Abstract

Hyper converged infrastructure (HCI) has promised the industry simplicity of deployment, ease of operation, and scale. However, the inherent design of most modern HCI systems limits their ability to deliver on one or more of these promises.

This white paper describes how NetApp® HCI brings simplicity of configuration, efficiency of operation, and elasticity of scale together in a single product.
Table 6) Yahoo! Cloud Serving Benchmark (YCSB) client-server VM. .........................................................31
Table 7) SQL VMs. ........................................................................................................................................31
Table 8) VDI VMs. ........................................................................................................................................31

LIST OF FIGURES
Figure 1) Minimum configuration.  ..................................................................................................................6
Figure 2) NetApp HCI with H610S storage nodes. ...........................................................................................8
Figure 3) HCI components. ..............................................................................................................................8
Figure 4) Compute node ports. ........................................................................................................................10
Figure 5) Six-cable compute option ..................................................................................................................10
Figure 6) Two-cable compute option. ...............................................................................................................11
Figure 7) ZeroConf. ........................................................................................................................................11
Figure 8) HCI protection domains ...................................................................................................................12
Figure 9) NetApp vCenter Plug-in for HCI .......................................................................................................13
Figure 10) NMA options.................................................................................................................................14
Figure 11) NetApp Monitoring Agent .............................................................................................................15
Figure 12) Active IQ capacity forecasting. ......................................................................................................15
Figure 13) Active IQ vCenter reporting. ..........................................................................................................16
Figure 14) Compute node physical to logical port map (VSS). ......................................................................18
Figure 15) VMkernel binding. ........................................................................................................................19
Figure 16) Management port groups configuration on VMware standard switches. ..................................19
Figure 17) vMotion and VM_Network configuration on VMware standard switches. ..............................20
Figure 18) iSCSI-A and iSCSI-B configuration on VMware standard switches. .........................................20
Figure 19) VDS uplink names .......................................................................................................................21
Figure 20) Compute node physical to logical port map (VDS). ....................................................................21
Figure 21) Management port groups configuration on VMware distributed switches. ..............................22
Figure 22) vMotion and VM_Network configuration on VMware distributed switches. ............................22
Figure 23) iSCSI-A configuration on VMware distributed switches ..............................................................23
Figure 24) iSCSI-B configuration on VMware distributed switches ..............................................................23
Figure 25) Compute node physical to logical port map (VDS 2 cable) ............................................................24
Figure 26) Example configuration for management, vMotion and user VM portgroups. ...............................25
Figure 27) Host IQN: iSCSI name. ................................................................................................................25
Figure 28) Volume Access Group. ................................................................................................................26
Figure 29) Default datastores. ........................................................................................................................27
Figure 30) Create datastore. ...........................................................................................................................27
Figure 31) Adding nodes to NetApp HCI. .........................................................................................................29
Figure 32) Mixed workloads. ..........................................................................................................................31
Figure 33) VDI boot storm with QoS disabled. ..............................................................................................32
Figure 34) VDI boot storm with QoS enabled. ...............................................................................................33
Figure 35) Data Fabric—ONTAP Select .................................................................35
Figure 36) ONTAP Select on HCI .................................................................35
Figure 37) SnapMirror .................................................................36
Figure 38) vRO workflows .................................................................37
Figure 39) vRealize Operations Manager plugin .................................................................38
Figure 40) External host access .................................................................39
Figure 41) HCI Collector interface .................................................................39
1 HCI and the Theory of Everything

NetApp® HCI is an enterprise-scale hybrid cloud solution that is ideally suited for customers who are looking to break free from first-generation HCI limitations.

NetApp HCI customers can run multiple applications with guaranteed performance to confidently deploy resources across their entire data center. This architecture allows you to deploy your infrastructure by simplifying management and independently scaling both compute and storage resources. NetApp HCI is Data Fabric ready out of the box for easy access to all your data across any public, private, or hybrid cloud. By moving to NetApp HCI, you can transform your data center, driving operational efficiencies and reducing costs.

The NetApp Data Fabric is a software-defined approach for data management that enables you to connect disparate data management and storage resources. NetApp HCI can streamline data management between on-premises and cloud storage for enhanced data portability, visibility, and protection.

1.1 Performance Guarantee

A common challenge for a data center is delivering predictable performance, a goal complicated by running multiple applications that share the same infrastructure. An application that interferes with other applications creates performance degradations, which forces IT administrators to spend valuable time troubleshooting the environment. Mainstream applications, such as virtual desktop infrastructure (VDI) and database applications, have unique I/O patterns that can affect one another’s performance during normal operations when they are deployed in a shared environment.

The NetApp HCI quality of service (QoS) feature enables fine-grained control of performance for every application, eliminating noisy neighbors, meeting unique performance needs, allowing higher utilization of infrastructure, and satisfying performance SLAs. The storage architecture, which is part of the NetApp HCI solution, eliminates performance variance in the context of data locality because the data is distributed across all the nodes in the HCI cluster.

1.2 Enterprise Scale

Unlike previous generations of HCI, which have fixed resource ratios, NetApp HCI scales compute and storage resources independently. Independent scaling avoids costly and inefficient overprovisioning and simplifies capacity and performance planning. NetApp HCI is an enterprise-scale hybrid cloud infrastructure solution that runs on innovative NetApp SolidFire® Element® technology and is delivered on an architecture designed by NetApp. NetApp HCI comes in 2RU x 4-node building blocks (chassis) in small, medium, and large storage and compute configurations that can be mixed and matched. HCI can be scaled so that you can rapidly meet changing business needs on your terms.

1.3 Streamline Operations

A common goal of IT organizations is to automate all routine tasks and eliminate the risk of user errors associated with manual operations. Automation allows you to focus valuable resources on higher value priorities that drive business efficiencies. The NetApp Deployment Engine (NDE) streamlines day zero installation from hours to minutes. Centralized management through the vCenter Plug-In gives you full control over your infrastructure with an intuitive UI. A robust suite of APIs allows you to seamlessly integrate higher-level management, orchestration, backup, and disaster-recovery tools.
1.4 Configuration

NetApp HCI is available with a range of configuration options for both compute and storage. A minimum starting configuration must have four storage nodes and two compute nodes (Figure 1).

Figure 1) Minimum configuration.

As shown in the configuration information in Table 1, each storage node can deploy 4.5TB to 78TB of effective capacity. From a compute-node perspective, 16 to 36 CPU cores and 384GB to 768GB of RAM are available, as shown in Table 2.

Table 1) NetApp HCI storage nodes.

<table>
<thead>
<tr>
<th>Model</th>
<th>Form Factor</th>
<th>Performance (4K IOPS)</th>
<th>Drive Size (GB)</th>
<th>Raw Block Capacity (TB)</th>
<th>Usable Capacity (TB)</th>
<th>Effective Capacity (TB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H300S</td>
<td>1RU, half width</td>
<td>50K</td>
<td>480</td>
<td>2.4</td>
<td>1.1</td>
<td>4.5</td>
</tr>
<tr>
<td>H500S</td>
<td>1RU, half width</td>
<td>50K</td>
<td>960</td>
<td>4.8</td>
<td>2.2</td>
<td>8.9</td>
</tr>
<tr>
<td>H700S</td>
<td>1RU, half width</td>
<td>100K</td>
<td>1920</td>
<td>9.6</td>
<td>4.5</td>
<td>17.9</td>
</tr>
<tr>
<td>H610S-1</td>
<td>1RU, full width</td>
<td>100K</td>
<td>960</td>
<td>10.6</td>
<td>4.9</td>
<td>19.6</td>
</tr>
<tr>
<td>H610S-2</td>
<td>1RU, full width</td>
<td>100K</td>
<td>1920</td>
<td>21.1</td>
<td>9.8</td>
<td>39.3</td>
</tr>
<tr>
<td>H610S-4</td>
<td>1RU, full width</td>
<td>100K</td>
<td>3840</td>
<td>42.2</td>
<td>19.6</td>
<td>78.6</td>
</tr>
</tbody>
</table>

Table 2) NetApp HCI compute nodes.

<table>
<thead>
<tr>
<th>Target Use Case</th>
<th>Model</th>
<th>RAM</th>
<th>Per-Node CPU Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Model</td>
</tr>
<tr>
<td>Virtualization</td>
<td>H300E</td>
<td>384GB</td>
<td>E5-2620v4</td>
</tr>
<tr>
<td>Virtualization</td>
<td>H500E</td>
<td>512GB</td>
<td>E5-2650v4</td>
</tr>
<tr>
<td>Target Use Case</td>
<td>Model</td>
<td>RAM</td>
<td>Model</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------</td>
<td>------</td>
<td>---------</td>
</tr>
<tr>
<td>Virtualization</td>
<td>H600E</td>
<td>768GB</td>
<td>E5-2695</td>
</tr>
<tr>
<td>VDI</td>
<td>H410C-14020</td>
<td>384GB</td>
<td>4110</td>
</tr>
<tr>
<td>VDI</td>
<td>H410C-15020</td>
<td>512GB</td>
<td>4110</td>
</tr>
<tr>
<td>VDI</td>
<td>H410C-17020</td>
<td>768GB</td>
<td>4110</td>
</tr>
<tr>
<td>VDI/Virtualization</td>
<td>H410C-25020</td>
<td>512GB</td>
<td>5120</td>
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<tr>
<td>VDI/Virtualization</td>
<td>H410C-27020</td>
<td>768GB</td>
<td>5120</td>
</tr>
<tr>
<td>VDI/Virtualization</td>
<td>H410C-28020</td>
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<td>Virtualization</td>
<td>H410C-57020</td>
<td>768GB</td>
<td>6138</td>
</tr>
<tr>
<td>Virtualization</td>
<td>H410C-58020</td>
<td>1TB</td>
<td>6138</td>
</tr>
<tr>
<td>Database</td>
<td>H410C-35020</td>
<td>512GB</td>
<td>5122</td>
</tr>
<tr>
<td>Database</td>
<td>H410C-37020</td>
<td>768GB</td>
<td>5122</td>
</tr>
</tbody>
</table>

For example, for a minimum-size starting solution, a configuration with two small compute nodes and four small storage nodes could have 32 cores with 768GB of memory and 18TB of effective capacity. As requirements change, you can add more compute or storage nodes of any size to the chassis independently of each other. The flexibility to add only compute or storage nodes provides unique scalability options for building an efficient and agile cloud in your data center for various use cases.

**H410C Series**

The NetApp HCI 1.4 release brings support for the H410C series of compute nodes. These nodes are based on the Skylake Scalable Processor family and offer a broad range of CPU and memory configurations to support a wide range of virtualization workloads.

**H610S Series**

The 1.4 release of NetApp HCI adds support for the H610S series nodes, which offer greater capacity and are more cost effective than other HCI storage-node types. The top line benefits of the new H610S nodes are as follows:

- More than four times the density of existing HCI storage nodes
- NVMe SSDs and 25GbE
- Compatible with existing HCI and SolidFire clusters
2 System Design and Architecture

2.1 Overview

Although NetApp HCI is a new product, it is built from best-in-class components available from VMware and NetApp SolidFire. The hypervisor layer is provided by vSphere 6.x, which is the premier virtualization provider in the market. The storage layer is provided by SolidFire Element version 10, which offers a robust and unique scale-out model for NetApp HCI. The management layer is provided by a vCenter Plug-In.

The NDE orchestrates the initial deployment and configuration of the HCI components. The NDE is responsible for collecting all user inputs that are required to completely install and configure the system. The NDE reduces the number of required user inputs from more than 400 to fewer than 40.

The following sections describe in detail the networking, virtualization, and storage pieces of the NetApp HCI solution.
2.2 Networking

During deployment of a NetApp HCI system, the NDE installs and configures multiple components. Therefore, it requires a properly configured and well-functioning network. In general, the network must support the following configuration:

- MTU 9000 on all 10/25GbE ports
- Separate VLANs for management, vMotion, and iSCSI (single VLAN deployments are not supported)
- All host ports should have a spanning tree configured to immediately enter a forwarding state (PortFast)

Table 3 describes the basic requirements for the networks ports of each node type.

Table 3) Node interface requirements.

<table>
<thead>
<tr>
<th>Node Type</th>
<th>Interface</th>
<th>Requirements</th>
</tr>
</thead>
</table>
| Storage node  | Bond1G - management ports A and B | Ping all other Bond1G devices  
Dedicated management VLAN  
Spanning tree edge port |
|               | Bond10G - iSCSI ports C and D | Ping all other Bond10G devices  
MTU set to 9000 (no fragmentation)  
Dedicated iSCSI VLAN  
Spanning tree edge port  
LACP (recommended but optional) |
| Compute node  | Bond1G - management ports A and B | Ping all other Bond1G devices  
Dedicated management VLAN  
No LACP  
Spanning tree edge port |
|               | Bond10G - iSCSI ports D and E | Ping all other Bond10G devices  
MTU set to 9000 (no fragmentation)  
Dedicated iSCSI VLAN  
No LACP  
Spanning tree edge port |
|               | VM_Network and vMotion ports C and F | MTU set to 9000 (no fragmentation)  
vMotion and VM_Network VLANs  
No LACP  
Spanning tree edge port |

Flexible Cabling for Compute Nodes

NetApp HCI 1.4 and later supports the FlexCable feature, which provides the option of configuring the NetApp HCI compute nodes with either two or six cables. When you are deploying a node with two cables, only ports D and E are configured by NDE. All traffic types are present on these two ports (management, vMotion, iSCSI, and VM traffic). VLANs are used to separate traffic types in this case.
This capability permits three possible deployment scenarios when running NDE:

- Connect and deploy with six cables (ports A through F)
- Connect six cables, deploy with two cables (ports D and E)
- Connect and deploy with two cables (ports D and E)

**Note:** Storage nodes require four cables to be connected and configured during deployment.

**Connect and Deploy with Six Cables**

Choose this option to get the optimum performance from your HCI deployment and the maximum number of options for separating out different traffic types.

This option requires the cabling of all network ports. The six-cable option provides dedicated ports for management (2 x 1/10GbE), virtual machines (2 x 10/25GbE), and storage (2 x 10/25GbE). VMware standard switches (VSS) are the default virtual switch type, with the vSphere distributed switch (VDS) being optional. To take advantage of the VDS option, you need a VMware Enterprise Plus license.

**Connect Six Cables, Select Two-Cable Configuration**

Choose this option when you want to leave ports A, B, C, and F unconfigured by NDE. This consolidates the NDE-managed port groups and traffic types to ports D and E. This scenario is beneficial for installations in which some network resources must be physically separated from the management and data plane of the core HCI infrastructure. Some possible use cases are a network DMZ and VMware NSX deployments. This option requires the use of a VDS.

**Note:** The VDS and VMware NSX require a VMware Enterprise Plus license.
Connect and Deploy with Two Cables

Choose this option when you must deploy with the smallest cable plant possible. Connecting and deploying with two cables is the least complicated network configuration because all NetApp HCI core infrastructure and customer network traffic share the two uplinks. This option requires the use of a VDS.

**Note:** The VDS requires a VMware Enterprise Plus license.

ZeroConf IP Assignment

NDE 1.3 and later includes the ZeroConf feature that autoconfigures a private nonroutable network on Bond10G interfaces. These private IPs are used to set up a temporary network for NDE to use for initial configuration. This eliminates the need to assign temporary routable IP addresses before starting the NDE.

ZeroConf requires the assignment of a single, temporary routable IP address to one of the storage nodes. This IP address is used to drive the NDE. During deployment, the permanent IP addresses are applied to all nodes in the system.

Figure 7) ZeroConf.
2.3 Storage Components

SolidFire Cluster

The first component to be configured during a system installation is the SolidFire storage cluster. The NDE uses the inputs for the desired user account, the management and storage IPs, and the nodes to include in the system to create and configure the SolidFire cluster.

After the cluster is created, the NDE adds all available drives to the cluster and then creates two 2TB volumes. These volumes are formatted with the Virtual Machine Filing System (VMFS) and receive the vCenter Server Appliance (VCSA) Open Virtual Application (OVA) and SolidFire mNode OVA when the NDE installs vSphere components. A volume access group is also created to hold the ESXi iSCSI qualified name (IQNs).

Protection Domains

Protection domains at the chassis level allow an HCI customer to scale their clusters in such a way that the failure of a chassis can be sustained even if there is more than one storage node in the chassis. The minimum allowed configuration is three chassis with two storage nodes each, for a six-node storage cluster. The system automatically lays out data correctly when the configuration is compatible with protection domains.

Protection domains provide the following benefits:

- Reduced risk of downtime due to a chassis failure
- Automatic detection of chassis and node configuration
- Self healing
- Domain-level capacity monitoring

Figure 8) HCI protection domains.
SolidFire mNode

The SolidFire management node (mNode) is one of the two virtual machines automatically deployed and configured on every NetApp HCI system during a new installation. The mNode enables the following features:

- NetApp HCI vCenter Plug-In
- NetApp Monitoring Agent (NMA)
- NetApp Active IQ® Collector
- SolidFire support reverse VPN tunnel
- System upgrades
- NetApp Kubernetes Service (NKS)

NetApp vCenter Plug-In for HCI

The NetApp vCenter Plug-In (VCP) is the management focal point for the HCI system. It brings day-to-day storage management tasks into vCenter and enables the NetApp Monitoring Agent.

Figure 9) NetApp vCenter Plug-In for HCI.

All common day-to-day storage management tasks are available in the VCP. The VCP has five sections related to SolidFire integration with vCenter:

- **Reporting.** Includes system overview, event logs, alerts, and running tasks on the SolidFire cluster.
• **Management.** Tasks for creating, deleting, and managing datastores and SolidFire volumes, accounts, access groups, and ESXi initiators. QoS policies can also be configured here.

• **Data protection.** Management of SolidFire replication, NetApp Snapshot™ copies, group Snapshot copies, and Snapshot copy schedules.

• **Cluster.** Tasks for adding and removing SolidFire nodes and disks to and from the cluster as well as managing virtual iSCSI networks.

• **VMware Virtual Volumes (VVols).** Reporting and management of VVols, storage containers, and protocol endpoints. The VVol feature is not enabled by default. For information about enabling and configuring VVols, see TR-4642: NetApp SolidFire VMware vSphere Virtual Volumes for SolidFire Storage Configuration Guide.

**NetApp Monitoring Agent**

The NetApp Monitoring Agent (NMA) is a component of the VCP that consolidates the events from the compute and storage components into a single view that can easily be consumed in vCenter. NMA features can be enabled or disabled from the SolidFire management node (mNode) interface.

![NMA options](image)

The NMA includes the following options:

• **Run alert monitor tests.** Tests the functionality of the NMA agent.

• **Collect alerts.** Toggles the collection of all alerts. Must be turned on to enable any of the alert collection options. Enabled by default.

• **Collect best practice alerts.** Enables reporting of best practice alerts from the SolidFire cluster to vCenter. This reporting includes network misconfigurations and other issues that indicate a suboptimal configuration. Disabled by default.

• **Send support data to Active IQ.** Sends vCenter alarms to Active IQ. Required for SolidFire to proactively engage support issues. Enabled by default.
• **Send compute node data to Active IQ.** Sends vCenter telemetry data and logs to Active IQ. This option enables Active IQ to collect support bundles and provide reporting specific to vCenter in Active IQ. Enabled by default.

Figure 11) NetApp Monitoring Agent.

For more information about using the VCP, see the vCenter Plug-In User Guide available under NetApp HCI Resources.

**Active IQ**

Active IQ is a comprehensive reporting platform for NetApp HCI and SolidFire systems that enables near–real time and historical reporting of configuration, alerting, and performance data.

Figure 12) Active IQ capacity forecasting.
With the NDE 1.6 release, Active IQ also now supports QoS recommendations based on historical data that are updated every day.

Figure 14) Active IQ QoS recommendations.

Quality of Service Recommendations

CLUSTER CAPACITY

Adding capacity to this cluster is recommended. Across all volumes, this cluster is operating at least 20% above maximum IOPS settings 94% of the time. Generally, this is an indicator that the workload on your cluster is too large for its capacity.

MINIMUM IOPS SETTING DISPARITY

The minimum IOPS settings for the volumes across your cluster are outside of the recommended range more than 25% of the time. This can lead to performance and load balancing issues.

MAXIMUM IOPS SETTING

Increase Recommended
Decrease Recommended

There are currently 14 volumes that spend at least 20% of their operating time at 80% to 100% of their max IOPS and are throttled 50% or more of the time.

VOLUME | Current Setting | Average Demand | Time Above Current Setting
--- | --- | --- | ---
Volume 11 | 150,000 | 210,203 | 89.2%
Volume 13 | 150,000 | 199,825 | 86.4%
Volume 14 | 150,000 | 187,252 | 79.2%
Volume 18 | 150,000 | 203,436 | 89.2%
Volume 20 | 120,000 | 182,826 | 89.2%

MINIMUM IOPS SETTING

Increase Recommended
Decrease Recommended

There are currently 9 volumes that spend at least 90% of their operating time 60% or more above their minimum IOPS setting.

VOLUME | Current Setting | Time Above Current Setting
--- | --- | ---
Volume 1 | 150,000 | 89.2%
Volume 4 | 150,000 | 86.4%
Volume 6 | 150,000 | 79.2%
Volume 2 | 150,000 | 89.2%
Volume 9 | 120,000 | 89.2%

More information about using Active IQ is available online at Active IQ Help.
2.4 vSphere Components

The NDE completely automates the installation and configuration of vSphere components and prepares the system according to established best practices.

**Note:** These versions do not contain the required patches for Spectre and Meltdown. For more information, see this [VMware KB article](#).

Table 4) vSphere components.

<table>
<thead>
<tr>
<th>Component</th>
<th>Automation Tasks</th>
</tr>
</thead>
</table>
| ESXi      | 1. Install ESXi 6.0 U3a, ESXi 6.5 U2, or ESXi 6.7 U1.  
2. Create vSwitches and port groups.  
3. Enable the software iSCSI adapter.  
4. Configure VMkernel ports for vMotion and iSCSI.  
5. Configure VMkernel port binding for iSCSI.  
6. Add a dynamic discovery address for the SolidFire storage virtual IP (SVIP) address.  
7. Add an ESXi iSCSI IQN to the SolidFire volume access group.  
8. Provision two VMFS datastores for vCenter and the SolidFire mNode. |
| vCenter   | 1. Deploy vCenter VCSA 6.5.0-9451637 or 6.7.0-10244745.  
2. Create default data center and cluster objects.  
3. Enable and configure the Distributed Resource Scheduler (DRS) and high availability (HA).  
4. Install and register the vCenter HCI Plug-In.  
5. Register the SolidFire system with the vCenter Plug-In.  

The NDE can be deployed with either VDS or VMware standard switches (VSS). VSS deployments require a six-cable configuration. For two-cable configurations, a VDS is required.

**Note:** If the NKS is deployed, then a VDS must be used. VSS installs are not supported by NKS.
Compute Node Physical-to-Logical Port Map (VSS – Six Cable)

Note: This deployment model is not compatible with the NKS.

Deployments based on VSS have a set of three logical switches configured:

- vSwitch0: management VMs and ESXi management interfaces
- vSwitch1: vMotion and customer VM network traffic
- vSwitch2: iSCSI interfaces

Figure 15) Compute node physical-to-logical port map (VSS).

For NetApp HCI compute nodes, the 1GbE interfaces eth2 and eth3 are bound to vSwitch0. These interfaces are used for VMware ESXi management traffic and the VCSA, mNode, and ONTAP Select management interfaces. NetApp recommends that the management VLAN be native on these interfaces.

10GbE interfaces eth5 and eth0 are assigned to vmnic0 and vmnic4, respectively, and bound to vSwitch1. The port groups for vMotion and VM_Network are assigned so that each port group has one active adapter and one standby adapter.

10GbE interfaces eth1 and eth4 are assigned to vmnic1 and vmnic5, respectively. These ports are configured for VMkernel port binding exclusively for storage connectivity and are configured in a manner to support it.
Any additional customer VMs or iSCSI clients that require direct access to iSCSI storage hosted on the storage nodes should have their network ports mapped to this vSwitch through an additional VM port group.

Figures 16, 17, and 18 show the NetApp HCI compute node virtual switch configuration when using VMware standard switches.

Figure 16) VMkernel binding.

![VMkernel binding table]

Figure 17) Management port groups configuration on VMware standard switches.

![Management port groups diagram]
Figure 18) vMotion and VM_Network configuration on VMware standard switches.

Standard switch: vSwitch1 (VM_Network)

Figure 19) iSCSI-A and iSCSI-B configuration on VMware standard switches.

Standard switch: vSwitch2 (iSCSI-A)
Compute Node Physical-to-Logical Port Map (VDS Six-Cable)

In VDS-based deployments, a single vSphere distributed switch is configured that contains all available host uplinks. The uplinks are named according to their role in the port groups configured on the VDS.

Figure 20) VDS uplink names.

Edit Uplink Names

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1:</td>
<td>NetApp_HCI_Virtualization_vnic0</td>
</tr>
<tr>
<td>2:</td>
<td>NetApp_HCI_Mgmt_vnic3</td>
</tr>
<tr>
<td>3:</td>
<td>NetApp_HCI_Virtualization_vnic4</td>
</tr>
<tr>
<td>4:</td>
<td>NetApp_HCI_Storage_vnic5</td>
</tr>
<tr>
<td>5:</td>
<td>NetApp_HCI_Storage_vnic1</td>
</tr>
<tr>
<td>6:</td>
<td>NetApp_HCI_Mgmt_vnic2</td>
</tr>
</tbody>
</table>

Figure 21) Compute node physical-to-logical port map (VDS).

<table>
<thead>
<tr>
<th>Port</th>
<th>A</th>
<th>B</th>
<th>F</th>
<th>C</th>
<th>D</th>
<th>E</th>
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<tr>
<td>Interface</td>
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<td>vSwitch</td>
<td>NetApp HCI VDS</td>
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<tr>
<td>Portgroup</td>
<td>HCl_Internal_vCenter_Network</td>
<td>HCl_Internal_mNode_Network</td>
<td>HCl_Internal_QTS_Network Management Network</td>
<td>vMotion VM_Network</td>
<td>iSCSI-A</td>
<td>iSCSI-B</td>
</tr>
<tr>
<td>VLAN</td>
<td>Management VLANs</td>
<td>User VMs/vMotion</td>
<td>iSCSI VLAN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>vmkernel</td>
<td>vmk0</td>
<td>vmk3</td>
<td>vmk1</td>
<td>vmk2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
For NetApp HCI compute nodes, the 1GbE interfaces eth2 and eth3 are bound to uplinks NetApp_HCI_Mgmt_vmnic2 and NetApp_HCI_Mgmt_vmnic3. These interfaces are used for VMware ESXi management traffic and the VCSA, mNode, and ONTAP Select management interfaces. The management VLAN should be native on these interfaces.

10GbE interfaces eth5 and eth0 are bound to uplinks NetApp_HCI_Virtualization_vmnic0 and NetApp_HCI_Virtualization_vmnic4 and back port groups for vMotion and VM_Network.

10GbE interfaces eth1 and eth4 are assigned to NetApp_HCI_Storage_vmnic5 and NetApp_HCI_Storage_vmnic1 respectively. These ports are configured for VMkernel port binding exclusively for storage connectivity and are configured in a manner to support it.

The following figures show the NetApp HCI compute node virtual switch configuration when using VMware distributed switches.

**Figure 22** Management port groups configuration on VMware distributed switches.

**Figure 23** vMotion and VM_Network configuration on VMware distributed switches.
Figure 24) iSCSI-A configuration on VMware distributed switches.

Figure 25) iSCSI-B configuration on VMware distributed switches.

Compute Node Physical-to-Logical Port Map (VDS Two-Cable)

In VDS-based deployments using a two-cable configuration, a single vSphere distributed switch is configured that contains the NetApp_HCI_Storage_vnic1 and NetApp_HCI_Storage_vnic5 uplinks. All management and data plane traffic for core infrastructure deployed by NDE traverses only these two uplinks.
There are three primary benefits to this arrangement:

- A reduction in cables for compute nodes from six to two
- Dedicated interfaces for customer workloads such as a DMZ or for software-defined networking solutions like VMware NSX
- Streamlined network configuration

All port groups except those in use for iSCSI are active/active across both uplinks. iSCSI port groups are configured with a single active uplink with the default load-balancing policy. iSCSI VMkernel port binding is also configured.
iSCSI Configuration

During the installation of ESXi, the software iSCSI IQN is extracted and automatically added to a default volume access group on the SolidFire cluster to provide access to storage. Any additional volumes created after the system configuration that are added to this default access group are visible to the ESXi hosts.

Additional ESXi hosts that are added to the HCI system should be added to the default access group NetApp–HCI to facilitate access to the existing storage volumes in use by the vCenter hosts. This process can be performed by editing the access group located under NetApp SolidFire Management > Management > Access Groups in the VCP.
ESXi servers deployed by NDE have a custom storage array type plug-in (SATP) rule created for SolidFire devices. The actual rule is created with the following command:

```
esxcli storage nmp satp rule add -s VMW_SATP_DEFAULT_AA -P VMW_PSP_RR -O iops="10" -V "SolidFire" -M "SSD SAN" -e "SolidFire custom SATP rule"
```

This rule performs the following tasks:

- Claims any volumes that match a vendor name of SolidFire and model of SSD SAN
- Sets the SATP to VMW_SATP_DEFAULT_AA
- Sets the path selection plug-in (PSP) to VMW_PSP_RR
- Sets the I/O Operations Limit (IOPS) to 10

This configuration creates better multipathing performance under higher queue depth situations. Any new SolidFire volumes created have this rule applied automatically. There is no need to reapply the rule.

**Datastores**

NDE configures two datastores that are automatically mapped to all ESXi hosts. The vCenter VCSA and mNode are both deployed to the NetApp-HCI-Datastore-01 datastore. The NetApp-HCI-Datastore-02 datastore is available for customer VMs. A local datastore is created from the leftover capacity on each ESXi host’s boot device. These datastores are on local devices and are not protected by any form of RAID, so NetApp does not recommend using them for storing customer production VMs.
More datastores should be created as needed when additional VMs are deployed on the system. You should create a datastore when either of the two following conditions is true:

- There are more than 50 VMs per existing datastore.
- The total IOPS required in an existing datastore is greater than 15,000.

Additional datastores can be created through the VCP by navigating to NetApp SolidFire Management > Management > Datastores > Create Datastore.

DRS and HA

Both DRS and HA are enabled with the VMware default configuration. NetApp supports customers changing the default DRS and HA rules to meet their specific requirements. Full information about configuring HA and DRS can be found at VMware Docs:

- Creating and Using vSphere HA Clusters
- Creating a DRS Cluster

vSphere Licensing

NetApp HCI comes with a 60-day, fully featured evaluation licenses for vCenter and ESXi. The customer can license the vSphere environment with any valid vSphere license. Depending on the license version applied, some automatically configured features, such as DRS or VDS, might not be available and must be unconfigured.

For more information about which features are available for each license level, see the VMware vSphere with Operations Management and VMware vSphere paper available on the VMware website.

3 Expanding NetApp HCI

The lack of ability to scale has been a consistent frustration with HCI. Nearly all early entrants into the HCI market had good solutions for point applications in which the footprint and number of workloads on the system were small. However, scaling these systems to larger configurations or mixing workloads was typically impractical for several reasons:

- **Reliance on homogenous workloads.** Early HCI systems worked well if the ratios of consumption for CPU, RAM, and storage were well understood and relatively constant. However, heterogeneous workloads could easily cause system hot spots.
- **Cost to scale the systems.** HCI systems used a core-sharing model in which compute and storage were included in each node. This approach led to extraneous costs when scaling one vector (CPU, RAM, or storage) was impossible or impractical.
- **System overhead from a controller VM on every node.** Sometimes this configuration led to the consumption of a significant amount of resources that were therefore not available for customer workloads.
- **Nonlinear performance due to reliance on data locality.**

NetApp HCI avoids these issues by employing the strength of the SolidFire scale-out architecture and by avoiding a core-sharing model:

- The combination of QoS and the SolidFire scale-out, node-based architecture enables true mixed workload capability. Every volume has a guaranteed performance level, which is further enhanced with VMware VVols.
- NetApp HCI does not use a core-sharing model. This approach enables the you to scale compute and storage resources separately, providing a finer-grained scaling model without extraneous costs.
- Compute nodes do not run a storage stack, so all hypervisor resources are available to run customer workloads.
- The SolidFire cluster dynamically spreads data over the entire cluster to eliminate hot spots.

3.1 Adding Nodes

The smallest configuration that can be deployed with NDE is two compute nodes and four storage nodes. The largest configuration is 64 compute nodes and 40 storage nodes. Usually, the installation time ranges from approximately 35 minutes for small configurations to approximately 1 hour for the largest configurations.
The expansion feature enables you to expand your NetApp HCI system by adding compute and/or storage nodes to the cluster up to the maximum configuration. You can use any combination of compute and storage nodes as long as basic requirements are met.

The workflow to expand a NetApp HCI system can be accessed by navigating to the management IP (MIP) for any of the storage nodes in the existing HCI system except for the cluster master.

**Note:** A list of cluster node MIPs can be found in the vCenter Plug-In under Cluster > Nodes.

**Adding Nodes**

Before adding new nodes to the cluster, the nodes must be loaded with the code version of the existing cluster and be on a network reachable from the existing cluster.

Figure 32) Adding nodes to NetApp HCI.

**Available Inventory**

Verify the available nodes and select at least one compute node or one storage node to add to your HCI installation.

**Compute Nodes**

<table>
<thead>
<tr>
<th>Serial Number</th>
<th>Chassis Serial Number / Slot</th>
<th>Node Type</th>
<th>Software Version</th>
<th>Physical CPU Cores</th>
<th>Memory</th>
<th>1 GbE Ports</th>
<th>10 GbE Ports</th>
</tr>
</thead>
<tbody>
<tr>
<td>2218010</td>
<td>/ C</td>
<td>H300E</td>
<td>1.4</td>
<td>8</td>
<td>384 GB</td>
<td>2 of 2 detected</td>
<td>2 of 4 detected</td>
</tr>
<tr>
<td>2218090</td>
<td>/ C</td>
<td>H300E</td>
<td>1.4</td>
<td>8</td>
<td>384 GB</td>
<td>2 of 2 detected</td>
<td>2 of 4 detected</td>
</tr>
<tr>
<td>0001740</td>
<td>/ D</td>
<td>H300E</td>
<td>1.4</td>
<td>8</td>
<td>384 GB</td>
<td>2 of 2 detected</td>
<td>4 of 4 detected</td>
</tr>
<tr>
<td>0001740</td>
<td>/ C</td>
<td>H300E</td>
<td>1.4</td>
<td>8</td>
<td>384 GB</td>
<td>2 of 2 detected</td>
<td>4 of 4 detected</td>
</tr>
</tbody>
</table>

2 compute nodes selected

**Storage Nodes**

<table>
<thead>
<tr>
<th>Serial Number</th>
<th>Chassis Serial Number / Slot</th>
<th>Node Type</th>
<th>Element Version</th>
<th>Drive Count</th>
<th>1 GbE Ports</th>
<th>10 GbE Ports</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001740</td>
<td>/ A</td>
<td>H300S</td>
<td>11.0.0.738</td>
<td>6 of 6 detected</td>
<td>2 of 2 detected</td>
<td>2 of 2 detected</td>
</tr>
<tr>
<td>0001740</td>
<td>/ B</td>
<td>H200S</td>
<td>11.0.0.728</td>
<td>6 of 6 detected</td>
<td>2 of 2 detected</td>
<td>2 of 2 detected</td>
</tr>
<tr>
<td>2217460</td>
<td>/ D</td>
<td>H300S</td>
<td>11.0.0.738</td>
<td>6 of 6 detected</td>
<td>2 of 2 detected</td>
<td>2 of 2 detected</td>
</tr>
<tr>
<td>2218020</td>
<td>/ C</td>
<td>H500S</td>
<td>11.0.0.738</td>
<td>6 of 6 detected</td>
<td>2 of 2 detected</td>
<td>2 of 2 detected</td>
</tr>
</tbody>
</table>

1 storage node selected

**Note:** When expanding a NetApp HCI system, the new nodes must have the same cable configuration as the cluster resource you are expanding.

The number of compute nodes can be expanded from the minimum configuration to a maximum of 64 nodes.
The number of storage nodes can be expanded from the minimum to a maximum of 40 nodes. Mixing storage node types is supported as long as a single node does not occupy more than one-third of the available capacity of the cluster.

For example, consider an initial system built with four H300S (small) storage nodes, each of which has a capacity of 2.4TB. The total cluster capacity is 9.6TB (2.4TB * 4). Suppose that you want to expand the cluster with H700S storage nodes with a capacity of 9.6TB per node.

**Example 1**
Adding a single H700S (large) storage node with a capacity of 9.6TB results in an invalid configuration.

4x H300S and 1x H700S:
- Total cluster capacity = (2.4TB * 4) + 9.6TB = 19.2TB
- H300S = 2.4TB = ~13% of cluster capacity per node
- H700S = 9.6TB = ~50% of cluster capacity per node (not valid)

**Example 2**
Adding two H700S nodes results in a valid configuration.

4x H300S and 2x H700S:
- Total cluster capacity = (2.4TB * 4) + (9.6TB * 2) = 28.8TB
- H300S = 2.4TB = ~8% of cluster capacity per node
- H700S = 9.6TB = ~33% of cluster capacity per node (valid configuration)

**VMware EVC and Mixed Node Types**
When expanding NetApp HCI compute resources using nodes with differing CPU models, you must configure VMware Enhanced vMotion Capability (EVC) to support the live migration of machines between nodes with different CPU families.

If you are adding a previous generation of nodes (H300E, 500E, or 700E) to a cluster composed of H410C nodes, you must enable EVC before attempting to expand the vSphere cluster. However, if you are adding H410C nodes to an existing Hx00E cluster, EVC is enabled automatically during the workflow to expand the vSphere cluster.

**4 Mixed Workloads**

One of the core strengths of the NetApp HCI platform is its ability to run true mixed workloads in production on the same system. Mixed workloads are enabled by the QoS and scale-out features of SolidFire systems.

An application that interferes with other applications creates performance degradation, causing IT administrators to spend valuable time troubleshooting the environment. Mainstream applications, such as VDI and database applications, have unique I/O patterns that can affect one another’s performance when deployed in a shared environment during normal operations. The NetApp HCI QoS feature allows fine-grained control of performance for every application, eliminating noisy neighbors, meeting unique performance needs, enabling higher utilization of infrastructure, and satisfying performance SLAs.

**4.1 Test Configuration**
As an example, a mixed workload test was conducted using Microsoft SQL Server, MongoDB, and VDI desktops running on a single HCI system.
Table 5, Table 6, Table 7, and Table 8 show the VMs configured for the application workloads.

**Table 5) Mongo replica set cluster VMs.**

<table>
<thead>
<tr>
<th>MongoDB Cluster</th>
<th>Qty</th>
<th>MongoDB Version</th>
<th>Type</th>
<th>Cores/vCPUs</th>
<th>RAM</th>
<th>OS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster 1</td>
<td>3</td>
<td>3.4</td>
<td>VMware</td>
<td>8</td>
<td>32GB</td>
<td>Red Hat Linux</td>
</tr>
<tr>
<td>Cluster 2</td>
<td>3</td>
<td>3.4</td>
<td>VMware</td>
<td>8</td>
<td>32GB</td>
<td>Red Hat Linux</td>
</tr>
</tbody>
</table>

**Table 6) Yahoo! Cloud Serving Benchmark (YCSB) client-server VM.**

<table>
<thead>
<tr>
<th>YCSB Client</th>
<th>Qty</th>
<th>YCSB Version</th>
<th>Type</th>
<th>Cores/vCPUs</th>
<th>RAM</th>
<th>OS</th>
</tr>
</thead>
<tbody>
<tr>
<td>YCSB</td>
<td>1</td>
<td>0.12.0</td>
<td>VMware</td>
<td>8</td>
<td>32GB</td>
<td>Red Hat Linux</td>
</tr>
</tbody>
</table>

**Table 7) SQL VMs.**

<table>
<thead>
<tr>
<th>SQL Cluster</th>
<th>Qty</th>
<th>Type</th>
<th>Cores/vCPUs</th>
<th>RAM</th>
<th>OS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hosts</td>
<td>5</td>
<td>VMware</td>
<td>8</td>
<td>16GB</td>
<td>Red Hat Linux</td>
</tr>
</tbody>
</table>

**Table 8) VDI VMs.**

<table>
<thead>
<tr>
<th>VM Type</th>
<th>Qty</th>
<th>Type</th>
<th>vCPUs</th>
<th>RAM</th>
<th>OS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtual desktops</td>
<td>400</td>
<td>VMware linked clones</td>
<td>2</td>
<td>4GB</td>
<td>Windows 10</td>
</tr>
</tbody>
</table>
4.2 Results

Results with QoS Disabled

The graph in Figure 34 shows the SQL Server and MongoDB workloads in steady state followed by a boot storm from the 400 VDI desktops.

Figure 34) VDI boot storm with QoS disabled.

![Graph showing mixed workloads without QoS type control](image)

The VDI boot storm significantly affected both the SQL and MongoDB workloads. This result exemplifies the performance characteristics of most traditional HCI solutions and shows why they are not typically used for mixed workloads at scale.
Results with QoS Enabled

The graph in Figure 35 shows the same workload, this time with QoS enabled.

Figure 35) VDI boot storm with QoS enabled.

The VDI boot storm had no impact on the SQL and MongoDB workloads on the system. This example shows the strength of the QoS capabilities of the platform. QoS controls enable true mixed workload applications for NetApp HCI.

For more detailed information about the mixed workload testing, see TR-4632: NetApp HCI QoS and Mixed Workloads.

5  Extending NetApp HCI

5.1  NetApp Kubernetes Service

The NetApp Kubernetes Service (NKS) has been extended to support on-premises NetApp HCI systems as a deployable cloud region. This enables NetApp HCI to act as a true hybrid multicloud component, and radically simplifies deployment, maintenance, and administration of a hybrid cloud environment.

The primary benefits of running NKS on NetApp HCI are as follows:

- A single point of control for hybrid cloud environments that span from hyperscalers to on-premises infrastructure
- A common framework for application development that is consistent between all cloud providers
- Freedom to move applications between on-premises to any cloud provider on demand
5.2 NetApp ONTAP Select

The SolidFire platform provides an enterprise-grade scalable architecture for NetApp HCI. However, SolidFire is a block-only solution. NetApp ONTAP Select 9.5 or later can be deployed as a customer-installed feature after system installation using the ONTAP Select Deploy appliance available from support.netapp.com.
For full information about configuring ONTAP Select for NetApp HCI systems, see TR-4669: HCI File Services Powered by ONTAP.

5.3 NetApp SnapMirror

The release of Element OS 10.1 and NetApp ONTAP 9.3 brought NetApp SnapMirror® support to NetApp HCI. SnapMirror relationships are managed through the Element UI at initial release.

Replication and restoration of volumes is a four-step process:

1. Replicate HCI volumes to a FAS system licensed for SnapMirror.
2. In a disaster recovery scenario, promote the FAS target volume to primary and run production.
3. After primary site recovery, resync the primary FAS volume back to HCI.
4. To resume production at the primary site, fail back the HCI volumes.
The FAS system chosen as the replication target must be licensed for SnapMirror. The HCI system requires no additional licenses.

The 1.4 release of NetApp HCI added the following enhancements:

- You can now create SnapMirror relationships with ONTAP Cloud instances hosted in public clouds. This enables disaster recovery to the cloud for NetApp HCI systems.
- ONTAP LUNs can now be replicated to HCI.
- The fan-in ratio increased to up to 32 HCI systems.
- SnapMirror to ONTAP Select is now supported.

For information about configuring SnapMirror for HCI systems, see TR-4641: NetApp HCI Data Protection.

5.4 vRealize Orchestrator Plug-In

The SolidFire vRealize Orchestrator Plug-In enables further automation of the NetApp HCI system. The plug-in and user guide are available at the NetApp SolidFire vRealize Orchestrator Plug-In page.

To further simplify the management of the NetApp HCI platform, NetApp has also provided a few example workflows for vRealize Orchestrator (vRO) that simplify repetitive storage-related tasks.
These workflows can be downloaded from this [source](#).

## 5.5 NetApp HCI and SolidFire vRealize Operations Management Pack

The Blue Medora management pack enhances VMware vRealize Operations (vROps) with at-a-glance KPI dashboards for navigating the entire environment to understand relationships and discover dependencies. This unique capability dramatically reduces mean time to recover (MTTR) and automates remediation. The Blue Medora out-of-the-box dashboards provide relational visibility into the following functions:

- NetApp HCI Cluster Overview
- NetApp HCI Health Investigation
- NetApp HCI Volume Overview
- NetApp HCI VVol Overview
The Blue Medora Plug-In is available here.

5.6 External Host Access

As a scale-out system, NetApp supports extending the storage resources of the HCI system to external hosts that are supported by the SolidFire platform. This approach allows additional consolidation of workloads onto the HCI platform.
The HCI Collector is an open-source project for graphing time series data from NetApp HCI and SolidFire systems. The HCI Collector solution uses Grafana for graphing performance data, Docker for containerizing the application stack, the Trident for Docker Plug-In for persistent storage of metrics and container state, and Graphite for storing the time-series data.
For information about deploying and using the HCI Collector, see TR-4694: Visualizing NetApp HCI Performance.

Conclusion

NetApp HCI is the embodiment of an API-driven, scale-out, multi-workload platform for the next-generation data center and hybrid multi-cloud environments. This combination enables several key capabilities, including the following:

- Making automation and orchestration first-class citizens in the data center
- Scaling the scarcest resources without overprovisioning the entire stack
- Driving true consolidation of workloads by pushing better system utilization
- Reducing go-forward capex and opex costs
- Integrating into the NetApp Data Fabric to leverage all NetApp products, increase data mobility, and reduce data silos

The solution yields significant efficiency and agility when deploying applications, helping the business to consolidate workloads with confidence.

Where to Find Additional Information

To learn more about the information described in this document, see the following documents and/or websites:

- NetApp HCI Documentation Resources
  http://mysupport.netapp.com/netapphci/resources

Version History

<table>
<thead>
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<th>Version</th>
<th>Date</th>
<th>Document Version History</th>
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</thead>
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<td>Version 1.0</td>
<td>October 2017</td>
<td>Initial release.</td>
</tr>
<tr>
<td>Version 1.1</td>
<td>December 2017</td>
<td>Updates for NetApp HCI v1.1</td>
</tr>
<tr>
<td>Version 1.2</td>
<td>March 2018</td>
<td>Updates for NetApp HCI v1.2</td>
</tr>
<tr>
<td>Version 1.3</td>
<td>June 2018</td>
<td>Updates for NetApp HCI v1.3</td>
</tr>
<tr>
<td>Version 1.4</td>
<td>November 2018</td>
<td>Updates for NetApp HCI v1.4</td>
</tr>
<tr>
<td>Version 1.6</td>
<td>July 2019</td>
<td>Updates for NetApp HCI v1.6 and NKS</td>
</tr>
</tbody>
</table>
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