Lab Insight

Scaling Performance for Enterprise HCI Environments

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NetApp®

Evaluator Group

Executive Summary

Hyperconverged Infrastructure (HCI) has quickly gained adoption in many IT environments due to its relative simplicity and the ability to efficiently scale the number of applications for private cloud and virtual environments. As HCI systems have matured, IT administrators and application owners have grown comfortable with their capabilities, particularly the ability to quickly scale their deployments while maintaining efficiency through the use of a consistent set of integrated management tools.

According to the latest Evaluator Group research of HCI, many companies express concern over the capabilities of their HCI environments, particularly regarding performance and scalability, along with data protection and disaster recovery features. In order to assess the capabilities of NetApp's HCI system, Evaluator Group was asked to evaluate it in our lab using a variety of typical enterprise workloads and use cases.

In this Lab Insight, we report on the findings of our in-depth testing of NetApp HCI in scenarios designed to represent typical usage in an enterprise hybrid cloud environment. Testing was designed to assess system usability, performance and Quality of Service (QoS) capabilities, along with scaling and availability. Additionally, the NetApp HCI system was evaluated during unplanned events in order to understand the potential impact to availability and performance.

In summary, the NetApp HCI system was able to leverage its disaggregated HCI design. Tested as a solution, the system was shown to scale storage performance and capacity independently from computing capabilities. Additionally, the impact of a storage failure was minimal while running a set of common virtual applications.

NetApp HCI Test Highlights:

- **Performance: Industry leading HCI storage performance (3 compute + 5 storage NetApp HCI)**
  - IOmark-VDI: Certified for 3,200 VDI users IOmark-VDI standard storage workload
  - IOmark-VM: Certified for 1,440 VM applications, using IOmark-VM storage workload
- **Scalability**: Ability to linearly scale capacity and performance of storage independently
- **Availability**: Tested ability to withstand storage node failure with minimal compute impact
- **Enterprise QoS**: Tested QoS control per volume and per VM (using iSCSI and VVOLs, respectively)
- **Always on Data Reduction**: All testing and results with data reduction enabled

Note: *IOmark testing certifies the storage performance of the system for a particular workload, without regard to the computing required. For NetApp-HCI with VDI or VM application workloads, sufficient compute nodes are required in order to fully utilize the storage performance and capacity delivered by the system tested.* *(See page #5 for details)*

Enterprise HCI

Enterprise users have rapidly adopted HCI as a means for rapidly deploying new applications using a common set of technologies and management interfaces. The high degree of integration is what enables IT administrators to deploy, scale and manage new application deployments much more efficiently than using older designs, processes and tools.

As HCI has matured, application owners and IT administrators have both gained confidence in these systems' capabilities to handle a wide variety of applications that were traditionally run on dedicated, highly customized systems.

> ***Evaluator Group Comments: By utilizing separate processing for storage, compute node CPU is always available for application processing. The independent scaling of storage and compute capabilities, together with QoS provides application consistency.***

Evaluator Group Research of Enterprise HCI

Evaluator Group conducts research into many areas of enterprise IT, including the usage of converged and hyperconverged infrastructure. Recent research results include factors for choosing and deploying CI and HCI, use cases and other topics. Some of the key insights gathered over the course of multiple studies include reasons companies are using both HCI and CI systems for an increasing number of applications. Some of top reasons cited for using HCI is the ability to consolidate equipment while reducing complexity and enabling faster deployment of new equipment.

Another rationale cited by many customers is the simplicity and manageability of HCI systems compared to both traditional IT and CI systems. However, in some instances customers are using CI due to its ability to flexibility in scaling compared with traditional HCI systems. These research studies are available to Evaluator Group clients on the website, **www.evaluatorgroup.com**.

In addition to current CI and HCI technologies, new methods for operating IT infrastructure are emerging, with container-based development and operation (dev/ops) gaining traction. However, the management of containers is relatively new and has not yet attained the maturity of more traditional methods for deploying and managing IT infrastructure.

As container technology matures, it is likely to play a role in some new applications, many of which are now being deployed on HCI infrastructure. Moreover, next generation container storage will need to provide many of the same features and capabilities as mainstream enterprise storage and HCI systems do currently. These capabilities include data protection, disaster recovery and differentiated quality of service and performance features. Thus, it is clear that IT administrators and application owners are both looking for solutions that enable them to flexibly deploy and manage applications with a consistent set of tools, while delivering the performance and reliability of traditional IT infrastructure.

Scaling Enterprise HCI

NetApp's HCI solution is different than many first generation HCI systems by utilizing independent resources for compute and storage. This architecture is often referred to as "disaggregated" in that it breaks apart some of the resources used to deliver an HCI platform. By separating resources, NetApp's HCI system is able to scale compute and storage performance independently, with almost no impact to other resources. Clearly, scaling performance is one advantage of disaggregation, but there are additional advantages including the ability to deliver high availability without impacting application performance.

The ability to insulate applications from each other has been a concern of application owners in shared environments, including for both virtualization and containers. For these reasons, many business-critical applications have resisted the use of shared resources, be that compute or storage. Isolation is one means of achieving predictable performance, although it comes at the price of reduced efficiency. The combination of dedicated storage processing insulates application demands from potential I/O delays for other applications, and the NetApp HCI QoS capabilities provide additional control for administrators and application owners. These enterprise-class features help enable cloud operators in both private and service provider environments to deliver consistent performance to applications regardless of what other workloads are running.

With traditional first generation HCI systems, compute resources are utilized to provide storage features including data protection, replication and high availability. Thus, when a node fails computing resources decrease, along with a reduction in storage availability, performance and capacity. Commonly, node failures place even higher demands on already degraded systems by forcing storage rebuilds, which consume additional resources and further diminish critical application resources. In contrast, NetApp's HCI uses independent resources for compute and storage, meaning a failure of a compute node does not reduce storage availability, performance or capacity. The NetApp HCI solution utilizes dedicated resources for compute and storage, each optimized to enable scaling while maintaining consistent performance characteristics, including during planned or un-planned outages.

Testing NetApp HCI

Test Environment

Evaluator Group extensively tested the NetApp HCI system in the Evaluator Group lab in early 2019. All equipment was located on-site with testing performed by Evaluator Group personnel. Initial setup and deployment was performed by NetApp personnel prior to arrival at the test facilities. All system administration, provisioning and testing was performed by Evaluator Group utilizing the provided user interfaces and plugins available for the NetApp HCI system. The primary interface for management is vCenter along with the HCI vCenter plugin that provides monitoring and administrative capabilities within vCenter. Additionally, the Element OS management UI was used for additional monitoring, and access to NetApp HCI specific capabilities.

The configured system included two, 2U 4-node chassis, along with two dedicated switches for node interconnections and connection into the main lab network. All storage was provided by the HCI storage nodes running ElementOS to the compute nodes running VMware vSphere. A high-level diagram of the test environment is shown in Figure 1.

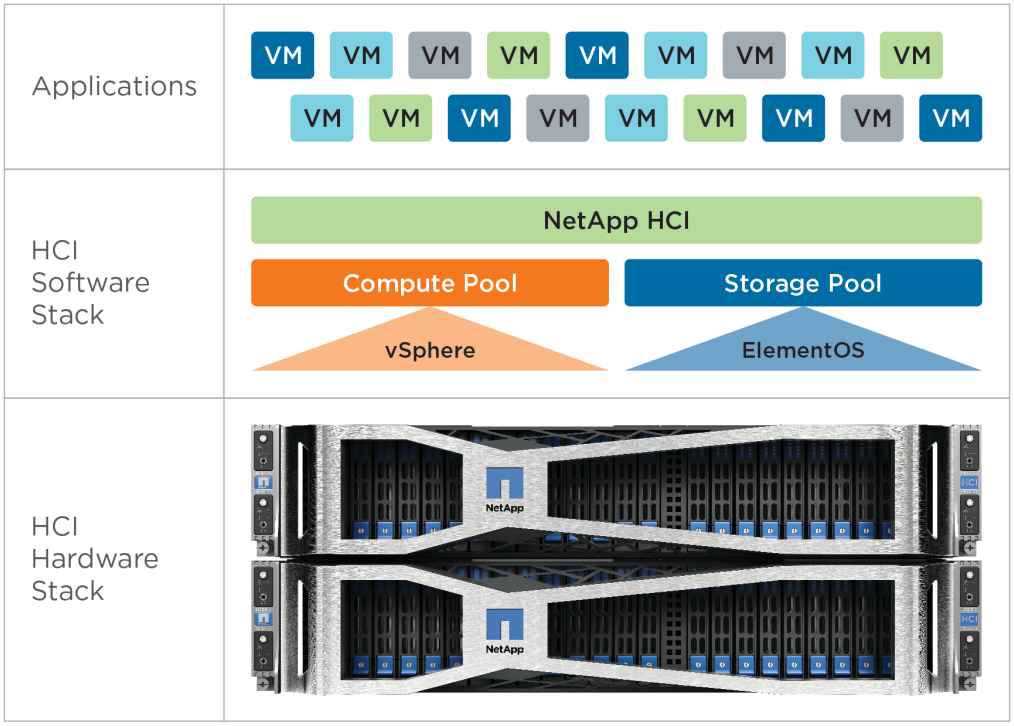

Figure 1: Test Environment – NetApp HCI

Test Results

Two application workloads were tested for performance, along with scalability, QoS and failure testing. All evaluations utilized the NetApp HCI environment depicted above, with either iSCSI or VMware VVOL storage for the virtual applications. Storage connectivity utilized multiple switched Ethernet connections between compute and storage nodes.

It is also notable that NetApp's performance results were achieved with deduplication and compression enabled, which is often disabled on competing HCI solutions during benchmark testing.

> ***Evaluator Group Comments: The NetApp HCI proved its ability to deliver scalable performance, including the most VDI instances for any HCI system Evaluator Group has tested and the most VM instances of any HCI configuration under $1M. The NetApp HCI achieved these records with data reduction enabled, providing significant capacity savings. In contrast, competing HCI solutions often disable data reduction during benchmarking.***

VM Workload

In order to assess the NetApp HCI's ability to support virtual applications, the IOmark-VM2 workload set was utilized. This standard benchmark measures the number of virtualized applications a storage system can support while still meeting application latency requirements. These certified results are available on the iomark.org website (www.iomark.org/sites/default/files/IOmark-VM_NetApp_HCI-VM_190802a.pdf).

These results are certified as a Hyperconverged solution, which assures the solution has sufficient storage, CPU and memory while meeting the application performance requirements.

- **NetApp HCI achieved 2nd highest IOmark-VM for hyperconverged systems**
- **IOmark-VM-HC certifies entire HCI system for 1,440 VM's at $454.86/ IOmark-VM-HC**
  - Configuration: 18 compute nodes + 5 storage nodes
  - System total = $655,000.00 ($655,000 / 1,440 = $454.86)

VDI Workload

Evaluator Group tested the NetApp HCI system using the IOmark-VDI "standard" workload set which measures the number of VDI instances a storage system is able to support while still meeting application latency requirements. These certified results are available on iomark.org website (www.iomark.org/sites/default/files/IOmark-VDI_NetApp_HCI-VDI_190802a.pdf).

These results are certified as a Hyperconverged solution, which assures the solution has sufficient storage, CPU and memory while meeting the application performance requirements.

- **NetApp HCI achieved the highest number of IOmark-VDI for hyperconverged systems**
- **IOmark-VDI-HC certifies entire HCI system for 3,200 desktops at $176.56 / IOmark-VDI-HC**
  - Configuration: 12 compute nodes + 5 storage nodes
  - System total = $565,000.00 ($565,000 / 3,200 = $176.56)

Additional Testing

In addition to VM and VDI workloads, Evaluator Group performed tests designed to understand the features and capability of the NetApp HCI system, including quality of service, scalability and error handling.

Scalability

Scaling performance is an important criterion for choosing cloud and hyperconverged infrastructure. The NetApp HCI was tested with 4 storage nodes and then scaled up to 5 storage nodes. The performance of the 4-node configuration was found to be approximately 20% lower than the 5-node configuration, using the IOmark-VM workload. More precisely, 5 storage nodes supported 1,440 VMs while 4 storage nodes supported 1,120 VMs at the required benchmark latency requirements. These results show that scalability was linear from 4 to 5 nodes and should continue scaling performance up to NetApp's supported configuration of 40 storage nodes.

VVOL and iSCSI

As stated, both iSCSI volumes and VMware VVOLs were used during testing. Some tests were repeated using both connectivity methods. We found no performance differences between the two methods of allocation. While many IT organizations prefer iSCSI due to its ubiquity and familiarity, VMware VVOLs provided several advantages.

Testing showed the following benefits of VVOLs:

- Improved manageability and reduction in administration time and number of actions required
  - Reduced storage admin. (appx. 1 hour to manually create 150 iSCSI volumes vs. 0 minutes with VVOLs)
  - No need to resize or delete datastores with VVOLs for configuration changes
- Ability to create native NetApp HCI snapshots using VMware tools
- Per VM and VMDK control of QoS and performance monitoring with VVOLs

> ***Evaluator Group Comments: The use of VVOLs was not part of the test plan. However, the efficiency and manageability of VVOLs helped reduce the time to perform test setup, performance monitoring and QoS. NetApp HCI's support for multiple storage connectivity such as iSCSI, VVOLs and container native storage via Trident is a competitive advantage.***

Quality of Service

Another consideration in shared environments is the ability to manage application performance, both for groups of applications and individually in some instances. QoS settings are available both for iSCSI volumes and at the VM and VMDK (VM virtual disk) level when using VVOLs. In both cases, multiple settings were available including minimum I/O rate, maximum sustained I/O and burst I/O rates. Settings are established via policies available through the UI, which are then applied to volumes. For VMware VVOLs, policies are established using VMware vCenter policy settings, with policies then applied to VMs or individual VMDKs as desired. Testing verified that limits are enforced allowing business-critical applications to operate without restrictions, while limiting less critical applications.

In order to support dynamic environments, QoS settings may be modified and applied to running volumes and may be changed both via the UI and through the ElementOS API. This provides application and IT administrators the ability to respond to business requirements and changing workloads in real time.

Error Recovery

Evaluator Group tested failure scenarios, manually rebooting a storage node either by a power switch or via the UI. The results showed that when running a moderate workload, storage latencies increased slightly while the node rebooted and came back online. After a 5-minute restart process, the system resumed operating at full performance after an additional 5 minutes, without any further impact. NetApp HCI is designed to tolerate a node reboot without migrating data, thus imposing no additional

performance overhead on remaining nodes. The overall system continued operations without any loss of application or data access or workloads terminating.

NetApp HCI Overview

NetApp's HCI system is designed for enterprise environments that require the ability to scale storage performance and capacity independently from computing, in order to match application requirements efficiently. NetApp's HCI architecture provides enterprise capabilities along with NetApp Data Fabric components to extend usage, data protection and deployment options.

NetApp HCI Features

- **Independent Scale-Out** – Scale storage performance and capacity independently from compute
- **Data Efficiency** – In-line deduplication, compression and thin provisioning increase storage efficiency by 5 – 10x
- **Storage Capacity** – From 11.5 TB - 1.8 PB raw capacity (50 TB - 5 PB+ usable with data reduction)
- **Clustering** – Compute scales to 64 nodes per cluster, storage nodes scales from 4 – 40 nodes
- **Quality of Service** – Integrated QoS provides ability to control I/O to isolate applications
- **Data Resiliency** – Dual redundant copies of data distributed to all nodes, automated drive rebuilds
- **Data Protection** – Native snapshot-based backup and restore functionality to object storage via S3 or SWIFT compatible API
- **DR & Replication** – Synchronous, asynchronous and snapshot replication locally and between remote clusters
- **Availability** – Automated failover and failback available between a cluster and up to four other clusters
- **Data Security** – Encryption with 256-bit AES for environments requiring data at rest protection
- **Connectivity** – Storage connectivity via iSCSI, Fibre Channel, VVOL's, and container native storage via NetApp Trident
- **Deployments** – Public and private cloud deployments enterprise environments
- **Integration** – VMware vCenter, VAAI, VVOLs, SRM/SRA, Microsoft VSS Provider, PowerShell - Integrated with OpenStack, Containers and NKS via Trident framework

Recommended Deployments

NetApp HCI is designed for private cloud and multi-tenant environments supporting a wide range of applications including general purpose VMs, VDI, Oracle, SQL Server, and NoSQL databases on VMware with support for RedHat OpenShift Container platform. The inherent capabilities of NetApp HCI provide data resiliency and protection, along with disaster recovery and other high availability features. To minimize application impact on shared resources, the system provides quality of service features for fine-grained control of performance.

For container deployments, NetApp Trident provides native container storage connectivity and integrates with the NetApp Kubernetes Service (NKS) to extend on-premises NetApp HCI to a multi-cloud component. NetApp NKS on HCI provides a single point of management with a common framework for managing and deploying applications.

Evaluation Summary

The NetApp HCI system utilizes a disaggregated architecture to enable independently scaling storage and compute capabilities in an integrated HCI appliance. According to Evaluator Group's continuing survey of enterprise use of hyperconverged systems, many value HCI systems' ability to be deployed more rapidly than traditional equipment, along with the ability to reduce complexity. However, some IT users express concerns regarding the ability to scale HCI performance and inflexibility of some HCI systems.

The NetApp HCI provides the benefits of a hyperconverged architecture, with increased scale and flexibility features of converged infrastructure, by enabling independent scaling of both storage and computing capabilities. Additionally, the system can be extended to leverage NetApp Data Fabric services, such as ONTAP Select for HCI, to add file and the full set of ONTAP data services to NetApp HCI. For disaster recovery, NetApp HCI may use SnapMirror replication to a NetApp ONTAP system.

With ability to scale capacity and storage performance, the NetApp HCI systems offers a greater degree of flexibility than many competing HCI systems. Additionally, the disaggregated architecture also allows a greater degree of isolation between storage and application demands, which was demonstrated by both the QoS capabilities and the sustained operations during a storage node outage. Many competing HCI solutions require over-provisioning resources, such as using fully redundant clusters, in order to provide continued performance during a node failure. NetApp HCI's QoS feature allows the system to operate at *higher utilization*, while still ensuring less important applications do not impact more critical ones.

Moreover, NetApp HCI provides a highly efficient HCI solution that delivers proven VM application and VDI performance levels that surpass comparable alternatives and does so at better price / performance levels.

Appendix A -Configuration Details

Provided below are the specific components and configuration details of the test environment.

Compute Nodes:

- H410C compute node: 2 socket, 20 cores at 2.1 Ghz (total 40 cores)
- 768 GB Memory 24 @ 32 GB DRAM
- 2 x 10 GbE connectivity

Storage Nodes:

- H410S-31110 storage node: 5 nodes, each with 6 @ 480 GB SSD drives per node (30 drives total)
- Total of 48 TB of usable capacity available (without data reduction)

Hypervisor:

- VMware ESXi 6.5 hypervisor and VMware vCenter 6.5 management

Other Infrastructure:

- 2 x Mellanox SN2010 (redundant ethernet switches

Benchmark Workloads

- IOmark-VM (a storage benchmark with a mixture of 8 different virtualized applications)
- IOmark-VDI (a storage benchmark for virtual desktop VMs, each running multiple applications)

Appendix B - NetApp HCI Test Details

The NetApp HCI user interface is shown below in Figure 2.

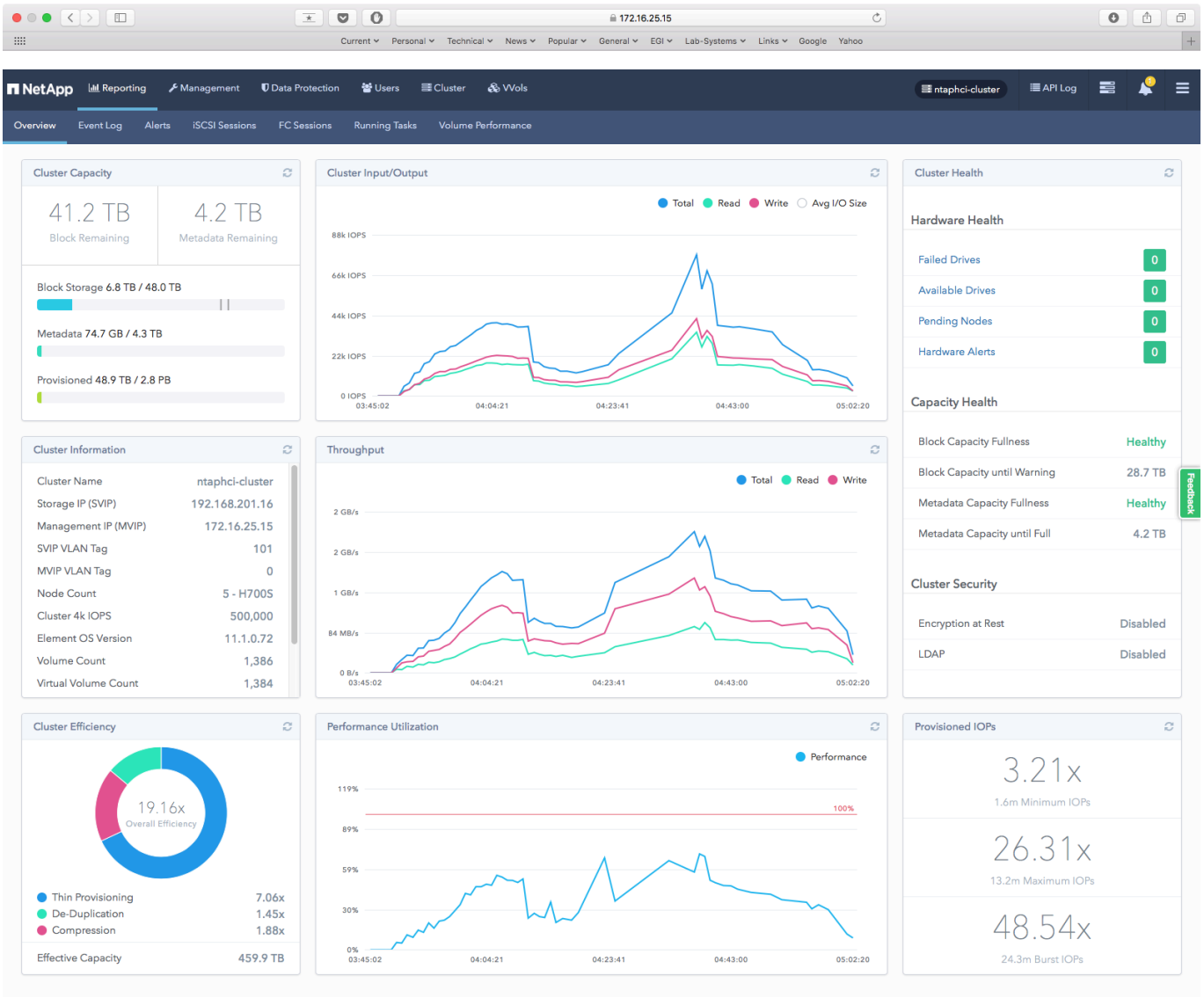

Figure 2: NetApp HCI UI (standalone UI, vCenter plugin view is similar)

HCI Storage Node Reboot Testing

Shown below is a view from vCenter for each of the compute nodes, during the storage node reboot test. There was a momentary spike in latency when the node rebooted up to approximately 1,000 ms. lasting for about 30 seconds. After approximately 10 minutes, the node is back online and again there is a momentary increase in latency during rebalancing before returning to normal.

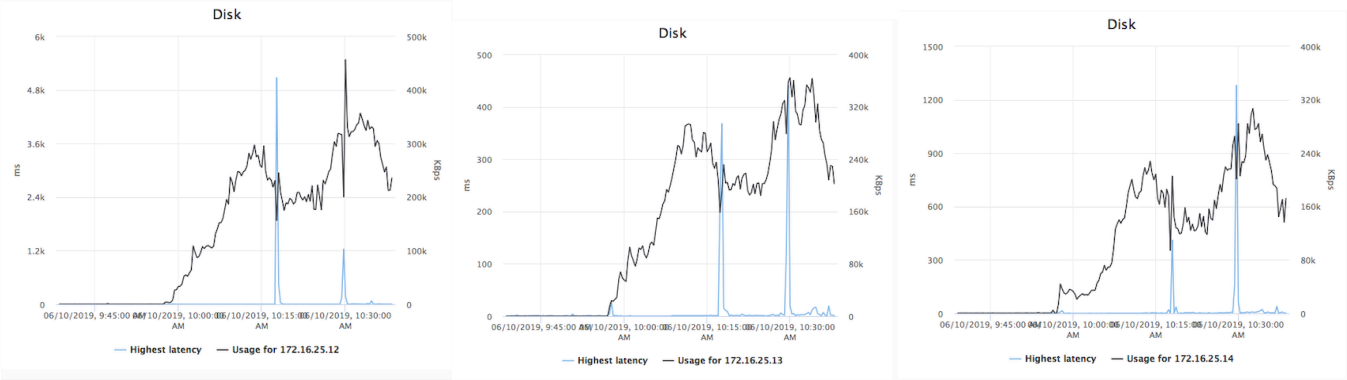

Figure 3: Storage I/O and Latency during node reboot (vCenter per host view)

NetApp HCI Pricing*:

Item	Description	Price
NetApp HCI compute	NetApp compute nodes, ea.	$ 15,000.00
NetApp HCI storage	NetApp storage nodes, ea.	$ 77,000.00
Total	Configuration dependent	$ N/A

***Note**: The stated prices were provided as representative pricing as of June 2019. Pricing may change and listed systems and prices may no longer be available. NetApp HCI pricing provided by NetApp Inc.*

About Evaluator Group

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