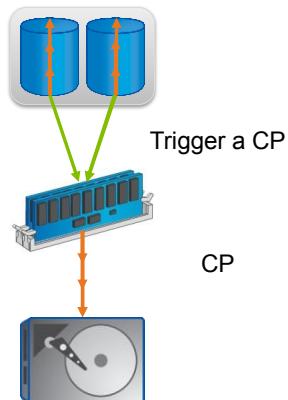
NVRAM is very fast.  
It is never the performance bottleneck.





## Back-to-Back CPs

- As an NVRAM buffer reaches its capacity (alternating), it signals to memory that it is time to flush the writes in memory to disk.
- If the second buffer reaches capacity while writes are still being sent to disk from the first buffer, the CP cannot occur.
- The CP can occur only after the first flush of writes is complete.



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

23

## BACK-TO-BACK CPS



## Lesson 5

### RAID



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

24

## LESSON 5: RAID



## The Value of Software RAID

- Tight integration with WAFL
  - Better write allocation
  - Better handling of failures
- More flexibility
  - Rapid RAID recovery
  - Flexibility in RAID type (RAID-DP technology)
  - Flexible disk layout (across adapters)
  - Better error handling

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

25

## THE VALUE OF SOFTWARE RAID



## RAID Storage Resiliency Features

RAID protects data in many ways:

- RAID checksums
- RAID scrub (validates checksums)
- Media scans (corrects media errors)
- Rapid RAID recovery (copies data to a new disk before an entire disk fails)
- Maintenance Center (tests disks)
- Lost-writes protection (protects against disk malfunctions)

## RAID STORAGE RESILIENCY FEATURES



## Module Summary

Now that you have completed this module, you should be able to:

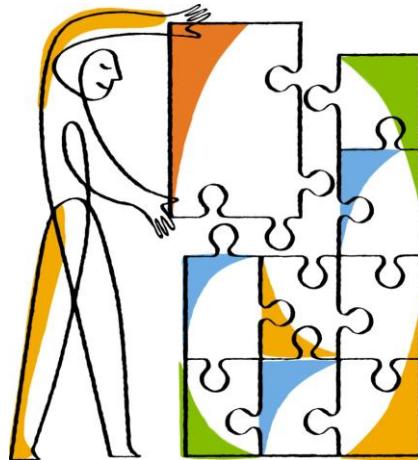
- Describe the layers within the Data ONTAP architecture
- List the advantages that are provided by the ability of WAFL to optimize writes
- Explain the purpose of NVRAM
- Diagram the flow of read and write requests through the network and protocol layers of Data ONTAP
- Describe the benefits that RAID provides

## MODULE SUMMARY



## Learning Activity Questions

Module 1: How a NetApp Storage System Works



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

28

### LEARNING ACTIVITY QUESTIONS



## Learning Activity: Questions

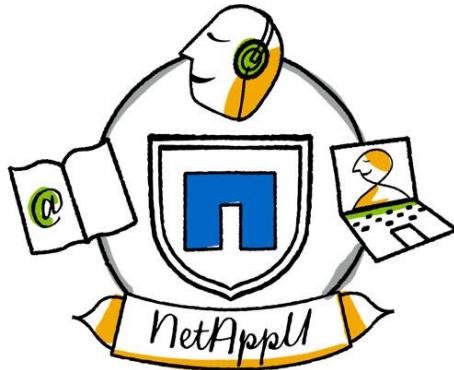
- What is the difference between direct and indirect data access?
- What Data ONTAP feature adds an additional layer of intelligence that Data ONTAP uses to keep the most relevant data in memory?
- Write operations are sent to disk from memory (not from NVRAM) in a \_\_\_\_\_.
- Which RAID feature copies data to a new disk before an entire disk fails?

## LEARNING ACTIVITY: QUESTIONS



## Module 2

### Performance Overview



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

1

## MODULE 2: PERFORMANCE OVERVIEW



## Module Objectives

After this module, you should be able to:

- Define performance-related terms, such as “baseline,” “bottleneck,” “Little’s law,” and “latency”
- Describe baseline performance guidelines and methodologies as they relate to NetApp storage systems

## MODULE OBJECTIVES



## First Rule for Performance Cases

### Have No Fear

1 = 6 =

2 = 7 =

3 = 8 =

4 = 9 =

5 =

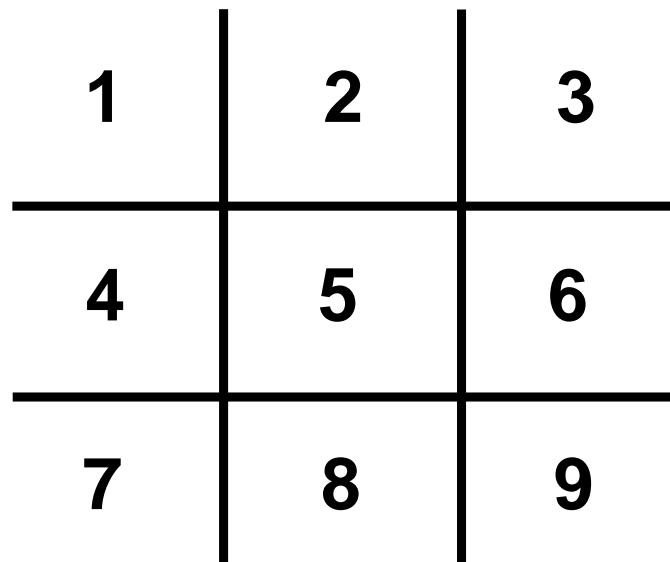
How long would you need to memorize  
this code?  
5 seconds?

## FIRST RULE FOR PERFORMANCE CASES: HAVE NO FEAR



## First Rule for Performance Cases

### Have No Fear



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

4

## FIRST RULE FOR PERFORMANCE CASES: HAVE NO FEAR



# Lesson 1

## Basic Terminology



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

5

### LESSON 1: BASIC TERMINOLOGY



## Terminology

### “Performance” and “Bottleneck”

- What is **performance**?

A comparison between the useful work that is accomplished by a computer system and the time and resources that are required to accomplish the work

- What is a **bottleneck**?

A component or resource that hinders the performance or capacity of a system

- What **bottlenecks** affect a storage system?

Storage system (CPU, memory, disk), network, host, and applications

## TERMINOLOGY: “PERFORMANCE” AND “BOTTLENECK”



## Terminology

### About Performance

- **Baseline:** a value or set of values that can serve as a comparison or control
- **Benchmark:** a controlled workload that is used to measure performance
- **Response time:** the time that is required to return an answer
- **Resource utilization:** the percentage of time that a resource is working
- **I/O rate:** the number of transactions per second or I/O operations per second (IOPS)
- **I/O time:** the time that is expended to service an I/O event
- **Seek time:** the time that is required to move the disk drive head to the data
- **Saturation:** the condition in which a component reaches its maximum throughput handling capability

## TERMINOLOGY: ABOUT PERFORMANCE



## Terminology

### About Workloads and Performance

- **Throughput:** how many operations are completed
- **Latency:** how fast operations are completed
- **Operation type:** Reads, writes, and more
- **Operation size:** how big the operations are
- **Randomness:** whether the operations are random or sequential
- **Concurrency:** how many operations occur during one latency period
- **Data set size:** how much data exists on system
- **Working set size:** how much of the data is active
- **Bandwidth:** how much data can be delivered in a specified amount of time

## TERMINOLOGY: ABOUT WORKLOADS AND PERFORMANCE

Workload characteristics affect storage system performance and are part of the performance equation.



# Workload Characteristics

## Random and Sequential

- **Random I/O:** blocks accessed from random locations on the disk
- **Sequential I/O:** blocks accessed from a contiguous area of the disk

### Random and Sequential Workload Examples

- **Databases (DBs)**
  - OLTP: 80% random
  - DSS: 20% random
  - Mixed DB workload: 50% random
- **Exchange**
  - 70% random
  - 30% sequential
- **CIFS and NFS**
  - 60% random
  - 15% sequential read
  - 25% sequential write
- **Mixed workload**
  - 80% random
  - 20% sequential

## WORKLOAD CHARACTERISTICS: RANDOM AND SEQUENTIAL

Workload characteristics define the type of data access that affects the system. With random activity, the storage system accesses blocks from random locations on the disk. Traditionally, a time penalty is incurred while the disk heads seek and the disk rotates. With sequential activity, the storage system accesses blocks that reside in a contiguous area of the disk.

## Lesson 2

### Little's Law



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

10

### LESSON 2: LITTLE'S LAW

Little's law is a theorem that was presented by John Little.



## Little's Law: Definition

Throughput and time of a system in steady state is:

$$\text{Requests} = \text{Throughput} * \text{Response Time}$$

The number of requests in a system ( $L$ )  
is equal to their arrival rate ( $\lambda$ )  
multiplied by their time in the system ( $W$ ) or

$$L = \lambda W$$

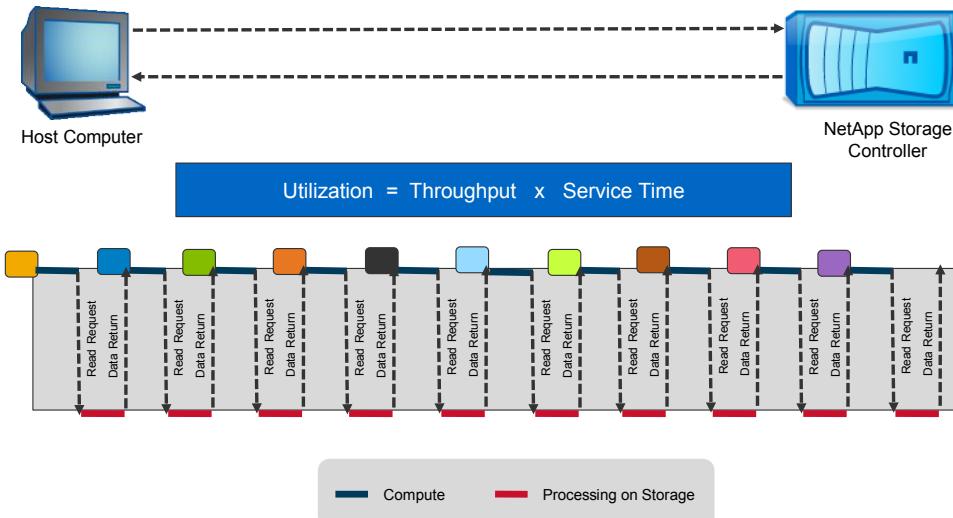
### LITTLE'S LAW: DEFINITION

Initially, Little's law was presented as a basic manufacturing principle; however, the law can be applied to the performance of any system. Little's law states that the long-term average number of customers (or requests, in this case) in a stable system ( $L$ ) is equal to the long-term average effective arrival rate ( $\lambda$ ) multiplied by the average amount of time that a customer (or request) spends in the system ( $W$ ). The law is expressed algebraically as " $L = \lambda W$ ."

The equation can also be expressed as "requests = throughput x response time." The term "requests" can be replaced by the term "utilization," as in "utilization = throughput x response time." And, the term "response time" can be replaced with the term "service time" or "latency."



## Little's Law: Example



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

12

### LITTLE'S LAW: EXAMPLE

Little's Law describes throughput as work in progress divided by response time. Response time is latency, and latency is consistent, regardless of the work in progress (or queue depth). The first example uses a queue depth of one, indicating that one task is being performed. For this example, assume that the latency is 2.88 ms. Throughput is then calculated as one divided by the response time, or one divided by 2.88 ms. Therefore, the throughput is .35 per ms, or, in other words, approximately one-third of the task was completed in one millisecond.

The second example uses a queue depth to ten and, again, a latency of 2.88 ms. Throughput is then calculated as ten divided by 2.88 ms. Therefore, throughput is 3.5 ms, or, in other words, three and one-half tasks were completed in one millisecond.

As demonstrated, the more tasks in the queue, the better the throughput; and the better the throughput, the better the system performance.



## Lesson 3

### Performance of Storage System Components



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

13

## LESSON 3: PERFORMANCE OF STORAGE SYSTEM COMPONENTS



## Controller Limits

- CPU
  - < 85% on one controller
  - < 50% on a controller pair
- Other factors
  - Limit
    - Controller PCIe bus limits
    - Controller memory bus limits
  - Improve
    - Flash Pool, Flash Cache, Flash Accel
    - Solid-state drives (SSD)

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

14

## CONTROLLER: LIMITS



## Disk Shelf Limits

Transport	Peak Throughput	75% of Peak (Recommended)
1 Gbps FC	120 MBps	90 MBps
2 Gbps FC	240 MBps	180 MBps
4 Gbps FC	480 MBps	360 MBps
3 Gbps SAS (IOM3)	1.2 GBps	0.9 GBps
6 Gbps SAS (IOM6)	2.4 GBps	1.8 GBps

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

15

## DISK SHELF: LIMITS



## Hard Disk Drive Theoretical Limits

Spindle Speed	Maximum Theoretical Random IOPS	Maximum Theoretical 4KB Random Throughput	Maximum Theoretical 64KB Random Throughput
7200 RPM	240 per spindle	0.9 MBps per spindle	15 Mbps per spindle
10000 RPM	333 per spindle	1.3 MBps per spindle	20 MBps per spindle
15000 RPM	500 per spindle	1.9 MBps per spindle	31 MBps per spindle

Theoretical throughput is never achieved.

## HARD DISK DRIVE: THEORETICAL LIMITS



## Hard Disk Drive Realistic Limits

Workload Type	Typical Measured Peak Throughput per Data Spindle (CPU Limited Configuration)	Target Throughput for Non-Performance Workloads (50% of Peak)	Target Throughput with 112 Spindles (98 Data Spindles)	Target Throughput with 512 Spindles (448 Data Spindles)
Random read	500 KBps	250 KBps	20 MBps	100 MBps
Random write	2.4 MBps	1.2 MBps	110 MBps	530 MBps
Sequential read	6.8 MBps	3.2 MBps	300 MBps	1.4 GBps
Sequential write	7.2 MBps	3.6 MBps	350 MBps	1.6 GBps

© 2013 NetApp, Inc. All rights reserved.

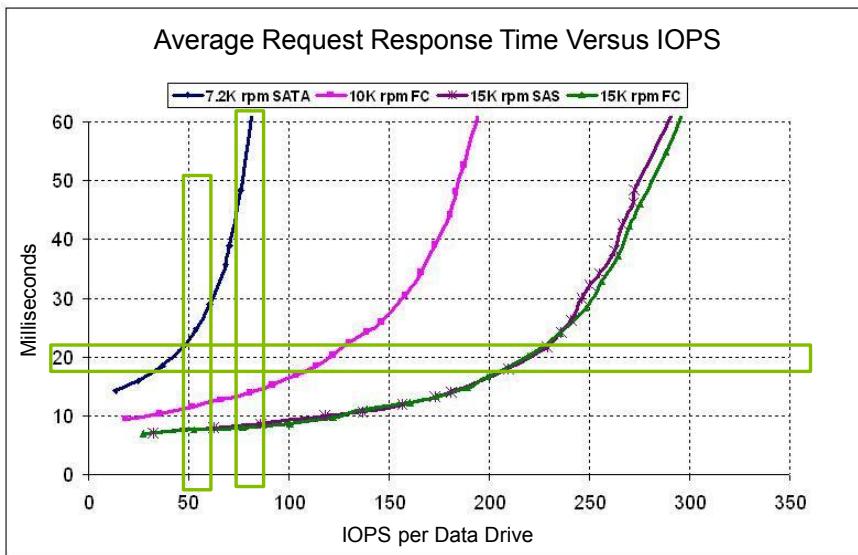
NetApp Confidential

17

## HARD DISK DRIVE: REALISTIC LIMITS



## Hard Disk Drive IOPS Versus Latency



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

18

### HARD DISK DRIVE: IOPS VERSUS LATENCY

This diagram shows drive capability for hard disk drives (HDDs) with different rotational speeds. The diagram answers the question “how many IOPS can be performed per drive within what response time?” For example, if the response time is 20 ms, drives with 7200 RPM have an I/O rate of approximately 40, drives with 10000 RPM have an I/O rate of approximately 120, and drives with 15000 RPM have an I/O rate of approximately 220. You should commit the information in this diagram to memory.

If drives with 7200 RPM are doing 80 or 90 IOPS, the efficiency of the drives must be improved, spindles must be added, or the workload must be moved to faster drives. Conversely, if drives with 15000 RPM are doing 100 IOPS, no action is needed.

In read-intensive environments, solid-state drives (SSDs) provide more latency and throughput benefits than do HDDs. For the latest information about the performance of SSDs, visit [netapp.com](http://netapp.com).



## Client Limits

Transport	Peak Throughput	75% of Peak (Recommended)
1 Gbe	100 - 120 MBps	90 MBps
10 Gbe	1.0 – 1.2 GBps	900 MBps
40 Gbe	~5 GBps	< 4 GBps
1 Gbps FC	120 MBps	90 MBps
2 Gbps FC	240 MBps	180 MBps
4 Gbps FC	480 MBps	360 MBps

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

19

## CLIENT: LIMITS



## Lesson 4

### Advanced Performance Analysis



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

20

## LESSON 4: ADVANCED PERFORMANCE ANALYSIS



## Performance Guidelines

- Know your environment
- Identify the characteristics of your workload
- Recognize possible trade-offs
- Understand the difference between latency and throughput
- Remember Little's Law
- Do not over use resources
- Identify potential bottlenecks
- Design tests carefully
- Understand your end-user applications

## PERFORMANCE GUIDELINES



## Performance Monitoring Methodology

1. Create and save performance **baselines** on a regular basis
2. Monitor for trends
3. Determine acceptable levels of performance
4. Take corrective action
5. Evaluate existing and create new performance **baselines**
6. Document what you see

## PERFORMANCE MONITORING METHODOLOGY



# Scientific Method

- Frame the case
- Develop the hypothesis
  - Predictions
  - Experiments
- Evaluate and iterate
- Confirm

## SCIENTIFIC METHOD

The scientific method is a body of techniques for investigating phenomena and acquiring knowledge as well as for correcting and integrating previous knowledge. The method is based on gathering observable, empirical, and measurable evidence and requires the application of specific principles of reasoning, the collection of data through observation and experimentation, and the formulation and testing of hypotheses. The process must be objective. The goal is to prove whether a theory is true or false.

### Framing the case

“Framing the case” is called “characterization.” Characterization is the systematic, careful collection of measurements and information about a case. The collection can be accompanied by measurements or estimates of uncertainty. Uncertainty is often estimated by making repeated measurements of the desired quantity. For example, you can count the number of NFS operations that occur each hour and compare the number of actual operations to the number of requests that are possible for the interface. Counts represent only a sample of desired quantities, with an uncertainty that depends upon the sampling method that is used and the number of samples that are collected. It is imperative that you consider the limitations of your data.

### Developing the hypothesis

A hypothesis is a suggested explanation of a phenomenon, or, alternately, a reasoned proposal that suggests a correlation between or among a set of phenomena.

### Predictions from a hypothesis

Any useful hypothesis enables predictions, which are usually obtained through deductive reasoning. You might predict the outcome of an experiment in a laboratory setting or the performance of a phenomenon in nature. Predictions can also involve statistics and probabilities.

To satisfy the requirements of a hypothesis, the outcome of a predication must be unknown. An outcome that is known is a consequence, not a predication. If predictions associated with a hypothesis are not accessible by observation or experience, the hypothesis is not useful.

## **Experiments**

Predictions can be tested by experimentation. If test results contradict the predication, the hypothesis is called into question, and you must seek explanations. When an experiment fails to prove a predication, you should look for fault in the logic or in the test before you conclude that the hypothesis is false.

If the results confirm the predictions, the hypothesis is considered to be correct.

## **Evaluate and iterate**

The scientific process is iterative. At any stage, some consideration may lead you to repeat an earlier part of the process. At any point, a hypothesis may be reevaluated, based on new information or on a new understanding of the facts.

## **Confirm**

Each performance case has a social-learning aspect. Communicating about a case enables you to share information with your community. Others learn, and you benefit from peer review.



## Typical Troubleshooting Pitfalls

- Making an assumption
- Jumping to conclusions
- Not testing the prediction
- Using the “solution of the week”
- Making circular arguments

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

24

## TYPICAL TROUBLESHOOTING PITFALLS



## Module Summary

Now that you have completed this module, you should be able to:

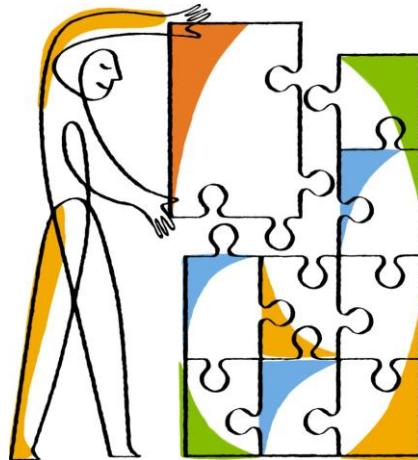
- Define performance-related terms, such as “baseline,” “bottleneck,” “Little’s law,” and “latency”
- Describe baseline performance guidelines and methodologies as they relate to NetApp storage systems

## MODULE SUMMARY



## Learning Activity Questions

Module 2: Performance Overview



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

26

### LEARNING ACTIVITY QUESTIONS



## Learning Activity: Questions

- Identify the two types of workloads.
- What is the correct term for “how many operations are completed?”
- What is the correct term for “how fast are operations completed?”
- What is a bottleneck?

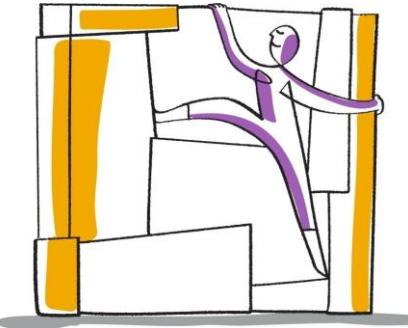
## LEARNING ACTIVITY: QUESTIONS



## Exercise

Module 2: Performance Overview

Time Estimate: 20 Minutes



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

28

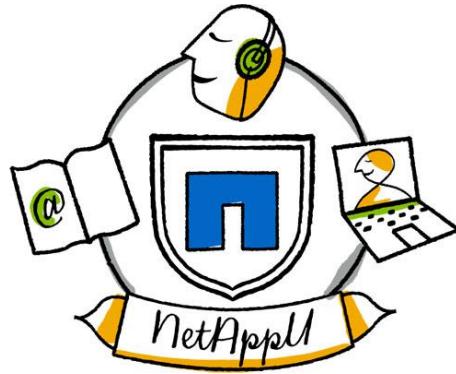
### EXERCISE

Please refer to your exercise guide.



## Module 3

Clustered Storage System  
Workloads and Bottlenecks



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

1

### MODULE 3: CLUSTERED STORAGE SYSTEM WORKLOADS AND BOTTLENECKS



## Module Objectives

After this module, you should be able to:

- Gather information about the workload of an existing storage system
- Identify the storage system components that can affect performance—become bottlenecks

## MODULE OBJECTIVES



## Lesson 1

### Gathering Workloads Characteristics



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

3

### LESSON 1: GATHERING WORKLOADS CHARACTERISTICS

This lesson discusses methods of determining workload characteristics for any given storage environment.



## Counters in Data ONTAP

Organized into objects, instances, and counters:

- An object has one or more instances.
- An instance has one or more counters.

Example:

1. Object = volume
2. Instance = accountsPayVol
3. Counter = total\_ops

## COUNTERS IN DATA ONTAP

In Data ONTAP, a counter is an entity that is displayed as an object, with one or more instances and one or more counters. For example, to display the total operations per second of the accounts payable volume, you specify an object of volume, an instance of accountsPayVol, and a counter of total\_ops.



## statistics catalog object show

Displays a list of objects. Parameters include  
**-fields**, **-describe**, **-object**, **-privilege**, and  
**-description**.

### statistics catalog object show

```
::*> statistics catalog object show -describe

Object: aggregate
Privilege: basic
Description: The Aggregate object reports activity on the disk aggregates.
The RAID subsystem exports the physical disks as logical disk
units (LUNs). LUNs are grouped into disk aggregates to be
carved into logical volumes. The volumes can be exported as
disks for SAN protocols or formatted and exported as a file
system for the NAS protocols.

Object: audit_ng
Privilege: basic
Description: CM object for exporting audit_ng performance counters

...
```

## STATISTICS CATALOG OBJECT SHOW

This command displays the names and descriptions of objects about which you can obtain performance data. The displayed data is either node-specific or cluster-wide, depending on which objects are specified.

Parameters:

**-fields <fieldname>, ...**

Displays the specified field or fields. You can use '-fields ?' to display a list of fields and then choose one or more fields from the list.

**-describe**

Displays detailed information about each object, including privilege level

**-object <text>**

Selects the objects for which you want to display information. If you do not specify this parameter, information is displayed for all of the objects.

**-privilege <text>**

(privilege: advanced)

Selects the objects that match the parameter value

**-description <text>**

Selects the objects that match the parameter value



## statistics catalog instance show

Displays a list of the instances that are associated with an object.

Parameters include **-fields**, **-object**,  
**-instance**, **-filter**, **-vserver**, and **-node**.

### statistics catalog instance show -object [obj]

```
::> statistics catalog instance show -object lif

Object: lif
  cluster1-01:clus1
  cluster1-01:clus2
  cluster1-01:mgmt1
...
  cluster1:cluster_mgmt
  vs2:vs2_cifs_nfs_lif1
  vs2:vs2_cifs_nfs_lif2
  vsISCSI1:cluster1-01_iscsi_lif_1
  vsISCSI1:cluster1-01_iscsi_lif_2
  vsISCSI1:cluster1-02_iscsi_lif_1
  vsISCSI1:cluster1-02_iscsi_lif_2
13 entries were displayed.
```

## STATISTICS CATALOG INSTANCE SHOW

This command displays the names of the instances that are associated with the specified object. The displayed data is either node-specific or cluster-wide, depending on the objects specified.

Parameters:

**-fields <fieldname>, ...**

Displays the specified field or fields. You can use '-fields ?' to display a list of fields and then choose one or more fields from the list.

**-object <text>**

Selects the object for which you want to display the list of instances. This parameter is required. To view a list of valid object names, type "statistics catalog instance show -object ?" or "statistics catalog object show."

**-instance <text>**

Selects the instances that match the parameter value. If you do not specify this parameter, the command displays all instances.

**-filter <text>**

Selects the instances that match the parameter value. For example, to display instances from vserver1, specify -filter "vserver\_name=vserver1".

**-vserver <vserver name>, ...**

Selects the instances that match the parameter value. If you do not specify this parameter, the command displays all of the vserver instances in the cluster.

**-node {<nodename>}|local}, ...**

Selects the instances that match the parameter value. If you do not specify this parameter, the command displays all node instances in the cluster.

**NOTE:** In discussion, the term “Vserver” has been replaced by the term “SVM.” However, this lesson uses “Vserver,” because the command syntax uses “vserver.”



## statistics catalog counter show

Displays a list of the counters in an object. Parameters include **-fields**, **-describe**, **-object**, **-counter**, **-filter**, **-label**, **-description**, **-privilege**, and **-is-key-counter**.

**statistics catalog counter show -object [obj]**

```
::*: statistics catalog counter show -object volume -fields counter
object counter
-----
volume avg_latency
volume cifs_other_latency
volume cifs_other_ops
volume cifs_protocol_other_latency
volume cifs_protocol_read_latency
volume cifs_protocol_write_latency
volume cifs_read_data
volume cifs_read_latency
volume cifs_read_ops
...
```

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

7

## STATISTICS CATALOG COUNTER SHOW

This command displays the names and descriptions of counters. The displayed data is either node-specific or cluster-wide, depending on the objects specified.

Parameters:

**-fields <fieldname>, ...**

Displays the specified field or fields. You can use '-fields ?' to display a list of fields and then choose one or more fields from the list.

**-describe**

Displays information about each counter, including privilege level, label, and whether the counter is a key counter.

**-object <text>**

Selects the object for which you want to display the list of counters. This parameter is required. To view a list of valid object names, type "statistics catalog counter show -object ?" or "statistics catalog object show."

**-counter <text>**

Selects the counters that match the parameter value. If you do not specify this parameter, the command displays information about all counters.

**-filter <text>**

Selects the counters that match the parameter value. For example, to display counters from node1, specify -filter "node\_name=node1".

**-label <text>, ...**

Selects the counters that match the parameter value. A label is the name of the bucket to which an array counter belongs.

**-description <text>**

Selects the counters that match the parameter value.

**-privilege <text>**

(privilege: advanced)

Selects the counters that match the parameter value.

**-is-key-counter {true|false}**

Selects the counters that are key counters (true) or are not key counters (false). A key counter uniquely identifies an instance across the cluster. The default setting is false. For example, "vserver\_name" and "node\_name" are key counters because they identify the Vserver or node to which the instance belongs.



## statistics start

NetApp®

- Use `statistics start` to begin data collection.
- Use `statistics stop` to end data collection.
- Use `statistics show` to display the collected data.

```
statistics start -object [obj] -instance [inst]
-counter [cnt] -sample-id [samp-id]
```

```
::> statistics start -object volume -sample-id sample1
Statistics collection is being started for Sample-id: sample1

::> statistics samples show

Vserver          Sample ID          Start Time      Stop Time      Status
-----          -----          -----          -----
cluster1        sample1           09/17 15:02:38 -          Ready

::> statistics stop -sample-id sample1
Statistics collection is being stopped for Sample-id: sample1
```

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

8

## STATISTICS START

You can collect more than one data sample at a time.

Parameters:

### **-object <text>**

Selects the objects for which you want to collect data. This parameter is required. To display a list of valid object names, type “`statistics catalog object show`” at the command prompt. To avoid negatively impacting system performance, select no more than a few objects.

### **-instance <text>**

Selects the instances for which you want to collect data. If you do not specify this parameter, the command collects statistics for all of the instances that are associated with the specified objects.

### **-counter <text>**

Selects the counters for which you want to collect data. If you do not specify this parameter, the command collects statistics for all of the counters in the specified objects.

### **-sample-id <text>**

Specifies an identifier for the data sample. Identifiers must be unique and are restricted to the characters 0-9, a-z, A-Z, and “\_”. If you do not specify this parameter, the command generates a sample identifier and defines the sample as the default sample for the CLI session. Then, if you run the `statistics show` command and do not specify the `-sample-id` parameter, the data from the default sample is displayed. If you run the `statistics start` command more than once during a CLI session and do not specify the `-sample-id` parameter on the subsequent runs, the sample that was displayed by the previous run is overwritten. When you close a session, the default sample is not deleted.

**-vserver <vserver name>**

Selects the vserver for which you want to collect data. If you do not specify this parameter, the command collects statistics for all of the Vservers in the cluster.

**-node {<nodename>|local}**

Selects the node for which you want to collect data. If you do not specify this parameter, the command collects statistics for all of the nodes in the cluster.

**-filter <text>**

(privilege: advanced)

Selects data for the instance that matches the specified filter criteria. For example, to display the instances from node1, specify -filter "node\_name=node1".



## statistics show

Displays one iteration of the statistics data that was collected by the `statistics start` command.

```
statistics show -object [obj] -instance [inst]  
-counter [cnt]
```

```
::> statistics show -object volume -instance vs2_vo101 -counter total_ops  
-sample-id sample1

Object: volume
Instance: vs2_vo101
Start-time: 7/17/2013 15:02:38
End-time: 7/17/2013 15:03:14
Cluster: cluster1

      Counter          Value
-----  
    total_ops        1278194
```

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

9

## STATISTICS SHOW

This command displays performance data for a particular period of time. The data is calculated based on the samples that the cluster collects. You use the `statistics start` and `statistics stop` commands to collect your data sample. You use the `-sample-id` parameter to display the sample data.

Parameters:

**-fields <fieldname>, ...**

Displays data for the specified field or fields. You can use `-fields ?` to display a list of fields and then choose one or more fields from the list

**-object <text>**

Selects the objects for which you want to display data. To view a list of valid object names, type “`statistics show -object ?`” or “`statistics catalog object show`.” To avoid significantly impacting performance, specify no more than a few objects.

**-instance <text>**

Selects the instances for which you want to display data. If you do not specify this parameter, the command displays statistics for all of the instances that are associated with the specified objects. For example, if you want to display disk-object statistics, you can use this parameter to specify the name of the disk whose statistics you want to view. If you do not specify this parameter, the command displays statistics for all of the disks in the system.

**-counter <text>**

Selects the counters for which you want to display data.

**-node {<nodename>|local}**

Selects the nodes for which you want to display data.

**-vserver <vserver name>**

Selects the Vserver for which you want to display data.

**-value <Counter64>**

(privilege: advanced)

Selects the data that matches the specified counter value.

**-labels <text>, ...**

(privilege: advanced)

Selects the data that matches the specified label.

**-values <text>, ...**

(privilege: advanced)

Displays only the statistics that have the specified values.

**-filter <text>**

(privilege: advanced)

Selects the data for the instance that matches the specified filter criteria. For example, to display the instances for which the total-ops counter is greater than 50, specify -filter "total\_ops>50".

**-sample-id <text>**

Displays data for the specified sample.



## statistics show

### Example 1 of 2

```
::> statistics show -object
aggregate          audit_ng
audit_ng:vserver   avoa
avfs              cifs
cifs:node         cifs:vserver
cluster            cluster_peer
cpx                disk
disk:raid_group   ext_cache
ext_cache_obj     fcache
fcp_lif            fcp_lif:node
fcp_lif:port       fcp_lif:vserver
hashd              hostadapter
ifnet              iscsi_conn
iscsi_conn:session iscsi_lif
iscsi_lif:node    iscsi_lif:vserver
lif                lif:vserver
logical_replication_destination logical_replication_source
lun                lun:constituent
nblade_cifs        nfsv3
nfsv3:constituent nfsv3:cpu
nfsv3:node         nfsv4
nfsv4:constituent nfsv4:cpu
nfsv4:node         nfsv4_1
nfsv4_1:constituent nfsv4_1:cpu
nfsv4_1:node       node
path               port
...
...
```

Press TAB to  
show available storage objects

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

10

## STATISTICS SHOW: EXAMPLE 1 OF 2



## statistics show

### Example 2 of 2

Press TAB to display the environment-specific instances of the storage object that is selected

```
::> statistics show -object volume -instance
lun_vsISCSI1_1_vol vol0          vs1_root
vs2_root           vs2_vol01      vsISCSI1_root
::> statistics show -object volume -instance vs2_vol01 -counter
avg_latency       cifs_protocol_other_latency
cifs_protocol_read_latency   cifs_protocol_write_latency
fcp_protocol_other_latency   fcp_protocol_read_latency
fcp_protocol_write_latency  instance_name
instance_uuid       iscsi_protocol_other_latency
iscsi_protocol_read_latency iscsi_protocol_write_latency
nfs_protocol_other_latency nfs_protocol_read_latency
nfs_protocol_write_latency node_name
node_uuid          other_latency
other_ops          process_name
read_data          read_latency
read_ops           total_ops
total_protocol_other_latency total_protocol_read_latency
total_protocol_write_latency vserver_name
vserver_uuid       write_data
write_latency      write_ops
::> statistics show -object volume -instance vs2_vol01 -counter total_ops
```

Press TAB to display the counters for the storage object instance that is selected

## STATISTICS SHOW: EXAMPLE 2 OF 2



## statistics show-periodic

Displays multiple iterations of statistics

```
statistics show-periodic -object [obj] -instance  
[inst] -counter [cntr]
```

```
::> statistics show-periodic -node node04 -object volume -instance iscsi_vol  
instance node avg total read read write write write other other  
name name latency ops data latency read_ops data latency ops latency ops  
-----  
0 0 461us 6830 320MB 522us 5135 105MB 279us 1694 0us 0  
0 0 397us 7356 342MB 444us 5492 116MB 261us 1864 0us 0  
node04: volume.iscsi_vol: 9/11/2012 17:02:42  
instance node avg total read read write write write other other  
name name latency ops data latency read_ops data latency ops latency ops  
-----  
Minimums:  
0 0 397us 6830 320MB 444us 5135 105MB 260us 1694 0us 0  
Averages for 3 samples:  
0 0 425us 7163 334MB 478us 5366 112MB 266us 1796 0us 0  
Maximums:  
0 0 461us 7356 342MB 522us 5492 116MB 279us 1864 0us 0
```

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

12

## STATISTICS SHOW-PERIODIC

The `statistics show-periodic` command uses the same parameters as the `statistics show` command.



## statistics show-periodic Example

```
::> statistics show-periodic
      cpu    total          data      data      data   cluster   cluster   cluster   disk   disk
      busy     ops   nfs-ops  cifs-ops  busy     recv     sent   busy     recv   sent   read   write
-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
      88%  50053  50053       0  92%  339MB  23.8MB  45%  261MB  291MB  40.8MB  422MB
      82%  66182  66182       0  75%  383MB  16.9MB  38%  309MB  250MB  42.4MB  385MB
      68%  50602  50602       0  69%  317MB  34.9MB  49%  263MB  297MB  44.7MB  396MB
      73%  44095  44095       0  68%  284MB  19.9MB  38%  230MB  240MB  38.4MB  395MB
      75%  48998  48998       0  75%  319MB  27.1MB  49%  263MB  295MB  44.3MB  404MB
      85%  56650  56650       0  89%  346MB  16.5MB  43%  271MB  212MB  49.2MB  432MB
      87%  62995  62995       0  69%  379MB  41.9MB  52%  306MB  343MB  42.5MB  347MB
      72%  43038  43038       0  64%  287MB  11.8MB  47%  220MB  218MB  41.1MB  410MB
cluster: 2/13/2008 11:10:15
      cpu    total          data      data      data   cluster   cluster   cluster   disk   disk
      busy     ops   nfs-ops  cifs-ops  busy     recv     sent   busy     recv   sent   read   write
-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
Minimuns:
      68%  43038  43038       0  64%  284MB  11.8MB  38%  220MB  212MB  38.4MB  347MB
Averages for 8 samples:
      78%  52826  52826       0  75%  332MB  24.1MB  45%  265MB  268MB  42.9MB  399MB
Maximums:
      88%  66182  66182       0  92%  383MB  41.9MB  52%  309MB  343MB  49.2MB  432MB
```

This point is when the administrator pressed Ctrl-C, and the summary, min, max, and average values were displayed.

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

13

## STATISTICS SHOW-PERIODIC: EXAMPLE

The `statistics show-periodic` command runs until Ctrl-C is pressed, with each line of output reporting the stats since the previous line of output (interval). The default interval is one second. When Ctrl-C is pressed, some summary data is presented.

This output can tell you much. If the “cluster busy” values are nonzero, it’s a good indication that the user data isn’t sent over the cluster links. The same is true if “cluster recv” and “cluster sent” values are in the KB range. Therefore, if operations occur with no data sent over the cluster network, the output shows that data is served locally, which is similar to when many reads are performed to LS mirror copies that are on the same nodes as the data logical interfaces (LIFs) that are accessed by the clients. When cluster traffic occurs, the “cluster recv” and “cluster sent” values are in the MB range.

Other good options to use with this command are:

- `statistics periodic -object latency -node node`
- `statistics periodic -object volume -node node -interval 1`
- `statistics show -node node -object volume -counter *latency` (This wildcard shows all the latency counters.)



## Measurements That Define Workload Characteristics

- Throughput
- Latency
- Operation size
- Randomness
- Concurrency

Command to access counter-manager statistics for the data

```
::> statistics show <object> <instance> <counter>
```

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

14

## MEASUREMENTS THAT DEFINE WORKLOAD CHARACTERISTICS



## Workload Characteristics

### Throughput

Throughput (operations per second)

- NFS example

```
::> statistics show -object nfsv3 -instance * -counter nfsv3_read_ops  
-sample-id sample_nfsv3  
::> statistics show -object nfsv3 -instance * -counter nfsv3_write_ops  
-sample-id sample_nfsv3
```

- CIFS example

```
::> statistics show -object cifs -instance * -counter cifs_read_ops  
-sample-id sample_cifs  
::> statistics show -object cifs -instance * -counter cifs_write_ops  
-sample-id sample_cifs
```

## WORKLOAD CHARACTERISTICS: THROUGHPUT



## Workload Characteristics

### Latency

Latency (time in milliseconds)

- NFS example

```
::> statistics show -object volume -instance * -counter nfs_read_latency  
-sample-id sample_nfsv3  
::> statistics show -object volume -instance * -counter nfs_write_latency  
-sample-id sample_nfsv3
```

- CIFS example

```
::> statistics show -object volume -instance * -counter cifs_read_latency  
-sample-id sample_cifs  
::> statistics show -object volume -instance * -counter cifs_write_latency  
-sample-id sample_cifs
```

## WORKLOAD CHARACTERISTICS: LATENCY



## Workload Characteristics

### Operation Size

Operation size (in kilobytes)

- NFS example

```
::> statistics show -object nfsv3 -instance * -counter  
    nfsv3_read_size_histo -sample-id sample_nfsv3  
::> statistics show -object nfsv3 -instance * -counter  
    nfsv3_write_size_histo -sample-id sample_nfsv3
```

- CIFS example

```
::*> statistics show -object cifs -instance * -counter  
    cifs_read_size_histo -sample-id sample_cifs  
::*> statistics show -object cifs -instance * -counter  
    cifs_write_size_histo -sample-id sample_cifs
```

## WORKLOAD CHARACTERISTICS: OPERATION SIZE

cifs\_read\_size\_histo and cifs\_write\_size\_histo are diagnostic privilege level counters and will only display if the sample was collected while in the diagnostic privilege level.



## Workload Characteristics

### Randomness

Randomness (random or sequential) read example

```
::*:> statistics show -object readahead -instance * -counter  
    rand_read_reqs -sample-id sample_readahead  
::*:> statistics show -object readahead -instance * -counter  
    seq_read_reqs -sample-id sample_readahead
```

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

18

## WORKLOAD CHARACTERISTICS: RANDOMNESS

rand\_read\_reqs and seq\_read\_reqs are diagnostic privilege level counters and will only display if the sample was collected while in the diagnostic privilege level.



## Workload Characteristics

### Concurrency

Not a specific counter but can be calculated by using the formula **throughput x latency**:

- Uses the numbers from the throughput and latency counters
- Produces a value that identifies the number of operations that occur within the latency window
  - Think of the axiom: the larger the number, the “better” the result
  - Consider the result in relation to operation size.

## WORKLOAD CHARACTERISTICS: CONCURRENCY



# Workload Characteristics Example

## Read Throughput

```
::*> statistics show -object nfsv3 -instance * -counter nfsv3_read_ops -sample-id sample_nfsv3

Object: nfsv3
Instance: vsProd
...
Number of Constituents: 4 (complete_aggregation)
  Counter                               Value
  -----
  nfsv3_read_ops                         6522
```

Characteristic	Observed Value	
	Read	Write
Throughput	6522 per sec	
Latency		
Operation size		
Concurrency		
Randomness		

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

20

## WORKLOAD CHARACTERISTICS EXAMPLE: READ THROUGHPUT

This example shows the process of determining the workload characteristics of a storage system:

- Read throughput
- Write throughput
- Read latency
- Write latency
- Read operation size
- Write operation size
- Read and write concurrency
- Random read
- Sequential read



## Workload Characteristics Example

### Write Throughput

```
::*:> statistics show -object nfsv3 -instance * -counter nfsv3_write_ops -sample-id sample_nfsv3

Object: nfsv3
Instance: vsProd
...
Number of Constituents: 4 (complete_aggregation)
  Counter                                Value
  -----
  nfsv3_write_ops                         721
```

Characteristic	Observed Value	
	Read	Write
Throughput	6522 per sec	721 per sec
Latency		
Operation size		
Concurrency		
Randomness		

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

21

## WORKLOAD CHARACTERISTICS EXAMPLE: WRITE THROUGHPUT



# Workload Characteristics Example

## Read Latency

```
::*:> statistics show -object volume -instance * -counter nfs_read_latency -  
sample-id sample_nfsv3  
  
Object: volume  
Instance: vsProd_vol09  
...  
Counter  
-----  
nfs_read_latency 2882.40us
```

Characteristic	Observed Value	
	Read	Write
Throughput	6522 per sec	721 per sec
Latency	2.88 ms	
Operation size		
Concurrency		
Randomness		

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

22

## WORKLOAD CHARACTERISTICS EXAMPLE: READ LATENCY



## Workload Characteristics Example

### Write Latency

```
::*:> statistics show -object volume -instance * -counter nfs_write_latency -  
sample-id sample_nfsv3  
  
Object: volume  
Instance: vsProd_vol09  
...  
Counter Value  
-----  
nfs_write_latency 1352.58us
```

Characteristic	Observed Value	
	Read	Write
Throughput	6522 per sec	721 per sec
Latency	2.88 ms	1.35 ms
Operation size		
Concurrency		
Randomness		

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

23

## WORKLOAD CHARACTERISTICS EXAMPLE: WRITE LATENCY



## Workload Characteristics Example

### Read Operation Size

```
::*:> statistics show -object nfsv3 -instance * -counter nfsv3_read_size_histo -  
sample-id sample_nfsv3  
  
Object: nfsv3  
Instance: vsProd  
...  
Counter  
-----  
nfsv3_read_size_histo  
...  
Value  
-  
<=4KB 356789
```

Characteristic	Observed Value	
	Read	Write
Throughput	6522 per sec	721 per sec
Latency	2.88 ms	1.35 ms
Operation size	4K	
Concurrency		
Randomness		

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

24

## WORKLOAD CHARACTERISTICS EXAMPLE: READ OPERATION SIZE



## Workload Characteristics Example

### Write Operation Size

```
::*:> statistics show -object nfsv3 -instance * -counter nfsv3_write_size_histo -  
sample-id sample_nfsv3  
  
Object: nfsv3  
Instance: vsProd  
...  
Counter  
-----  
nfsv3_write_size_histo  
...  
Value  
-  
<=4KB 12345
```

Characteristic	Observed Value	
	Read	Write
Throughput	6522 per sec	721 per sec
Latency	2.88 ms	1.35 ms
Operation size	4K	4K
Concurrency		
Randomness		

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

25

## WORKLOAD CHARACTERISTICS EXAMPLE: WRITE OPERATION SIZE



## Workload Characteristics Example

### Read and Write Concurrency

Concurrency = Throughput x Latency

```
Read: 6522 per sec * 0.00288 (2.88 ms) = 18.8  
Write: 721 per sec * 0.00135 (1.35 ms) = 0.97
```

Characteristic	Observed Value	
	Read	Write
Throughput	6522 per sec	721 per sec
Latency	2.88 ms	1.35 ms
Operation size	4K	4K
Concurrency	18.8	0.97
Randomness		

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

26

## WORKLOAD CHARACTERISTICS EXAMPLE: READ AND WRITE CONCURRENCY



# Workload Characteristics Example

## Random Read

```
::*:> statistics show -object readahead -instance * -counter rand_read_reqs -  
sample-id sample_nfsv3  
  
Object: readahead  
Instance: readahead  
...  
Counter  
-----  
rand_read_reqs  
UNUSED  
4K  
Value  
-  
-  
99
```

Characteristic	Observed Value	
	Read	Write
Throughput	6522 per sec	721 per sec
Latency	2.88 ms	1.35 ms
Operation size	4K	4K
Concurrency	18.8	0.97
Randomness	Random	

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

27

## WORKLOAD CHARACTERISTICS EXAMPLE: RANDOM READ



## Workload Characteristics Example

### Sequential Read

```
::*:> statistics show -object readahead -instance * -counter seq_read_reqs -  
sample-id sample_nfsv3  
  
Object: readahead  
Instance: readahead  
...  
Counter Value  
-----  
seq_read_reqs -  
UNUSED -  
4K 0
```

Characteristic	Observed Value	
	Read	Write
Throughput	6522 per sec	721 per sec
Latency	2.88 ms	1.35 ms
Operation size	4K	4K
Concurrency	18.8	0.97
Randomness	Random	

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

28

## WORKLOAD CHARACTERISTICS EXAMPLE: SEQUENTIAL READ

The characteristics of the example workload can be defined as many more reads than writes, small operations, some concurrency, and random reads.



## Analyzing Workload Characteristics Data

After you gather all of the workload characteristics, you can use the information in several ways:

- Critical for any storage system sizing exercise
- Helpful in determining what technologies should be considered to improve storage system performance
  - Small block random operations can benefit significantly from the use of Flash Cache or Flash Pool.
  - Caching technologies or pure SSD aggregates can significantly reduce operation latency.

## ANALYZING WORKLOAD CHARACTERISTICS DATA



## Lesson 2

### Identifying Storage System Bottlenecks



© 2013 NetApp, Inc. All rights reserved.

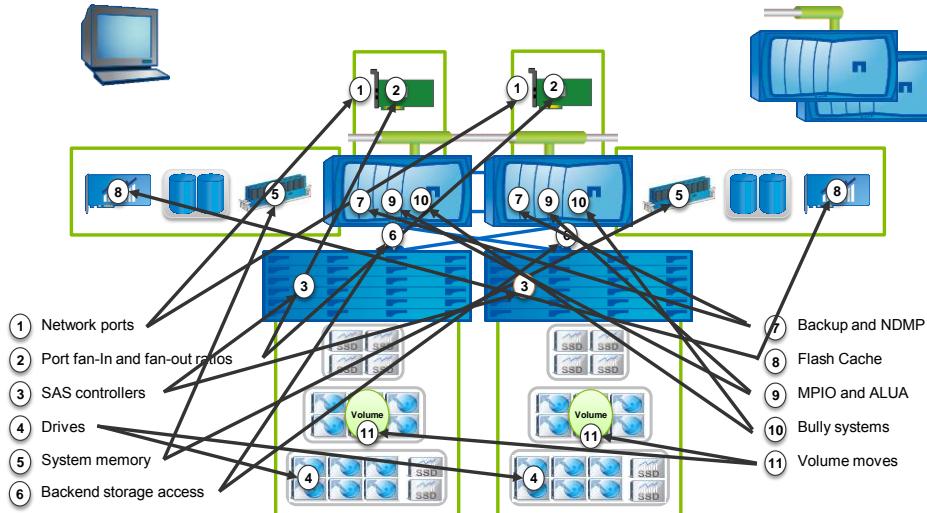
NetApp Confidential

30

## LESSON 2: IDENTIFYING STORAGE SYSTEM BOTTLENECKS



# Bottlenecks Storage System



© 2013 NetApp, Inc. All rights reserved.

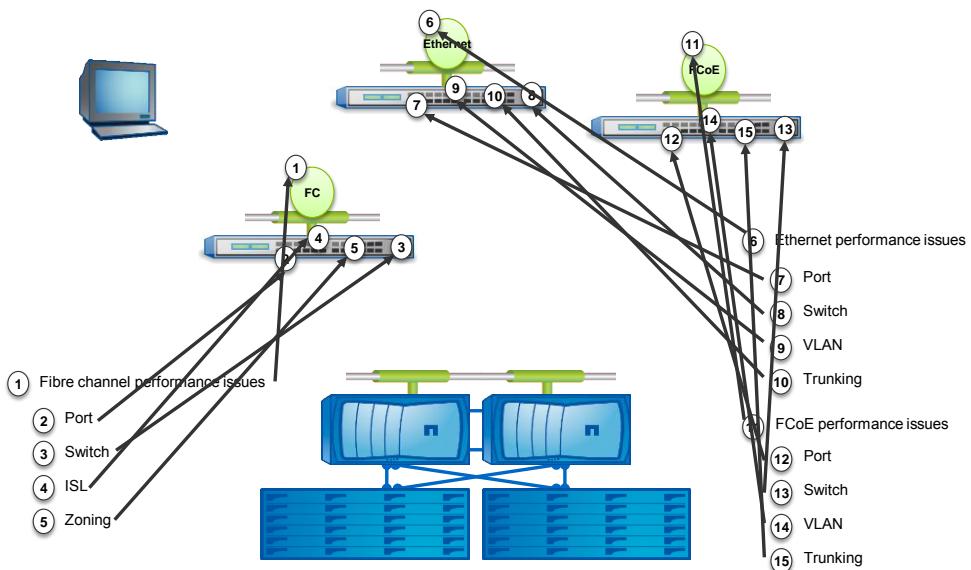
NetApp Confidential

31

## BOTTLENECKS: STORAGE SYSTEM



# Bottlenecks Network



© 2013 NetApp, Inc. All rights reserved.

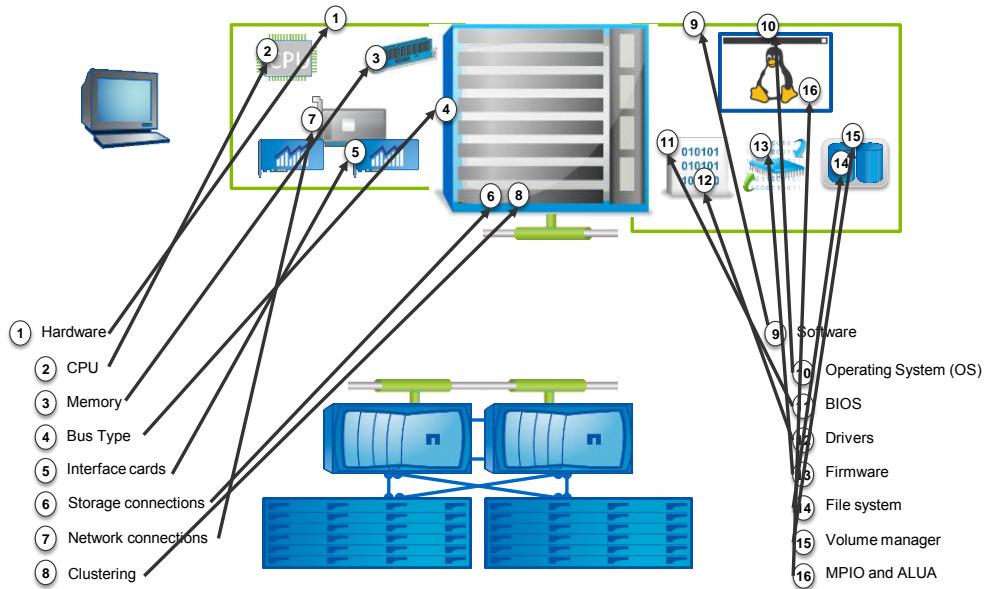
NetApp Confidential

32

## BOTTLENECKS: NETWORK



# Bottlenecks Host



© 2013 NetApp, Inc. All rights reserved.

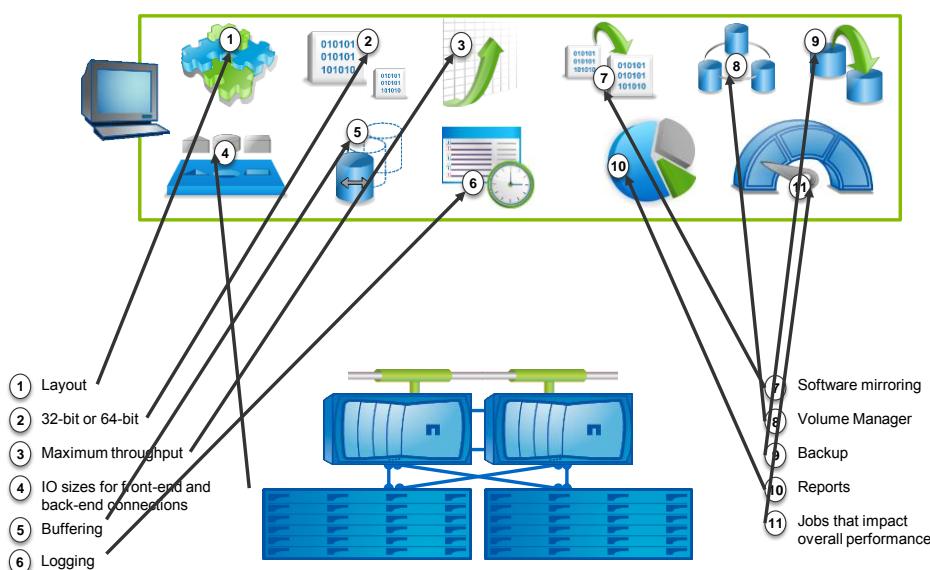
NetApp Confidential

33

## BOTTLENECKS: HOST



## Bottlenecks Application



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

34

## BOTTLENECKS: APPLICATION



# Storage System Bottlenecks

## Summary

- Storage system
  - Network ports
  - Memory and Flash Cache
  - SAS controllers
  - Drives (type, size, speed, number)
  - MPIO and ALUA
  - Port fan-In and fan-out ratios
  - Bulky systems
  - Backend storage access
  - Volume moves
  - Backup and NDMP
- Network
  - FC performance issues (port, switch, ISL, zoning)
  - Ethernet performance issues (port, switch, VLAN, trunking)
  - FCoE performance issues (port, switch, ISL, zoning)
- Host
  - Hardware (CPU, memory, bus type, interface cards, storage connections, network connections, clustering)
  - Software (OS, BIOS, drivers, firmware, file system, volume manager, MPIO and ALUA)
- Applications
  - Layout
  - 32-bit or 64-bit
  - Maximum throughput
  - IO sizes for front-end and back-end connections
  - Buffering
  - Logging
  - Software mirroring
  - Volume Manager
  - Backup
  - Reports
  - Jobs that impact overall performance

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

35

## STORAGE SYSTEM BOTTLENECKS: SUMMARY



## Module Summary

Now that you have completed this module, you should be able to:

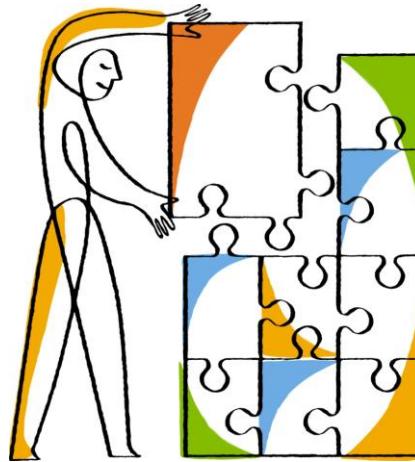
- Gather information about the workload of an existing storage system
- Identify the storage system components that can affect performance—become bottlenecks

## MODULE SUMMARY



## Learning Activity Questions

Module 3: Clustered Storage System Workloads and Bottlenecks



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

37

### LEARNING ACTIVITY QUESTIONS



## Learning Activity: Questions

- What command displays the names and descriptions of the objects from which you can obtain performance data?
- Data ONTAP statistics are organized into \_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_.
- Name the five vital measurements that define the storage system's workload characteristics.
- Concurrency is not a specific counter, but it can be calculated by using the formula \_\_\_\_\_.

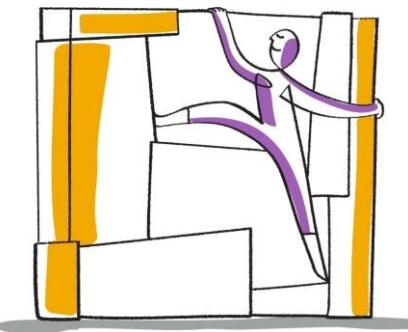
### LEARNING ACTIVITY: QUESTIONS



## Exercise

Module 3: Clustered Storage System  
Workloads and Bottlenecks

Time Estimate: 90 Minutes



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

39

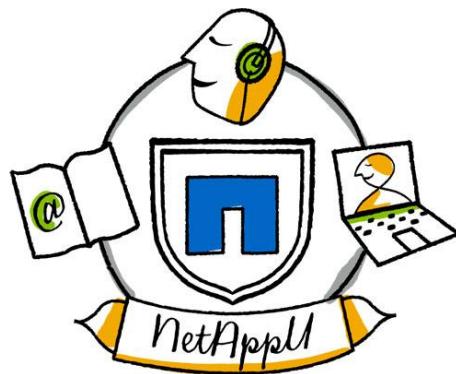
### EXERCISE

Please refer to your exercise guide.



## Module 4

Cluster Performance  
Monitoring and Analysis



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

1

## MODULE 4: CLUSTER PERFORMANCE MONITORING AND ANALYSIS



## Module Objectives

After this module, you should be able to:

- Describe the performance analysis tools and commands that are commonly used for cluster health checks
- Identify the key performance commands and describe the command output that they produce
- Explain how to use NetApp tools for performance measurement
- Describe the benefits of using the AutoSupport support tool for performance analysis

## MODULE OBJECTIVES



## Lesson 1

### Health Checks



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

3

### LESSON 1: HEALTH CHECKS

This lesson discusses methods of determining the health of a clustered storage system.



## Cluster Health

- Are all the nodes healthy?

```
::> cluster show  
::*> cluster ring show
```

(advanced privilege)

- For two-node clusters only, is two-node high availability (HA) configured?

```
::> cluster ha show
```

- Is the cluster network OK?

```
::*> cluster ping-cluster <node>
```

(advanced privilege)

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

4

## CLUSTER HEALTH

The cluster commands provide a quick check on the health of the cluster. Remember that a two-node cluster must have two-node high availability (HA) enabled. If this step is forgotten, problems arise, especially during storage failover (SFO).

The `cluster ping-cluster` command is a great way to ensure that all the cluster ports and cluster LIFs are working properly.



## cluster ping-cluster Command

```
::*:> cluster ping-cluster -node cluster1-01
Host is cluster1-01
Getting addresses from network interface table...
Local = 169.254.53.210 169.254.183.127
Remote = 169.254.62.30 169.254.208.181
Ping status:
4 paths up, 0 paths down at 1500 size
4 paths up, 0 paths down at 4500 size
4 paths up, 0 paths down at 9000 size
RPC status:
2 paths up, 0 paths down (tcp check)
2 paths up, 0 paths down (udp check)
```

## CLUSTER PING-CLUSTER COMMAND



## dashboard Commands

- **dashboard alarm show**
- **dashboard alarm thresholds show**
- **dashboard health vserver show**
- **dashboard health vserver show-aggregate**
- **dashboard health vserver show-all**
- **dashboard health vserver show-port**
- **dashboard health vserver show-protocol**
- **dashboard health vserver show-lif**
- **dashboard health vserver show-volume**
- **dashboard storage show**
- **dashboard performance show**

---

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

6

## DASHBOARD COMMANDS

The dashboard commands provide quick views of the nodes and the cluster.



## dashboard storage show Command

```
::> dashboard storage show -week  
          ~1 day      ~2 days      ~3 days      ~7 days  
Aggregate  Size  Used Vols  Used Vols  Used Vols  Used Vols  Used Vols  
-----  
cluster1-01_aggr0  
    113.5GB 99.91GB   1   620KB   0   1.18MB   0   1.77MB   0   4.36MB   0  
cluster1-01_aggr2  
    908.3GB 50.00GB   1     4KB   0   12KB   0   16KB   0   40KB   0  
cluster1-02_aggr0  
    113.5GB 99.91GB   1   612KB   0   1.13MB   0   1.68MB   0   4.02MB   0  
cluster1-03_aggr0  
    229.1GB 109.9GB   2   648KB   0   1.23MB   0   1.84MB   0   4.34MB   0  
cluster1-03_aggr1  
    687.3GB 110.1GB   7   48KB   0   80KB   0   128KB   0   344KB   0  
cluster1-04_aggr0  
    229.1GB 99.92GB   1   624KB   0   1.18MB   0   1.74MB   0   4.06MB   0  
cluster1-04_aggr1  
    687.3GB 90.08GB   8   56KB   0   108KB   0   164KB   0   436KB   0  
7 entries were displayed.
```

## DASHBOARD STORAGE SHOW COMMAND

By default, the storage dashboard displays the:

- Aggregate name
- Aggregate size, in GB
- Aggregate available space, in GB
- Aggregate used space, in GB
- Percentage of space that is used
- Number of volumes
- Four-hour change in used size
- Four-hour change in number of volumes
- Eight-hour change in used size
- Eight-hour change in number of volumes
- Operational status



## Data Storage Health

- Are the aggregates online?

```
::> storage aggregate show  
::> storage aggregate show -state  
!online
```

- Are any disks broken or reconstructing?

```
::> storage disk show -state broken  
::> storage disk show -state  
reconstructing
```

- Are the volumes online?

```
::> volume show -state !online
```

## DATA STORAGE HEALTH

For the most part, the commands on this slide are self-explanatory. Most `show` commands provide a view of what's happening in a particular area of the cluster. Also, most `show` commands have some powerful query capabilities that, if you take the time to learn them, can help you to pinpoint potential problems.

In the `volume show -state !online` command, the exclamation point means “not” (negation). Therefore, this command shows all volumes that do not have a state of “online.” Because you'll want to know about other states that exist, it's important to use `!online` rather than `offline`.



## Storage Failover Health

- Is SFO healthy?

```
::> storage failover show  
::> storage failover show -instance
```

- Every node needs its vol0 (and thus, the aggregate that contains its vol0) in order to boot.
- After a takeover, the vol0 aggregate must be given back first.
- A persistent “waiting for giveback” state indicates an SFO problem.

## STORAGE FAILOVER HEALTH

When the aggregates of one node fail over to the HA partner node, the aggregate that contains the vol0 volume of that node goes, too. Each node needs its vol0 to boot, so when the rebooted node begins to boot, the first thing that happens is that it signals the partner to do a giveback of that one aggregate and then waits for that to happen. If SFO is working properly, giveback happens quickly, the node has its vol0 and can boot, and when it gets far enough in its boot process, the rest of the aggregates are given back. If problems exist, you probably see the rebooted node go into a “waiting for giveback” state. If this happens, it’s possible that its aggregates are stuck in a transition state between the two nodes and might not be owned by either node. If this happens, contact NetApp Global Support.



## Networking Health

- Are all the ports OK?

```
::> network port show
```

- Are all the LIFs OK and home?

```
::> net int show
```

```
::> net int show -is-home false
```

## NETWORKING HEALTH

You must verify that all the network ports, including the cluster ports, are OK. If those ports are fine, verify that the LIFs are working properly, and note which ones are home and which ones aren't home. If the LIFs are not home, it doesn't mean that a problem exists, but this condition might give you a sense of what's happening.



## Lesson 2

### Baseline Performance Monitoring



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

11

### LESSON 2: BASELINE PERFORMANCE MONITORING

This lesson discusses baseline performance monitoring for any given clustered storage system.



# Baseline Monitoring Commands

1 of 3

- `statistics show-periodic -node <node>`  
  `-instance node`
- `dashboard performance show`
- `dashboard performance show -operations`
- `dashboard performance show -instance`
- `statistics show-periodic -instance`  
  `latency`
- `statistics show-periodic -node <node>`  
  `-instance latency`
- `statistics show-periodic`
- `statistics show-periodic -object volume`  
  `-instance <volume>`

## BASELINE MONITORING COMMANDS: 1 OF 3



## Baseline Monitoring Commands

2 of 3

- `statistics show-periodic -object ifnet  
-instance a0a -node <node>`
- `statistics show-periodic -object lif  
-instance <vserver>:<lif>`
- `statistics show -object volume -counter  
*latency -sample-id <sample>`
- `statistics show-periodic -object volume  
-instance vs2_vo101`
- `statistics show -object volume -counter  
*data -sample-id <sample>`
- `statistics show -object aggregate  
-counter user_reads|user_writes  
-sample-id <sample>`

## BASELINE MONITORING COMMANDS: 2 OF 3



## Baseline Monitoring Commands

3 of 3

- **statistics show -object disk -counter \*latency -sample-id <sample>**
- **statistics show -object port -counter \*data -sample-id <sample>**
- **statistics show -object lif -counter \*data -sample-id <sample>**

## BASELINE MONITORING COMMANDS: 3 OF 3



## Baseline Performance Monitoring

- Begin performance monitoring from top to bottom
  - **statistics show-periodic**
    - By cluster, node, or object
    - Similar to **sysstat** in Data ONTAP 7-Mode
  - **dashboard performance show**
    - Very powerful
    - Useful summary information
- Narrow down the search to values and objects that you want to monitor  
**statistics show**

## BASELINE PERFORMANCE MONITORING

Top to bottom (cluster down to node component).



## dashboard performance show Command

Display per-second performance figures

```
dashboard performance show -instance  
-operation -fields <fieldname>
```

```
::*> dashboard performance show ?  
[ -instance | -operations | -fields <fieldname>, ... ]  
[ [-node] <nodename>] Node  
[ -avg-latency <Counter64> ] Average Latency (usec)  
[ -cpu-busy <Counter> ] CPU Busy  
[ -total-ops <Counter64> ] Total Ops/s  
[ -nfs-ops <Counter64> ] NFS Ops/s  
[ -cifs-ops <Counter64> ] CIFS Ops/s  
[ -data-busy <Counter> ] Data Network Utilization  
[ -data-recv <Counter64> ] Data Network Received (per sec)  
[ -data-sent <Counter64> ] Data Network Sent (per sec)  
[ -cluster-busy <Counter> ] Cluster Network Utilization  
[ -cluster-recv <Counter64> ] Cluster Network Received (per sec)  
[ -cluster-sent <Counter64> ] Cluster Network Sent (per sec)  
[ -storage-read <Counter64> ] Storage Read (per sec)  
[ -storage-write <Counter64> ] Storage Write (per sec)  
[ -cifs-latency <Counter64> ] CIFS Average Latency  
[ -nfs-latency <Counter64> ] NFS Average Latency
```

## DASHBOARD PERFORMANCE SHOW: COMMAND



## dashboard performance show Example

```
::> dashboard performance show
      Average   ---Data-Network--- -Cluster--Network- ---Storage---
      Total Latency   CPU Busy   Recv   Sent Busy   Recv   Sent   Read Write
      Ops/s in usec  Busy Util   MB/s   MB/s Util   MB/s   MB/s   MB/s   MB/s
-----
```

Node	Total Ops/s	Latency (usec)	CPU Busy (%)	Data Network Util (%)	Recv (MB/s)	Sent (MB/s)	Cluster Network Util (%)	Recv (MB/s)	Sent (MB/s)	Read (MB/s)	Write (MB/s)
hydra01	0	0	2%	0%	0	0	0%	0	0	0	0
hydra02	0	2224	2%	0%	0	0	0%	0	0	0	0
hydra03	0	3517	2%	0%	0	0	0%	0	0	0	0
hydra04	0	4260	70%	0%	0	0	30%	71	1	19	88
...											
hydra23	27113	10903	62%	11%	140	9	29%	5	71	5	80
hydra24	0	2743	76%	0%	0	0	29%	71	5	6	82
cluster:summary	42729	11090	76%	25%	237	20	30%	183	181	42	285

24 entries were displayed.

In this example, there are 24 nodes in the cluster, but we're suppressing the output from 18 of them.

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

17

## DASHBOARD PERFORMANCE SHOW: EXAMPLE

By default, the performance dashboard displays the following information about system and cluster performance:

- Node name or cluster summary
- Average operation latency, in microseconds
- Total number of operations
- Percentage of data network use
- Data that is received on the data network, in MBps
- Data that is sent on the data network, in MBps
- Percentage of cluster network use
- Data that is received on the cluster network, in MBps
- Data that is sent on the cluster network, in MBps
- Data that is read from storage, in MBps
- Data that is written to storage, in MBps

This command can display a wide range of performance information. See the reference page for the command for further details.

This performance view can be used in conjunction with `statistics show -node <node> -object <object>` to get more detailed statistics.



## Lesson 3

### Analyzing and Isolating Storage System Bottlenecks



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

18

## LESSON 3: ANALYZING AND ISOLATING STORAGE SYSTEM BOTTLENECKS

This lesson discusses methods of analyzing and isolating storage system bottlenecks for any given clustered storage system.



## Analyzing Storage System Bottlenecks

- Use top-to-bottom baseline process
  - **statistics show-periodic**
  - **dashboard performance show**
  - **statistics show**
- Analyze key storage controller resources
  - Disk
  - Processor utilization
- Define workload characteristics when analyzing client performance problems  
**statistics show -object [obj]  
-instance [inst] -counter [cnt]**

## ANALYZING STORAGE SYSTEM BOTTLENECKS



## Analyze Key Storage Controller Resources

- Disks
  - Aggregate disk busy > 50%
  - Aggregate free space < 15%
- Processor utilization
  - > 85% on a single controller
  - > 50% each on a controller pair

## ANALYZE KEY STORAGE CONTROLLER RESOURCES



## Lesson 4

### Common Performance Topics



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

21

### LESSON 4: COMMON PERFORMANCE TOPICS

This lesson analyzes common performance topics as they relate to the clustered Data ONTAP storage system. Aggregate free space, CPU and memory headroom, disk-bound configurations, and cache hits are covered.



## Aggregate Free Space

WAFL (Write Anywhere File Layout) free space recommendation:

- For data sets with a low rate of change, 3% free space in the aggregate is recommended; otherwise, allow 5% free space.
- This space is used primarily for metadata.
- Insufficient free space pushes data into the WAFL reserve.

WAFL reserve:

- Allocate 10% aggregate capacity for the WAFL reserve.
- The reserve ensures that WAFL can keep open allocation areas for long-term write performance.

## AGGREGATE FREE SPACE



## Displaying Aggregate Space in Data ONTAP

Clustered Data ONTAP 8.2 and later  
**storage aggregate show-space**

```
::> storage aggregate show-space
Aggregate : aggr1

  Feature           Used      Used%
-----  -----
Volume Footprints   60.61MB    1%
Aggregate Metadata  724KB     0%

Total Used          61.32MB    1%
```

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

23

### DISPLAYING AGGREGATE SPACE IN DATA ONTAP

To display aggregate space in clustered Data ONTAP 8.2 and later, use the `storage aggregate show-space` command.



## CPU and Memory Headroom

Determining your current CPU and memory utilization is **not** as simple as looking at the percent utilization:

- High CPU or disk utilization can be the result of background processing.
- Systems with high utilization see larger impacts to performance during failover events.

## CPU AND MEMORY HEADROOM

Determining your current CPU and memory utilization is *not* as simple as looking at the percent utilization. High CPU or disk utilization can be the result of background processing because the system consumes idle system resources for background operations. Systems with high utilization see larger impacts to performance during failover events because the surviving controller must now host its own workload and the workload from the HA partner.



## Disk-Bound Configurations

Back-to-back consistency points (CPs) generally indicate that the workload has outgrown the storage system.

- Infrequent back-to-back CPs:
  - Something to monitor, but likely the result of peaks in the workload
  - Possibly caused by disk reconstruction or some other scanner type of activity
- Frequent back-to-back CPs:
  - Slow drives or an undersized storage configuration should be considered; use [faster drives](#) or [add additional spindles](#).
  - A [volume move](#) should also be considered to provide additional memory resources.
  - Finally, a [controller upgrade](#) might be necessary to provide the required memory resources.

## DISK-BOUND CONFIGURATIONS

Back-to-back consistency points (CPs) generally indicate that the workload has outgrown the storage system. Infrequent back-to-back CPs are something to monitor, but it is likely to be the result of peaks in the workload, which might be caused by disk reconstruction or some other scanner type of activity. Frequent back-to-back CPs might be the result of slow drives or an undersized storage configuration; use faster drives or add additional spindles. A volume move from the hot aggregate to a lesser utilized aggregate should also be considered. As a last resort, a controller upgrade might be necessary to provide the memory resources required by the workload.



## Disk-Bound Configuration Example

Use the **sysstat -x <interval>** command to see CP types occurring on the storage system. Look for:

- Peak CP time and disk utilization
- CP type "b" or "B"

```
> sysstat -x 1
CPU      NFS      ... Cache  Cache   CP     CP    Disk ...
          ... age    hit    time   ty util ...
13%       0       ... 7    100% 100% #f 100% ...
13%       0       ... 7    100% 100% #f 100% ...
87%      1556     ... 7    100% 100% bf 96% ...
36%      1708     ... 7    100% 100% :f 100% ...
36%      1692     ... 7    100% 100% :f 100% ...
```

CP time  
and Disk  
util are  
indicating  
no  
"breaks"  
in activity.

A "b" type CP  
is occurring.

## DISK-BOUND CONFIGURATION EXAMPLE

Use the **sysstat -x <interval>** command to see CP types that are occurring on the storage system. Look for peak CP time and disk utilization, and also look for "b" or "B" type CPs that are occurring. Remember to use the **system node run** command when running this command on a clustered Data ONTAP system.



## Cache Hits

- Read I/O statistics describe where read I/O is serviced by the system. (The example shows a diag privilege level command.)

```
:*:> statistics show -object wafl -instance wafl -counter read_io_type -sample-id sample_wafl

Object: wafl
Instance: wafl
...
Cluster: cluster1

      Counter          Value
----- -----
read_io_type
    cache           30 System Memory
    ext_cache       40 Flash Cache
    disk            20 HDD
    bamboo_ssd     10 Pure SSD
    hya_hdd         0 Flash Pool HDD
    hya_cache       0 Flash Pool SSD
    hya_non_cache   0
read_io_type
...
2 entries were displayed.
```

## CACHE HITS

Read I/O statistics describe where read I/O is serviced by the system. A special diag privilege of the `statistics show` command displays cache hits for system memory, Flash Cache, hard disks, solid-state drives (SSDs), hard disks in a Flash Pool, and SSDs in a Flash Pool.



## Lesson 5

### Key Performance Tools



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

28

## LESSON 5: KEY PERFORMANCE TOOLS

This lesson introduces the clustered Data ONTAP operating system performance tools.



## Performance and Statistics Collector

- Performance and Statistics Collector (Perfstat) is a diagnostics data collection tool.
- Key features of Perfstat:
  - Use Perfstat to capture performance information.
  - Performance information is captured simultaneously for cross correlation.
  - It is supported for all NetApp platforms and most client platforms.
  - It can gather client and storage performance statistics.
  - Perfstat output is supported by other data analysis tools for parsing and analysis.

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

29

## PERFORMANCE AND STATISTICS COLLECTOR

One of the most important performance and statistics collection tools is Perfstat.



# Perfstat Download

Perfstat is available from the ToolChest page of the NetApp Support site.

The screenshot shows the NetApp Support website interface. At the top, there's a navigation bar with links for Log Out, NetApp Sites, Library, Communities, Contact Us, SEARCH, My Systems, My Contracts, My Cases, Print, Favorites, and Send. Below the navigation is a banner for 'Performance and Statistics Collector (Perfstat) - Overview'. A callout bubble from the bottom left points to the 'Converged' version of Perfstat listed in the support matrix table. The table compares Perfstat versions (7 and Converged) against ONTAP 7.0, 8.0.x, 8.1+, and 8.1.1+ modes. The 'Converged' version is supported across all modes except 7.0 mode, which is N/A. A note at the bottom of the page states: 'NOTE: For Data ONTAP 8.1+ 7-mode, Converged Perfstat supports SystemShell data collection while same is not available in Perfstat7.'

Perfstat version	ONTAP 7.0	ONTAP 8.0.x (7-mode)	ONTAP 8.0.x (E-mode)	ONTAP 8.1.+ (7-mode)	ONTAP 8.1.+ (E-mode)
Perfstat 7	Supported	Supported	N/A	Supported	N/A
Perfstat Converged	N/A	N/A	Supported	Supported	Supported

Remember to always run the latest version of Perfstat.

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

30

## PERFSTAT DOWNLOAD

Remember, when collecting performance data for a NetApp support case, always run the latest version of Perfstat.



## Perfstat Collection During a Known Workload Timeframe

- Workload should run during at least one entire Perfstat iteration.
- More iterations are always better than a single iteration.
- Example (10-minute workload):  
Start a Perfstat run with five iterations and five minutes per iteration:

```
# perfstat8 cluster-management-IP -t 5 -i 5
```

## PERFSTAT COLLECTION DURING A KNOWN WORKLOAD TIMEFRAME

Follow these guidelines when collecting Perfstat data during a known workload timeframe. The workload should run during at least one entire Perfstat iteration, and more iterations are always better than a single iteration. This example includes a 10-minute workload. First, start a Perfstat run with five iterations and five minutes per iteration. The first iteration captures workload data as the workload is getting ramped up. The workload starts sometime in the second iteration and runs during the entire third iteration. The workload finishes during the fourth iteration. Following these guidelines ensures that the entire workload is captured.



## Perfstat Collection During an Unknown Workload Timeframe

- Use a script to continuously run Perfstat (see KB 1012616).
- Accompany the Perfstat data with Performance Advisor (or a comparable tool) output that shows when a high-latency event occurred.

## PERFSTAT COLLECTION DURING AN UNKNOWN WORKLOAD TIMEFRAME

Collecting Perfstat data during an unknown workload timeframe requires either the use of a script to continuously run Perfstat or a tool such as the Performance Advisor to execute Perfstat during a user-defined alert that can be set up to automate the Perfstat execution.



## Perfstat Data Analysis

- Find the Perfstat iteration with highest latency and highest throughput for the protocol of interest.
- Is the latency value acceptable?
  - If so, you might need to look elsewhere for the problem.
- If the latency is high, are there bottlenecks?
  - Is CPU over 85% utilized?
  - Are disks busy?
  - Is a network or FC interface too busy?

## PERFSTAT DATA ANALYSIS

When analyzing Perfstat data, find the Perfstat iteration with the highest latency and highest throughput for the protocol of interest. Is the latency value acceptable? If so, you might need to look at some of the other potential components or resources that might be hindering the performance. If the latency is high, are there bottlenecks? Is CPU over 85% utilized? Are the disks busy? Remember to refer to the Disk IOPS Versus Latency chart in the previous module. Is a network or FC interface too busy?

By pursuing each of these questions, you can isolate the potential problem more easily.



## Perfstat Example: [perfstat\\_system](#)

```
TIME: 10:58:55
TIME_DELTA: 5:5 (305s)
system:system:nfs_ops:2829/s
system:system:cifs_ops:0/s
system:system:http_ops:0/s
system:system:dafs_ops:0/s
system:system:fcp_ops:0/s
system:system:iscsi_ops:0/s
system:system:net_data_recv:44442KB/s
system:system:net_data_sent:52079KB/s
system:system:disk_data_read:55127KB/s
system:system:disk_data_written:50582KB/s
system:system:cpu_busy:46%
system:system:avg_processor_busy:27%
system:system:total_processor_busy:110%
system:system:num_processors:4
system:system:nc_urls:0/s
system:system:streaming_pkts:0/s
system:system:time:1213372732s
system:system:uptime:256954s
```

1

2

3

### Areas to Recognize

1. Protocol operations
2. Read and write rates
3. CPU utilization

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

34

## [PERFSTAT EXAMPLE: PERFSTAT\\_SYSTEM](#)

This example shows Perfstat system output. There are a few areas that you should recognize from the output. First, notice the protocol operations. This example shows 100% NFS OPS. Next, notice the read and write rates, and finally, the CPU utilization.



## Perfstat Example: `perfstat_nfs`

```
TIME: 10:58:55
TIME_DELTA: 5.5 (305s)
nfsv3:nfs:nfsv3_ops:2829/s
  nfsv3:nfs:nfsv3_read_latency:4535.56us
  nfsv3:nfs:nfsv3_read_ops:1532/s
  nfsv3:nfs:nfsv3_write_latency:2071.76us
  nfsv3:nfs:nfsv3_write_ops:1297/s
  nfsv3:nfs:nfsv3_op_count.null:0
  nfsv3:nfs:nfsv3_op_count.getattr:1
  nfsv3:nfs:nfsv3_op_count.setattr:0
  nfsv3:nfs:nfsv3_op_count.lookup:0
  nfsv3:nfs:nfsv3_op_count.access:0
  nfsv3:nfs:nfsv3_op_count.readlink:0
  nfsv3:nfs:nfsv3_op_count.read:465875
  nfsv3:nfs:nfsv3_op_count.write:394314
  nfsv3:nfs:nfsv3_read_size_histo.0-511:0
  nfsv3:nfs:nfsv3_read_size_histo.512-1023:0
  nfsv3:nfs:nfsv3_read_size_histo.1K-2047:0
  nfsv3:nfs:nfsv3_read_size_histo.2K-4095:0
  nfsv3:nfs:nfsv3_read_size_histo.4K-8191:0
  nfsv3:nfs:nfsv3_read_size_histo.8K-16383:0
  nfsv3:nfs:nfsv3_read_size_histo.16K-32767:199
  nfsv3:nfs:nfsv3_read_size_histo.32K-65535:465676
  nfsv3:nfs:nfsv3_read_size_histo.64K-131071:0
  nfsv3:nfs:nfsv3_write_size_histo.0-511:0
  nfsv3:nfs:nfsv3_write_size_histo.512-1023:9
  nfsv3:nfs:nfsv3_write_size_histo.1K-2047:18
  nfsv3:nfs:nfsv3_write_size_histo.2K-4095:7
  nfsv3:nfs:nfsv3_write_size_histo.4K-8191:6
  nfsv3:nfs:nfsv3_write_size_histo.8K-16383:2
  nfsv3:nfs:nfsv3_write_size_histo.16K-32767:292
  nfsv3:nfs:nfsv3_write_size_histo.32K-65535:393580
  nfsv3:nfs:nfsv3_write_size_histo.64K-131071:0
```

1

2

3

### Areas to Recognize

1. Read and write latencies
2. Operation type counts
3. Read and write I/O sizes

## PERFSTAT EXAMPLE: `PERFSTAT_NFS`

This example shows Perfstat NFS output. Note these areas in the output. First, notice the read and write latencies. Next, notice the operation type counts, and finally, the read and write I/O sizes.



# NetApp AutoSupport Support Tool

- AutoSupport is a “phone home” mechanism that allows the storage controller to automatically report configuration, status, and exceptions in near-time.
- Some of the information collected from an AutoSupport message:
  - Date and timestamp of the message
  - Data ONTAP software version
  - Serial number of the storage system
  - Host name of the storage system
  - Output of commands that provide system information
  - Registry information
  - Usage information
  - Service statistics
  - Boot-time statistics
  - NVLOG statistics
  - WAFL check log
  - Modified configurations
  - Information about the boot device (such as the CompactFlash card)

## NETAPP AUTOSUPPORT SUPPORT TOOL

AutoSupport is an integrated and efficient monitoring and reporting feature. It’s one of the most important troubleshooting tools for any NetApp storage system, and it can aid in providing performance-related information when no other baseline information is available. Some of the information that is collected in an AutoSupport message includes usage information, service statistics, boot-time statistics, and NVLOG statistics. Most of the commands introduced in this course are also part of every AutoSupport payload.



## AutoSupport Performance Data

Performance AutoSupport messages:

- Are generated weekly
- Provide technical support with comprehensive performance information
- Are enabled by default

Enabling performance AutoSupport messages on clustered Data ONTAP:

```
::> system node autosupport modify -node <node name> -perf true
```

## AUTOSUPPORT PERFORMANCE DATA

NetApp technical support personnel use AutoSupport performance messages to monitor and track the performance of the system and, as indicated, offer recommendations to improve performance. Performance messages can be quite large, so by default they are sent only to technical support. A basic set of performance statistics is collected using an hourly granularity, which is a suitable granularity for trending. For example, these statistics are used to display the performance graphs for the storage system in My AutoSupport. The AutoSupport performance message is enabled (or true) by default. If a system has AutoSupport performance messaging disabled, you can enable it by entering the `system node autosupport modify` command.

**My AutoSupport**

**DATASTORE2 (Serial#:700000956011)** based on latest log from 31-Mar-2013

**System Tools**

- Performance
- Upgrade Advisor
- EMR Log Viewer
- Event Viewer [New]

**Autosupport Tools**

- Visualizations
- Logs
- Raw Autosupport Data
- Storage Efficiency 2.0 (beta)

**Configuration Details**

Hostname: DATASTORE2  
Serial #: 1873886998  
System ID: F4A52E5  
Model: 8.1P [Cluster-Mode]  
OS Version: 7.1.2  
Board Hardware: [datastore1](#)  
Cluster: [datastore1](#)  
HA-Partner: [datastore1](#)

**Storage Efficiency**

Total raw capacity: 3.0 TiB  
Free Capacity: 2.46 TiB  
Unused Reserve: 0.46 TiB  
RAID 4 Spare: 0.54 TiB  
Fixed Reserve: 0.54 TiB

Total effective capacity: 2.88 TiB  
Free Capacity: 2.46 TiB  
Unused Reserve: 0.46 TiB  
RAID 4 Spare: 0.54 TiB  
Fixed Reserve: 0.54 TiB

**Health Summary**

User rating: **Excellent** (4.8)  
Average rating: **Excellent** (4.8)

**Health Check Details**

Warnings: 0  
Notices: 0

**System Risk Details**

Risks: 2  
Shares Modules with out-of-date firmware since 10/22/2012  
Remote Support Agent (RSA) not configured since 02/11/2013

**Performance**

Throughput by Protocol: NFS (blue), CIFS (green), FCP (red), ISCSI (purple)

Raw Storage Efficiency : 30%

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

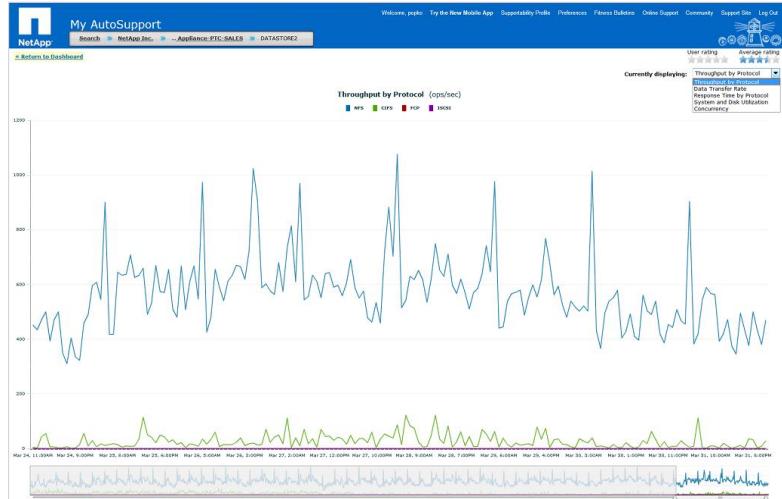
Historical performance trending charts

## MY AUTOSUPPORT

My AutoSupport is a web-based application that extends the capability of the AutoSupport system and helps you to improve the operational and storage efficiency of your NetApp storage system. Performance information, if available, is displayed on the dashboard.



# My AutoSupport: Performance View



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

39

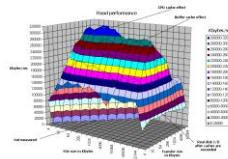
## MY AUTOSUPPORT: PERFORMANCE VIEW

Click the performance data to bring up a larger view of the performance information on the dashboard. A drop-down list enables you to choose throughput by protocol, data transfer rate, response time by protocol, system and disk utilization, or concurrency. This information can be very useful when you are diagnosing performance-related problems, or when you are trying to get an idea of baseline performance for a particular storage system.



# Workload Generators

- SIO (simulated I/O) tool
  - Created by NetApp to generate artificial I/O workloads against any device
- Iometer
  - Read and write workload generator, available from SourceForge (open source)
- IOzone
  - File system benchmark tool
  - Generates and measures a variety of file operations
  - Ported to many machines and runs under many operating systems



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

40

## WORKLOAD GENERATORS

Workload generators are tools that attempt to simulate load on a system. A number of I/O workload generators attempt to simulate application I/O to test performance characteristics of a system. SIO (an abbreviation for simulated I/O) is a tool that NetApp created to generate artificial I/O workloads. Iometer and IOzone are similar tools that simulate I/O workloads. This lesson focuses on SIO.



## NetApp Simulated I/O Tool: [sio\\_ntap](#)

### Purpose:

To generate various I/O loads, controlling the following:

- Read and write mix
- Random or sequential I/O patterns
- Access in various block sizes
- Access over a variable amount of file space (starting at offset 0)
- Adjustable run time (in seconds)
- Single or multiple concurrent threads performing I/O
- Access to one or more files or devices (for example, raw devices)

## [NETAPP SIMULATED I/O TOOL: SIO\\_NTAP](#)

SIO's main purpose is to create I/O workloads that can emulate many different application workloads.



## Command Options for `sio_ntap`

```
sio [read%] [random%] [block_size] [file_size]
[run_time_seconds] [threads] <filenames>
```

- **read%:** Percentage of accesses that are reads (as opposed to writes)
- **random%:** Percentage of accesses that are random (as opposed to sequential)
- **block\_size:** Size of I/O requests that are issued
- **file\_size:** Size of the area to be accessed in the file or files  
Can be <= to actual file size; same for all files
- **run\_time\_seconds:** Run time (specified in seconds), minimum of 10 seconds (60 or more recommended) and zero (0) will run indefinitely
- **threads:** Number of concurrent threads issuing I/O
- **filenames:** One or more files as the target for the I/O that is generated

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

42

### **COMMAND OPTIONS FOR SIO\_NTAP**

SIO supports a number of different parameters for manipulating the simulated workload's characteristics.



## Module Summary

Now that you have completed this module, you should be able to:

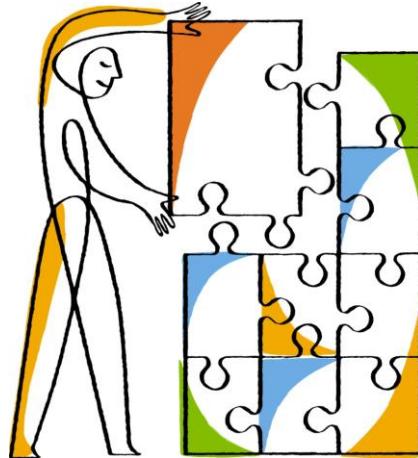
- Describe the performance analysis tools and commands that are commonly used for cluster health checks
- Identify the key performance commands and describe the command output that they produce
- Explain how to use NetApp tools for performance measurement
- Describe the benefits of using the AutoSupport support tool for performance analysis

## MODULE SUMMARY



## Learning Activity Questions

Module 4: Cluster Performance Monitoring and Analysis



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

44

### LEARNING ACTIVITY QUESTIONS



## Learning Activity: Questions

- Disk-bound storage system configurations can generally be recognized with \_\_\_\_\_.
- When running Perfstat, remember to always \_\_\_\_\_.
- Performance AutoSupport messages are generated hourly, or daily, or weekly?
- Name three I/O workload generators.

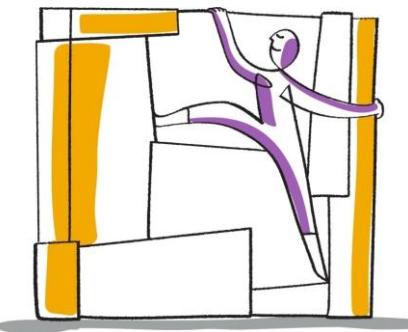
## LEARNING ACTIVITY: QUESTIONS



## Exercise

Module 4: Cluster Performance Monitoring and Analysis

Time Estimate: 120 Minutes



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

46

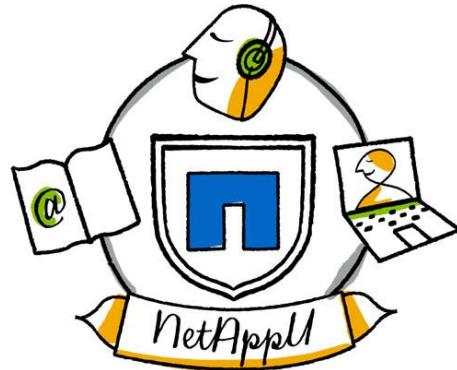
### EXERCISE

Please refer to your exercise guide.



## Module 5

OnCommand Management Tools



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

1

### MODULE 5: ONCOMMAND MANAGEMENT TOOLS



## Module Objectives

After this module, you should be able to:

- List the three categories of performance tools
- Explain the features and functions of Insight Perform
- Explain the features and functions of OnCommand Balance
- Use OnCommand management tools to view performance data

## MODULE OBJECTIVES



## Categories of Performance Tools

- Monitoring
- Collection
- Analysis



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

3

### CATEGORIES OF PERFORMANCE TOOLS

Performance tools can be divided into three categories: monitoring, collection, and analysis. You have reviewed a number of performance commands that can be executed on the Data ONTAP CLI. Most of the commands are in the monitoring category, but a few are in the collection category.



## Lesson 1

### OnCommand Insight



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

4

### LESSON 1: ONCOMMAND INSIGHT

This lesson introduces OnCommand Insight and takes a look at the features and functions that OnCommand Insight provides.



# What OnCommand Insight Provides

- 100% agentless, read-only access to storage, both SAN and NAS, and virtual server devices
- Multivendor and multiprotocol support
- End-to-end physical and logical visibility
- Performance analysis and optimization
- Risk identification and avoidance
- Built-in tools for root-cause analysis, capacity planning, and monitoring
- Tracking of capacity trends and forecasting
- Flexible enterprise and business-level reporting

**NOTE:** Insight does not provide provisioning or active management of devices.



## WHAT ONCOMMAND INSIGHT PROVIDES

OnCommand Insight is a suite of storage management software:

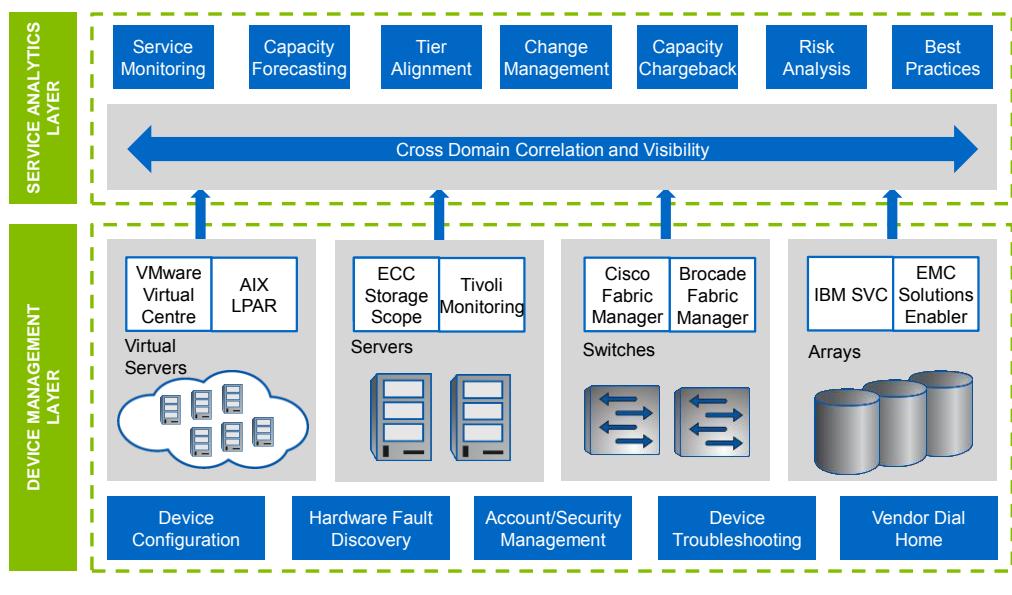
- Extends data-center automation—by providing agentless, heterogeneous, service-level views of both SAN and NAS storage environments
- Provides end-to-end data-center visibility—by discovering and gathering inventory data in real time from switches and multivendor storage arrays and identifying hosts
- Helps you manage storage proactively—by automatically correlating discovered data with application-relevant storage service paths
- Identifies all of the storage resources in the service path for an application
- Monitors changes to the storage environment as the changes are made
- Assesses the impact of changes on relevant services and applications, provides alerts about changed information, and provides root-cause analysis for faster troubleshooting

Because Insight is agentless, it does not provide host information. However, if EMC ECC (Enterprise Content Center) or Tivoli is in the environment, Insight can see host information. Insight also does not perform storage provisioning. You can plan for provisioning or create tasks to provision, but you cannot use Insight for active management.

After you add data sources are added to your Insight installation, you can identify relationships between the devices, view the paths in a topology view, and apply policies to devices and paths.



# Cross-Domain Correlation and Visibility



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

6

## CROSS-DOMAIN CORRELATION AND VISIBILITY

The Insight configuration management system is specifically for the storage domain. The system sits logically above the device management layer, pulling information from physical and virtual server environments, from the storage network, and from storage systems. Insight then analyzes the information and correlates it into service paths. Service paths represent end-to-end data access between a host or virtual host and a volume.



## Lesson 2

### OnCommand Insight Perform



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

7

## LESSON 2: ONCOMMAND INSIGHT PERFORM



## What Insight Perform Does

Insight Perform collects and maintains service performance information that helps administrators

- Manage storage resources and services
- Manage SAN infrastructure resources
- Optimize virtual server and virtual machine (VM) resources
- Reclaim over utilized and under utilized storage resources
- Optimize and manage tiers
- Analyze storage-virtualization efficiency
- Optimize the virtual-host environment
- Improve load balancing
- Troubleshoot performance-related congestion and contention
- Improve resource utilization to optimize services

## WHAT INSIGHT PERFORM DOES



## Best Practices for Insight Perform

- Avoid setting the performance polling rate below the default rate.
- If you are troubleshooting a performance issue, consider decreasing the polling rate for a very short time.
- Depending on your environment, you might need to optimize polling rates for performance and inventory polls.
- When you add a data source, do not enable the collection of performance data.
- After a data source has collected inventory, edit the source to enable the collection of performance data.
- Before you enable the collection of performance data, consider how much the additional data will increase the size of the Insight database.

### BEST PRACTICES FOR INSIGHT PERFORM

By setting the performance polling rate below the default, you avoid placing an unnecessarily heavy load on the device that is trying to respond to the polls.

If you decrease the polling rate (as you are troubleshooting an issue), be sure to return to the original polling rate after you resolve the issue.



# Displaying Storage-Performance Metrics

The screenshot shows three separate windows of the Table Customization dialog box, each displaying a list of performance metrics with checkboxes for visibility. A central callout box contains the text: "Use the Table Customization dialog box to add and remove performance metrics columns to and from the views." Blue arrows point from the callout to the top-left and top-right windows.

Name	Visible
Disk Accessed	<input type="checkbox"/>
Disk IOPS	<input checked="" type="checkbox"/>
Disk IOPS (R)	<input type="checkbox"/>
Disk IOPS (W)	<input type="checkbox"/>
Disk Throughput	<input type="checkbox"/>
Disk Throughput (R)	<input type="checkbox"/>
Disk Throughput (W)	<input type="checkbox"/>
Disk Utilization	<input type="checkbox"/>
Disk Utilization (R)	<input type="checkbox"/>
Disk Utilization (W)	<input type="checkbox"/>
End of Line	<input type="checkbox"/>
Family	<input type="checkbox"/>
Floor	<input type="checkbox"/>
Hot	<input type="checkbox"/>
Internal Volume Accessed	<input type="checkbox"/>
Internal Volume IOPS	<input type="checkbox"/>
Internal Volume IOPS (R)	<input type="checkbox"/>
Internal Volume IOPS (W)	<input type="checkbox"/>
Internal Volume Response Time	<input type="checkbox"/>
Internal Volume Response Time (R)	<input type="checkbox"/>
Internal Volume Response Time (W)	<input type="checkbox"/>
Internal Volume Throughput	<input type="checkbox"/>
Internal Volume Throughput (R)	<input type="checkbox"/>
Internal Volume Throughput (W)	<input type="checkbox"/>
Microcode Version	<input type="checkbox"/>
Model	<input type="checkbox"/>
Name	<input type="checkbox"/>

Name	Visible
Sunset	<input type="checkbox"/>
Tier	<input type="checkbox"/>
Top Disk IOPS	<input type="checkbox"/>
Top Disk Throughput	<input type="checkbox"/>
Top Disk Utilization	<input type="checkbox"/>
Top Internal Volume IOPS	<input checked="" type="checkbox"/>
Top Internal Volume Response Time	<input type="checkbox"/>
Top Internal Volume Throughput	<input type="checkbox"/>
Top Volume IOPS	<input type="checkbox"/>
Top Volume Response Time	<input type="checkbox"/>
Top Volume Throughput	<input type="checkbox"/>
Vendor	<input type="checkbox"/>
Volume Accessed	<input type="checkbox"/>
Volume Cache Hit Ratio	<input type="checkbox"/>
Volume Cache Hit Ratio (R)	<input type="checkbox"/>
Volume Cache Hit Ratio (W)	<input type="checkbox"/>
Volume IOPS	<input type="checkbox"/>
Volume IOPS (R)	<input type="checkbox"/>
Volume IOPS (W)	<input type="checkbox"/>
Volume Partial RW	<input type="checkbox"/>
Volume Response Time	<input type="checkbox"/>
Volume Response Time (R)	<input type="checkbox"/>
Volume Response Time (W)	<input type="checkbox"/>
Volume Throughput	<input type="checkbox"/>
Volume Throughput (R)	<input type="checkbox"/>
Volume Throughput (W)	<input type="checkbox"/>
Write Pending	<input type="checkbox"/>

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

10

## DISPLAYING STORAGE-PERFORMANCE METRICS

Insight Perform retains performance metrics for 14 days, after which it rolls the metrics into a histogram.

During the extract, transform, load (ETL) process, Insight Perform uploads some performance information to the data warehouse. This information is used for analysis and enterprise-level reporting. In the data warehouse, performance data is aggregated with capacity information from Insight Plan to provide for reporting of capacity versus IOPS at the enterprise, array, volume, internal volume, and disk levels. The combination of performance data and capacity data provides unique information about how the capacity is being accessed, how often it is being accessed, and which workloads (applications) are accessing it. From the performance and capacity data, you can also determine how applications and business entities (the owners of the applications) are using storage and VM resources.

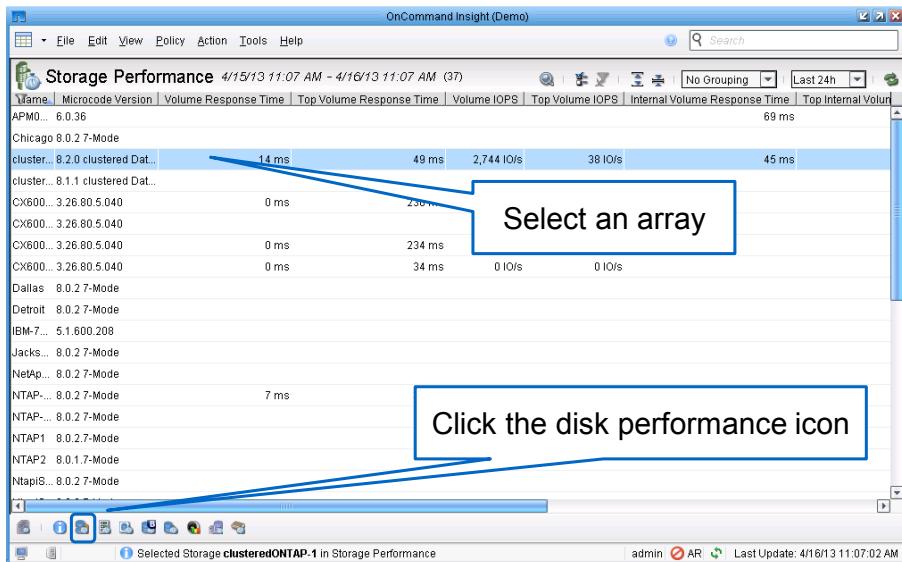
Performance metrics are displayed in the Storage Performance table.

To add or remove columns to and from the Storage Performance table, you use the Table Customization dialog box. To open the Table Customization dialog box, in the Storage Performance table, click the table customization icon.

In the dialog box, select the checkboxes of the items that you want to add and clear the checkboxes of the items that you want to remove.



# Selecting Arrays



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

11

## SELECTING ARRAYS

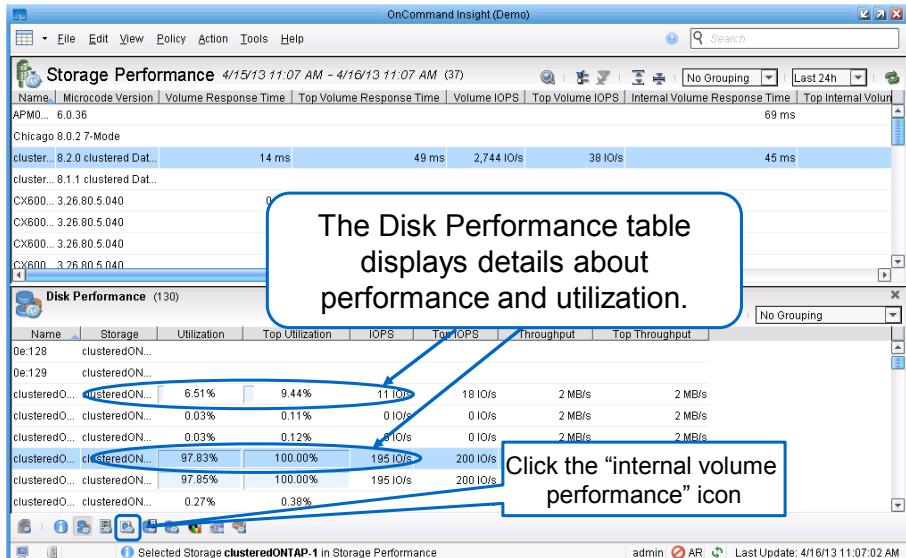
Insight Perform collects performance information from many vendor arrays. Most of the information that is reported from the arrays is in the same format.

To review the performance information collected and displayed for a clustered Data ONTAP array, do the following:

1. In the Storage Performance table, select a clustered Data ONTAP array.
2. Click the disk performance icon to display information about disks.



# Displaying Disk-Performance Metrics



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

12

## DISPLAYING DISK-PERFORMANCE METRICS

The Disk Performance table displays detailed disk-performance information for the NetApp arrays that you select. You can add and remove items to and from the table, just as you did with the Storage Performance table.

You can use disk-performance information to quickly identify disks that have high and low usage and to optimize the disks in the storage pools.

If you select multiple arrays in the Storage Performance table, all of the disks from the selected arrays are listed in the Disk Performance table. For example, you can sort by the utilization or top utilization columns to review the performance of all of the disks in the cluster at the same time.

To display information about volumes, click the “internal volume performance” icon.



# Displaying Volume-Performance Metrics

The screenshot shows the OnCommand Insight interface. The top window is titled "Storage Performance" and displays a table with columns: Name, Microcode Version, Volume Response, APM0, and Chicago 8.0.2 7-Mode. Below it is a "Disk Performance" table with columns: Internal, Disk Performance (130), and Disk Performance (46). The "Disk Performance (46)" table has columns: Name, Storage Pool, Response Time, and Top Response Time. A callout box points to the "Response Time" column in this table with the text: "Select the header of the Response Time column and arrange the values in descending order by response time." Another callout box points to the "Internal" icon in the "Disk Performance (130)" table with the text: "Click the datastore performance icon." A blue arrow labeled "High Response Time" points from the "Response Time" column in the main table to the "Response Time" column in the "Disk Performance (130)" table.

Name	Microcode Version	Volume Response	APM0	Chicago 8.0.2 7-Mode
clustered...	8.2.0 clustered Dat...			
clustered...	8.1.1 clustered Dat...			
CX600...	3.26.80.5.040			
CX600...	3.26.80.5.040			

Internal	Disk Performance (130)	Disk Performance (46)
No Grouping	No Grouping	No Grouping
Top Utilization	IOPS	Response Time
clustered... clusteredONTA...	6.5	121 ms
clustered... clusteredONTA...	0.035	119 ms
clustered... clusteredONTA...	0.119	13 ms
clustered... clusteredONTA...	0.119	13 ms
clustered... clusteredONTA...	0.119	13 ms
clustered... clusteredONTA...	0.119	24 ms

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

13

## DISPLAYING VOLUME-PERFORMANCE METRICS

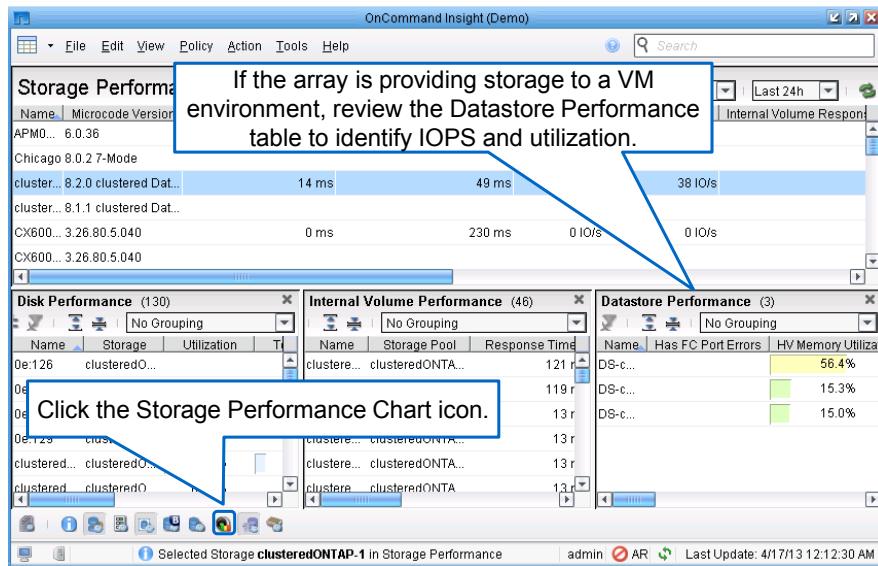
The Internal Volume Performance table displays response time, throughput, and IOPS for the FlexVol volumes of the clustered Data ONTAP array that you selected. If you selected multiple arrays, you can see all of the FlexVol volumes in the cluster.

If you select the header of Response Time column, you can sort the table, so that the volumes are listed by response time (highest to lowest). You can use the scroll bar to display additional volumes.

To display information about datastores, click the datastore performance icon.



# Displaying Datastore-Performance Metrics



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

14

## DISPLAYING DATASTORE-PERFORMANCE METRICS

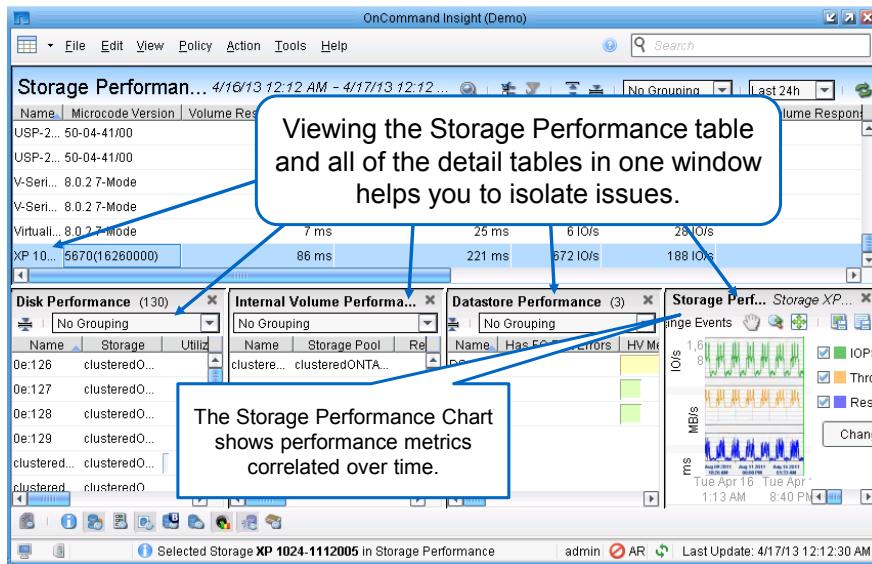
Assume that you selected an array that provides storage to a VM environment. In this case, Insight Performance increases the amount of performance information that is provided about the virtual environment.

The Datastore Performance table displays performance information, including virtual machine disk (VMDK) IOPS, VMDK throughput, and latency. The table also provides information about the CPU and memory utilization for the hypervisor. Using the sidebar, you can review storage performance metrics for each hypervisor.

To view information about trends, click the “storage performance chart” icon.



# Viewing All Information in One Window



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

15

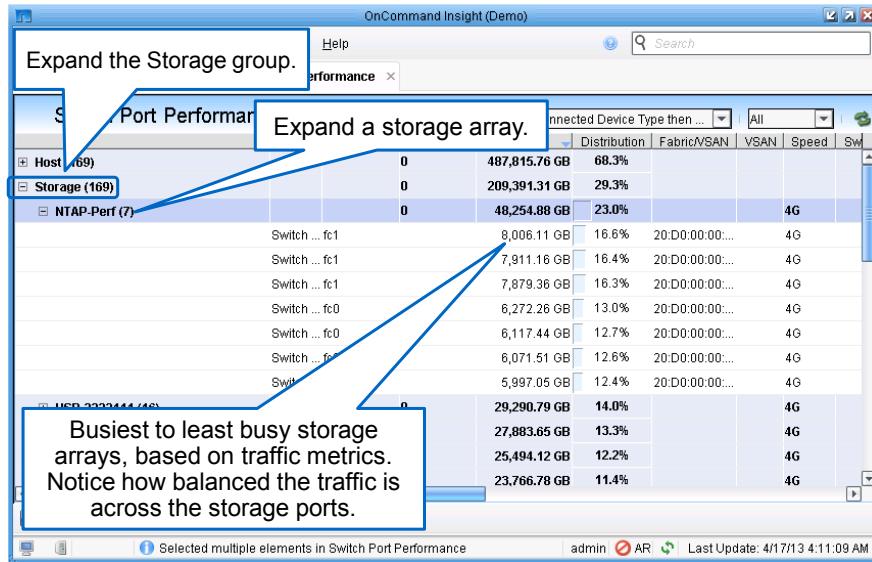
## VIEWING ALL INFORMATION IN ONE WINDOW

You can use the Storage Performance chart to identify and analyze performance trends and to develop your understanding of how performance metrics are related.

The window is crowded, so the details of the program information can be difficult to review. But, being able to see all of the information in one window can help you identify and isolate issues. Then, you can select one or more tables and one or more columns, sort the information, and navigate to the details that you need.



# Displaying Array-Specific Metrics



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

16

## DISPLAYING ARRAY-SPECIFIC METRICS

Expand first the Storage group and then a storage array.

The Value column indicates how traffic is balanced across the storage ports.

Scroll to the bottom of the Storage list. You might be surprised to find that some expensive tier 1 arrays are hardly being accessed. You can move the applications that are accessing the expensive tiers to less expensive tier 2 or tier 3 arrays, and you can archive any application that you no longer need. Then, to further reduce the cost of storage, you can optimize, repurpose, or decommission arrays.

**NOTE:** The least busy arrays *might* be the arrays that contain the most storage. However, the storage is likely to be dead, rather than active. An array that is 80% full might be less than 20% used.



## Lesson 3

Analyzing Performance with  
OnCommand Insight Perform



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

17

### LESSON 3: ANALYZING PERFORMANCE WITH ONCOMMAND INSIGHT PERFORM



## Tools for Analyzing Functionality

Function	Tool	Description
Analyze	Insight Perform	Analyze the performance of storage resources that have been affected by a violation
Analyze contention	Insight Perform	Determine the reasons for poor performance and identify where performance is degraded
Analyze storage pools	Insight Assure	Analyze a storage pool and assess its status relative to thin-provisioning policies

© 2013 NetApp, Inc. All rights reserved.

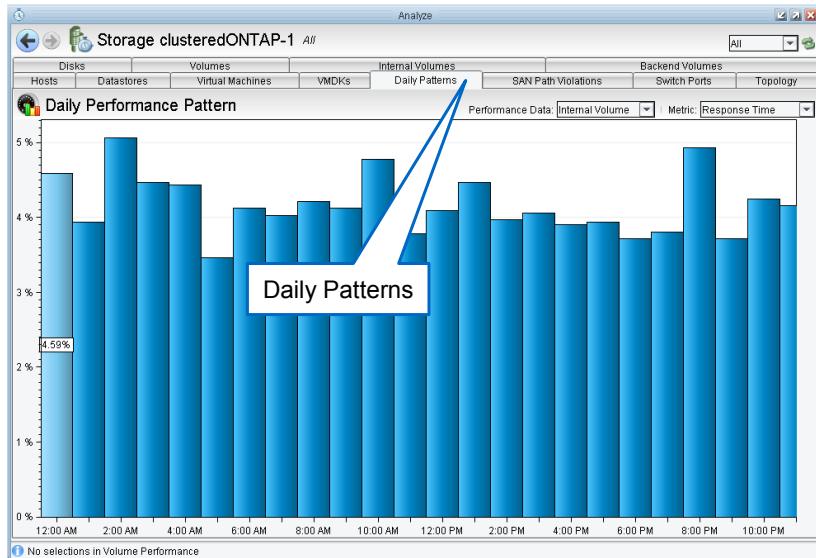
NetApp Confidential

18

## TOOLS FOR ANALYZING FUNCTIONALITY



# Analyzing Storage Resources



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

19

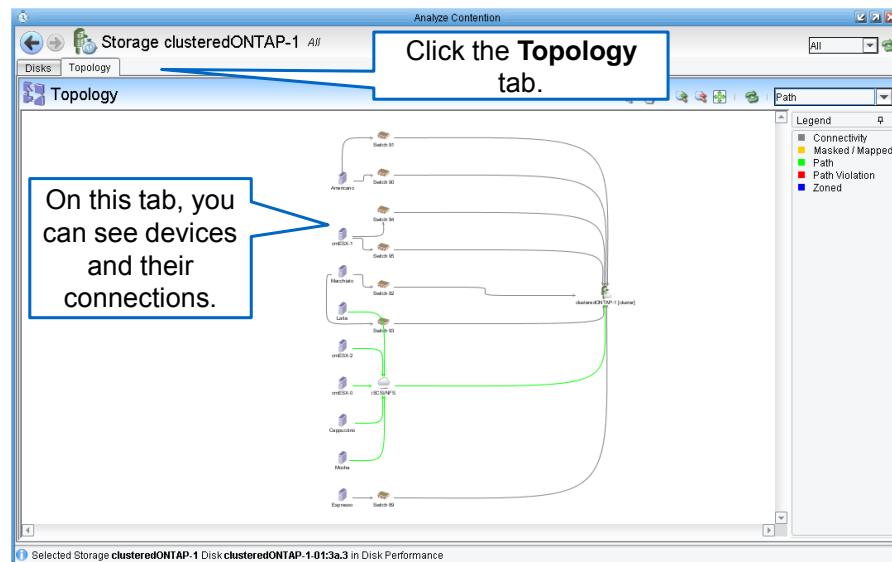
## ANALYZING STORAGE RESOURCES

To analyze storage resources for a clustered Data ONTAP array:

1. Right-click the array, and select **Analyze**.  
The Analyze dialog box is displayed, with the Disks tab selected by default. You click each of the tabs, in turn, to view information about the array from various perspectives.
2. Click the **Volumes** tab.  
From this tab, you can review the performance of volumes and internal volumes.
3. Click the **Hosts** tab.  
From this tab, you can view the performance of the storage that is related to the hosts and also the performance of internal ESX servers.
4. Click the **Daily Patterns** tab.  
From this tab, you can view performance patterns for disks, internal volumes, volumes, and back-end volumes. You can also review metrics such as response time, IOPS, and throughput.



# Analyzing Contention



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

20

## ANALYZING CONTENTION

The Analyze Contention dialog box enables you to determine the reasons for poor performance and to identify where performance is degraded.

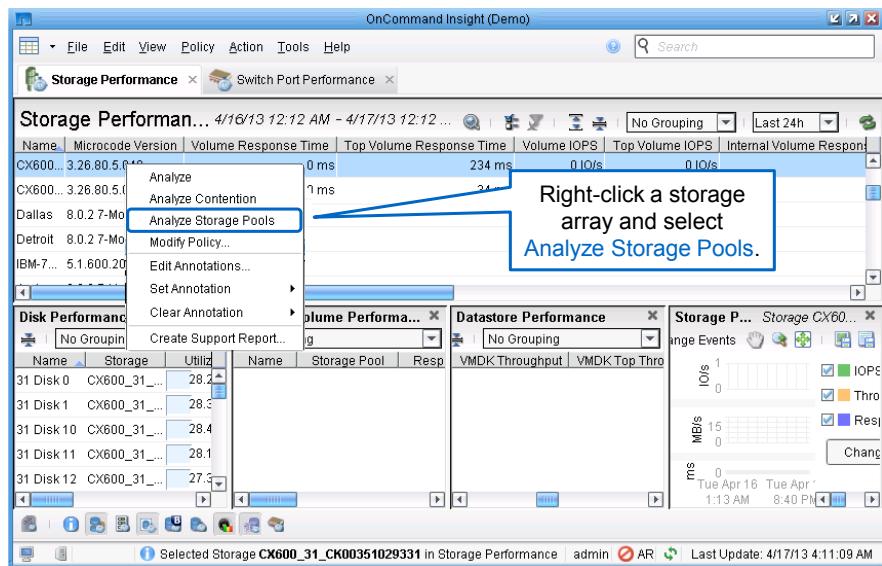
To analyze contention:

1. Right-click a storage array that is performing poorly and select **Analyze Contention**.  
The Analyze Contention dialog box is displayed. The Disks tab, which contains the Disk Performance table, is selected.
2. Review the performance data for the applications that are listed on the Disks tab.  
In this example, three applications are running on the storage array. Two applications, Consumer Feedback and Heat Loss Calculations, are from different business units but use storage from the same disks. These two applications are causing high utilization. The QA application has acceptable utilization.
3. Click the **Topology** tab.  
This tab provides a diagram of the hosts that are using the array, as well as the various topologies involved.

Using the information from the Analyze Contention dialog box, you have identified an issue and can now move one of the applications to a volume that uses other disks.



# Selecting a Storage Pools Option



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

21

## SELECTING A STORAGE POOLS OPTION

In the Storage Performance table, right-click a storage array that includes thin-provisioned storage pools and select **Analyze Storage Pools**.



# Analyzing Storage Pools

The screenshot shows the 'Analyze Storage Pools' dialog box. At the top, there's a table titled 'Storage Pools' with two rows:

Name	Storage	Capacity (GB)	Used Capacity (GB)	Used Capacity (%)	Over-committed Capacity (GB)	Commit Ratio	Used Raw Capacity (GB)	Unused Raw Capacity (GB)
v110	APM000910025	400.00	400.00	100%	400	200%	800.00	-80
v111	APM000910025	400.00	400.00	100%	400	200%	800.00	-80

A callout box points to this table with the text: "Lists the capacity and utilization details for all storage pools".

Below the table, there are sections for 'Properties' (Storage: APM000910025, Vendor: EMC, Family: Celerra SledgeHammer, Model: Celerra NS-480, Storage Pool: v110, Storage Pool Size: 400 GB, Commit Ratio: 200%) and 'Violations' (Capacity Assurance Violation: Storage Pool "v110" has 0 GB free space, less than the combined free space of 3 volumes; Capacity Violation: Storage Pool "v110" used capacity is currently at 100% of the total capacity, exceeding the policy threshold of 100%; Over Commit Violation: Storage Pool "v110" has a committed capacity of 200%, exceeding the policy threshold of 100%).

On the right, a callout box lists violations: "Capacity", "Thin-provisioned", "Unused storage", "Violations", and "Over commitment".

At the bottom, there are two charts: 'Capacity' and 'Unused Capacity'. The 'Capacity' chart shows 'Used' (green), 'Unused' (grey), and 'Over-Committed' (light grey) storage. The 'Unused Capacity' chart shows 'Unused Allocated' (blue) and 'Unused' (pink) storage.

© 2013 NetApp, Inc. All rights reserved. NetApp Confidential 22

## ANALYZING STORAGE POOLS

Using the Analyze Storage Pools dialog box, you can determine how close a thin-provisioned storage pool is to reaching its policy limit.

The Storage Pools summary pane provides performance and configuration information about:

- Storage pools
- Thin provisioning
- Used storage versus the overcommitment rate
- Violations of thin provisioning policies

Using data from the Analyze Storage Pools dialog box, you can review all storage pools and troubleshoot thin-provisioning issues. You can also use this dialog box, instead of the Violations Browser pane, to proactively review thin-provisioning violations and determine how close the storage pool is to reaching the policy limits.



## Additional Training OnCommand Insight

For in-depth, hands-on training on OnCommand Insight, visit the NetApp Learning Center and enroll in [NetApp OnCommand Insight Operations and Best Practices](#)

- Instructor-led training (ILT)
- Three days

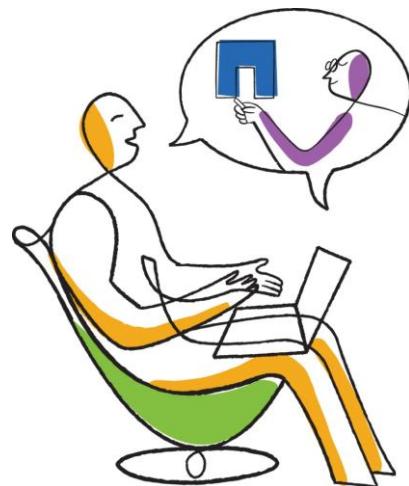
The image shows a course catalog page from NetApp University. At the top left is the NetApp logo. To the right is a cartoon character of a person holding a briefcase with the NetApp logo on it. The title of the course is "NetApp OnCommand Insight Operation and Best Practices". Below the title, there is a "COURSE DESCRIPTION" section which provides a detailed overview of the course content. There are also sections for "PREREQUISITES", "PRICING AND CANCELLATION POLICY", and "OBJECTIVES". The "OBJECTIVES" section lists specific learning outcomes for the course.

## ADDITIONAL TRAINING: ONCOMMAND INSIGHT



## Lesson 4

### OnCommand Balance



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

24

## LESSON 4: ONCOMMAND BALANCE



## OnCommand Balance

OnCommand Balance provides actionable guidance by collecting raw data from individual resources and applying powerful analytics.



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

25

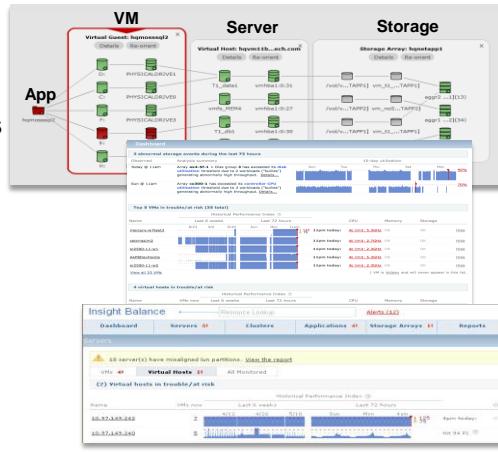
### ONCOMMAND BALANCE

OnCommand Balance provides directions to optimize the performance and capacity of shared infrastructures. Unlike some products that simply deliver statistics, OnCommand Balance provides actionable guidance by collecting raw data from individual resources and applying powerful analytics. It's the analytics that provide the intelligence, giving actionable information and directions that are beyond the capabilities of a dashboard.



# Features of OnCommand Balance

- **Troubleshoot** issues
  - Visibility: Is it VM, server, storage?
  - Which workloads are victims and which are bullies?
- **Optimize** performance
  - How much headroom do I have?
  - Where can I put my VM or application for best performance?
- **Predict** problems
  - How can I proactively avoid bottlenecks?
  - How can I avoid issues?



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

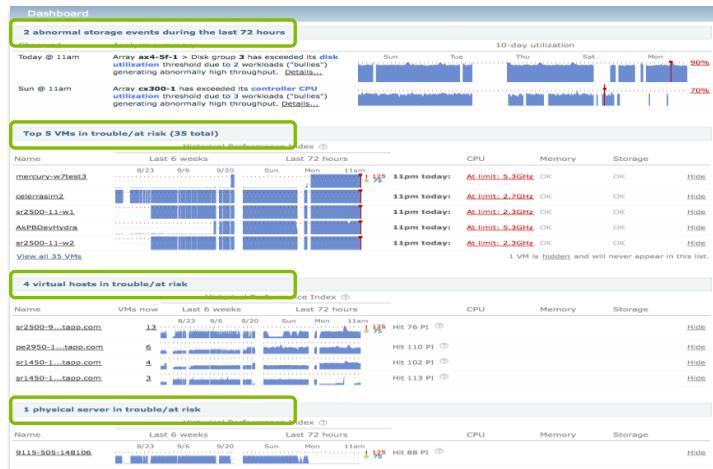
26

## FEATURES OF ONCOMMAND BALANCE

OnCommand Balance helps in three areas of performance analysis: troubleshooting, optimization, and problem prediction.



# OnCommand Balance Dashboard



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

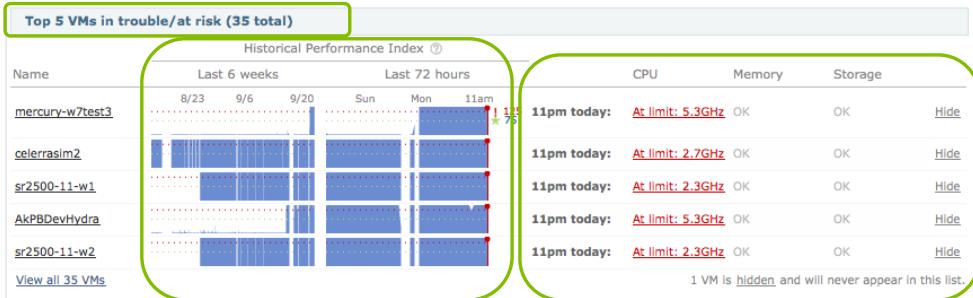
27

## ONCOMMAND BALANCE: DASHBOARD

With one glance, administrators can see which resources are experiencing contention and other performance problems and which of their analytics or key performance indicators have exceeded their thresholds.



## OnCommand Balance VM Alerts



- Identify poorly performing VMs

- Identify the root causes of performance issues and quickly locate under-provisioned VMs (CPU, memory, and storage)

© 2013 NetApp, Inc. All rights reserved.

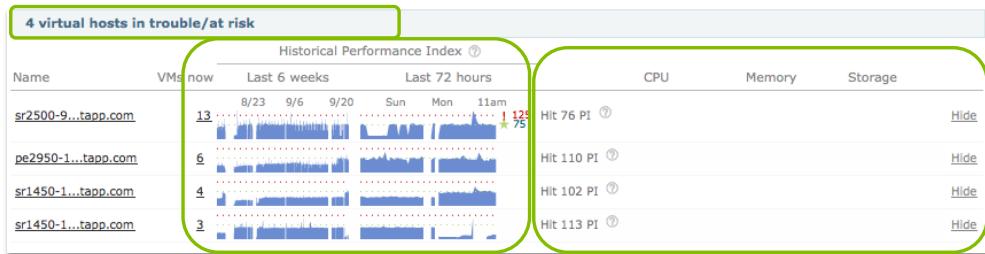
NetApp Confidential

28

## ONCOMMAND BALANCE: VM ALERTS



## OnCommand Balance Virtual Host Alerts



- Identify poorly performing virtual hosts, including under-provisioned or misconfigured hosts
- Identify the root causes of performance issues and quickly locate under-provisioned hosts (CPU, memory, and storage)
- Identify VM workloads for offloading, making resource management extremely efficient

© 2013 NetApp, Inc. All rights reserved.

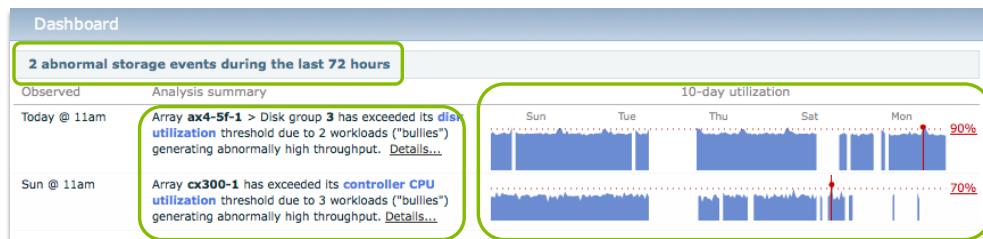
NetApp Confidential

29

## ONCOMMAND BALANCE: VIRTUAL HOST ALERTS



## OnCommand Balance Storage Alerts



- Alerts on abnormal events are provided.
- Analysis identifies the root cause (bully) of a performance issue and the affected VMs or hosts (victims).

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

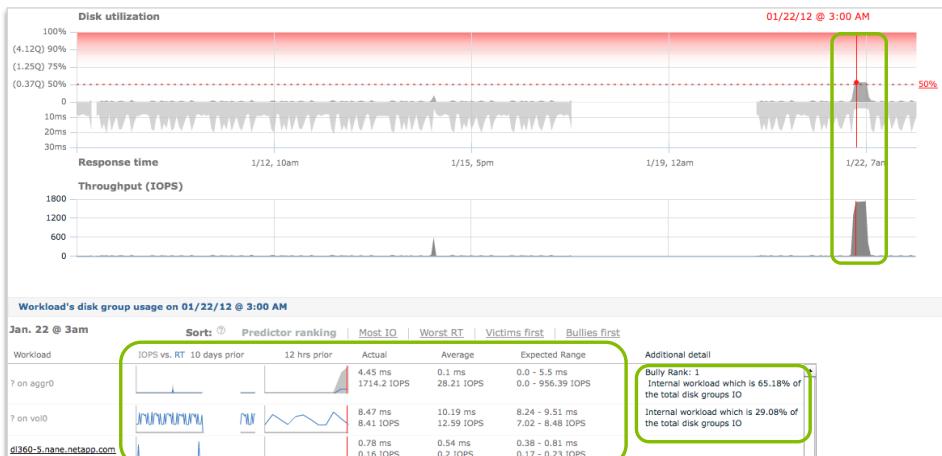
30

## ONCOMMAND BALANCE: STORAGE ALERTS

The storage health panel alerts administrators to abnormal storage events and lists the arrays that have experienced a performance alert in the last 72 hours. The display includes a 10-day utilization chart for alerting analytics, alert explanations, and links for access to detailed analyses.



# OnCommand Balance Workload Alerts



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

31

## ONCOMMAND BALANCE: WORKLOAD ALERTS

As a result of disk scrubbing, Balance can display the internal workload of a disk group. This visibility helps administrators understand how application workloads are impacted by internal workloads.



# OnCommand Balance Server Alerts

The screenshot shows a 'Data Topology' view for the 'Windows2003\_1\_MsSQL' server. A yellow warning bar at the top says 'This server has 3 misaligned LUNs.' Below it, a table lists 'Servers With Misaligned Partitions'. The table columns are: Server Name, LUN Name, Average Throughput (DPS), Average Response Time (ms), Alignment Offset (bytes), Recommended Alignment Offset (bytes), and Storage Configuration (Vendor). The data includes:

Server Name	LUN Name	Average Throughput (DPS)	Average Response Time (ms)	Alignment Offset (bytes)	Recommended Alignment Offset (bytes)	Storage Configuration (Vendor)
Rvwin2k3	Virtual Windows server [Server 2003, Enterprise Edition - SP 2 (5.2.3790)] PHYSICALDRIVE0	712.45	7.02	31.5	4/2 [EVA]	0/0.0
PITest2	Virtual Windows server [Server 2003, Enterprise Edition - SP 2 (5.2.3790)] PHYSICALDRIVE1	807.36	2.15	73.5	8/4 [NetApp]	0/0.0
	PHYSICALDRIVE2	1.65	24.43	63/31.5	256/128 [Engenio]	0/0.0
Windows2003_1_MsSQL	Virtual Windows server [Server 2003, Enterprise Edition - SP 2 (5.2.3790)] PHYSICALDRIVE0	479.80	16.02	63/31.5	256/128 [Engenio]	0/0.0
	PHYSICALDRIVE1	1.55	78.23	63/31.5	256/128 [Engenio]	0/0.0
	PHYSICALDRIVE2	0.00	8.83	63/31.5	256/128 [Engenio]	0/0.0
Win2k3_Converter	Virtual Windows server [Server 2003, Enterprise Edition - SP 2 (5.2.3790)] PHYSICALDRIVE0	212.99	177.02	63/31.5	256/128 [Engenio]	0/0.0
	PHYSICALDRIVE1	1.75	122.12	63/31.5	256/128 [Engenio]	0/0.0

- Detect misaligned LUNs before I/O issues occur
- Identify whether misaligned LUNs are impacting performance
- See through server and storage virtualization
- Help ensure that the layout of the VMware environment is safe
- Can be viewed in the GUI or in a report

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

32

## ONCOMMAND BALANCE: SERVER ALERTS

OnCommand Balance detects misaligned LUNS and partitions that can lead to performance degradation. With just one click, you can display a detailed analysis of the misaligned LUNS (the LUN, average throughput and response time, and manufacturer's recommended alignment configurations).

OnCommand Balance can be leveraged to predict and resolve performance problems, optimize workloads, plan capacity to ensure the best possible performance level for the lowest cost, and manage the infrastructure service that supports your applications.



## Additional Training OnCommand Balance

For in-depth training on OnCommand Balance, visit the NetApp Learning Center and enroll in the [NetApp OnCommand Balance Getting Started Series](http://www.netapp.com/gettingstarted).

<http://www.netapp.com/gettingstarted>

The screenshot shows the NetApp University homepage. At the top, there's a navigation bar with links for Home, Activity, Communications, Actions, Apps, Browse, Create, and a search bar. The main content area features a graduation cap icon and the text "Getting Started with NetApp Software in NetApp University". Below this, there's a section titled "OnCommand Balance" which lists three items: "Installing OnCommand Balance", "Configuring OnCommand Balance", and "Using OnCommand Balance Key Performance Indicators".

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

33

## ADDITIONAL TRAINING: ONCOMMAND BALANCE



## Module Summary

Now that you have completed this module, you should be able to:

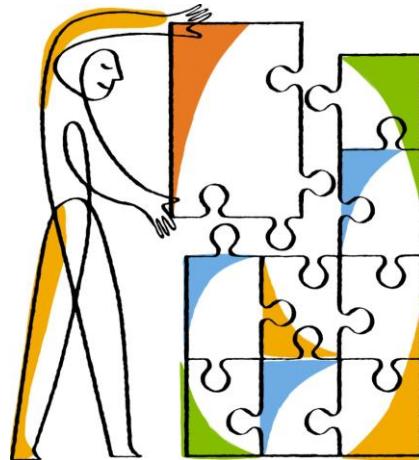
- List the three categories of performance tools
- Explain the features and functions of Insight Perform
- Explain the features and functions of OnCommand Balance
- Use OnCommand management tools to view performance data

## MODULE SUMMARY



## Learning Activity Questions

Module 5: OnCommand Management Tools



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

35

### LEARNING ACTIVITY QUESTIONS



## Learning Activity: Questions

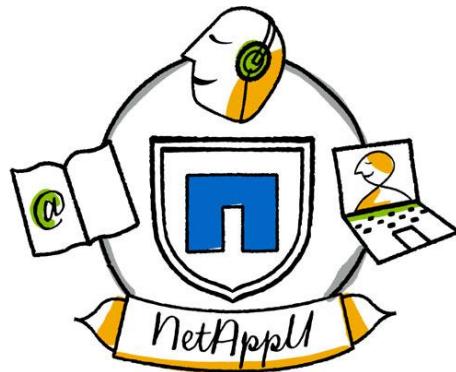
- What are the three categories of performance tools?
- OnCommand Insight provides \_\_\_\_\_ and \_\_\_\_\_ support.
- What are the three primary performance-analysis functions of OnCommand Insight?
- OnCommand Balance provides actionable guidance by \_\_\_\_\_.

## LEARNING ACTIVITY: QUESTIONS



## Module 6

### Storage QoS



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

1

## MODULE 6: STORAGE QOS



## Module Objectives

After this module, you should be able to:

- Discuss how the Storage Quality of Service (QoS) feature works in a clustered Data ONTAP environment
- Identify the commands that are used to manage policy groups
- Monitor workload performance

## MODULE OBJECTIVES



## Storage QoS

- Provide consistent performance
  - Meet performance goals for critical workloads
  - Avoid performance degradation as the number of users or tenants increases
- Maintain isolated performance
  - Prevent user and tenant workloads from impacting each other
  - Prevent system processes from impacting user workloads

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

3

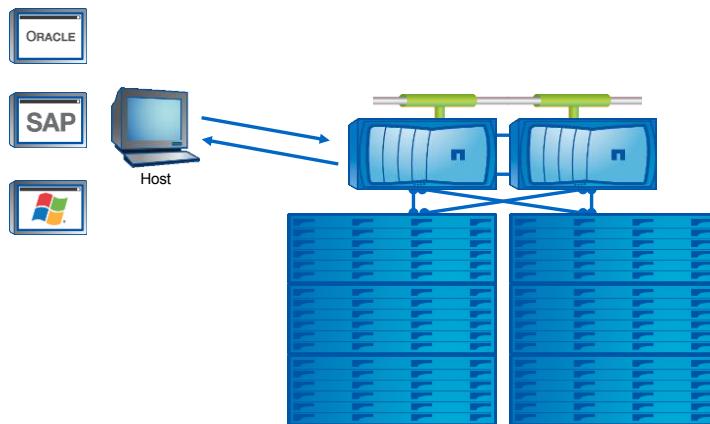
## STORAGE QOS

The Storage Quality of Service (QoS) feature of clustered Data ONTAP 8.2 enables administrators to reactively limit throughput to workloads and proactively monitor workload performance. To accomplish these tasks, administrators associate workloads with QoS policy groups.

**NOTE:** The Storage QoS feature does not guarantee service levels. It is designed to set throughput limits.



## How Storage QoS Works Workloads



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

4

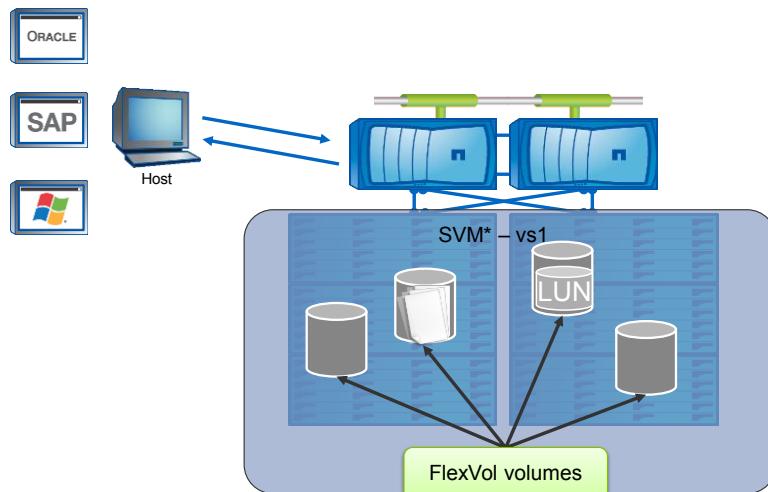
### HOW STORAGE QOS WORKS: WORKLOADS

A workload is the input and output operations of a storage object.



# How Storage QoS Works

## Storage Objects



\*The term "SVM" is replacement for the term "Vserver."

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

5

## HOW STORAGE QOS WORKS: STORAGE OBJECTS

A storage object is a storage virtual server (SVM) with FlexVol volumes, a FlexVol volume, a LUN, or a file (which typically represents a virtual machine).

**NOTE:** The term “SVM” is a replacement for the term “Vserver”: two terms, one meaning. This course uses both “SVM” and “Vserver.”



## How Storage QoS Works

### Policy Groups

Clustered Data ONTAP 8.2 capabilities:

- Defines boundaries between workloads
- Contains one or more **storage objects**
- Is SVM-scoped
- Can contain up to 3,500 policy groups per cluster
- Can contain up to eight nodes per cluster
- Does not allow assignment of nested storage objects to a policy group

## HOW STORAGE QOS WORKS: POLICY GROUPS

By associating workloads with QoS policy groups, administrators can monitor workload performance and identify the level of performance of each workload. They can then associate policy groups with higher performing workloads. Thereby, they can throttle the higher performing workloads, make resources available to underperforming workloads, and improve overall performance.



## How Storage QoS Works

### Policies

Clustered Data ONTAP 8.2 capabilities:

- Defines throughput limits (IOPS or MBps) for a **policy group**
- Applies throughput limits at the protocol stack
  - Throughput is throttled at the protocol layer.
  - I/O that is queued as a result of throttling does not impact cluster resources.
- Shares the performance limit of a **policy group** among the objects within the group

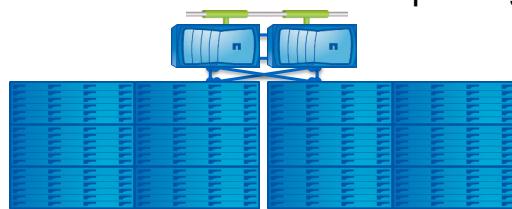
## HOW STORAGE QOS WORKS: POLICIES

When objects share a policy group, each object shares in the performance limit of the group, as opposed to each object having its own performance limit.



## When to Use Storage QoS

- Reactively respond to problem workloads
  - Throttle workloads that are performing beyond SLAs
- Proactively prevent workloads from becoming a problem
  - Set workload limits before problems occur
- Isolate tenant workloads
  - Prevent user and tenant workloads from impacting each other



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

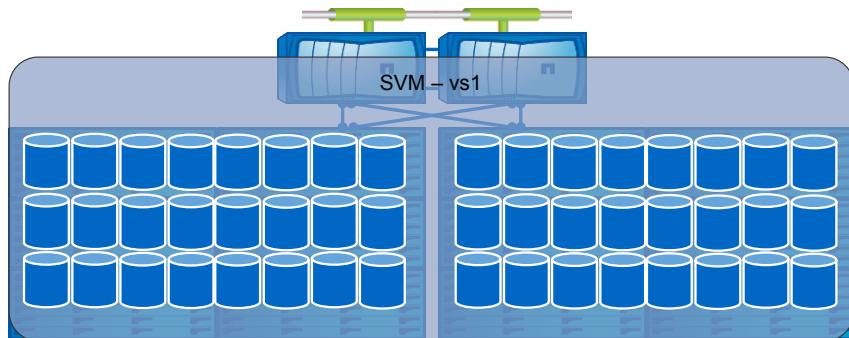
8

## WHEN TO USE STORAGE QOS



## When to Use Storage QoS

### Reactive



#### Reactive Scenario

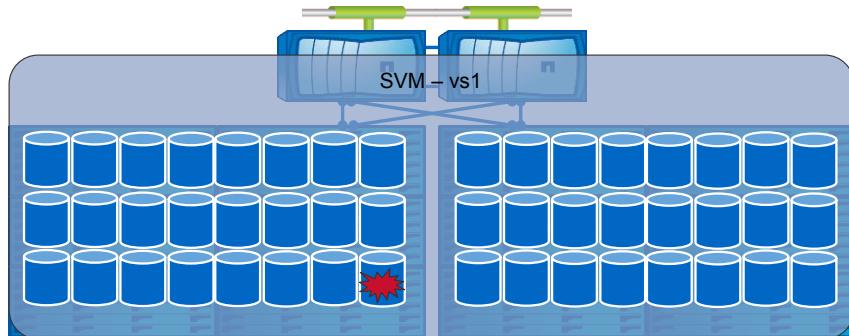
- Storage administrator has not set QoS policies.

## WHEN TO USE STORAGE QOS: REACTIVE



## When to Use Storage QoS

### Reactive



#### Reactive Scenario

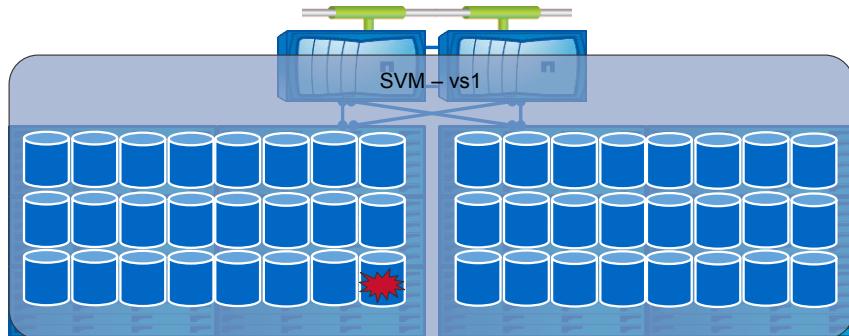
- Storage administrator has not set QoS policies.
- A workload impacts the performance of other workloads.

## WHEN TO USE STORAGE QOS: REACTIVE



## When to Use Storage QoS

### Reactive



#### Reactive Scenario

- Storage administrator has not set QoS policies.
- A workload impacts the performance of other workloads.

#### Solution

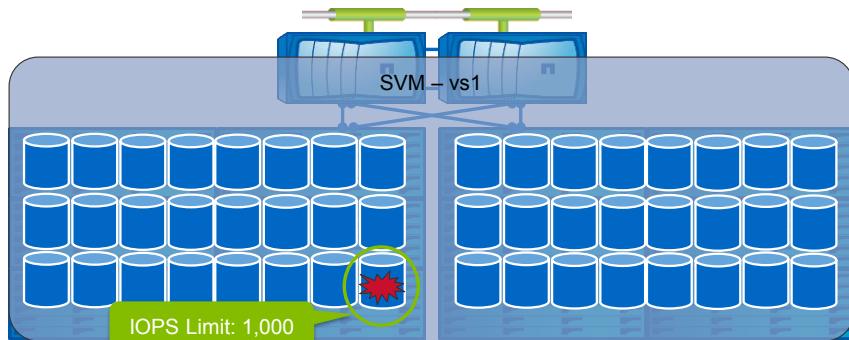
- Use Data ONTAP statistics to identify the problem workload.

## WHEN TO USE STORAGE QOS: REACTIVE



## When to Use Storage QoS

### Reactive



#### Reactive Scenario

- Storage administrator has not set QoS policies.
- A workload impacts the performance of other workloads.

#### Solution

- Use Data ONTAP statistics to identify the problem workload.
- Isolate the problem workload by assigning it to a policy group with a throughput limit.

## WHEN TO USE STORAGE QOS: REACTIVE



## Reactive Workload Throttling

- Create a policy group with a throughput limit.

```
::> qos policy-group create maxtp_policy -vserver vs1  
-max-throughput 1000iops
```

Policy group with throughput limit created with qos command from the clustershell

- Assign the problem volume to the policy group

```
::> volume modify vol1 -qos-policy-group maxtp_policy -vserver vs1
```

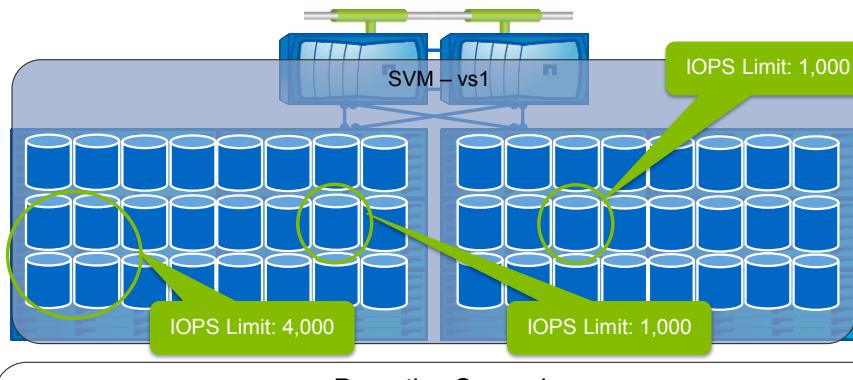
Volume modify used to assign a pre-existing storage object to a policy group

## REACTIVE WORKLOAD THROTTLING

The command line uses “vserver,” rather than “SVM.”



## When to Use Storage QoS Proactive



### Proactive Scenario

- Storage administrator proactively sets QoS policies with throughput limits.
- New volumes are associated to a policy during the volume create.

## WHEN TO USE STORAGE QOS: PROACTIVE

The use of QoS policies with throughput limits ensures that new and possible runaway workloads do not negatively impact performance.



## Proactive Workload Throttling

- Create a policy group with a throughput limit.

```
::> qos policy-group create prevent_policy -vserver vs1  
-max-throughput 1000iops
```

- Create a volume and assign it to the new policy group.

```
::> volume create -vserver vs1 -volume voll -aggregate aggr1  
-qos-policy-group prevent_policy
```

- Monitor the application workload.

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

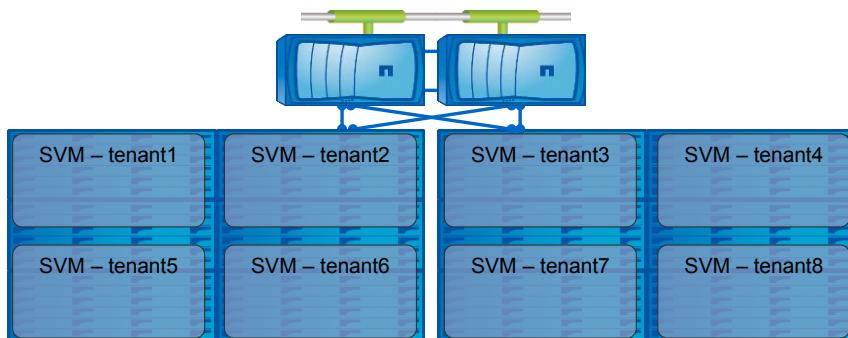
- Modify the throughput limit of the policy.

```
::> qos policy-group modify prevent_policy -max-throughput 3000iops
```

## PROACTIVE WORKLOAD THROTTLING



## When to Use Storage QoS Tenant Isolation



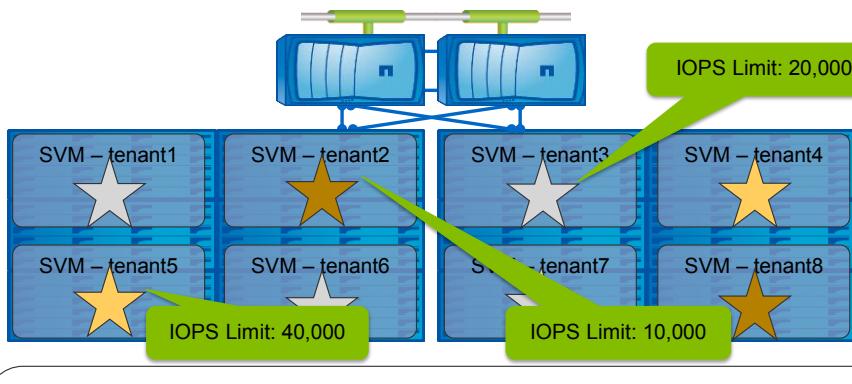
### Scenario

- Each tenant (SVM) is isolated.

## WHEN TO USE STORAGE QOS: TENANT ISOLATION



## When to Use Storage QoS Tenant Isolation



### Scenario

- Each tenant (SVM) is isolated.
- A QoS policy group is created for each SVM.
- QoS policy group performance limits are based on service levels (example: gold = 40,000 IOPS, silver = 20,000 IOPS, and bronze = 10,000 IOPS).

## WHEN TO USE STORAGE QOS: TENANT ISOLATION



## Tenant Isolation Workload Throttling

- Create a policy group with a throughput limit that is associated with a service level for the tenant.

```
::> qos policy-group create tenant5_gold_policy -vserver tenant5  
-max-throughput 40000iops
```

- Create the SVM for tenant5 and assign it to the new policy group.

```
::> vserver create -vserver tenant5  
-qos-policy-group tenant5_gold_policy
```

## TENANT ISOLATION WORKLOAD THROTTLING



## Storage QoS Monitoring Commands

- Monitor latency by policy group (within clustered Data ONTAP, latency is measured from and to the networking layer and the data layer).

```
::> qos statistics latency show
Policy Group      Latency      Network      Cluster      Data      Disk      QoS
----- -total- ----- ----- ----- ----- ----- -----
          16ms       6ms        2ms       3ms       4ms      1ms
```

- Monitor performance by policy group.

```
::> qos statistics performance show
Policy Group      IOPS      Throughput      Latency
----- -total- ----- ----- ----- -----
          12224     47.75MB/s    512.45us
maxdp_policy      7216     28.19MB/s    420.00us
prevent_policy     5008     19.56MB/s    92.45us
```

## STORAGE QOS MONITORING COMMANDS

Storage QoS limits I/O to and from the cluster. The rate of I/O that the cluster experiences can differ from the rate of I/O that an application experiences. For example, reads from the application can go to the file system buffer cache and not to the cluster. Due to this behavior, you should monitor performance from the cluster and not from a host-side tool.



## Storage QoS Design Considerations

- All protocols are supported.
- All client I/O (both disk and metadata) are counted toward IOPS limit, regardless of I/O block size.
- Transactional workloads should use IOPS limits.
- Large block I/O workloads should use MBps limits.
- AutoSupport and archival data reporting is supported.

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

20

## STORAGE QOS DESIGN CONSIDERATIONS



## Additional Design Considerations

- Throughput limits can be exceeded, based on an error margin.
- Storage QoS performance overhead is less than 2% per node.
- Storage QoS is always on.
- Policy groups must be re-created on data-protection target storage.
- Infinite volumes and V-Series are not supported.

## ADDITIONAL DESIGN CONSIDERATIONS



## Module Summary

Now that you have completed this module, you should be able to:

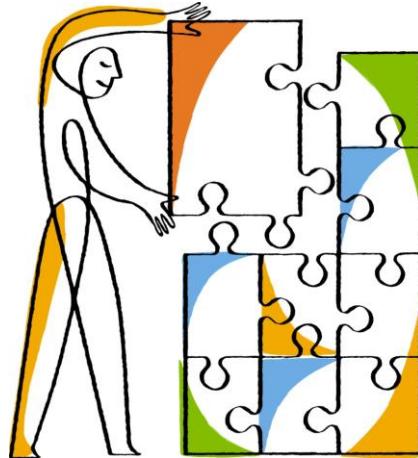
- Discuss how Storage QoS works in a clustered ONTAP environment
- Identify the commands that are used to manage policy groups
- Monitor workload performance

## MODULE SUMMARY



## Learning Activity Questions

Module 6: Storage QoS



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

23

### LEARNING ACTIVITY QUESTIONS



## Learning Activity: Questions

- A storage object is \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, or \_\_\_\_\_.
- \_\_\_\_\_ cannot be assigned to a policy group.
- The objects within a policy group \_\_\_\_\_.
- True or False: All protocols are supported by Storage QoS.

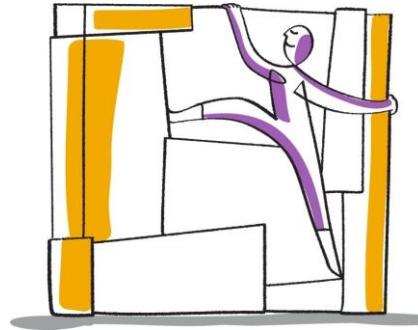
## LEARNING ACTIVITY: QUESTIONS



## Exercise

Module 6: Storage QoS

Time Estimate: 60 Minutes



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

25

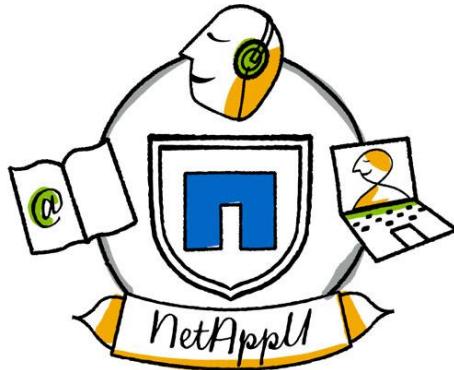
### EXERCISE

Please refer to your exercise guide.



## Module 7

### Summary



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

1

## MODULE 7: SUMMARY



## Module Objectives

After this module, you should be able to:

- Summarize what you have learned in this course
- Locate resources and information that help you maximize system performance

## MODULE OBJECTIVES



## Lesson 1

Highlights of *Performance Analysis*  
on Clustered Data ONTAP



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

3

### LESSON 1: HIGHLIGHTS OF PERFORMANCE ANALYSIS ON CLUSTERED DATA ONTAP

This lesson reviews the key topics covered in this course.



# Clustered Data ONTAP Data Access

## Direct Data Access

The target volume is **owned** by the controller that is hosting the LIF

## Indirect Data Access

The target volume is **not owned** by the controller that is hosting the LIF

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

4

## CLUSTERED DATA ONTAP DATA ACCESS

Both clustered Data ONTAP and Data ONTAP operating in 7-Mode support direct data access; however, only clustered Data ONTAP supports indirect data access.



## Measurements That Define Workload Characteristics

- Throughput
- Latency
- Operation size
- Randomness
- Concurrency

To display information about the characteristics, use the following command:

```
::> statistics show <object> <instance> <counter>
```

## MEASUREMENTS THAT DEFINE WORKLOAD CHARACTERISTICS



## Data About Workload Characteristics

You can use information about workload characteristics in various ways:

- Is critical for a storage-system sizing exercise
- Can help you determine what technologies you should use to improve storage system performance
  - Small-block, random operations can benefit significantly from the use of Flash Cache or Flash Pool.
  - Caching technologies or pure SSD aggregates can greatly reduce operation latency.

## DATA ABOUT WORKLOAD CHARACTERISTICS



## Cluster Performance Monitoring and Analysis

- Cluster health checks
- Baseline performance monitoring
- Analysis and isolation of storage system bottlenecks

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

7

### CLUSTER PERFORMANCE MONITORING AND ANALYSIS



## Performing Cluster Health Checks

- Check the health of each node and of the cluster network
  - `cluster show`
  - `cluster ring show`
  - `cluster ping-cluster <node>`
  - `dashboard health vserver show`
- Check the health of each aggregate and volume
  - `storage aggregate show`
  - `storage disk show -state broken`
- Check the health of the network
  - `network port show`
  - `network interface show`

## PERFORMING CLUSTER HEALTH CHECKS



## Monitoring Performance

- Work from top (cluster) to bottom (node)
  - **statistics show-periodic**
    - Operates by cluster, node, or object
    - Is similar to **sysstat** in Data ONTAP 7-Mode
  - **dashboard performance show**
    - Is very powerful
    - Provides useful summary information
- Narrow the search to values and objects that you want to monitor
  - **statistics show**

## MONITORING PERFORMANCE



## Analyzing Storage System Bottlenecks

- Use a top-to-bottom baseline process
  - `statistics show-periodic`
  - `dashboard performance show`
  - `statistics show`
- Analyze key storage controller resources
  - Disks
  - Processor utilization
- When you analyze client-performance problems, define workload characteristics  
`statistics show -object [obj]`  
`-instance [inst] -counter [cnt]`

## ANALYZING STORAGE SYSTEM BOTTLENECKS



## Lesson 2

Resources for Learning More  
About Clustered Data ONTAP  
Performance



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

11

### LESSON 2: RESOURCES FOR LEARNING MORE ABOUT CLUSTERED DATA ONTAP PERFORMANCE

This lesson discusses where to find additional clustered Data ONTAP performance information.



# NetApp Storage Performance Primer for Clustered Data ONTAP (TR-4211)

NetApp

Technical Report

NetApp Storage Performance Primer  
Clustered Data ONTAP 8.2

Roy Scott, Paul Updike, Chris Wilson, NetApp  
July 2013 | TR-4211

**Abstract**  
This paper describes the basic performance concepts as they relate to the system and the clustered Data ONTAP operating system. It details how requests are processed by the system, how different features in clustered Data ONTAP affect performance, and how to observe the performance of a cluster.

TABLE OF CONTENTS

1 Introduction

1.1 Performance Fundamentals

1.2 Normal Performance Relationships

2 System Architecture Overview

2.1 Connectivity: NICs and HBAs

2.2 Controller Subsystem: Memory, CPU, NVRAM

2.3 Storage Subsystem: Disk, Flash Cache, and Flash Pool

3 Data Storage and Retrieval

3.1 Cluster Operators

3.2 Node Operations

4 Introduction to Storage Quality of Service

4.1 The Need for Storage QoS

4.2 Storage QoS Concepts

4.3 Examples of Using Storage QoS

5 Performance Management with Clustered Data ONTAP

5.1 Basic Workload Characterization

5.2 Observing and Monitoring Performance

5.3 Managing Workloads with Data Placement

6 A Performance Management Scenario

6.1 Estimator Monitoring

6.2 Root Cause Analysis

6.3 Resolve Performance Problem

7 Conclusion

Appendices

Data ONTAP 8.2 Upgrade Recommendations

Running and Interpreting Self Report -I

References

Version History

LIST OF TABLES

Table 1: QoS Limits

Table 2: SLA Levels

2 NetApp Storage Performance Primer for Clustered Data ONTAP 8.2

Review the product documentation and [TR-4090, Performance Advisor Features and Diagnosis](#).

©2013 NetApp, Inc. All rights reserved.

Figure 13) Performance Advisor Dashboard

Without any configuration, Performance Advisor will collect data at regular fixed intervals and present this data in bar graphs. By default the biggest, or top, objects are presented in the dashboard.

Figure 14) Volume Latency Summary

Besides the dashboard, individual objects, both logical and physical, are observable using the View tab. For instance, if the latency of a specific volume is interesting, use the View capability and drill down into the volume in the logical object tree.

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

12

## NETAPP STORAGE PERFORMANCE PRIMER FOR CLUSTERED DATA ONTAP (TR-4211)

This primer addresses the following topics:

- System architecture
- Direct versus indirect access
- Storage QoS
- Performance Advisor
- Cluster operations
- Protocols

# Flash Pool Design and Implementation (TR-4070)

Technical Report

## Flash Pool Design and Implementa

Paul Updike, NetApp

May 2012 | TR-4070

### TABLE OF CONTENTS

<b>1</b>	<b>What is a Flash Pool?</b>
1.1	About WAFL Blocks
<b>2</b>	<b>How Flash Pool Works</b>
2.1	Read Caching
2.2	Read Eviction Mechanism
2.3	Write Caching
2.4	Write Eviction Mechanism
<b>3</b>	<b>Creating a Flash Pool</b>
3.1	7-Mode CU
3.2	Cluster CU
<b>4</b>	<b>Determining the Flash Pool Insertion Policy for a Volume</b>
4.1	Insetstor Policies
4.2	Read Caching Policies
4.3	Write Caching Policies
4.4	Flash Pool Policy Changes in Data ONTAP Operating in Cluster-Mode
<b>5</b>	<b>Flash Pool SSD, RAID, and WAFL Design Considerations</b>
5.1	RAID Considerations When Creating a Flash Pool
5.2	Adding SSDs to an Existing Flash Pool
5.3	SSD RAID Group RAID Type
5.4	Appropriate Granularity
5.5	SAS Sheer and Storage Stack Considerations
5.6	Incorporates Granularity for Flash Pool
5.7	Flash Cache and Flash Pool Interaction
<b>6</b>	<b>Nondisruptive Performance Expectations</b>
<b>7</b>	<b>Flash Pool and Predictive Cache Statistics</b>
<b>8</b>	<b>Performance Analysis</b>
8.1	Fast Flash Read Operations
<b>9</b>	<b>Performance Analysis of Data ONTAP Operating In Cluster-Mode</b>
<b>10</b>	<b>Frequently Asked Questions About Flash Pool</b>

### Overview

This Technical Report covers the design considerations and best practices for NetApp Flash Pool.

### read-cache-random-read

The random read policy is the default policy and should rarely be changed. When this policy is set, both user data and meta data are read into the Flash Pool SSDs for that volume. Random reads are described in section 2.1, "Read Caching."

Figure 4) Random-read policy encompasses random reads and metadata.

### FLASHPOOL-ONTAP-FFS-prm.set advanced

Warning: These advanced commands are potentially dangerous; use them only when directed to do so by NetApp.

FLASHPOOL-ONTAP-FFS-prm.priority hybrid-cache-set vol1 read-cache-random-read

FLASHPOOL-ONTAP-FFS-prm.read-cache-random-read.read-cache-policy-info: Read cache random-read policy has been modified to "random-read".

### FLASHPOOL-ONTAP-FFS-prm.set advanced

Warning: These advanced commands are potentially dangerous; use them only when directed to do so by NetApp.

FLASHPOOL-ONTAP-FFS-prm.priority hybrid-cache-set vol1 read-cache-random-read

FLASHPOOL-ONTAP-FFS-prm.read-cache-random-read.read-cache-policy-info: Read cache random-read policy has been modified to "random-read".

### read-cache-random-read-write

This is a read caching policy, not a write caching policy. For random-read/write, random read and random write blocks are written into the read cache and are immediately available for reads. This allows random writes to be cached and immediately available for random reads. This also allows random reads to be written into the write cache.

This can help some workloads with a high ratio of read/write cache misses when it is desirable to avoid going to disk for any read operations. This policy does not result in write-offload from the HDFS or any other storage system, only in very specific situations.

### FLASHPOOL-ONTAP-FFS-prm.set advanced

Warning: These advanced commands are potentially dangerous; use them only when directed to do so by NetApp.

FLASHPOOL-ONTAP-FFS-prm.priority hybrid-cache-set vol1 read-cache-random-read-write

FLASHPOOL-ONTAP-FFS-prm.read-cache-random-read-write.read-cache-policy-info: Read cache random-read/write policy has been modified to "random-read/write".

### FLASHPOOL-ONTAP-FFS-prm.set advanced

Warning: These advanced commands are potentially dangerous; use them only when directed to do so by NetApp.

FLASHPOOL-ONTAP-FFS-prm.priority hybrid-cache-set vol1 read-cache-random-read-write

FLASHPOOL-ONTAP-FFS-prm.read-cache-random-read-write.read-cache-policy-info: Read cache random-read/write policy has been modified to "random-read/write".

### read-cache-none

When this policy is set for a volume, data from that volume is not available to be cached in the Flash Pool.

### FLASHPOOL-ONTAP-FFS-prm.set advanced

Warning: These advanced commands are potentially dangerous; use them only when directed to do so by NetApp.

FLASHPOOL-ONTAP-FFS-prm.priority hybrid-cache-set vol1 read-cache-random-read-write

FLASHPOOL-ONTAP-FFS-prm.read-cache-random-read-write.read-cache-policy-info: Read cache random-read/write policy has been modified to "none".

### FLASHPOOL-ONTAP-FFS-prm.set advanced

Warning: These advanced commands are potentially dangerous; use them only when directed to do so by NetApp.

FLASHPOOL-ONTAP-FFS-prm.priority hybrid-cache-set vol1 read-cache-random-read-write

FLASHPOOL-ONTAP-FFS-prm.read-cache-random-read-write.read-cache-policy-info: Read cache random-read/write policy has been modified to "none".

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

13

FLASH POOL DESIGN AND IMPLEMENTATION (TR-4070)

This technical report addresses the following topics and answers frequently asked questions.

- What a flash pool is
  - How the Flash Pool feature works
  - How to create a flash pool
  - How to analyze performance



## Additional Training OnCommand Insight

For in-depth hands-on training on OnCommand Insight, visit the NetApp Learning Center and enroll in [NetApp OnCommand Insight Operations and Best Practices](#)

- Instructor-led training (ILT)
- Three days

The brochure cover features the NetApp logo at the top left. At the top right is a cartoon character of a person holding a briefcase with the NetApp logo on it. The title "NETAPP UNIVERSITY" is above the course name "NetApp OnCommand Insight Operation and Best Practices". Below the title is a small description of the course content. The "PREREQUISITES" section lists "Getting Started" and "OnCommand Insight Installation & Configuration". The "OBJECTIVES" section lists various learning goals related to managing storage systems. The "DELIVERY TYPE" is listed as "Instructor-led training (ILT)". The "DURATION" is "Three days". The "AUDIENCE" includes "Customers, Professional Services employees, and Professional Services partners". The "TRAINING UNITS" are numbered 36. At the bottom right is the NetApp logo and the URL "www.netapp.com".

## ADDITIONAL TRAINING: ONCOMMAND INSIGHT



## Additional Training OnCommand Balance

For in-depth training on OnCommand Balance, visit the NetApp Learning Center and enroll in the [NetApp OnCommand Balance Getting Started Series](#).

<http://www.netapp.com/gettingstarted>



Getting Started with NetApp Software in NetApp University ▾

OnCommand Balance

- Installing OnCommand Balance
- Configuring OnCommand Balance
- Using OnCommand Balance Key Performance Indicators

© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

15

## ADDITIONAL TRAINING: ONCOMMAND BALANCE



## Module Summary

Now that you have completed this module, you should be able to:

- Summarize what you have learned in this course
- Locate resources and information that help you maximize system performance

## MODULE SUMMARY



## Course Summary

1 of 2

Now that you have completed this course, you should be able to:

- Describe how data flows through the network and protocol layers of clustered Data ONTAP
- Define performance-related terms and describe basic methodologies
- Identify the methods that can be used to monitor and analyze storage system performance
- Use various methods and tools to collect performance data

### COURSE SUMMARY: 1 OF 2



## Course Summary

### 2 of 2

Now that you have completed this course, you should be able to:

- Use command output to analyze system performance and identify performance bottlenecks
- Use OnCommand management tools to view performance data
- Implement configurations that are based on recommended practices for resiliency and performance
- Locate resources and information that help you maximize system performance

## COURSE SUMMARY: 2 OF 2

Thank you



© 2013 NetApp, Inc. All rights reserved.

NetApp Confidential

19

**THANK YOU**