Virtualization

NetApp Solutions

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NetApp Solutions for Virtualization

WP-7353: ONTAP tools for VMware vSphere - Product Security

Chance Bingen, Dan Tulledge, Jenn Schrie, NetApp

This document describes the techniques and technology used to secure ONTAP tools for VMware vSphere 9.X from both existing and emerging threats in product environments.

Secure development activities

Software engineering with NetApp ONTAP Tools for VMware vSphere employs the following secure development activities:

- **Threat modeling.** The purpose of threat modelling is to discover security flaws in a feature, component, or product early in the software development life cycle. A threat model is a structured representation of all the information that affects the security of an application. In essence, it is a view of the application and its environment through the lens of security.
- **Dynamic Application Security Testing (DAST).** This technology is designed to detect vulnerable conditions on applications in their running state. DAST tests the exposed HTTP and HTML interfaces of web-enable applications.
- **Third-party code currency.** As part of software development with open-source software (OSS), you must address security vulnerabilities that might be associated with any OSS incorporated into your product. This is a continuing effort because a new OSS version might have a newly discovered vulnerability reported at any time.
- **Vulnerability scanning.** The purpose of vulnerability scanning is to detect common and known security vulnerabilities in NetApp products before they are released to customers.
- **Penetration testing.** Penetration testing is the process of evaluating a system, web application, or network to find security vulnerabilities that could be exploited by an attacker. Penetration tests (pen tests) at NetApp are conducted by a group of approved and trusted third-party companies. Their testing scope includes the launching of attacks against an application or software similar to hostile intruders or hackers using sophisticated exploitation methods or tools.

Product security features

NetApp ONTAP tools for VMware vSphere includes the following security features in each release.

- **Login banner.** SSH is disabled by default and only allows one-time logins if enabled from the VM console. The following login banner is shown after the user enters a username in the login prompt:

  WARNING: Unauthorized access to this system is forbidden and will be prosecuted by law. By accessing this system, you agree that your actions may be monitored if unauthorized usage is suspected.

  After the user completes login through the SSH channel, the following text is displayed:

```
Linux vsc1 4.19.0-12-amd64 #1 SMP Debian 4.19.152-1 (2020-10-18) x86_64
The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.
Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
```

- **Role-based access control (RBAC).** Two kinds of RBAC controls are associated with ONTAP tools:
  - Native vCenter Server privileges
  - vCenter plug-in specific privileges. For details, see this link.
- **Encrypted communications channels.** All external communication happens over HTTPS using version 1.2 of TLS.
- **Minimal port exposure.** Only the necessary ports are open on the firewall.

  The following table describes the open port details.

TCP v4/v6 port #	Direction	Function
8143	inbound	HTTPS connections for REST API
8043	inbound	HTTPS connections
9060	inbound	HTTPS connections Used for SOAP over https connections This port must be opened to allow a client to connect to the ONTAP tools API server.
22	inbound	SSH (Disabled by default)
9080	inbound	HTTPS connections - VP and SRA - Internal connections from loopback only
9083	inbound	HTTPS connections - VP and SRA Used for SOAP over https connections
1162	inbound	VP SNMP trap packets
1527	internal only	Derby database port, only between this computer and itself, external connections not accepted — Internal connections only
443	bi-directional	Used for connections to ONTAP clusters

- **Support for certificate authority (CA) signed certificates.** ONTAP tools for VMware vSphere supports CA signed certificates. See this kb article for more information.
- **Audit logging.** Support bundles can be downloaded and are extremely detailed. ONTAP tools logs all user login and logout activity in a separate log file. VASA API calls are logged in a dedicated VASA audit log (local cxf.log).
- **Password policies.** The following password policies are followed:
  - Passwords are not logged in any log files.

- Passwords are not communicated in plain text.
- Passwords are configured during the installation process itself.
- Password history is a configurable parameter.
- Minimum password age is set to 24 hours.
- Auto complete for the password fields are disabled.
- ONTAP tools encrypts all stored credential information using SHA256 hashing.

VMware Virtualization for ONTAP

NetApp ONTAP Benefits for VMware vSphere Administrators

Introduction to ONTAP for vSphere Administrators

Why ONTAP for vSphere?

NetApp ONTAP simplifies storage and data management operations and distinctly complements VMware environments, whether deploying on-premises or to the cloud. NetApp best-in-class data protection, storage efficiency innovations, and outstanding performance in both SAN- and NAS-based VMware architectures are among the reasons why tens of thousands of customers have selected ONTAP as their storage solution for vSphere deployments.

NetApp provides numerous VMware plug-ins, validations, and qualifications of various VMware products to support customers facing the unique challenges of administering a virtualization environment. NetApp does for storage and data management what VMware does for virtualization, allowing customers to focus on their core competencies rather than managing physical storage. This nearly 20-year partnership between VMware and NetApp continues to evolve and add customer value as new technologies, such as VMware Cloud Foundation and Tanzu, emerge, while continuing to support the foundation of vSphere.

Key factors customers value include:

- **Unified storage**
- **Storage efficiency**
- **Virtual volumes and storage policy-based management**
- **Hybrid cloud**

For more information regarding supported NetApp and VMware solutions, see the following resources:

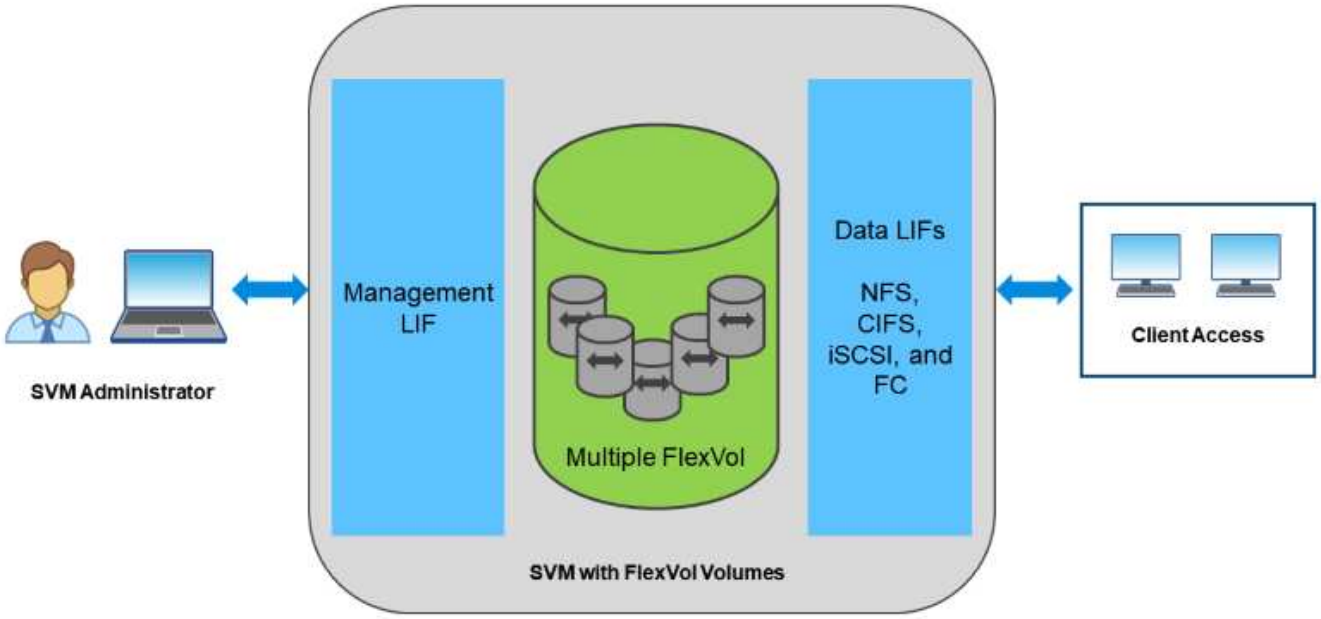
- The NetApp Interoperability Matrix Tool (IMT). The IMT defines the qualified components and versions you can use to build FC/FCoE, iSCSI, NFS and CIFS configurations.
- The VMware Compatibility Guide. The VMware Compatibility guide lists System, I/O, Storage/SAN and Backup compatibility with VMware Infrastructure and software products
- NetApp ONTAP Tools for VMware. ONTAP tools for VMware vSphere is a single vCenter Server plug-in that includes the VSC, VASA Provider, and Storage Replication Adapter (SRA) extensions.

ONTAP Unified Storage

About Unified Storage

Systems running ONTAP software are unified in several significant ways. Originally this approach referred to

supporting both NAS and SAN protocols on one storage system, and ONTAP continues to be a leading platform for SAN along with its original strength in NAS.
A storage virtual machine (SVM) is a logical construct allowing client access to systems running ONTAP software. SVMs can serve data concurrently through multiple data access protocols via logical interfaces (LIFs). SVMs provide file-level data access through NAS protocols, such as CIFS and NFS, and block-level data access through SAN protocols, such as iSCSI, FC/FCoE, and NVMe. SVMs can serve data to SAN and NAS clients independently at the same time.



In the vSphere world, this approach could also mean a unified system for virtual desktop infrastructure (VDI) together with virtual server infrastructure (VSI). Systems running ONTAP software are typically less expensive for VSI than traditional enterprise arrays and yet have advanced storage efficiency capabilities to handle VDI in the same system. ONTAP also unifies a variety of storage media, from SSDs to SATA, and can extend that easily into the cloud. There's no need to buy one flash array for performance, a SATA array for archives, and separate systems for the cloud. ONTAP ties them all together.

For more information on SVMs, unified storage and client access, see Storage Virtualization in the ONTAP 9 Documentation center.

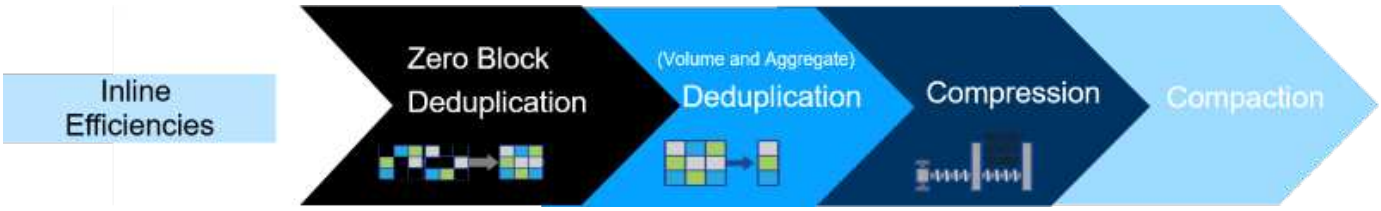
ONTAP storage efficiencies

About storage efficiencies

Although NetApp was the first to deliver deduplication for production workloads, this innovation wasn't the first or last one in this area. It started with ONTAP Snapshot copies, a space-efficient data protection mechanism with no performance effect, along with FlexClone technology to instantly make read/write copies of VMs for production and backup use. NetApp went on to deliver inline capabilities, including deduplication, compression, and zero-block deduplication, to squeeze out the most storage from expensive SSDs. Most recently, ONTAP added compaction to strengthen our storage efficiencies.

- **Inline zero-block deduplication.** Eliminates space wasted by all-zero blocks.

- **Inline compression.** Compresses data blocks to reduce the amount of physical storage required.
- **Inline deduplication.** Eliminates incoming blocks with existing blocks on disk.
- **Inline data compaction.** Packs smaller I/O operations and files into each physical block.



You can run deduplication, data compression, and data compaction together or independently to achieve optimal space savings on a FlexVol volume. The combination of these capabilities has resulted in customers seeing savings of up to 5:1 for VSI and up to 30:1 for VDI.

For more information on ONTAP storage efficiencies, see Using deduplication, data compression, and data compaction to increase storage efficiency in the ONTAP 9 Documentation center.

Virtual Volumes (vVols) and Storage Policy Based Management (SPBM)

About vVols and SPBM

NetApp was an early design partner with VMware in the development of vSphere Virtual Volumes (vVols), providing architectural input and early support for vVols and VMware vSphere APIs for Storage Awareness (VASA). Not only did this approach bring VM granular storage management to VMFS, it also supported automation of storage provisioning through Storage Policy-Based Management (SPBM).

SPBM provides a framework that serves as an abstraction layer between the storage services available to your virtualization environment and the provisioned storage elements via policies. This approach allows storage architects to design storage pools with different capabilities that can be easily consumed by VM administrators. Administrators can then match virtual machine workload requirements against the provisioned storage pools, allowing for granular control of various settings on a per-VM or virtual disk level.

ONTAP leads the storage industry in vVols scale, supporting hundreds of thousands of vVols in a single cluster, whereas enterprise array and smaller flash array vendors support as few as several thousand vVols per array. NetApp is also driving the evolution of VM granular management with upcoming capabilities in support of vVols 3.0.

For more information on VMware vSphere Virtual Volumes, SPBM, and ONTAP, see TR-4400: VMware vSphere Virtual Volumes with ONTAP.

Hybrid Cloud with ONTAP and vSphere

About Hybrid Cloud

Whether used for an on-premises private cloud, public-cloud infrastructure, or a hybrid cloud that combines the best of both, ONTAP solutions help you build your data fabric to streamline and optimize data management. Start with high-performance, all-flash systems, then couple them with either disk or cloud storage systems for data protection and cloud compute.

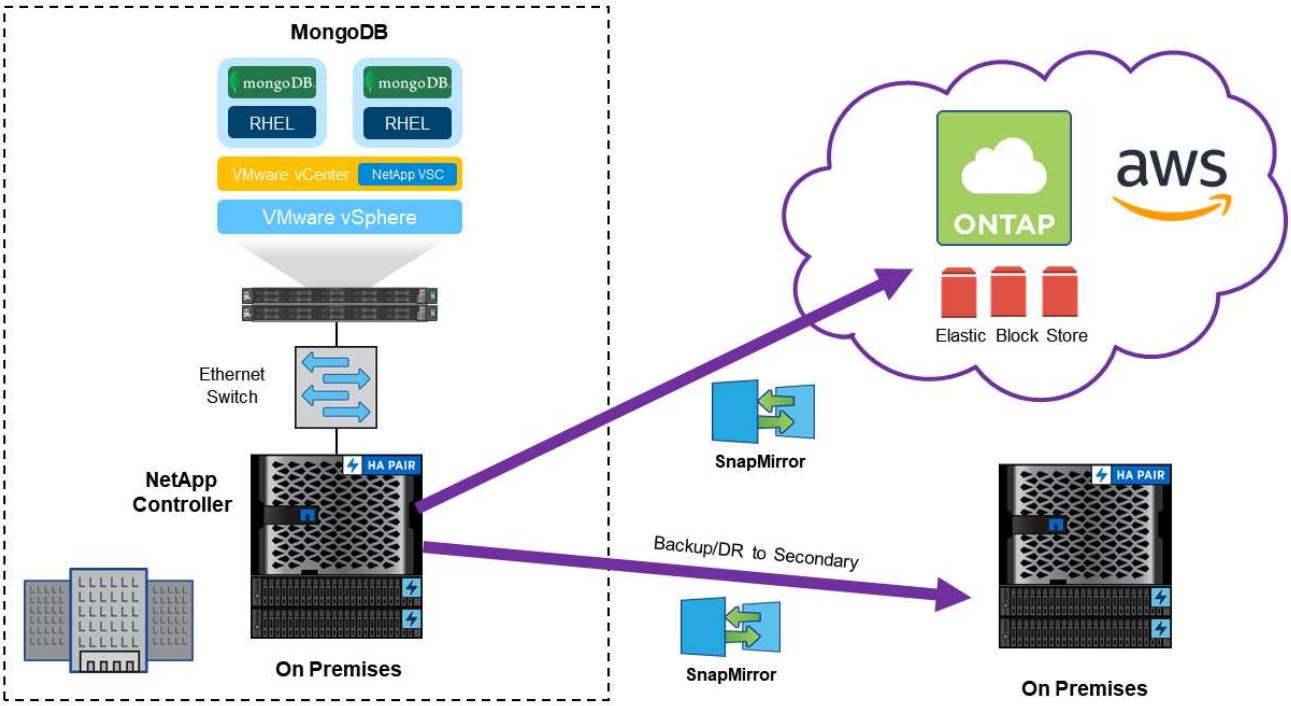
Choose from Azure, AWS, IBM, or Google clouds to optimize costs and avoid lock-in. Leverage advanced support for OpenStack and container technologies as needed.

Data protection is often the first thing customers try when they begin their cloud journey. Protection can be as simple as asynchronous replication of key data or as complex as a complete hot-backup site. Data protection is based primarily on NetApp SnapMirror technology.

Some customers choose to move entire workloads to the cloud. This can be more complicated than just using the cloud for data protection, but ONTAP makes moving easier because you do not have to rewrite your applications to use cloud-based storage. ONTAP in the cloud works just like on-premises ONTAP does. Your on-premises ONTAP system offers data efficiency features that enable you to store more data in less physical space and to tier rarely used data to lower cost storage. Whether you use a hybrid cloud configuration or move an entire workload to the cloud, ONTAP maximizes storage performance and efficiency.

NetApp also offers cloud-based backup (SnapMirror Cloud, Cloud Backup Service, and Cloud Sync) and storage tiering and archiving tools (FabricPool) for ONTAP to help reduce operating expenses and leverage the broad reach of the cloud.

The following figure provides a sample hybrid cloud use case.



For more information on ONTAP and hybrid clouds, see ONTAP and the Cloud in the ONTAP 9 Documentation Center.

TR-4597: VMware vSphere for ONTAP

Karl Konnerth, NetApp

NetApp ONTAP software has been a leading storage solution for VMware vSphere environments for almost two decades and continues to add innovative capabilities to simplify management while reducing costs. This document introduces the ONTAP solution for vSphere, including the latest product information and best practices, to streamline deployment, reduce risk, and simplify management.

Best practices supplement other documents such as guides and compatibility lists. They are developed based on lab testing and extensive field experience by NetApp engineers and customers. They might not be the only supported practices that work in every environment, but they are generally the simplest solutions that meet the needs of most customers.

This document is focused on capabilities in recent releases of ONTAP (9.x) running on vSphere 6.0 or later. See the section ONTAP and vSphere release-specific information for details related to specific releases.

Why ONTAP for vSphere?

There are many reasons why tens of thousands of customers have selected ONTAP as their storage solution for vSphere, such as a unified storage system supporting both SAN and NAS protocols, robust data protection capabilities using space-efficient NetApp Snapshot copies, and a wealth of tools to help you manage application data. Using a storage system separate from the hypervisor allows you to offload many functions and maximize your investment in vSphere host systems. This approach not only makes sure your host resources are focused on application workloads, but it also avoids random performance effects on applications from storage operations.

Using ONTAP together with vSphere is a great combination that lets you reduce host hardware and VMware software expenses. You can also protect your data at lower cost with consistent high performance. Because virtualized workloads are mobile, you can explore different approaches using Storage vMotion to move VMs across VMFS, NFS, or vVols datastores, all on the same storage system.

Here are key factors customers value today:

- **Unified storage.** Systems running ONTAP software are unified in several significant ways. Originally this approach referred to both NAS and SAN protocols, and ONTAP continues to be a leading platform for SAN along with its original strength in NAS. In the vSphere world, this approach could also mean a unified system for virtual desktop infrastructure (VDI) together with virtual server infrastructure (VSI). Systems running ONTAP software are typically less expensive for VSI than traditional enterprise arrays and yet have advanced storage efficiency capabilities to handle VDI in the same system. ONTAP also unifies a variety of storage media, from SSDs to SATA, and can extend that easily into the cloud. There's no need to buy one flash array for performance, a SATA array for archives, and separate systems for the cloud. ONTAP ties them all together.
- **Virtual volumes and storage policy-based management.** NetApp was an early design partner with VMware in the development of vSphere Virtual Volumes (vVols), providing architectural input and early support for vVols and VMware vSphere APIs for Storage Awareness (VASA). Not only did this approach bring granular VM storage management to VMFS, it also supported automation of storage provisioning through storage policy-based management. This approach allows storage architects to design storage pools with different capabilities that can be easily consumed by VM administrators. ONTAP leads the storage industry in vVol scale, supporting hundreds of thousands of vVols in a single cluster, whereas enterprise array and smaller flash array vendors support as few as several thousand vVols per array. NetApp is also driving the evolution of granular VM management with upcoming capabilities in support of vVols 3.0.
- **Storage efficiency.** Although NetApp was the first to deliver deduplication for production workloads, this innovation wasn't the first or last one in this area. It started with ONTAP Snapshot copies, a space-efficient data protection mechanism with no performance effect, along with FlexClone technology to instantly make read/write copies of VMs for production and backup use. NetApp went on to deliver inline capabilities, including deduplication, compression, and zero-block deduplication, to squeeze out the most storage from expensive SSDs. Most recently, ONTAP added the ability to pack smaller I/O operations and files into a disk block using compaction. The combination of these capabilities has resulted in customers seeing savings of up to 5:1 for VSI and up to 30:1 for VDI.
- **Hybrid cloud.** Whether used for on-premises private cloud, public cloud infrastructure, or a hybrid cloud

that combines the best of both, ONTAP solutions help you build your data fabric to streamline and optimize data management. Start with high-performance all-flash systems, then couple them with either disk or cloud storage systems for data protection and cloud compute. Choose from Azure, AWS, IBM, or Google clouds to optimize costs and avoid lock-in. Leverage advanced support for OpenStack and container technologies as needed. NetApp also offers cloud-based backup (SnapMirror Cloud, Cloud Backup Service, and Cloud Sync) and storage tiering and archiving tools (FabricPool) for ONTAP to help reduce operating expenses and leverage the broad reach of the cloud.

- **And more.** Take advantage of the extreme performance of NetApp AFF A-Series arrays to accelerate your virtualized infrastructure while managing costs. Enjoy completely nondisruptive operations, from maintenance to upgrades to complete replacement of your storage system, using scale-out ONTAP clusters. Protect data at rest with NetApp encryption capabilities at no additional cost. Make sure performance meets business service levels through fine-grained quality of service capabilities. They are all part of the broad range of capabilities that come with ONTAP, the industry's leading enterprise data management software.

ONTAP capabilities for vSphere

Protocols

ONTAP supports all major storage protocols used for virtualization, such as iSCSI, Fibre Channel (FC), Fibre Channel over Ethernet (FCoE), or Non-Volatile Memory Express over Fibre Channel (NVMe/FC) for SAN environments, as well as NFS (v3 and v4.1) and SMB or S3 for guest connections. Customers are free to pick what works best for their environment and can combine protocols as needed on a single system. For example, one can augment general use of NFS datastores with a few iSCSI LUNs or guest shares.

Features

There are many ONTAP features that are useful for managing virtualized workloads. Some that require additional product licenses are described in the next section. Others packaged as standalone tools, some for ONTAP and others for the entire NetApp portfolio, are described after that.

Here are further details about base ONTAP features:

- **NetApp Snapshot copies.** ONTAP offers instant Snapshot copies of a VM or datastore with zero performance effects when you create or use a Snapshot copy. They can be used to create a restoration point for a VM prior to patching or for simple data protection. Note that these are different from VMware (consistency) snapshots. The easiest way to make an ONTAP Snapshot copy is to use the SnapCenter Plug-In for VMware vSphere to back up VMs and datastores.
- **Storage efficiency.** ONTAP supports inline and background deduplication and compression, zero-block deduplication, and data compaction.
- **Volume and LUN move.** Allows nondisruptive movement of volumes and LUNs supporting vSphere datastores and vVols within the ONTAP cluster to balance performance and capacity or support nondisruptive maintenance and upgrades.
- **QoS.** QoS allows for managing performance on an individual LUN, volume, or file. This function can be used to limit an unknown or bully VM or to make sure an important VM gets sufficient performance resources.
- **NetApp Volume Encryption and NetApp Aggregate Encryption.** NetApp encryption options offer easy software-based encryption to protect data at rest.
- **FabricPool.** This feature tiers colder data automatically at the block level to a separate object store, freeing up expensive flash storage.
- **REST and Ansible.** Use ONTAP REST APIs to automate storage and data management, and Ansible modules for configuration management of your ONTAP systems.

Note that some ONTAP features are not well-suited for vSphere workloads. For example, FlexGroup technology prior to ONTAP 9.8 did not have full cloning support and was not tested with vSphere (see the FlexGroup section for the latest on using it with vSphere). FlexCache technology is also not optimal for vSphere as it is designed for read-mostly workloads. Writes can be problematic when the cache is disconnected from the origin, resulting in NFS datastore errors on both sides.

ONTAP licensing

Some ONTAP features that are valuable for managing virtualized workloads require an additional license, whether available at no additional cost, in a license bundle, or a la carte. For many customers, the most cost-effective approach is with a license bundle. Here are the key licenses relevant to vSphere and how they are used:

- **FlexClone.** FlexClone enables instant, space-efficient clones of ONTAP volumes and files. This cloning is used when operations are offloaded to the storage system by VMware vSphere Storage APIs – Array Integration (VAAI), for backup verification and recovery (SnapCenter software), and for vVols cloning and Snapshot copies. Here is how they are used:
  - VAAI is supported with ONTAP for offloaded copy in support of vSphere clone and migration (Storage vMotion) operations. The FlexClone license allows for fast clones within a NetApp FlexVol volume, but, if not licensed, it still allows clones using slower block copies.
  - A FlexClone license is required for vVols functionality. It enables cloning of vVols within a single datastore or between datastores, and it enables vSphere-managed Snapshot copies of vVols, which are offloaded to the storage system.
- The storage replication adapter (SRA) is used with VMware Site Recovery Manager, and a FlexClone license is required to test recovery in both NAS and SAN environments. SRA may be used without FlexClone for discovery, recovery, and reprotection workflows.
- **SnapRestore.** SnapRestore technology enables instant recovery of a volume in place without copying data. It is required by NetApp backup and recovery tools such as SnapCenter where it is used to mount the datastore for verification and restore operations.
- **SnapMirror.** SnapMirror technology allows for simple, fast replication of data between ONTAP systems on-premises and in the cloud. SnapMirror supports the version flexibility of logical replication with the performance of block replication, sending only changed data to the secondary system. Data can be protected with mirror and/or vault policies, allowing for disaster recovery as well as long-term data retention for backup. SnapMirror supports asynchronous as well as synchronous relationships, and ONTAP 9.8 introduces transparent application failover with SnapMirror Business Continuity.

  SnapMirror is required for SRA replication with Site Recovery Manager. It is also required for SnapCenter to enable replication of Snapshot copies to a secondary storage system.

- **SnapCenter.** SnapCenter software provides a unified, scalable platform and plug-in suite for application-consistent data protection and clone management. A SnapCenter license is included with the data protection license bundles for AFF and FAS systems. SnapCenter Plug-in for VMware vSphere is a free product if you are using the following storage systems: FAS, AFF, Cloud Volumes ONTAP, or ONTAP Select. However, SnapRestore and FlexClone licenses are required.
- **MetroCluster.** NetApp MetroCluster is a synchronous replication solution combining high availability and disaster recovery in a campus or metropolitan area to protect against both site disasters and hardware outages. It provides solutions with transparent recovery from failure, with zero data loss (0 RPO) and fast recovery (RTO within minutes). It is used in vSphere environments as part of a vSphere Metro Storage Cluster configuration.

Virtualization tools for ONTAP

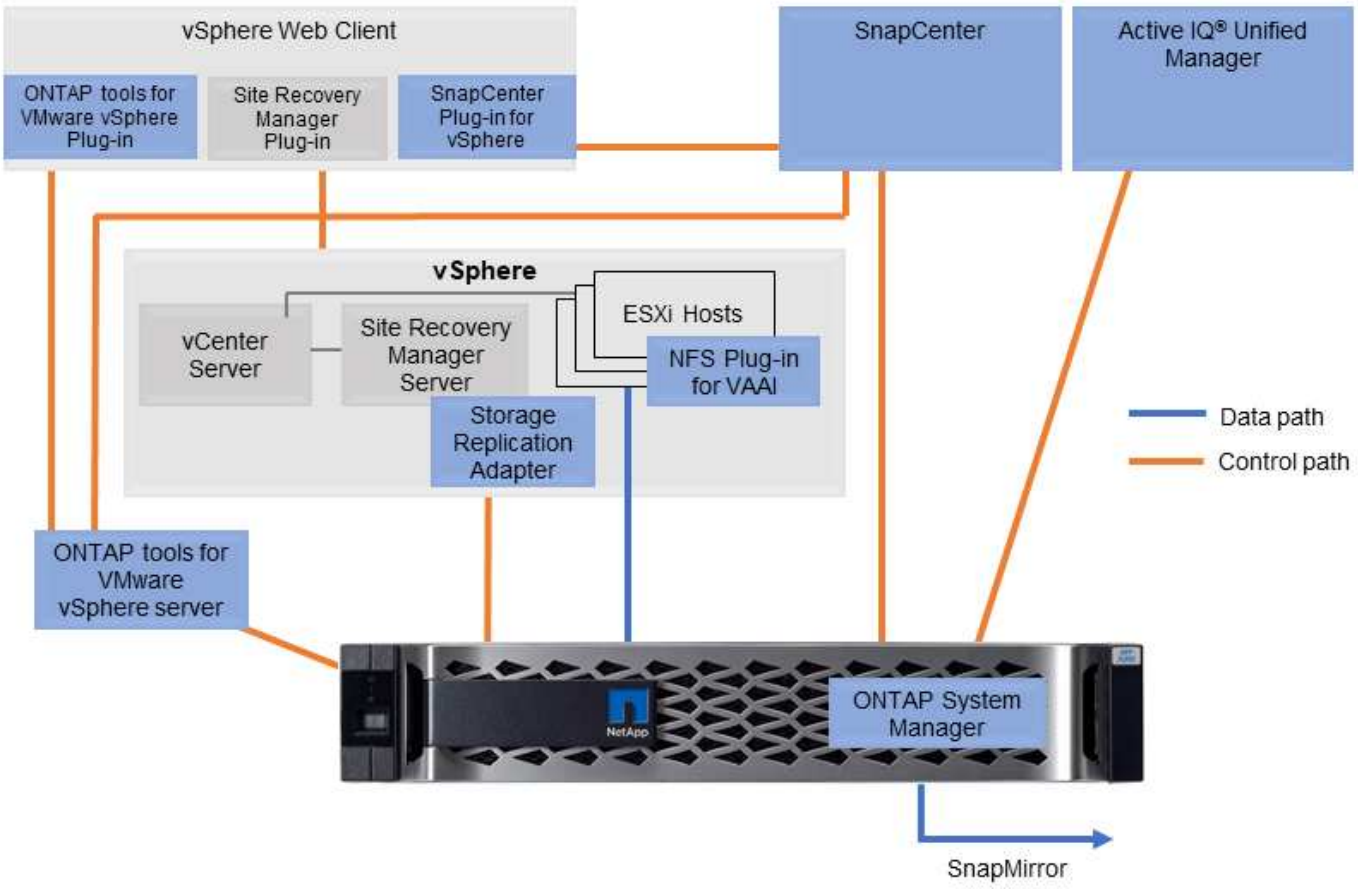
NetApp offers several standalone software tools that can be used together with ONTAP and vSphere to manage your virtualized environment. The following tools are included with the ONTAP license at no additional cost. See Figure 1 for a depiction of how these tools work together in your vSphere environment.

ONTAP tools for VMware vSphere

ONTAP tools for VMware vSphere is a set of tools for using ONTAP storage together with vSphere. The vCenter plug-in, formerly known as the Virtual Storage Console (VSC), simplifies storage management and efficiency features, enhances availability, and reduces storage costs and operational overhead, whether you are using SAN or NAS. It uses best practices for provisioning datastores and optimizes ESXi host settings for NFS and block storage environments. For all these benefits, NetApp recommends using these ONTAP tools as a best practice when using vSphere with systems running ONTAP software. It includes a server appliance, user interface extensions for vCenter, VASA Provider, and Storage Replication Adapter. Nearly everything in ONTAP tools can be automated by using simple REST APIs, consumable by most modern automation tools.

- **vCenter UI extensions.** The ONTAP tools UI extensions simplify the job of operations teams and vCenter admins by embeding easy-to-use, context-sensitive menus for managing hosts and storage, informational portlets, and native alerting capabilities directly in the vCenter UI for streamlined workflows.
- **VASA Provider for ONTAP.** The VASA Provider for ONTAP supports the VMware vStorage APIs for Storage Awareness (VASA) framework. It is supplied as part of ONTAP tools for VMware vSphere as a single virtual appliance for ease of deployment. VASA Provider connects vCenter Server with ONTAP to aid in provisioning and monitoring VM storage. It enables VMware Virtual Volumes (vVols) support, management of storage capability profiles and individual VM vVols performance, and alarms for monitoring capacity and compliance with the profiles.
- **Storage Replication Adapter.** The SRA is used together with VMware Site Recovery Manager (SRM) to manage data replication between production and disaster recovery sites and test the DR replicas nondisruptively. It helps automate the tasks of discovery, recovery, and reprotection. It includes both an SRA server appliance and SRA adapters for the Windows SRM server and SRM appliance.

The following figure depicts ONTAP tools for vSphere.



NFS Plug-In for VMware VAAI

The NetApp NFS Plug-In for VMware VAAI is a plug-in for ESXi hosts that allows them to use VAAI features with NFS datastores on ONTAP. It supports copy offload for clone operations, space reservation for thick virtual disk files, and Snapshot copy offload. Offloading copy operations to storage is not necessarily faster to complete, but it does reduce network bandwidth requirements and offloads host resources such as CPU cycles, buffers, and queues. You can use ONTAP tools for VMware vSphere to install the plug-in on ESXi hosts or, where supported, vSphere Lifecycle Manager (vLCM).

Datastores and protocols

vSphere datastore and protocol features

Seven protocols are used to connect VMware vSphere to datastores on a system running ONTAP software:

- FCP
- FCoE
- NVMe/FC
- NVMe/TCP
- iSCSI
- NFS v3
- NFS v4.1

FCP, FCoE, NVMe/FC, NVMe/TCP, and iSCSI are block protocols that use the vSphere Virtual Machine File System (VMFS) to store VMs inside ONTAP LUNs or NVMe namespaces that are contained in an ONTAP

FlexVol volume. Note that, starting from vSphere 7.0, VMware no longer supports software FCoE in production environments. NFS is a file protocol that places VMs into datastores (which are simply ONTAP volumes) without the need for VMFS. SMB (CIFS), iSCSI, NVMe/TCP, or NFS can also be used directly from a guest OS to ONTAP.

The following tables presents vSphere supported traditional datastore features with ONTAP. This information does not apply to vVols datastores, but it does generally applies to vSphere 6.x and later releases using supported ONTAP releases. You can also consult VMware Configuration Maximums for specific vSphere releases to confirm specific limits.

Capability/Feature	FC/FCoE	iSCSI	NVMe-oF	NFS
Format	VMFS or raw device mapping (RDM)	VMFS or RDM	VMFS	N/A
Maximum number of datastores or LUNs	1024 LUNs per host	1024 LUNs per server	256 Namespeces per server	256 mounts Default NFS. MaxVolumes is 8. Use ONTAP tools for VMware vSphere to increase to 256.
Maximum datastore size	64TB	64TB	64TB	100TB FlexVol volume or greater with FlexGroup volume
Maximum datastore file size	62TB	62TB	62TB	16TB or 62TB with ONTAP 9.12.1RC1 and later with large files enabled
Optimal queue depth per LUN or file system	64	64	Autonegotiated	Refer to NFS.MaxQueueDepth in Recommended ESXi host and other ONTAP settings.

The following table lists supported VMware storage-related functionalities.

Capacity/Feature	FC/FCoE	iSCSI	NVMe-oF	NFS
vMotion	Yes	Yes	Yes	Yes
Storage vMotion	Yes	Yes	Yes	Yes
VMware HA	Yes	Yes	Yes	Yes
Storage Distributed Resource Scheduler (SDRS)	Yes	Yes	Yes	Yes
VMware vStorage APIs for Data Protection (VADP)–enabled backup software	Yes	Yes	Yes	Yes

Capacity/Feature	FC/FCoE	iSCSI	NVMe-oF	NFS
Microsoft Cluster Service (MSCS) or failover clustering within a VM	Yes	Yes*	Yes*	Not supported
Fault Tolerance	Yes	Yes	Yes	Yes
Site Recovery Manager	Yes	Yes	No**	V3 only**
Thin-provisioned VMs (virtual disks)	Yes	Yes	Yes	Yes This setting is the default for all VMs on NFS when not using VAAI.
VMware native multipathing	Yes	Yes	Yes, using the new High Performance Plugin (HPP)	N/A

The following table lists supported ONTAP storage management features.

Capability/Feature	FC/FCoE	iSCSI	NVMe-oF	NFS
Data deduplication	Savings in the array	Savings in the array	Savings in the array	Savings in the datastore
Thin provisioning	Datastore or RDM	Datastore or RDM	Datastore	Datastore
Resize datastore	Grow only	Grow only	Grow only	Grow, autogrow, and shrink
SnapCenter plug-ins for Windows, Linux applications (in guest)	Yes	Yes	No	Yes
Monitoring and host configuration using ONTAP tools for VMware vSphere	Yes	Yes	No	Yes
Provisioning using ONTAP tools for VMware vSphere	Yes	Yes	No	Yes

The following table lists supported backup features.

Capability/Feature	FC/FCoE	iSCSI	NVMe-oF	NFS
ONTAP Snapshot copies	Yes	Yes	Yes	Yes
SRM supported by replicated backups	Yes	Yes	No**	V3 only**
Volume SnapMirror	Yes	Yes	Yes	Yes

Capability/Feature	FC/FCoE	iSCSI	NVMe-oF	NFS
VMDK image access	VADP-enabled backup software	VADP-enabled backup software	VADP-enabled backup software	VADP-enabled backup software, vSphere Client, and vSphere Web Client datastore browser
VMDK file-level access	VADP-enabled backup software, Windows only	VADP-enabled backup software, Windows only	VADP-enabled backup software, Windows only	VADP-enabled backup software and third-party applications
NDMP granularity	Datastore	Datastore	Datastore	Datastore or VM

*NetApp recommends using in-guest iSCSI for Microsoft clusters rather than multiwriter-enabled VMDKs in a VMFS datastore. This approach is fully supported by Microsoft and VMware, offers great flexibility with ONTAP (SnapMirror to ONTAP systems on-premises or in the cloud), is easy to configure and automate, and can be protected with SnapCenter. vSphere 7 adds a new clustered VMDK option. This is different from multiwriter-enabled VMDKs, which requires a datastore presented via the FC protocol that has clustered VMDK support enabled. Other restrictions apply. See VMware's Setup for Windows Server Failover Clustering documentation for configuration guidelines.

**Datastores using NVMe-oF and NFS v4.1 require vSphere replication. Array-based replication is not supported by SRM.

Selecting a storage protocol

Systems running ONTAP software support all major storage protocols, so customers can choose what is best for their environment, depending on existing and planned networking infrastructure and staff skills. NetApp testing has generally shown little difference between protocols running at similar line speeds, so it is best to focus on your network infrastructure and staff capabilities over raw protocol performance.

The following factors might be useful in considering a choice of protocol:

- **Current customer environment.** Although IT teams are generally skilled at managing Ethernet IP infrastructure, not all are skilled at managing an FC SAN fabric. However, using a general-purpose IP network that's not designed for storage traffic might not work well. Consider the networking infrastructure you have in place, any planned improvements, and the skills and availability of staff to manage them.
- **Ease of setup.** Beyond initial configuration of the FC fabric (additional switches and cabling, zoning, and the interoperability verification of HBA and firmware), block protocols also require creation and mapping of LUNs and discovery and formatting by the guest OS. After the NFS volumes are created and exported, they are mounted by the ESXi host and ready to use. NFS has no special hardware qualification or firmware to manage.
- **Ease of management.** With SAN protocols, if more space is needed, several steps are necessary, including growing a LUN, rescanning to discover the new size, and then growing the file system). Although growing a LUN is possible, reducing the size of a LUN is not, and recovering unused space can require additional effort. NFS allows easy sizing up or down, and this resizing can be automated by the storage system. SAN offers space reclamation through guest OS TRIM/UNMAP commands, allowing space from deleted files to be returned to the array. This type of space reclamation is more difficult with NFS datastores.
- **Storage space transparency.** Storage utilization is typically easier to see in NFS environments because thin provisioning returns savings immediately. Likewise, deduplication and cloning savings are immediately available for other VMs in the same datastore or for other storage system volumes. VM density is also

typically greater in an NFS datastore, which can improve deduplication savings as well as reduce management costs by having fewer datastores to manage.

Datastore layout

ONTAP storage systems offer great flexibility in creating datastores for VMs and virtual disks. Although many ONTAP best practices are applied when using the VSC to provision datastores for vSphere (listed in the section Recommended ESXi host and other ONTAP settings), here are some additional guidelines to consider:

- Deploying vSphere with ONTAP NFS datastores results in a high-performing, easy-to-manage implementation that provides VM-to-datastore ratios that cannot be obtained with block-based storage protocols. This architecture can result in a tenfold increase in datastore density with a correlating reduction in the number of datastores. Although a larger datastore can benefit storage efficiency and provide operational benefits, consider using at least four datastores (FlexVol volumes) to store your VMs on a single ONTAP controller to get maximum performance from the hardware resources. This approach also allows you to establish datastores with different recovery policies. Some can be backed up or replicated more frequently than others based on business needs. Multiple datastores are not required with FlexGroup volumes for performance because they scale by design.
- NetApp recommends the use of FlexVol volumes and, starting with ONTAP 9.8 FlexGroup volumes, NFS datastores. Other ONTAP storage containers such as qtrees are not generally recommended because these are not currently supported by ONTAP tools for VMware vSphere. Deploying datastores as multiple qtrees in a single volume might be useful for highly automated environments that can benefit from datastore-level quotas or VM file clones.
- A good size for a FlexVol volume datastore is around 4TB to 8TB. This size is a good balance point for performance, ease of management, and data protection. Start small (say, 4TB) and grow the datastore as needed (up to the maximum 100TB). Smaller datastores are faster to recover from backup or after a disaster and can be moved quickly across the cluster. Consider the use of ONTAP autosize to automatically grow and shrink the volume as used space changes. The ONTAP tools for VMware vSphere Datastore Provisioning Wizard use autosize by default for new datastores. Additional customization of the grow and shrink thresholds and maximum and minimum size can be done with System Manager or the command line.
- Alternately, VMFS datastores can be configured with LUNs that are accessed by FC, iSCSI, or FCoE. VMFS allows traditional LUNs to be accessed simultaneously by every ESX server in a cluster. VMFS datastores can be up to 64TB in size and consist of up to 32 2TB LUNs (VMFS 3) or a single 64TB LUN (VMFS 5). The ONTAP maximum LUN size is 16TB on most systems, and 128TB on All-SAN-Array systems. Therefore, a maximum size VMFS 5 datastore on most ONTAP systems can be created by using four 16TB LUNs. While there can be a performance benefit for high-I/O workloads with multiple LUNs (with high-end FAS or AFF systems), this benefit is offset by added management complexity to create, manage, and protect the datastore LUNs and increased availability risk. NetApp generally recommends using a single, large LUN for each datastore and only span if there is a special need to go beyond a 16TB datastore. As with NFS, consider using multiple datastores (volumes) to maximize performance on a single ONTAP controller.
- Older guest operating systems (OSs) needed alignment with the storage system for best performance and storage efficiency. However, modern vendor-supported OSs from Microsoft and Linux distributors such as Red Hat no longer require adjustments to align the file system partition with the blocks of the underlying storage system in a virtual environment. If you are using an old OS that might require alignment, search the NetApp Support Knowledgebase for articles using “VM alignment” or request a copy of TR-3747 from a NetApp sales or partner contact.
- Avoid the use of defragmentation utilities within the guest OS, as this offers no performance benefit and affects storage efficiency and Snapshot copy space usage. Also consider turning off search indexing in the guest OS for virtual desktops.
- ONTAP has led the industry with innovative storage efficiency features, allowing you to get the most out of

your usable disk space. AFF systems take this efficiency further with default inline deduplication and compression. Data is deduplicated across all volumes in an aggregate, so you no longer need to group similar operating systems and similar applications within a single datastore to maximize savings.

- In some cases, you might not even need a datastore. For the best performance and manageability, avoid using a datastore for high-I/O applications such as databases and some applications. Instead, consider guest-owned file systems such as NFS or iSCSI file systems managed by the guest or with RDMs. For specific application guidance, see NetApp technical reports for your application. For example, TR-3633: Oracle Databases on Data ONTAP has a section about virtualization with helpful details.
- First Class Disks (or Improved Virtual Disks) allow for vCenter-managed disks independent of a VM with vSphere 6.5 and later. While primarily managed by API, they can be useful with vVols, especially when managed by OpenStack or Kubernetes tools. They are supported by ONTAP as well as ONTAP tools for VMware vSphere.

Datastore and VM migration

When migrating VMs from an existing datastore on another storage system to ONTAP, here are some practices to keep in mind:

- Use Storage vMotion to move the bulk of your virtual machines to ONTAP. Not only is this approach nondisruptive to running VMs, it also allows ONTAP storage efficiency features such as inline deduplication and compression to process the data as it migrates. Consider using vCenter capabilities to select multiple VMs from the inventory list and then schedule the migration (use Ctrl key while clicking Actions) at an appropriate time.
- While you could carefully plan a migration to appropriate destination datastores, it is often simpler to migrate in bulk and then organize later as needed. If you have specific data protection needs, such as different Snapshot schedules, you might want to use this approach to guide your migration to different datastores.
- Most VMs and their storage may be migrated while running (hot), but migrating attached (not in datastore) storage such as ISOs, LUNs, or NFS volumes from another storage system might require cold migration.
- Virtual machines that need more careful migration include databases and applications that use attached storage. In general, consider the use of the application's tools to manage migration. For Oracle, consider using Oracle tools such as RMAN or ASM to migrate the database files. See TR-4534 for more information. Likewise, for SQL Server, consider using either SQL Server Management Studio or NetApp tools such as SnapManager for SQL Server or SnapCenter.

ONTAP tools for VMware vSphere

The most important best practice when using vSphere with systems running ONTAP software is to install and use the ONTAP tools for VMware vSphere plug-in (formerly known as Virtual Storage Console). This vCenter plug-in simplifies storage management, enhances availability, and reduces storage costs and operational overhead, whether using SAN or NAS. It uses best practices for provisioning datastores and optimizes ESXi host settings for multipath and HBA timeouts (these are described in Appendix B). Because it's a vCenter plug-in, it's available to all vSphere web clients that connect to the vCenter server.

The plug-in also helps you use other ONTAP tools in vSphere environments. It allows you to install the NFS Plug-In for VMware VAAI, which enables copy offload to ONTAP for VM cloning operations, space reservation for thick virtual disk files, and ONTAP Snapshot copy offload.

The plug-in is also the management interface for many functions of the VASA Provider for ONTAP, supporting storage policy-based management with vVols. After ONTAP tools for VMware vSphere is registered, use it to create storage capability profiles, map them to storage, and make sure of datastore compliance with the profiles over time. The VASA Provider also provides an interface to create and manage vVol datastores.

In general, NetApp recommends using the ONTAP tools for VMware vSphere interface within vCenter to provision traditional and vVols datastores to make sure best practices are followed.

General Networking

Configuring network settings when using vSphere with systems running ONTAP software is straightforward and similar to other network configuration. Here are some things to consider:

- Separate storage network traffic from other networks. A separate network can be achieved by using a dedicated VLAN or separate switches for storage. If the storage network shares physical paths such as uplinks, you might need QoS or additional uplink ports to make sure of sufficient bandwidth. Don't connect hosts directly to storage; use switches to have redundant paths and allow VMware HA to work without intervention.
- Jumbo frames can be used if desired and supported by your network, especially when using iSCSI. If they are used, make sure they are configured identically on all network devices, VLANs, and so on in the path between storage and the ESXi host. Otherwise, you might see performance or connection problems. The MTU must also be set identically on the ESXi virtual switch, the VMkernel port, and also on the physical ports or interface groups of each ONTAP node.
- NetApp only recommends disabling network flow control on the cluster network ports within an ONTAP cluster. NetApp makes no other recommendations for best practices for the remaining network ports used for data traffic. You should enable or disable as necessary. See TR-4182 for more background on flow control.
- When ESXi and ONTAP storage arrays are connected to Ethernet storage networks, NetApp recommends configuring the Ethernet ports to which these systems connect as Rapid Spanning Tree Protocol (RSTP) edge ports or by using the Cisco PortFast feature. NetApp recommends enabling the Spanning-Tree PortFast trunk feature in environments that use the Cisco PortFast feature and that have 802.1Q VLAN trunking enabled to either the ESXi server or the ONTAP storage arrays.
- NetApp recommends the following best practices for link aggregation:
  - Use switches that support link aggregation of ports on two separate switch chassis using a multichassis link aggregation group approach such as Cisco's Virtual PortChannel (vPC).
  - Disable LACP for switch ports connected to ESXi unless you are using dvSwitches 5.1 or later with LACP configured.
  - Use LACP to create link aggregates for ONTAP storage systems with dynamic multimode interface groups with IP hash.
  - Use an IP hash teaming policy on ESXi.

The following table provides a summary of network configuration items and indicates where the settings are applied.

Item	ESXi	Switch	Node	SVM
IP address	VMkernel	No**	No**	Yes
Link aggregation	Virtual switch	Yes	Yes	No*
VLAN	VMkernel and VM port groups	Yes	Yes	No*
Flow control	NIC	Yes	Yes	No*
Spanning tree	No	Yes	No	No

Item	ESXi	Switch	Node	SVM
MTU (for jumbo frames)	Virtual switch and VMkernel port (9000)	Yes (set to max)	Yes (9000)	No*
Failover groups	No	No	Yes (create)	Yes (select)

*SVM LIFs connect to ports, interface groups, or VLAN interfaces that have VLAN, MTU, and other settings. However, the settings are not managed at the SVM level.

**These devices have IP addresses of their own for management, but these addresses are not used in the context of ESXi storage networking.

SAN (FC, FCoE, NVMe/FC, iSCSI), RDM

In vSphere, there are three ways to use block storage LUNs:

- With VMFS datastores
- With raw device mapping (RDM)
- As a LUN accessed and controlled by a software initiator from a VM guest OS

VMFS is a high-performance clustered file system that provides datastores that are shared storage pools. VMFS datastores can be configured with LUNs that are accessed using FC, iSCSI, FCoE, or NVMe namespaces accessed by the NVMe/FC protocol. VMFS allows traditional LUNs to be accessed simultaneously by every ESX server in a cluster. The ONTAP maximum LUN size is generally 16TB; therefore, a maximum-size VMFS 5 datastore of 64TB (see the first table in this section) is created by using four 16TB LUNs (All SAN Array systems support the maximum VMFS LUN size of 64TB). Because the ONTAP LUN architecture does not have small individual queue depths, VMFS datastores in ONTAP can scale to a greater degree than with traditional array architectures in a relatively simple manner.

vSphere includes built-in support for multiple paths to storage devices, referred to as native multipathing (NMP). NMP can detect the type of storage for supported storage systems and automatically configures the NMP stack to support the capabilities of the storage system in use.

Both NMP and NetApp ONTAP support Asymmetric Logical Unit Access (ALUA) to negotiate optimized and nonoptimized paths. In ONTAP, an ALUA-optimized path follows a direct data path, using a target port on the node that hosts the LUN being accessed. ALUA is turned on by default in both vSphere and ONTAP. The NMP recognizes the ONTAP cluster as ALUA, and it uses the ALUA storage array type plug-in (`VMW_SATP_ALUA`) and selects the round robin path selection plug-in (`VMW_PSP_RR`).

ESXi 6 supports up to 256 LUNs and up to 1,024 total paths to LUNs. Any LUNs or paths beyond these limits are not seen by ESXi. Assuming the maximum number of LUNs, the path limit allows four paths per LUN. In a larger ONTAP cluster, it is possible to reach the path limit before the LUN limit. To address this limitation, ONTAP supports selective LUN map (SLM) in release 8.3 and later.

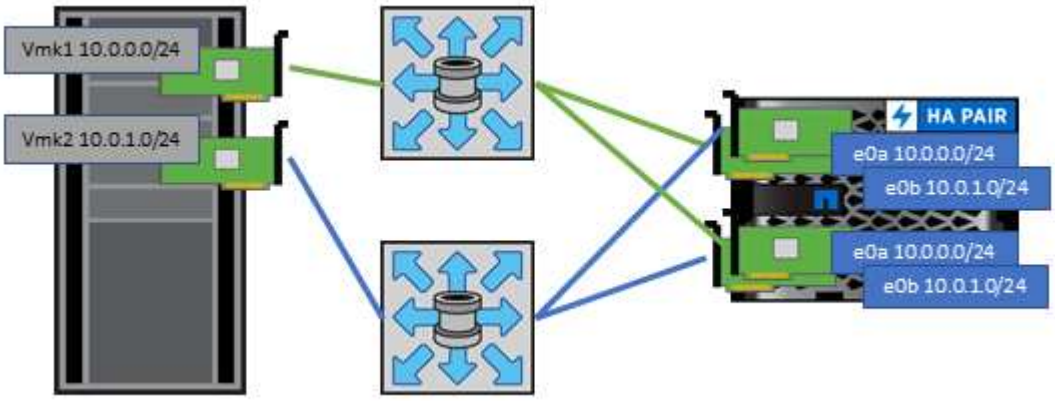
SLM limits the nodes that advertise paths to a given LUN. It is a NetApp best practice to have at least one LIF per node per SVM and to use SLM to limit the paths advertised to the node hosting the LUN and its HA partner. Although other paths exist, they aren’t advertised by default. It is possible to modify the paths advertised with the add and remove reporting node arguments within SLM. Note that LUNs created in releases prior to 8.3 advertise all paths and need to be modified to only advertise the paths to the hosting HA pair. For more information about SLM, review section 5.9 of TR-4080. The previous method of portsets can also be used to further reduce the available paths for a LUN. Portsets help by reducing the number of visible paths through which initiators in an igroup can see LUNs.

- SLM is enabled by default. Unless you are using portsets, no additional configuration is required.
- For LUNs created prior to Data ONTAP 8.3, manually apply SLM by running the `lun mapping remove-reporting-nodes` command to remove the LUN reporting nodes and restrict LUN access to the LUN-owning node and its HA partner.

Block protocols (iSCSI, FC, and FCoE) access LUNs by using LUN IDs and serial numbers, along with unique names. FC and FCoE use worldwide names (WWNNs and WWPNs), and iSCSI uses iSCSI qualified names (IQNs). The path to LUNs inside the storage is meaningless to the block protocols and is not presented anywhere in the protocol. Therefore, a volume that contains only LUNs does not need to be internally mounted at all, and a junction path is not needed for volumes that contain LUNs used in datastores. The NVMe subsystem in ONTAP works similarly.

Other best practices to consider:

- Make sure that a logical interface (LIF) is created for each SVM on each node in the ONTAP cluster for maximum availability and mobility. ONTAP SAN best practice is to use two physical ports and LIFs per node, one for each fabric. ALUA is used to parse paths and identify active optimized (direct) paths versus active nonoptimized paths. ALUA is used for FC, FCoE, and iSCSI.
- For iSCSI networks, use multiple VMkernel network interfaces on different network subnets with NIC teaming when multiple virtual switches are present. You can also use multiple physical NICs connected to multiple physical switches to provide HA and increased throughput. The following figure provides an example of multipath connectivity. In ONTAP, configure either a single-mode interface group for failover with two or more links that are connected to two or more switches, or use LACP or other link-aggregation technology with multimode interface groups to provide HA and the benefits of link aggregation.
- If the Challenge-Handshake Authentication Protocol (CHAP) is used in ESXi for target authentication, it must also be configured in ONTAP using the CLI (`vserver iscsi security create`) or with System Manager (edit Initiator Security under Storage > SVMs > SVM Settings > Protocols > iSCSI).
- Use ONTAP tools for VMware vSphere to create and manage LUNs and igroups. The plug-in automatically determines the WWPNs of servers and creates appropriate igroups. It also configures LUNs according to best practices and maps them to the correct igroups.
- Use RDMs with care because they can be more difficult to manage, and they also use paths, which are limited as described earlier. ONTAP LUNs support both physical and virtual compatibility mode RDMs.
- For more on using NVMe/FC with vSphere 7.0, see this ONTAP NVMe/FC Host Configuration guide and TR-4684.The following figure depicts multipath connectivity from a vSphere host to an ONTAP LUN.



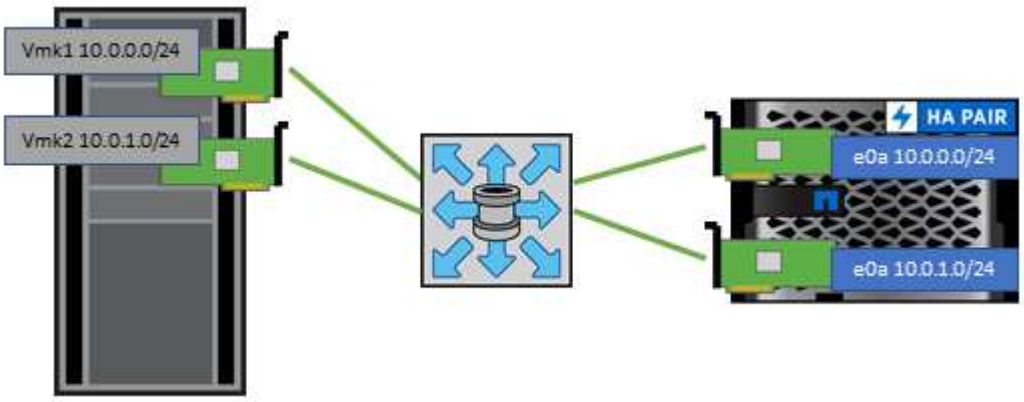
NFS

vSphere allows customers to use enterprise-class NFS arrays to provide concurrent access to datastores to all the nodes in an ESXi cluster. As mentioned in the datastore section, there are some ease of use and storage efficiency visibility benefits when using NFS with vSphere.

The following best practices are recommended when using ONTAP NFS with vSphere:

- Use a single logical interface (LIF) for each SVM on each node in the ONTAP cluster. Past recommendations of a LIF per datastore are no longer necessary. While direct access (LIF and datastore on same node) is best, don't worry about indirect access because the performance effect is generally minimal (microseconds).
- VMware has supported NFSv3 since VMware Infrastructure 3. vSphere 6.0 added support for NFSv4.1, which enables some advanced capabilities such as Kerberos security. Where NFSv3 uses client-side locking, NFSv4.1 uses server-side locking. Although an ONTAP volume can be exported through both protocols, ESXi can only mount through one protocol. This single protocol mount does not preclude other ESXi hosts from mounting the same datastore through a different version. Make sure to specify the protocol version to use when mounting so that all hosts use the same version and, therefore, the same locking style. Do not mix NFS versions across hosts. If possible, use host profiles to check compliancy.
  - Because there is no automatic datastore conversion between NFSv3 and NFSv4.1, create a new NFSv4.1 datastore and use Storage vMotion to migrate VMs to the new datastore.
  - Please refer to the NFS v4.1 Interoperability table notes in the NetApp Interoperability Matrix tool for specific ESXi patch levels required for support.
- NFS export policies are used to control access by vSphere hosts. You can use one policy with multiple volumes (datastores). With NFSv3, ESXi uses the sys (UNIX) security style and requires the root mount option to execute VMs. In ONTAP, this option is referred to as superuser, and when the superuser option is used, it is not necessary to specify the anonymous user ID. Note that export policy rules with different values for `-anon` and `-allow-suid` can cause SVM discovery problems with the ONTAP tools. Here's a sample policy:
  - Access Protocol: nfs3
  - Client Match Spec: 192.168.42.21
  - RO Access Rule: sys
  - RW Access Rule: sys
  - Anonymous UID
  - Superuser: sys
- If the NetApp NFS Plug-In for VMware VAAI is used, the protocol should be set as `nfs` when the export policy rule is created or modified. The NFSv4 protocol is required for VAAI copy offload to work, and specifying the protocol as `nfs` automatically includes both the NFSv3 and the NFSv4 versions.
- NFS datastore volumes are junctioned from the root volume of the SVM; therefore, ESXi must also have access to the root volume to navigate and mount datastore volumes. The export policy for the root volume, and for any other volumes in which the datastore volume's junction is nested, must include a rule or rules for the ESXi servers granting them read-only access. Here's a sample policy for the root volume, also using the VAAI plug-in:
  - Access Protocol: nfs (which includes both nfs3 and nfs4)
  - Client Match Spec: 192.168.42.21
  - RO Access Rule: sys
  - RW Access Rule: never (best security for root volume)

    - Anonymous UID
    - Superuser: sys (also required for root volume with VAAI)
- Use ONTAP tools for VMware vSphere (the most important best practice):
    - Use ONTAP tools for VMware vSphere to provision datastores because it simplifies management of export policies automatically.
    - When creating datastores for VMware clusters with the plug-in, select the cluster rather than a single ESX server. This choice triggers it to automatically mount the datastore to all hosts in the cluster.
    - Use the plug- in mount function to apply existing datastores to new servers.
    - When not using ONTAP tools for VMware vSphere, use a single export policy for all servers or for each cluster of servers where additional access control is needed.
- Although ONTAP offers a flexible volume namespace structure to arrange volumes in a tree using junctions, this approach has no value for vSphere. It creates a directory for each VM at the root of the datastore, regardless of the namespace hierarchy of the storage. Thus, the best practice is to simply mount the junction path for volumes for vSphere at the root volume of the SVM, which is how ONTAP tools for VMware vSphere provisions datastores. Not having nested junction paths also means that no volume is dependent on any volume other than the root volume and that taking a volume offline or destroying it, even intentionally, does not affect the path to other volumes.
- A block size of 4K is fine for NTFS partitions on NFS datastores. The following figure depicts connectivity from a vSphere host to an ONTAP NFS datastore.



The following table lists NFS versions and supported features.

vSphere Features	NFSv3	NFSv4.1
vMotion and Storage vMotion	Yes	Yes
High availability	Yes	Yes
Fault tolerance	Yes	Yes
DRS	Yes	Yes
Host profiles	Yes	Yes
Storage DRS	Yes	No
Storage I/O control	Yes	No
SRM	Yes	No

vSphere Features	NFSv3	NFSv4.1
Virtual volumes	Yes	No
Hardware acceleration (VAAI)	Yes	Yes
Kerberos authentication	No	Yes (enhanced with vSphere 6.5 and later to support AES, krb5i)
Multipathing support	No	No

FlexGroup

ONTAP 9.8 adds support for FlexGroup datastores in vSphere, along with the ONTAP tools for VMware vSphere 9.8 release. FlexGroup simplifies the creation of large datastores and automatically creates a number of constituent volumes to get maximum performance from an ONTAP system. Use FlexGroup with vSphere for a single, scalable vSphere datastore with the power of a full ONTAP cluster.

In addition to extensive system testing with vSphere workloads, ONTAP 9.8 also adds a new copy offload mechanism for FlexGroup datastores. This uses an improved copy engine to copy files between constituents in the background while allowing access on both source and destination. Multiple copies use instantly available, space-efficient file clones within a constituent when needed based on scale.

ONTAP 9.8 also adds new file-based performance metrics (IOPS, throughput, and latency) for FlexGroup files, and these metrics can be viewed in the ONTAP tools for VMware vSphere dashboard and VM reports. The ONTAP tools for VMware vSphere plug-in also allows you to set Quality of Service (QoS) rules using a combination of maximum and/or minimum IOPS. These can be set across all VMs in a datastore or individually for specific VMs.

Here are some additional best practices that NetApp has developed:

- Use FlexGroup provisioning defaults. While ONTAP tools for VMware vSphere is recommended because it creates and mounts the FlexGroup within vSphere, ONTAP System Manager or the command line might be used for special needs. Even then, use the defaults such as the number of constituent members per node because this is what has been tested with vSphere.
- When sizing a FlexGroup datastore, keep in mind that the FlexGroup consists of multiple smaller FlexVol volumes that create a larger namespace. As such, size the datastore to be at least 8x the size of your largest virtual machine. For example, if you have a 6TB VM in your environment, size the FlexGroup datastore no smaller than 48TB.
- Allow FlexGroup to manage datastore space. Autosize and Elastic Sizing have been tested with vSphere datastores. Should the datastore get close to full capacity, use ONTAP tools for VMware vSphere or another tool to resize the FlexGroup volume. FlexGroup keeps capacity and inodes balanced across constituents, prioritizing files within a folder (VM) to the same constituent if capacity allows.
- VMware and NetApp do not currently support a common multipath networking approach. For NFSv4.1, NetApp supports pNFS, whereas VMware supports session trunking. NFSv3 does not support multiple physical paths to a volume. For FlexGroup with ONTAP 9.8, our recommended best practice is to let ONTAP tools for VMware vSphere make the single mount, because the effect of indirect access is typically minimal (microseconds). It’s possible to use round-robin DNS to distribute ESXi hosts across LIFs on different nodes in the FlexGroup, but this would require the FlexGroup to be created and mounted without ONTAP tools for VMware vSphere. Then the performance management features would not be available.
- FlexGroup vSphere datastore support has been tested up to 1500 VMs with the 9.8 release.
- Use the NFS Plug-In for VMware VAAI for copy offload. Note that while cloning is enhanced within a FlexGroup datastore, ONTAP does not provide significant performance advantages versus ESXi host copy when copying VMs between FlexVol and/or FlexGroup volumes.

- Use ONTAP tools for VMware vSphere 9.8 to monitor performance of FlexGroup VMs using ONTAP metrics (dashboard and VM reports), and to manage QoS on individual VMs. These metrics are not currently available through ONTAP commands or APIs.
- QoS (max/min IOPS) can be set on individual VMs or on all VMs in a datastore at that time. Setting QoS on all VMs replaces any separate per-VM settings. Settings do not extend to new or migrated VMs in the future; either set QoS on the new VMs or re-apply QoS to all VMs in the datastore.
- SnapCenter Plug-In for VMware vSphere release 4.4 supports backup and recovery of VMs in a FlexGroup datastore on the primary storage system. While SnapMirror may be used manually to replicate a FlexGroup to a secondary system, SCV 4.4 does not manage the secondary copies.

Other capabilities for vSphere

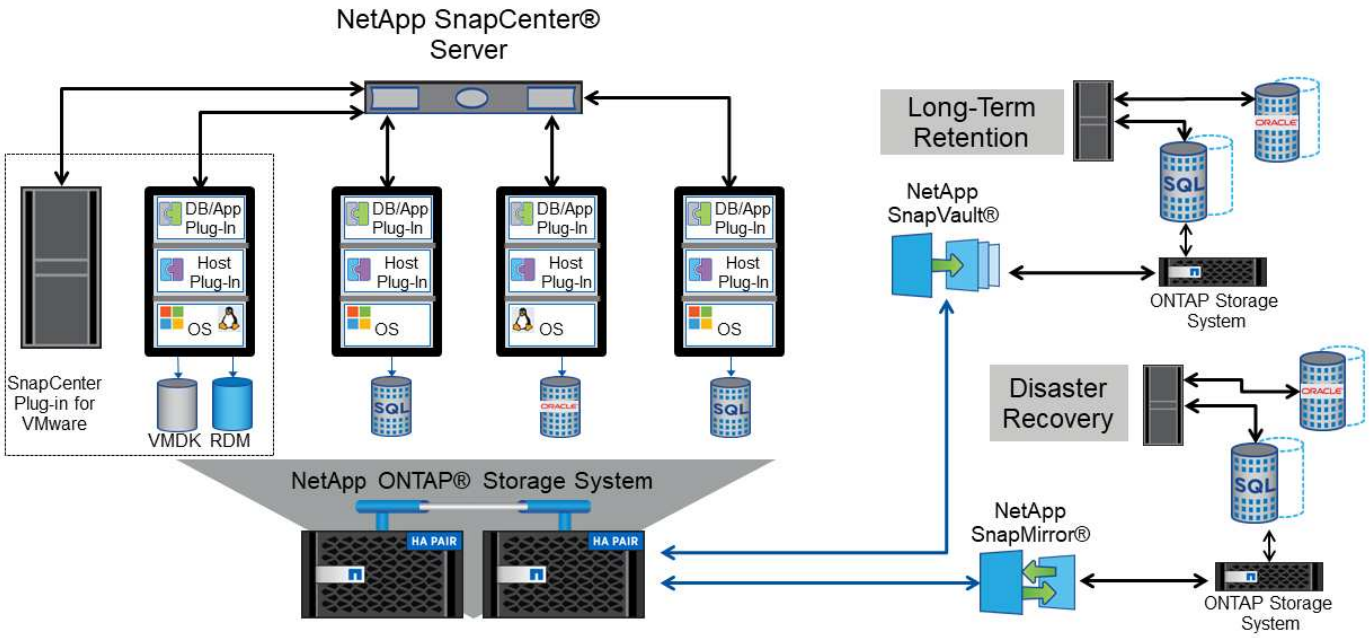
Data protection

Backing up your VMs and quickly recovering them are among the great strengths of ONTAP for vSphere, and it is easy to manage this ability inside vCenter with the SnapCenter Plug-In for VMware vSphere. Use Snapshot copies to make quick copies of your VM or datastore without affecting performance, and then send them to a secondary system using SnapMirror for longer-term off-site data protection. This approach minimizes storage space and network bandwidth by only storing changed information.

SnapCenter allows you to create backup policies that can be applied to multiple jobs. These policies can define schedule, retention, replication, and other capabilities. They continue to allow optional selection of VM-consistent snapshots, which leverages the hypervisor's ability to quiesce I/O before taking a VMware snapshot. However, due to the performance effect of VMware snapshots, they are generally not recommended unless you need the guest file system to be quiesced. Instead, use ONTAP Snapshot copies for general protection, and use application tools such as SnapCenter plug-ins to protect transactional data such as SQL Server or Oracle. These Snapshot copies are different from VMware (consistency) snapshots and are suitable for longer term protection. VMware snapshots are only recommended for short term use due to performance and other effects.

These plug-ins offer extended capabilities to protect the databases in both physical and virtual environments. With vSphere, you can use them to protect SQL Server or Oracle databases where data is stored on RDM LUNs, iSCSI LUNs directly connected to the guest OS, or VMDK files on either VMFS or NFS datastores. The plug-ins allow specification of different types of database backups, supporting online or offline backup, and protecting database files along with log files. In addition to backup and recovery, the plug-ins also support cloning of databases for development or test purposes.

The following figure depicts an example of SnapCenter deployment.



For enhanced disaster recovery capabilities, consider using the NetApp SRA for ONTAP with VMware Site Recovery Manager. In addition to support for the replication of datastores to a DR site, it also enables nondisruptive testing in the DR environment by cloning the replicated datastores. Recovery from a disaster and reprotecting production after the outage has been resolved are also made easy by automation built into SRA.

Finally, for the highest level of data protection, consider a VMware vSphere Metro Storage Cluster (vMSC) configuration using NetApp MetroCluster. vMSC is a VMware-certified solution that combines synchronous replication with array-based clustering, giving the same benefits of a high-availability cluster but distributed across separate sites to protect against site disaster. NetApp MetroCluster offers cost-effective configurations for synchronous replication with transparent recovery from any single storage component failure as well as single-command recovery in the event of a site disaster. vMSC is described in greater detail in TR-4128.

Space reclamation

Space can be reclaimed for other uses when VMs are deleted from a datastore. When using NFS datastores, space is reclaimed immediately when a VM is deleted (of course, this approach only makes sense when the volume is thin provisioned, that is, the volume guarantee is set to none). However, when files are deleted within the VM guest OS, space is not automatically reclaimed with an NFS datastore. For LUN-based VMFS datastores, ESXi as well as the guest OS can issue VAAI UNMAP primitives to the storage (again, when using thin provisioning) to reclaim space. Depending on the release, this support is either manual or automatic.

In vSphere 5.5 and later, the `vmkfstools -y` command is replaced by the `esxcli storage vmfs unmap` command, which specifies the number of free blocks (see VMware KB 2057513 for more info). In vSphere 6.5 and later when using VMFS 6, space should be automatically reclaimed asynchronously (see Storage Space Reclamation in the vSphere documentation), but can also be run manually if needed. This automatic UNMAP is supported by ONTAP, and ONTAP tools for VMware vSphere sets it to low priority. Keep in mind that, when provisioning a LUN for usage as a VMFS datastore, you must manually enable the space-allocation option on the LUN. When using ONTAP tools for VMware vSphere, the LUN is automatically configured to support space reclaimation and no further actions are required. See this knowledge base article for more details.

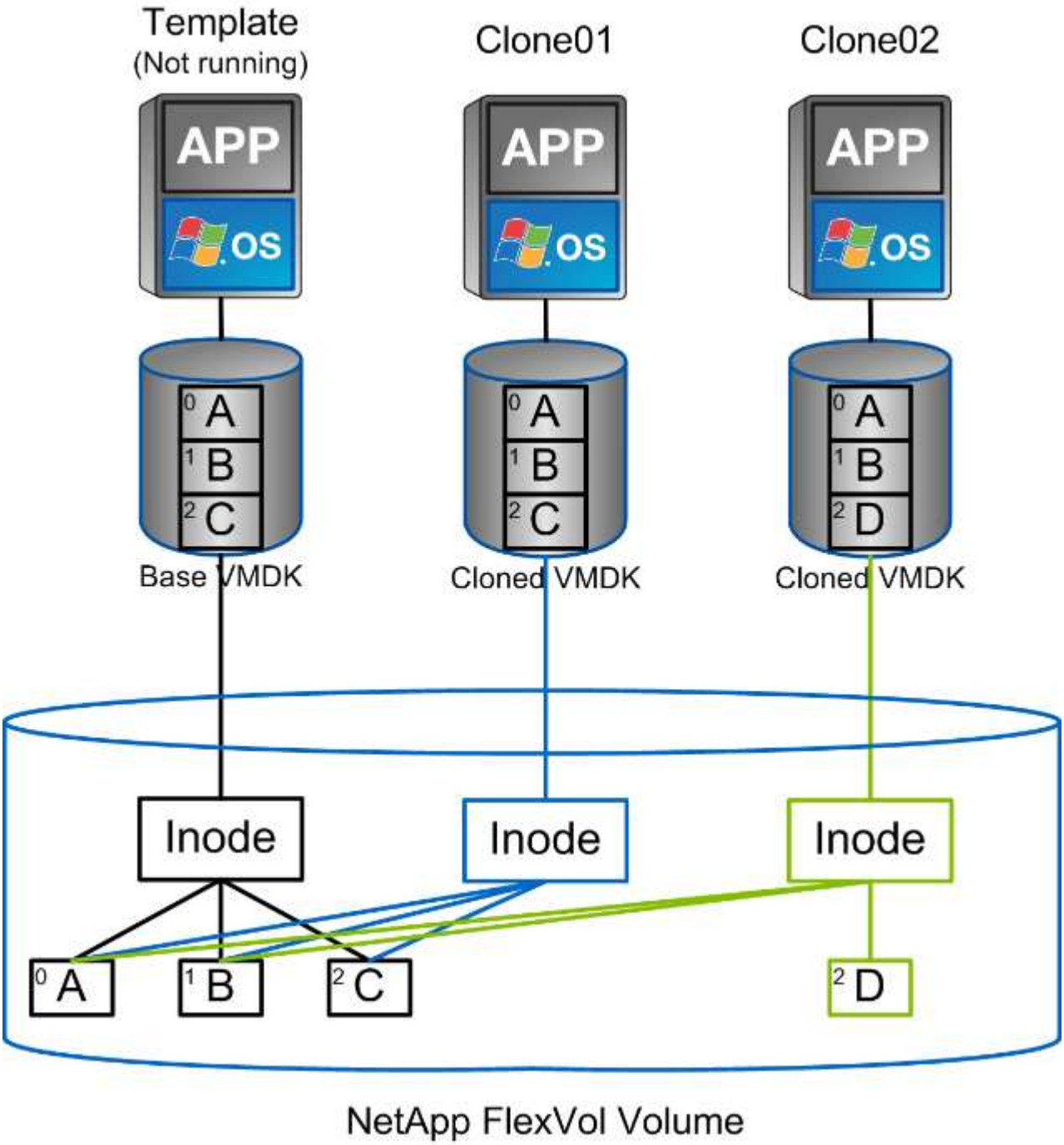
VM and datastore cloning

Cloning a storage object allows you to quickly create copies for further use, such as provisioning additional VMs, backup/recovery operations, and so on. In vSphere, you can clone a VM, virtual disk, vVol, or datastore.

After being cloned, the object can be further customized, often through an automated process. vSphere supports both full copy clones, as well as linked clones, where it tracks changes separately from the original object.

Linked clones are great for saving space, but they increase the amount of I/O that vSphere handles for the VM, affecting performance of that VM and perhaps the host overall. That's why NetApp customers often use storage system-based clones to get the best of both worlds: efficient use of storage and increased performance.

The following figure depicts ONTAP cloning.



Cloning can be offloaded to systems running ONTAP software through several mechanisms, typically at the VM, vVol, or datastore level. These include the following:

- vVols using the NetApp vSphere APIs for Storage Awareness (VASA) Provider. ONTAP clones are used to support vVol Snapshot copies managed by vCenter that are space-efficient with minimal I/O effect to create and delete them. VMs can also be cloned using vCenter, and these are also offloaded to ONTAP, whether within a single datastore/volume or between datastores/volumes.
- vSphere cloning and migration using vSphere APIs – Array Integration (VAAI). VM cloning operations can be offloaded to ONTAP in both SAN and NAS environments (NetApp supplies an ESXi plug-in to enable VAAI for NFS). vSphere only offloads operations on cold (powered off) VMs in a NAS datastore, whereas operations on hot VMs (cloning and storage vMotion) are also offloaded for SAN. ONTAP uses the most efficient approach based on source, destination, and installed product licenses. This capability is also used by VMware Horizon View.
- SRA (used with VMware Site Recovery Manager). Here, clones are used to test recovery of the DR replica nondisruptively.
- Backup and recovery using NetApp tools such as SnapCenter. VM clones are used to verify backup operations as well as to mount a VM backup so that individual files can be copied.

ONTAP offloaded cloning can be invoked by VMware, NetApp, and third-party tools. Clones that are offloaded to ONTAP have several advantages. They are space-efficient in most cases, needing storage only for changes to the object; there is no additional performance effect to read and write them, and in some cases performance is improved by sharing blocks in high-speed caches. They also offload CPU cycles and network I/O from the ESXi server. Copy offload within a traditional datastore using a FlexVol volume can be fast and efficient with FlexClone licensed, but copies between FlexVol volumes might be slower. If you maintain VM templates as a source of clones, consider placing them within the datastore volume (use folders or content libraries to organize them) for fast, space efficient clones.

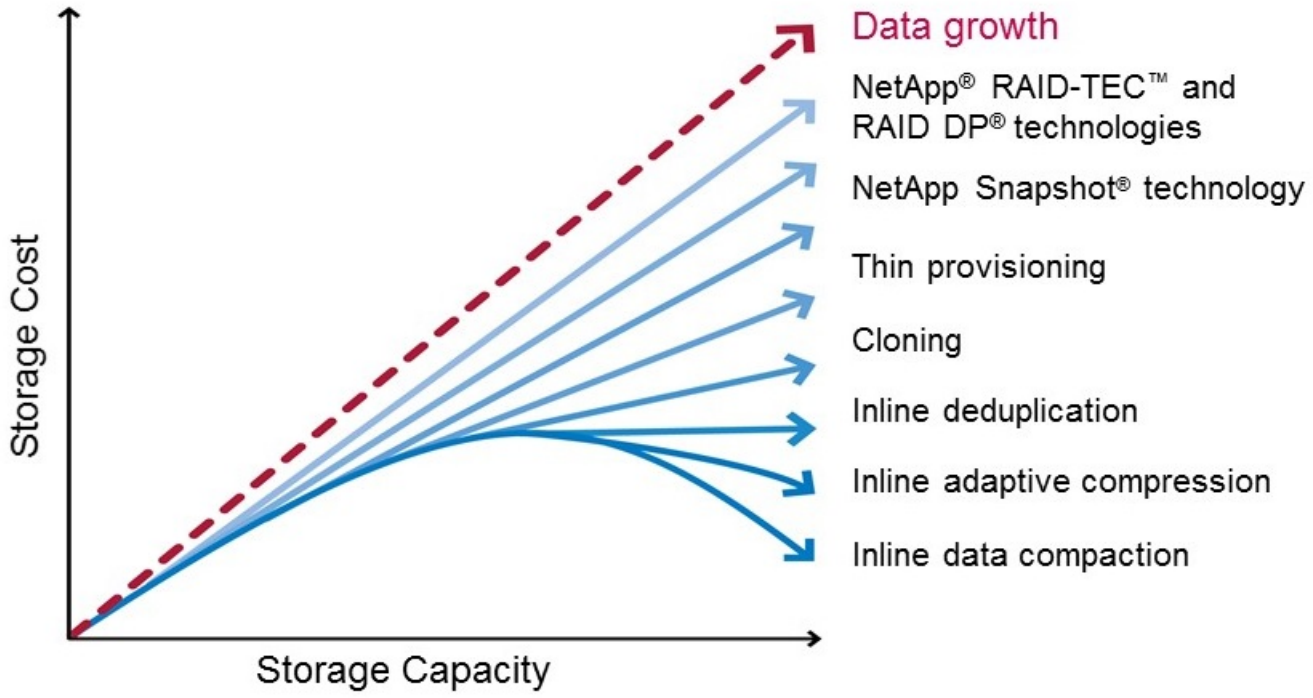
You can also clone a volume or LUN directly within ONTAP to clone a datastore. With NFS datastores, FlexClone technology can clone an entire volume, and the clone can be exported from ONTAP and mounted by ESXi as another datastore. For VMFS datastores, ONTAP can clone a LUN within a volume or a whole volume, including one or more LUNs within it. A LUN containing a VMFS must be mapped to an ESXi initiator group (igroup) and then resignatured by ESXi to be mounted and used as a regular datastore. For some temporary use cases, a cloned VMFS can be mounted without resignaturing. After a datastore is cloned, VMs inside it can be registered, reconfigured, and customized as if they were individually cloned VMs.

In some cases, additional licensed features can be used to enhance cloning, such as SnapRestore for backup or FlexClone. These licenses are often included in license bundles at no additional cost. A FlexClone license is required for vVol cloning operations as well as to support managed Snapshot copies of a vVol (which are offloaded from the hypervisor to ONTAP). A FlexClone license can also improve certain VAAI-based clones when used within a datastore/volume (creates instant, space-efficient copies instead of block copies). It is also used by the SRA when testing recovery of a DR replica, and SnapCenter for clone operations and to browse backup copies to restore individual files.

Storage efficiency and thin provisioning

NetApp has led the industry with storage-efficiency innovation such as the first deduplication for primary workloads, and inline data compaction, which enhances compression and stores small files and I/O efficiently. ONTAP supports both inline and background deduplication, as well as inline and background compression.

The following figure depicts the combined effect of ONTAP storage efficiency features.



Here are recommendations on using ONTAP storage efficiency in a vSphere environment:

- The amount of data deduplication savings realized is based on the commonality of the data. With ONTAP 9.1 and earlier, data deduplication operated at the volume level, but with aggregate deduplication in ONTAP 9.2 and later, data is deduplicated across all volumes in an aggregate on AFF systems. You no longer need to group similar operating systems and similar applications within a single datastore to maximize savings.
- To realize the benefits of deduplication in a block environment, the LUNs must be thin provisioned. Although the LUN is still seen by the VM administrator as taking the provisioned capacity, the deduplication savings are returned to the volume to be used for other needs. NetApp recommends deploying these LUNs in FlexVol volumes that are also thin provisioned (ONTAP tools for VMware vSphere size the volume about 5% larger than the LUN).
- Thin provisioning is also recommended (and is the default) for NFS FlexVol volumes. In an NFS environment, deduplication savings are immediately visible to both storage and VM administrators with thin-provisioned volumes.
- Thin provisioning applies to the VMs as well, where NetApp generally recommends thin-provisioned VMDKs rather than thick. When using thin provisioning, make sure you monitor available space with ONTAP tools for VMware vSphere, ONTAP, or other available tools to avoid out-of-space problems.
- Note that there is no performance penalty when using thin provisioning with ONTAP systems; data is written to available space so that write performance and read performance are maximized. Despite this fact, some products such as Microsoft failover clustering or other low-latency applications might require guaranteed or fixed provisioning, and it is wise to follow these requirements to avoid support problems.
- For maximum deduplication savings, consider scheduling background deduplication on hard disk-based systems or automatic background deduplication on AFF systems. However, the scheduled processes use system resources when running, so ideally they should be scheduled during less active times (such as weekends) or run more frequently to reduce the amount of changed data to be processed. Automatic background deduplication on AFF systems has much less effect on foreground activities. Background compression (for hard disk–based systems) also consumes resources, so it should only be considered for secondary workloads with limited performance requirements.

- NetApp AFF systems primarily use inline storage efficiency capabilities. When data is moved to them using NetApp tools that use block replication such as the 7-Mode Transition Tool, SnapMirror, or Volume Move, it can be useful to run compression and compaction scanners to maximize efficiency savings. Review this NetApp Support KB article for additional details.
- Snapshot copies might lock blocks that could be reduced by compression or deduplication. When using scheduled background efficiency or one-time scanners, make sure that they run and complete before the next Snapshot copy is taken. Review your Snapshot copies and retention to make sure you only retain needed Snapshot copies, especially before a background or scanner job is run.

The following table provide storage efficiency guidelines for virtualized workloads on different types of ONTAP storage:

Workload	Storage efficiency guidelines		
	AFF	Flash Pool	Hard Disk Drives
VDI and SVI	For primary and secondary workloads, use: • Adaptive inline compression • Inline deduplication • Background deduplication • Inline data compaction	For primary and secondary workloads, use: • Adaptive inline compression • Inline deduplication • Background deduplication • Inline data compaction	For primary workloads, use: • Background deduplication For secondary workloads, use: • Adaptive inline compression • Adaptive background compression • Inline deduplication • Background deduplication • Inline data compaction

Quality of service (QoS)

Systems running ONTAP software can use the ONTAP storage QoS feature to limit throughput in MBps and/or I/Os per second (IOPS) for different storage objects such as files, LUNs, volumes, or entire SVMs.

Throughput limits are useful in controlling unknown or test workloads before deployment to make sure they don’t affect other workloads. They can also be used to constrain a bully workload after it is identified. Minimum levels of service based on IOPS are also supported to provide consistent performance for SAN objects in ONTAP 9.2 and for NAS objects in ONTAP 9.3.

With an NFS datastore, a QoS policy can be applied to the entire FlexVol volume or individual VMDK files within it. With VMFS datastores using ONTAP LUNs, the QoS policies can be applied to the FlexVol volume that contains the LUNs or individual LUNs, but not individual VMDK files because ONTAP has no awareness of the VMFS file system. When using vVols, minimum and/or maximum QoS can be set on individual VMs using the storage capability profile and VM storage policy.

The QoS maximum throughput limit on an object can be set in MBps and/or IOPS. If both are used, the first limit reached is enforced by ONTAP. A workload can contain multiple objects, and a QoS policy can be applied to one or more workloads. When a policy is applied to multiple workloads, the workloads share the total limit of the policy. Nested objects are not supported (for example, files within a volume cannot each have their own policy). QoS minimums can only be set in IOPS.

The following tools are currently available for managing ONTAP QoS policies and applying them to objects:

- ONTAP CLI
- ONTAP System Manager
- OnCommand Workflow Automation
- Active IQ Unified Manager
- NetApp PowerShell Toolkit for ONTAP
- ONTAP tools for VMware vSphere VASA Provider

To assign a QoS policy to a VMDK on NFS, note the following guidelines:

- The policy must be applied to the `vmname- flat.vmdk` that contains the actual virtual disk image, not the `vmname.vmdk` (virtual disk descriptor file) or `vmname.vmx` (VM descriptor file).
- Do not apply policies to other VM files such as virtual swap files (`vmname.vswp`).
- When using the vSphere web client to find file paths (Datastore > Files), be aware that it combines the information of the `- flat.vmdk` and `. vmdk` and simply shows one file with the name of the `. vmdk` but the size of the `- flat.vmdk`. Add `-flat` into the file name to get the correct path.

To assign a QoS policy to a LUN, including VMFS and RDM, the ONTAP SVM (displayed as Vserver), LUN path, and serial number can be obtained from the Storage Systems menu on the ONTAP tools for VMware vSphere home page. Select the storage system (SVM), and then Related Objects > SAN. Use this approach when specifying QoS using one of the ONTAP tools.

Maximum and minimum QoS can be easily assigned to a vVol-based VM with ONTAP tools for VMware vSphere or Virtual Storage Console 7.1 and later. When creating the storage capability profile for the vVol container, specify a max and/or min IOPS value under the performance capability and then reference this SCP with the VM's storage policy. Use this policy when creating the VM or apply the policy to an existing VM.

FlexGroup datastores offer enhanced QoS capabilities when using ONTAP tools for VMware vSphere 9.8 and later. You can easily set QoS on all VMs in a datastore or on specific VMs. See the FlexGroup section of this report for more information.

ONTAP QoS and VMware SIOC

ONTAP QoS and VMware vSphere Storage I/O Control (SIOC) are complementary technologies that vSphere and storage administrators can use together to manage performance of vSphere VMs hosted on systems running ONTAP software. Each tool has its own strengths, as shown in the following table. Because of the different scopes of VMware vCenter and ONTAP, some objects can be seen and managed by one system and not the other.

Property	ONTAP QoS	VMware SIOC
When active	Policy is always active	Active when contention exists (datastore latency over threshold)
Type of units	IOPS, MBps	IOPS, shares
vCenter or application scope	Multiple vCenter environments, other hypervisors and applications	Single vCenter server
Set QoS on VM?	VMDK on NFS only	VMDK on NFS or VMFS
Set QoS on LUN (RDM)?	Yes	No

Property	ONTAP QoS	VMware SIOC
Set QoS on LUN (VMFS)?	Yes	No
Set QoS on volume (NFS datastore)?	Yes	No
Set QoS on SVM (tenant)?	Yes	No
Policy-based approach?	Yes; can be shared by all workloads in the policy or applied in full to each workload in the policy.	Yes, with vSphere 6.5 and later.
License required	Included with ONTAP	Enterprise Plus

VMware Storage Distributed Resource Scheduler

VMware Storage Distributed Resource Scheduler (SDRS) is a vSphere feature that places VMs on storage based on the current I/O latency and space usage. It then moves the VM or VMDKs nondisruptively between the datastores in a datastore cluster (also referred to as a pod), selecting the best datastore in which to place the VM or VMDKs in the datastore cluster. A datastore cluster is a collection of similar datastores that are aggregated into a single unit of consumption from the vSphere administrator's perspective.

When using SDRS with the NetApp ONTAP tools for VMware vSphere, you must first create a datastore with the plug-in, use vCenter to create the datastore cluster, and then add the datastore to it. After the datastore cluster is created, additional datastores can be added to the datastore cluster directly from the provisioning wizard on the Details page.

Other ONTAP best practices for SDRS include the following:

- All datastores in the cluster should use the same type of storage (such as SAS, SATA, or SSD), be either all VMFS or NFS datastores, and have the same replication and protection settings.
- Consider using SDRS in default (manual) mode. This approach allows you to review the recommendations and decide whether to apply them or not. Be aware of these effects of VMDK migrations:
  - When SDRS moves VMDKs between datastores, any space savings from ONTAP cloning or deduplication are lost. You can rerun deduplication to regain these savings.
  - After SDRS moves VMDKs, NetApp recommends recreating the Snapshot copies at the source datastore because space is otherwise locked by the VM that was moved.
  - Moving VMDKs between datastores on the same aggregate has little benefit, and SDRS does not have visibility into other workloads that might share the aggregate.

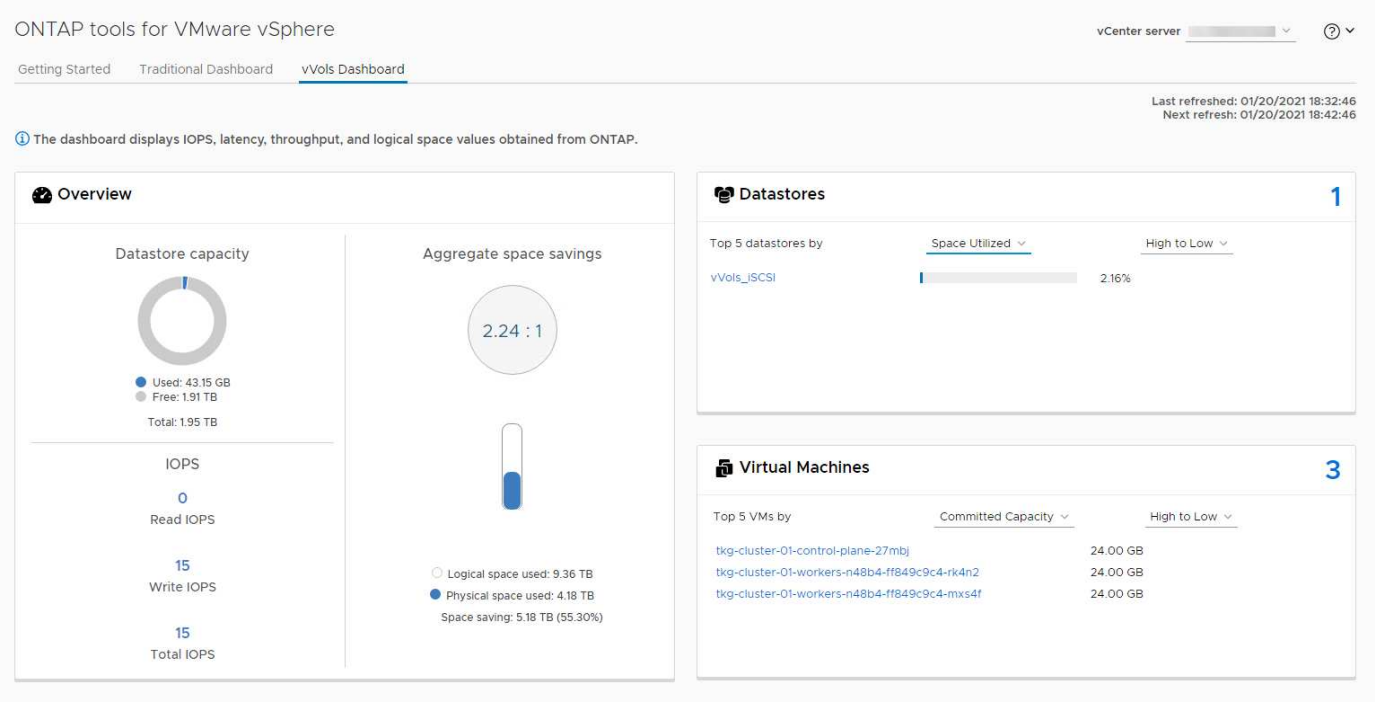
Storage policy-based management and vVols

VMware vSphere APIs for Storage Awareness (VASA) make it easy for a storage administrator to configure datastores with well-defined capabilities and let the VM administrator use those whenever needed to provision VMs without having to interact with each other. It's worth taking a look at this approach to see how it can streamline your virtualization storage operations and avoid a lot of trivial work.

Prior to VASA, VM administrators could define VM storage policies, but they had to work with the storage administrator to identify appropriate datastores, often by using documentation or naming conventions. With VASA, the storage administrator can define a range of storage capabilities, including performance, tiering, encryption, and replication. A set of capabilities for a volume or a set of volumes is called a storage capability profile (SCP).

The SCP supports minimum and/or maximum QoS for a VM's data vVols. Minimum QoS is supported only on AFF systems. ONTAP tools for VMware vSphere includes a dashboard that displays VM granular performance and logical capacity for vVols on ONTAP systems.

The following figure depicts ONTAP tools for VMware vSphere 9.8 vVols dashboard.



After the storage capability profile is defined, it can be used to provision VMs using the storage policy that identifies its requirements. The mapping between the VM storage policy and the datastore storage capability profile allows vCenter to display a list of compatible datastores for selection. This approach is known as storage policy-based management.

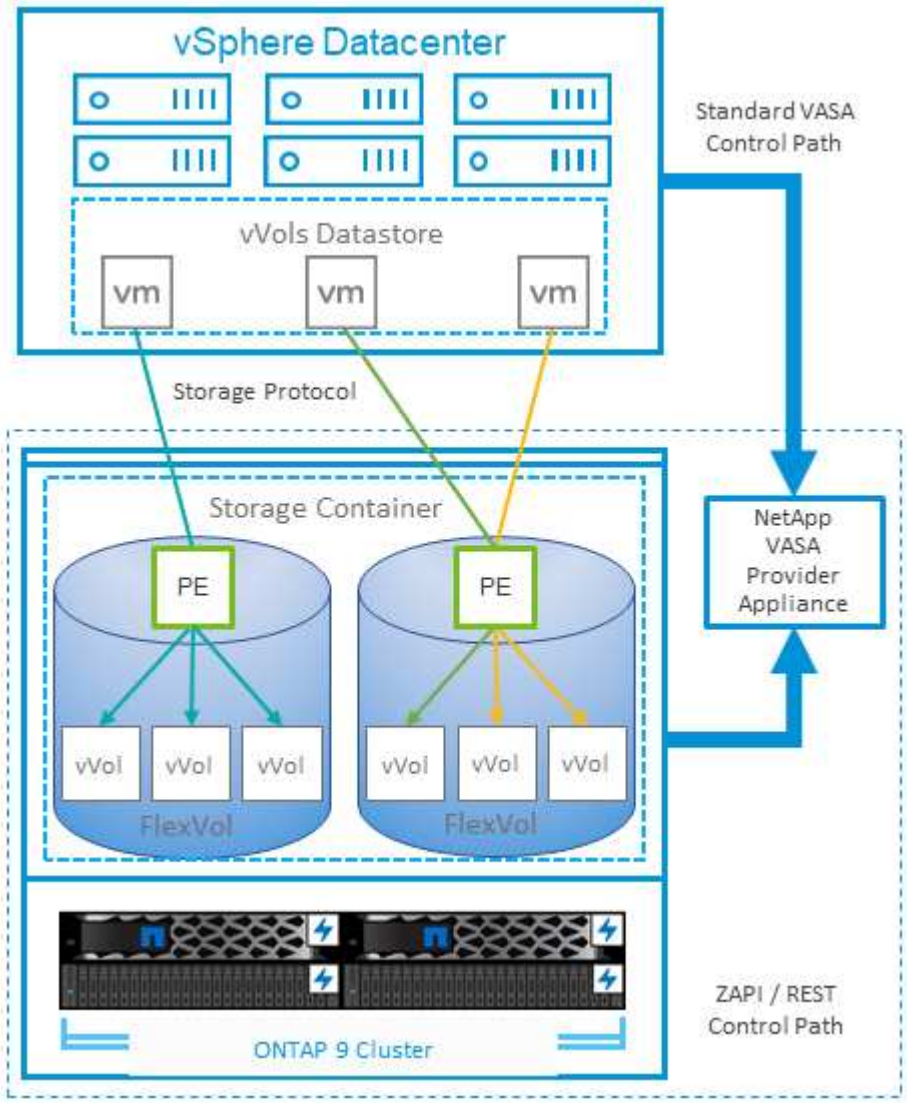
VASA provides the technology to query storage and return a set of storage capabilities to vCenter. VASA vendor providers supply the translation between the storage system APIs and constructs and the VMware APIs that are understood by vCenter. NetApp's VASA Provider for ONTAP is offered as part of the ONTAP tools for VMware vSphere appliance VM, and the vCenter plug-in provides the interface to provision and manage vVol datastores, as well as the ability to define storage capability profiles (SCPs).

ONTAP supports both VMFS and NFS vVol datastores. Using vVols with SAN datastores brings some of the benefits of NFS such as VM-level granularity. Here are some best practices to consider, and you can find additional information in TR-4400:

- A vVol datastore can consist of multiple FlexVol volumes on multiple cluster nodes. The simplest approach is a single datastore, even when the volumes have different capabilities. SPBM makes sure that a compatible volume is used for the VM. However, the volumes must all be part of a single ONTAP SVM and accessed using a single protocol. One LIF per node for each protocol is sufficient. Avoid using multiple ONTAP releases within a single vVol datastore because the storage capabilities might vary across releases.
- Use the ONTAP tools for VMware vSphere plug-in to create and manage vVol datastores. In addition to managing the datastore and its profile, it automatically creates a protocol endpoint to access the vVols if needed. If LUNs are used, note that LUN PEs are mapped using LUN IDs 300 and higher. Verify that the ESXi host advanced system setting `Disk.MaxLUN` allows a LUN ID number that is higher than 300 (the default is 1,024). Do this step by selecting the ESXi host in vCenter, then the Configure tab, and find `Disk.MaxLUN` in the list of Advanced System Settings.

- Do not install or migrate VASA Provider, vCenter Server (appliance or Windows based), or ONTAP tools for VMware vSphere itself onto a vVols datastore, because they are then mutually dependent, limiting your ability to manage them in the event of a power outage or other data center disruption.
- Back up the VASA Provider VM regularly. At a minimum, create hourly Snapshot copies of the traditional datastore that contains VASA Provider. For more about protecting and recovering the VASA Provider, see this KB article.

The following figure shows vVols components.



Cloud migration and backup

Another ONTAP strength is broad support for the hybrid cloud, merging systems in your on-premises private cloud with public cloud capabilities. Here are some NetApp cloud solutions that can be used in conjunction with vSphere:

- **Cloud Volumes.** NetApp Cloud Volumes Service for AWS or GCP and Azure NetApp Files for ANF provide high-performance, multi-protocol managed storage services in the leading public cloud environments. They can be used directly by VMware Cloud VM guests.
- **Cloud Volumes ONTAP.** NetApp Cloud Volumes ONTAP data management software delivers control, protection, flexibility, and efficiency to your data on your choice of cloud. Cloud Volumes ONTAP is cloud-

native data management software built on NetApp ONTAP storage software. Use together with Cloud Manager to deploy and manage Cloud Volumes ONTAP instances together with your on-premises ONTAP systems. Take advantage of advanced NAS and iSCSI SAN capabilities together with unified data management, including snapshot copies and SnapMirror replication.

- **Cloud Services.** Use Cloud Backup Service or SnapMirror Cloud to protect data from on-premises systems using public cloud storage. Cloud Sync helps migrate and keep your data in sync across NAS, object stores, and Cloud Volumes Service storage.
- **FabricPool.** FabricPool offers quick and easy tiering for ONTAP data. Cold blocks in Snapshot copies can be migrated to an object store in either public clouds or a private StorageGRID object store and are automatically recalled when the ONTAP data is accessed again. Or use the object tier as a third level of protection for data that is already managed by SnapVault. This approach can allow you to store more Snapshot copies of your VMs on primary and/or secondary ONTAP storage systems.
- **ONTAP Select.** Use NetApp software-defined storage to extend your private cloud across the Internet to remote facilities and offices, where you can use ONTAP Select to support block and file services as well as the same vSphere data management capabilities you have in your enterprise data center.

When designing your VM-based applications, consider future cloud mobility. For example, rather than placing application and data files together use a separate LUN or NFS export for the data. This allows you to migrate the VM and data separately to cloud services.

Encryption for vSphere data

Today, there are increasing demands to protect data at rest through encryption. Although the initial focus was on financial and healthcare information, there is growing interest in protecting all information, whether it's stored in files, databases, or other data types.

Systems running ONTAP software make it easy to protect any data with at-rest encryption. NetApp Storage Encryption (NSE) uses self-encrypting disk drives with ONTAP to protect SAN and NAS data. NetApp also offers NetApp Volume Encryption and NetApp Aggregate Encryption as a simple, software-based approach to encrypt volumes on any disk drives. This software encryption doesn't require special disk drives or external key managers and is available to ONTAP customers at no additional cost. You can upgrade and start using it without any disruption to your clients or applications, and they are validated to the FIPS 140-2 level 1 standard, including the onboard key manager.

There are several approaches for protecting the data of virtualized applications running on VMware vSphere. One approach is to protect the data with software inside the VM at the guest OS level. Newer hypervisors such as vSphere 6.5 now support encryption at the VM level as another alternative. However, NetApp software encryption is simple and easy and has these benefits:

- **No effect on the virtual server CPU.** Some virtual server environments need every available CPU cycle for their applications, yet tests have shown up to 5x CPU resources are needed with hypervisor-level encryption. Even if the encryption software supports Intel's AES-NI instruction set to offload encryption workload (as NetApp software encryption does), this approach might not be feasible due to the requirement for new CPUs that are not compatible with older servers.
- **Onboard key manager included.** NetApp software encryption includes an onboard key manager at no additional cost, which makes it easy to get started without high-availability key management servers that are complex to purchase and use.
- **No effect on storage efficiency.** Storage efficiency techniques such as deduplication and compression are widely used today and are key to using flash disk media cost-effectively. However, encrypted data cannot typically be deduplicated or compressed. NetApp hardware and storage encryption operate at a lower level and allow full use of industry-leading NetApp storage efficiency features, unlike other approaches.

- **Easy datastore granular encryption.** With NetApp Volume Encryption, each volume gets its own AES 256-bit key. If you need to change it, you can do so with a single command. This approach is great if you have multiple tenants or need to prove independent encryption for different departments or apps. This encryption is managed at the datastore level, which is a lot easier than managing individual VMs.

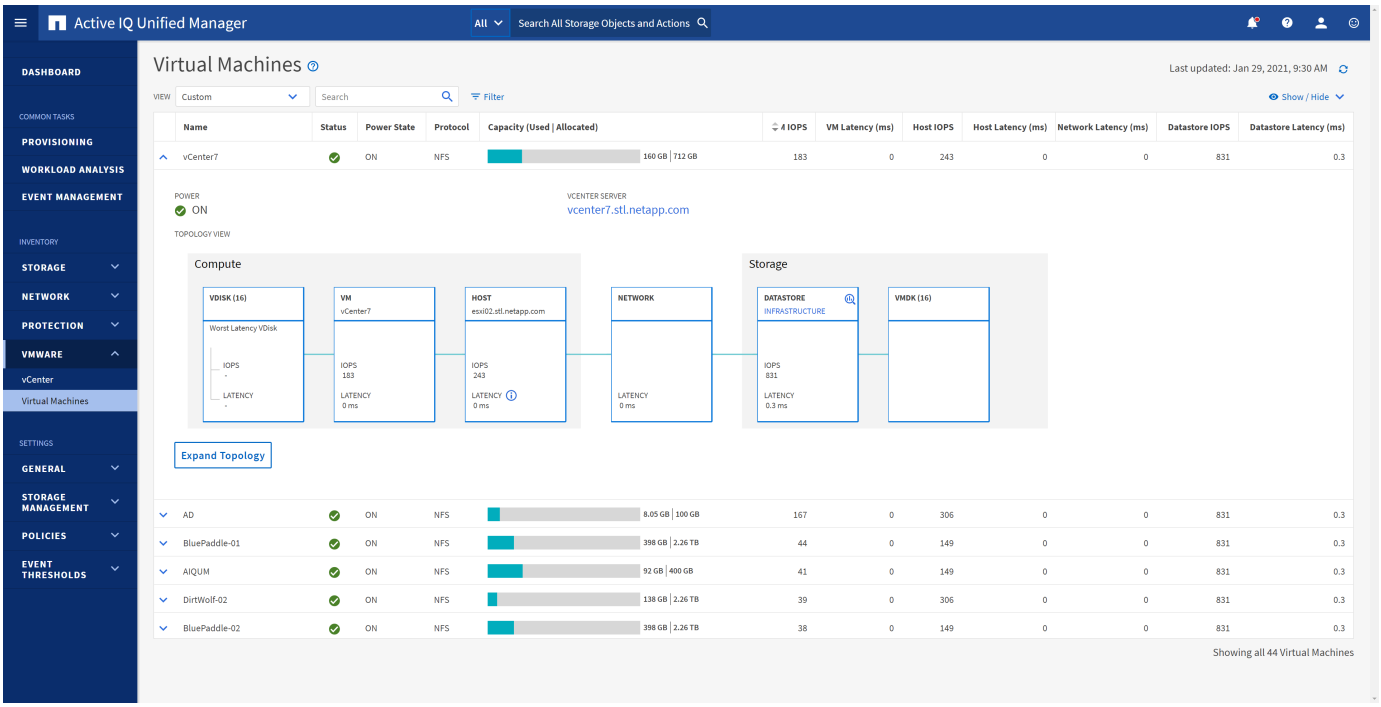
It's simple to get started with software encryption. After the license is installed, simply configure the onboard key manager by specifying a passphrase and then either create a new volume or do a storage-side volume move to enable encryption. NetApp is working to add more integrated support for encryption capabilities in future releases of its VMware tools.

Active IQ Unified Manager

Active IQ Unified Manager provides visibility into the VMs in your virtual infrastructure and enables monitoring and troubleshooting storage and performance issues in your virtual environment.

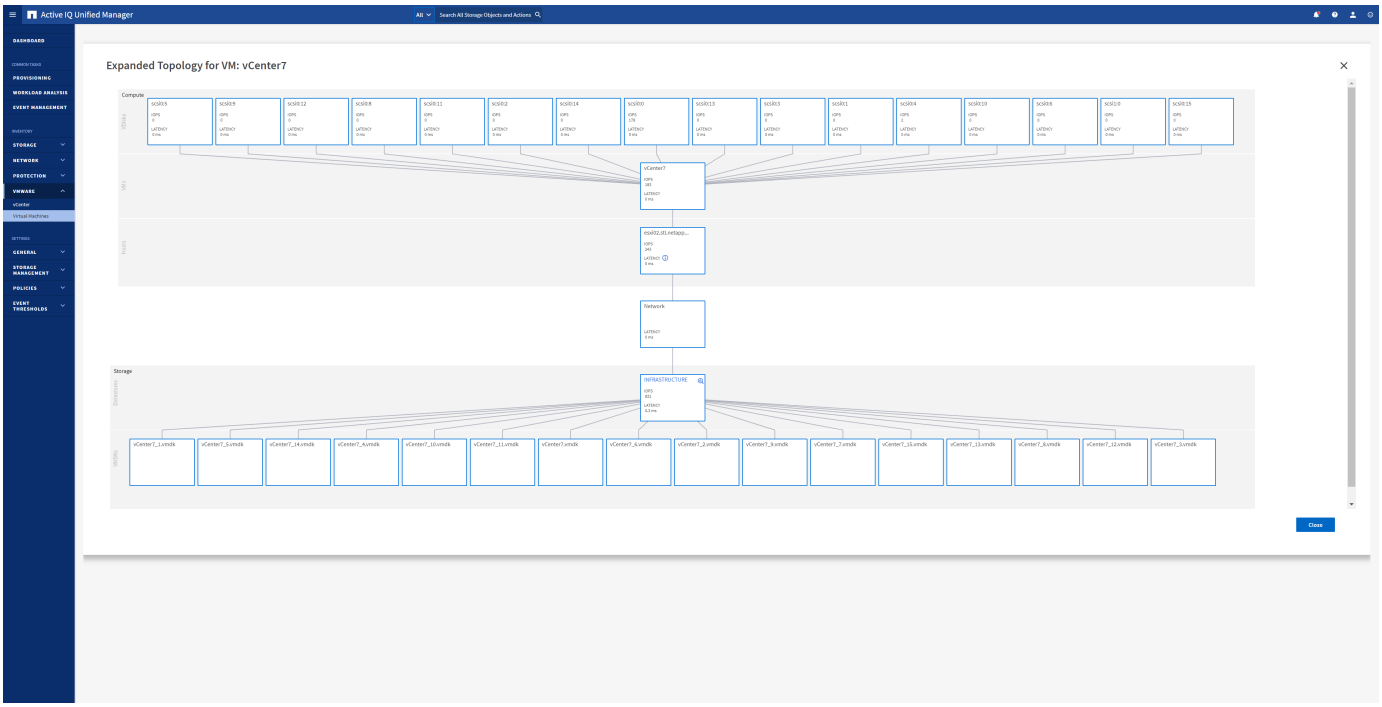
A typical virtual infrastructure deployment on ONTAP has various components that are spread across compute, network, and storage layers. Any performance lag in a VM application might occur due to a combination of latencies faced by the various components at the respective layers.

The following screenshot shows the Active IQ Unified Manager Virtual Machines view.



Unified Manager presents the underlying sub-system of a virtual environment in a topological view for determining whether a latency issue has occurred in the compute node, network, or storage. The view also highlights the specific object that causes the performance lag for taking remedial steps and addressing the underlying issue.

The following screenshot shows the AIQUM expanded topology.



ONTAP and vSphere release-specific information

This section provides guidance on capabilities supported by specific releases of ONTAP and vSphere. NetApp recommends confirming a specific combination of releases with the NetApp Interoperability Matrix.

ONTAP releases

At the time of publication, NetApp provides full support for these release families:

- ONTAP 9.5
- ONTAP 9.6
- ONTAP 9.7
- ONTAP 9.8

vSphere and ESXi support

NetApp ONTAP has broad support for vSphere ESXi hosts. The four major release families just described (9.5, 9.6, 9.7, and 9.8) are fully supported as data storage platforms for recent vSphere releases, including 6.0, 6.5, and 7.0 (including updates for these releases). NFS v3 interoperability is broadly defined, and NetApp supports any client, including hypervisors, that is compliant with the NFS v3 standard. NFSv4.1 support is limited to vSphere 6.0 through 7.0.

For SAN environments, NetApp conducts extensive testing of SAN components. In general, NetApp supports standard X86-64 rack servers and Cisco UCS servers together with standard Ethernet adapters for iSCSI connections. FC, FCoE, and NVMe/FC environments have more specifically defined support due to the HBA firmware and drivers needed.

Always check the NetApp Interoperability Matrix to confirm support for a specific hardware and software configuration.

NFS Plug-In for VMware VAAI

This plug-in for ESXi hosts helps by offloading operations to ONTAP using VAAI. The latest release, 1.1.2, includes support for NFSv4.1 datastores, including Kerberos (krb5 and krb5i) support. It is supported with ESXi 6.0, 6.5, and 7.0 together with ONTAP 9.5-9.8.

VASA Provider

NetApp's VASA Provider supports vVol provisioning and management (see section 3.7). Recent VASA Provider releases support ESXi 6.0, 6.5, and 7.0 together with ONTAP 9.5-9.8.

ONTAP tools for VMware vSphere

ONTAP tools for VMware vSphere is key for managing ONTAP storage together with vSphere (using it is a best practice). The latest release, 9.8, is supported with vSphere 6.5 and 7.0 together with ONTAP 9.5-9.8.

Recommended ESXi host and other ONTAP settings

NetApp has developed a set of ESXi host multipathing and HBA timeout settings for proper behavior with ONTAP based on NetApp testing. These are easily set using ONTAP tools for VMware vSphere. From the Summary dashboard, click Edit Settings in the Host Systems portlet or right-click the host in vCenter, then navigate to ONTAP tools > Set Recommended Values. Here are the currently recommended host settings with the 9.8 release.

Host Setting	NetApp Recommended Value	Reboot Required
ESXi Advanced Configuration		
VMFS3.HardwareAcceleratedLocking	Leave as set (VMware default is 1)	No
VMFS3.EnableBlockDelete	Leave as set (VMware default is 0, but this is not needed for VMFS6). For more information, see VMware KB 2007427	No
NFS Settings		
Net.TcpipHeapSize	vSphere 6.0 or later, set to 32. All other NFS configurations, set to 30	Yes
Net.TcpipHeapMax	Set to 512MB for most vSphere 6.X releases. Set to 1024MB for 6.5U3, 6.7U3, and 7.0 or later.	Yes
NFS.MaxVolumes	vSphere 6.0 or later, set to 256 All other NFS configurations, set to 64.	No
NFS41.MaxVolumes	vSphere 6.0 or later, set to 256.	No
NFS.MaxQueueDepth[1]	vSphere 6.0 or later, set to 128	Yes
NFS.HeartbeatMaxFailures	Set to 10 for all NFS configurations	No
NFS.HeartbeatFrequency	Set to 12 for all NFS configurations	No
NFS.HeartbeatTimeout	Set to 5 for all NFS configurations.	No
SunRPC.MaxConnPerIP	vSphere 7.0 or later, set to 128.	No

FC/FCoE Settings		
Path selection policy	Set to RR (round robin) when FC paths with ALUA are used. Set to FIXED for all other configurations. Setting this value to RR helps provide load balancing across all active/optimized paths. The value FIXED is for older, non-ALUA configurations and helps prevent proxy I/O. In other words, it helps keep I/O from going to the other node of a high-availability (HA) pair in an environment that has Data ONTAP operating in 7-Mode	No
Disk.QFullSampleSize	Set to 32 for all configurations. Setting this value helps prevent I/O errors.	No
Disk.QFullThreshold	Set to 8 for all configurations. Setting this value helps prevent I/O errors.	No
Emulex FC HBA timeouts	Use the default value.	No
QLogic FC HBA timeouts	Use the default value.	No
iSCSI Settings		
Path selection policy	Set to RR (round robin) for all iSCSI paths. Setting this value to RR helps provide load balancing across all active/optimized paths.	No
Disk.QFullSampleSize	Set to 32 for all configurations. Setting this value helps prevent I/O errors	No
Disk.QFullThreshold	Set to 8 for all configurations. Setting this value helps prevent I/O errors.	No

1 - NFS advanced configuration option MaxQueueDepth may not work as intended when using VMware vSphere ESXi 7.0.1 and VMware vSphere ESXi 7.0.2. Please reference VMware KB 86331 for more information.

ONTAP tools also specify certain default settings when creating ONTAP FlexVol volumes and LUNs:

ONTAP Tool	Default Setting
Snapshot reserve (-percent-snapshot-space)	0
Fractional reserve (-fractional-reserve)	0
Access time update (-atime-update)	False
Minimum readahead (-min-readahead)	False
Scheduled Snapshot copies	None
Storage efficiency	Enabled
Volume guarantee	None (thin provisioned)
Volume Autosize	grow_shrink
LUN space reservation	Disabled

LUN space allocation	Enabled

Other host multipath configuration considerations

While not currently configured by available ONTAP tools, NetApp suggests considering these configuration options:

- In high-performance environments or when testing performance with a single LUN datastore, consider changing the load balance setting of the round-robin (VMW_PSP_RR) path selection policy (PSP) from the default IOPS setting of 1000 to a value of 1. See VMware KB 2069356 for more info.
- In vSphere 6.7 Update 1, VMware introduced a new latency load balance mechanism for the Round Robin PSP. The new option considers I/O bandwidth and path latency when selecting the optimal path for I/O. You might benefit from using it in environments with non-equivalent path connectivity, such as cases where there are more network hops on one path than another, or when using a NetApp All SAN Array system. See Path Selection Plug-Ins and Policies for more information.

Where to find additional information

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

- VMware Product Documentation
  https://www.vmware.com/support/pubs/
- NetApp Product Documentation
  https://docs.netapp.com

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Do you have comments about this technical report?

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TR-4400: VMware vSphere Virtual Volumes (vVols) with NetApp ONTAP

Author(s): Chance Bingen, NetApp

Why vVols for vSphere?

NetApp ONTAP® software has been a leading storage solution for VMware vSphere environments for over two decades and continues to add innovative capabilities to simplify management while reducing costs. This document covers ONTAP capabilities for VMware vSphere Virtual Volumes (vVols), including the latest product information and use cases along with best practices and other information to streamline deployment and reduce errors.

Best practices supplement other documents such as guides and compatibility lists. They are developed based on lab testing and extensive field experience by NetApp engineers and customers. They might not be the only practices that work or are supported but are generally the simplest solutions that meet the needs of most customers.

This document has been updated to include new vVols features found in vSphere 8.0 update 1 which are supported with the ONTAP tools 9.12 release.

Virtual Volumes (vVols) Overview

NetApp began working with VMware to support vSphere APIs for Storage Awareness (VASA) for vSphere 5 in 2012. This early VASA Provider allowed for the definition of storage capabilities in a profile that could be used to filter datastores when provisioning and for checking compliance with the policy afterwards. Over time this evolved to add new capabilities to enable more automation in provisioning, as well as adding Virtual Volumes or vVols, where individual storage objects are used for virtual machine files and virtual disks. These objects could be LUNs, files, and now with vSphere 8 - NVMe namespaces.NetApp worked closely with VMware as a reference partner for vVols released with vSphere 6 in 2015, and again as a design partner for vVols using NVMe over fabrics in vSphere 8. NetApp continues to enhance vVols to take advantage of the latest capabilities in ONTAP.

There are several components to be aware of:

VASA Provider	This is the software component that handles communication between VMware vSphere and the storage system. For ONTAP, the VASA Provider runs in an appliance known as ONTAP tools for VMware vSphere (ONTAP tools for short). ONTAP tools also includes a vCenter plugin, a storage replication adapter (SRA) for VMware Site Recovery Manager, and REST API server for building your own automation. Once ONTAP tools is configured and registered with vCenter, there is little need to directly interact with the ONTAP system anymore, since nearly all of your storage needs can be managed from directly within the vCenter UI, or through REST API automation.
Protocol Endpoint (PE)	The protocol endpoint is a proxy for I/O between the ESXi hosts and the vVols datastore. The ONTAP VASA Provider creates these automatically, either one protocol endpoint LUN (4MB in size) per FlexVol® volume of the vVols datastore, or one NFS mount point per NFS interface (LIF) on the storage node hosting a FlexVol volume in the datastore. The ESXi host mounts these protocol endpoints directly rather than individual vVol LUNs and virtual disk files. There is no need to manage the protocol endpoints as they are created, mounted, unmounted, and deleted automatically by the VASA Provider, along with any necessary interface groups or export policies.
Virtual Protocol Endpoint (vPE)	New in vSphere 8, when using NVMe over Fabrics (NVMe-oF) with vVols, the concept of a protocol endpoint is no longer relevant in ONTAP. Instead, a virtual PE is instantiated automatically by the ESXi host for each ANA group as soon as the first VM is powered on. ONTAP automatically creates ANA groups for each FlexVol volume used by the datastore. An additional advantage to using NVMe-oF for vVols is that there are no bind requests required of the VASA Provider. Instead, the ESXi host handles vVol binding functionality internally based on the vPE. This reduces the opportunity for a vVol bind storm to impact service. For more information, see NVMe and Virtual Volumes on VMware.com
Virtual Volume Datastore	The Virtual Volume datastore is a logical datastore representation of a vVols container which is created and maintained by a VASA Provider. The container represents a pool of storage capacity provisioned from storage systems managed by the VASA Provider. ONTAP tools supports allocating multiple FlexVol volumes (referred to as backing volumes) to a single vVols datastore, and these vVols datastores can span multiple nodes in an ONTAP cluster, combining flash and hybrid systems with different capabilities. The administrator may create new FlexVol volumes using the provisioning wizard or REST API, or select pre-created FlexVol volumes for backing storage if they are available.

Virtual Volumes (vVols)	vVols are the actual virtual machine files and disks stored in the vVols datastore. Using the term vVol (singular) is referring to a single specific file, LUN, or namespace. ONTAP creates NVMe namespaces, LUNs or files depending on what protocol the datastore uses. There are several distinct types of vVols; most common are Config (metadata files), Data (virtual disk or VMDK), and Swap (created when VM is powered on). vVols protected by VMware VM encryption will be of type Other. VMware VM encryption should not be confused with ONTAP volume or aggregate encryption.

Policy-Based Management

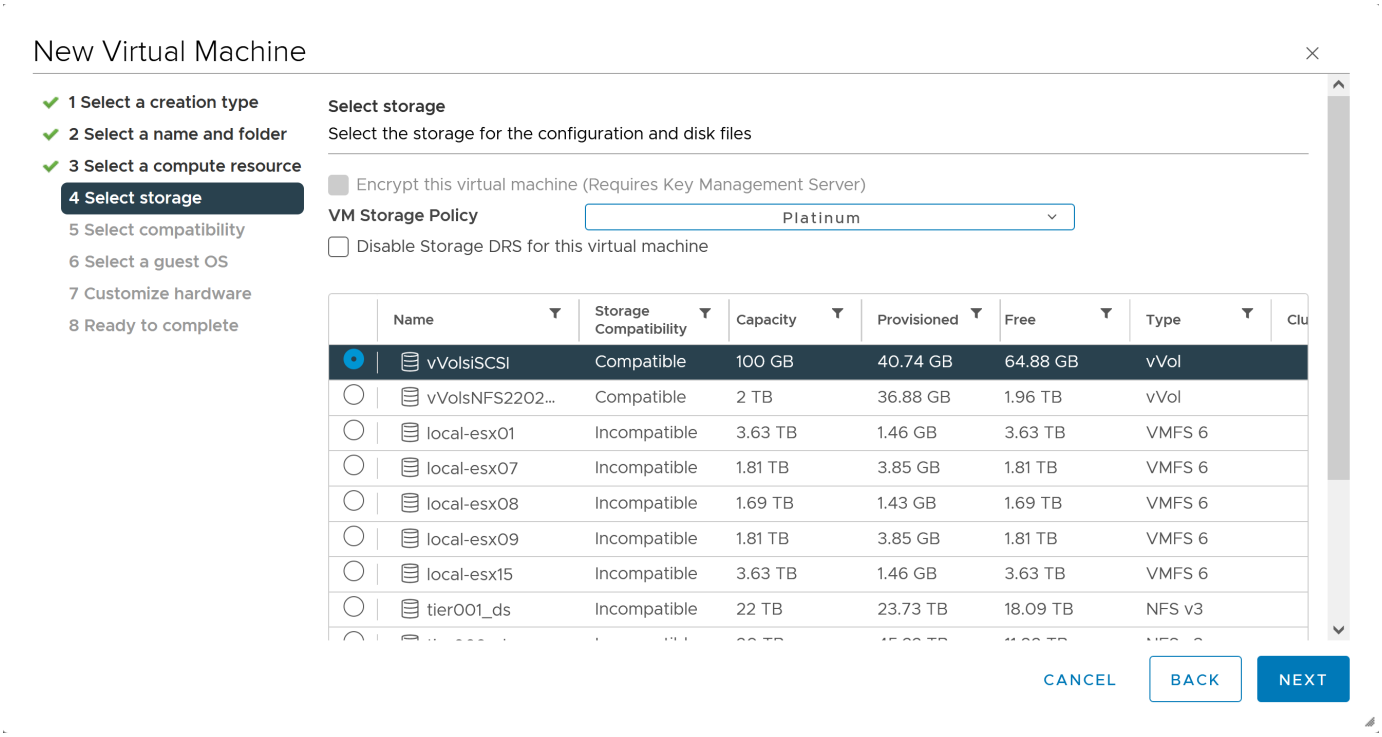
VMware vSphere APIs for Storage Awareness (VASA) make it easy for a VM administrator to use whatever storage capabilities are needed to provision VMs without having to interact with their storage team. Prior to VASA, VM administrators could define VM storage policies, but had to work with their storage administrators to identify appropriate datastores, often by using documentation or naming conventions. With VASA, vCenter administrators with the appropriate permissions can define a range of storage capabilities which vCenter users can then use to provision VMs. The mapping between VM storage policy and datastore storage capability profile allows vCenter to display a list of compatible datastores for selection, as well as enabling other technologies like Aria (formerly known as vRealize) Automation or Tanzu Kubernetes Grid to automatically select storage from an assigned policy. This approach is known as storage policy-based management. While storage capability profiles and policies may also be used with traditional datastores, our focus here is on vVols datastores.

There are two elements:

1. **Storage Capability Profile (SCP)**
   A storage capability profile (SCP) is a form of storage template that allows the vCenter admin to define what storage features they require without actually needing to understand how to manage those features in ONTAP. By taking a template style approach, it allows the admin to easily deliver storage services in a consistent and predictable way. Capabilities described in an SCP include performance, protocol, storage efficiency, and other features. Specific features vary by version. They are created using the ONTAP tools for VMware vSphere menu within the vCenter UI. You can also use REST APIs to create SCPs. They may be manually created by selecting individual capabilities, or automatically generated from existing (traditional) datastores.
2. **VM Storage Policy**
   VM Storage Policies are created in vCenter under Policies and Profiles. For vVols, create a ruleset using rules from the NetApp vVols storage type provider. ONTAP tools provides a simplified approach by allowing you to simply select an SCP rather than forcing you to specify individual rules.

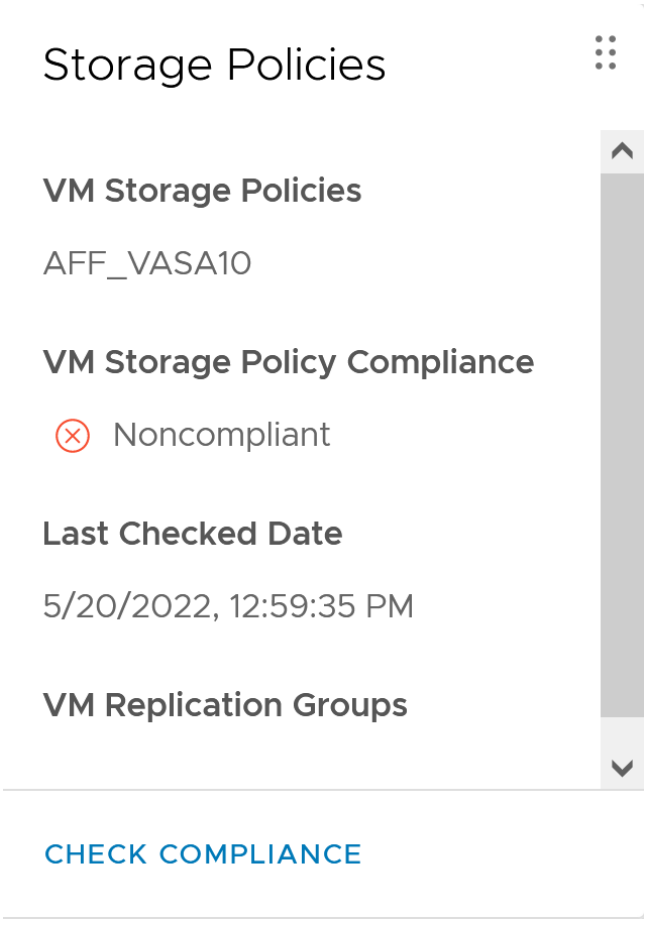
As mentioned above, using policies can help streamline the task of provisioning a volume. Simply select an appropriate policy, and the VASA Provider will show vVols datastores that support that policy and place the vVol into an individual FlexVol volume that is compliant (Figure 1).

Deploy VM using Storage Policy



Once a VM is provisioned, the VASA Provider will continue to check compliance, and alert the VM administrator with an alarm in vCenter when the backing volume is no longer compliant with the policy (Figure 2).

VM Storage Policy Compliance



NetApp vVols Support

NetApp ONTAP has supported the VASA specification since its initial release in 2012. While other NetApp storage systems may support VASA, this document focuses on currently supported releases of ONTAP 9.

NetApp ONTAP

In addition to ONTAP 9 on AFF, ASA, and FAS systems, NetApp supports VMware workloads on ONTAP Select, Amazon FSx for NetApp ONTAP with VMware Cloud on AWS, Azure NetApp Files with Azure VMware Solution, Cloud Volumes Service with Google Cloud VMware Engine, and NetApp Private Storage in Equinix, but specific functionality may vary based on service provider and available network connectivity. Access from vSphere guests to data stored in those configurations as well as Cloud Volumes ONTAP is also available.

At the time of publication, hyperscaler environments are limited to traditional NFS v3 datastores only, therefore, vVols are only available with on-premises ONTAP systems, or cloud connected systems that offer the full functionality of an on-premises systems such as those hosted by NetApp partners and services providers around the world.

For more information about ONTAP, see ONTAP product documentation

For more information about ONTAP and VMware vSphere best practices, see TR-4597

Benefits of Using vVols with ONTAP

When VMware introduced vVols support with VASA 2.0 in 2015 they described it as “an integration and management framework delivering a new operational model for external storage (SAN/NAS).” This operational model offers several benefits together with ONTAP storage.

Policy-Based Management

As covered in section 1.2, policy-based management allows VMs to be provisioned and subsequently managed using pre-defined policies. This can help IT operations in several ways:

- **Increase velocity.** ONTAP tools eliminates the requirement for the vCenter administrator to open tickets with the storage team for storage provisioning activities. However, ONTAP tools RBAC roles in vCenter and on the ONTAP system still allow for independent teams (such as storage teams), or independent activities by the same team by restricting access to specific functions if desired.
- **Smarter provisioning.** Storage system capabilities can be exposed through the VASA APIs, allowing provisioning workflows to take advantage of advanced capabilities without the VM administrator needing to understand how to manage the storage system.
- **Faster provisioning.** Different storage capabilities can be supported in a single datastore and automatically selected as appropriate for a VM based on the VM policy.
- **Avoid mistakes.** Storage and VM policies are developed in advance and applied as needed without having to customize storage each time a VM is provisioned. Compliance alarms are raised when storage capabilities drift from the defined policies. As previously mentioned, SCPs make the initial provisioning predictable and repeatable, while basing VM storage policies on the SCPs guarantees accurate placement.
- **Better capacity management.** VASA and ONTAP tools make it possible to view storage capacity down to the induvial aggregate level if needed and provide multiple layers of alerting in the event capacity starts to run low.

VM Granular Management on the modern SAN

SAN storage systems using Fibre Channel and iSCSI were the first to be supported by VMware for ESX, but

they have lacked the ability to manage individual VM files and disks from the storage system. Instead, LUNs are provisioned and VMFS manages the individual files. This makes it difficult for the storage system to directly manage individual VM storage performance, cloning, and protection. vVols bring storage granularity that customers using NFS storage already enjoy, with the robust, high performance SAN capabilities of ONTAP.

Now, with vSphere 8 and ONTAP tools for VMware vSphere 9.12 and later, those same granular controls used by vVols for legacy SCSI based protocols are now available in the modern Fibre Channel SAN using NVMe over Fabrics for even greater performance at scale. With vSphere 8.0 update 1, it is now possible to deploy a complete end-to-end NVMe solution using vVols without any I/O translation in the hypervisor storage stack.

Greater Storage Offload Capabilities

While VAAI offers a variety of operations that are offloaded to storage, there are some gaps that are addressed by the VASA Provider. SAN VAAI is not able to offload VMware managed snapshots to the storage system. NFS VAAI can offload VM managed snapshots, but there are limitations placed a VM with storage native snapshots. Since vVols use individual LUNs, namespaces, or files for virtual machine disks, ONTAP can quickly and efficiently clone the files or LUNs to create VM-granular snapshots that no longer require delta files. NFS VAAI also does not support offloading clone operations for hot (powered on) Storage vMotion migrations. The VM must be powered off to allow offload of the migration when using VAAI with traditional NFS datastores. The VASA Provider in ONTAP tools allows for near instant, storage efficient clones for hot and cold migrations, and it also supports near instant copies for cross-volume migrations of vVols. Because of these significant storage efficiency benefits, you may be able to take full advantage of vVols workloads under the Efficiency Guarantee program. Likewise, if cross volume clones using VAAI don't meet your requirements, you will likely be able to solve your business challenge thanks to the improvements in the copy experience with vVols.

Common Use Cases for vVols

In addition to these benefits, we also see these common use cases for vVol storage:

- **On-Demand Provisioning of VMs**
  - Private cloud or service provider IaaS.
  - Leverage automation and orchestration via the Aria (formerly vRealize) suite, OpenStack, etc.
- **First Class Disks (FCDs)**
  - VMware Tanzu Kubernetes Grid [TKG] persistent volumes.
  - Provide Amazon EBS-like services though independent VMDK lifecycle management.
- **On-Demand Provisioning of Temporary VMs**
  - Test/dev labs
  - Training environments

Common benefits with vVols

When used to their full advantage, such as in the above use cases, vVols provide the following specific improvements:

- Clones are quickly created within a single volume, or across multiple volumes in an ONTAP cluster, which is an advantage when compared to traditional VAAI enabled clones. They are also storage efficient. Clones within a volume use ONTAP file clone, which are like FlexClone® volumes and only store changes from the source vVol file/LUN/namespace. So long-term VMs for production or other application purposes are created quickly, take minimal space, and can benefit from VM level protection (using NetApp SnapCenter plugin for VMware vSphere, VMware managed snapshots or VADP backup) and performance management (with ONTAP QoS).

- vVols are the ideal storage technology when using TKG with the vSphere CSI, providing discrete storage classes and capacities managed by the vCenter administrator.
- Amazon EBS-like services can be delivered through FCDs because an FCD VMDK, as the name suggests, is a first-class citizen in vSphere and has a lifecycle which can be independently managed separate from VMs that it might be attached to.

Using vVols with ONTAP

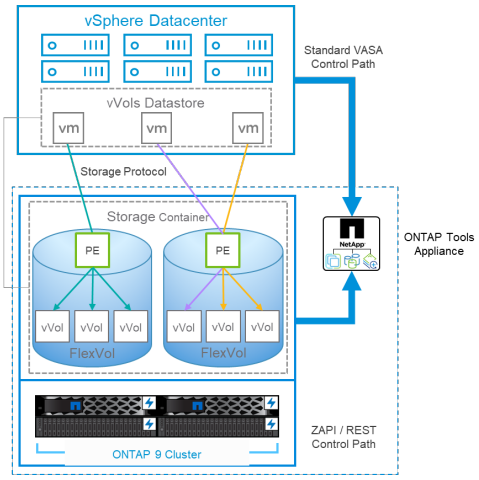
The key to using vVols with ONTAP is the VASA Provider software included as part of the ONTAP tools for VMware vSphere virtual appliance.

ONTAP tools also includes the vCenter UI extensions, REST API server, Storage Replication Adapter for VMware Site Recovery Manager, Monitoring and Host configuration tools, and an array of reports which help you better manage your VMware environment.

Products and Documentation

The ONTAP FlexClone license (included with ONTAP One) and the ONTAP tools appliance are the only additional products required to use vVols with NetApp ONTAP. Recent releases of ONTAP tools are supplied as a single unified appliance that runs on ESXi, providing the functionality of what formerly were three different appliances and servers. For vVols, it is important to use the ONTAP tools vCenter UI extensions or REST APIs as general management tools and user interfaces for ONTAP functions with vSphere, together with the VASA Provider which provides specific vVols functionality. The SRA component is included for traditional datastores, but VMware Site Recovery Manager does not use SRA for vVols, instead implementing new services in SRM 8.3 and later which leverage the VASA provider for vVols replication.

ONTAP tools VASA Provider architecture when using iSCSI or FCP



Product Installation

For new installations, deploy the virtual appliance into your vSphere environment. Current releases of ONTAP tools will automatically register themselves with your vCenter and enable the VASA Provider by default. In addition to ESXi host and vCenter Server information, you will also need the IP address configuration details for the appliance. As previously stated, the VASA Provider requires the ONTAP FlexClone license be already installed onto any ONTAP clusters you plan to use for vVols. The appliance has a built-in watchdog to ensure availability, and as a best practice should be configured with VMware High Availability and optionally Fault Tolerance features. See section 4.1 for additional details. Do not install or move the ONTAP tools appliance or vCenter Server appliance (VCSA) to vVols storage as this can prevent the appliances from restarting.

In-place upgrades of ONTAP tools are supported by using the upgrade ISO file available for download on the NetApp Support Site (NSS). Follow the Deployment and Setup Guide instructions to upgrade the appliance.

For sizing your virtual appliance, and understanding the configuration limits, refer to this knowledge base article: Sizing Guide for ONTAP tools for VMware vSphere

Product Documentation

The following documentation is available to help you deploy ONTAP tools.

For the complete documentation repository, visit this link to docs.netapp.com

Get started

- Release notes
- Learn about ONTAP tools for Vmware vSphere
- ONTAP tools Quick start
- Deploy ONTAP tools
- Upgrade ONTAP tools

Use ONTAP tools

- Provision traditional datastores
- Provision vVols datastores
- Configure role-based access control
- Configure remote diagnostics
- Configure high availability

Protect and manage datastores

- Protect traditional datastores with SRM
- Protect vVols based virtual machines with SRM
- Monitor traditional datastores and virtual machines
- Monitor vVols datastores and virtual machines

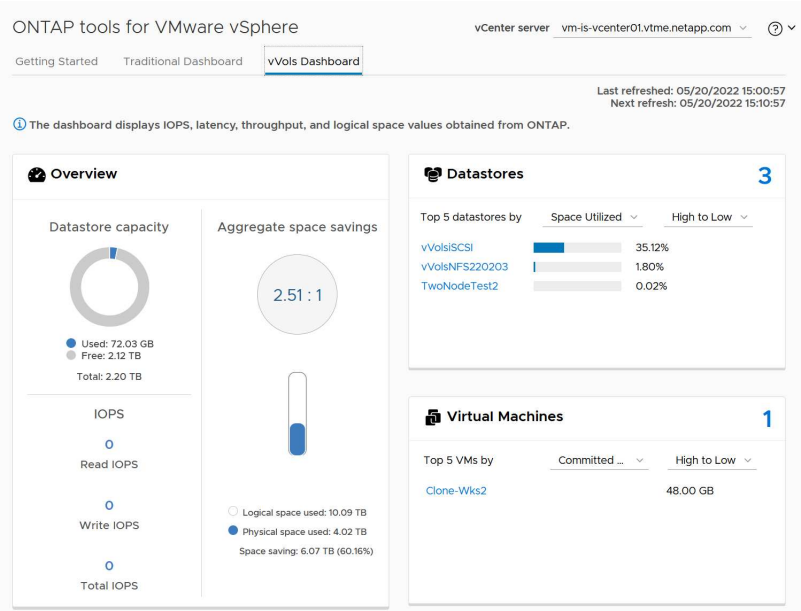
In addition to product documentation, there are Support Knowledgebase articles that may be useful.

- How to perform a VASA Provider Disaster Recovery

VASA Provider Dashboard

The VASA Provider includes a dashboard with performance and capacity information for individual vVols VMs. This information comes directly from ONTAP for the vVol files and LUNs, including latency, IOPS, throughput, and uptime for the top 5 VMs, and latency and IOPS for the top 5 datastores. It is enabled by default when using ONTAP 9.7 or later. It can take up to 30 minutes for initial data to be retrieved and displayed in the dashboard.

ONTAP tools vVols dashboard



Best Practices

This section collects known best practices for using vVols with ONTAP along with other information.

Limits

In general, ONTAP supports vVols limits as defined by VMware (see published Configuration Maximums). The following table summarizes specific ONTAP limits in size and number of vVols. Always check the NetApp Hardware Universe for updated limits on numbers and sizes of LUNs and files.

ONTAP vVols Limits

Capacity/Feature	SAN (SCSI or NVMe-oF)	NFS
Maximum vVols size	62 TiB[1]	62 TiB[1]
Maximum number of vVols per FlexVol volume	1024	2 billion
Maximum number of vVols per ONTAP node	Up to 12,288[2]	50 billion
Maximum number of vVols per ONTAP pair	Up to 24,576[2]	50 billion
Maximum number of vVols per ONTAP cluster	Up to 98,304[2]	No specific cluster limit
Maximum QoS objects (shared policy group and individual vVols service level)	12,000 through ONTAP 9.3; 40,000 with ONTAP 9.4 and later	

NOTE:
[1] Size limit based on ASA systems or AFF and FAS systems running ONTAP 9.12.1P2 and later.

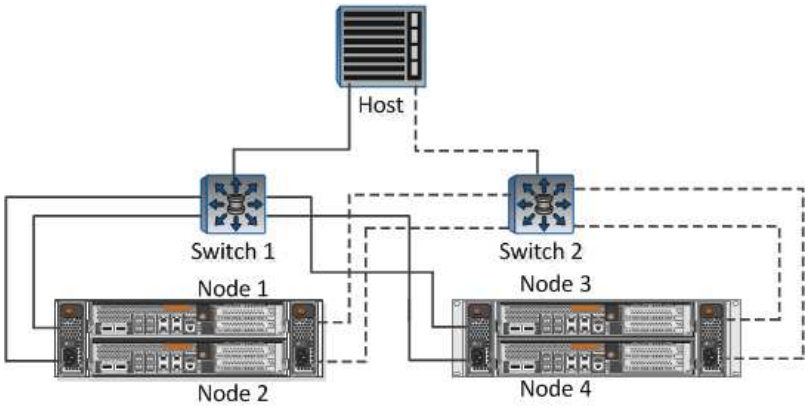
[2] Number of SAN vVols (NVMe namespaces or LUNs) varies based on platform. Always check the NetApp Hardware Universe for updated limits on numbers and sizes of LUNs and files.

Best Practices for using vVols with ONTAP

Using ONTAP vVols with vSphere is simple and follows published vSphere methods (see Working with Virtual Volumes under vSphere Storage in VMware documentation for your version of ESXi). Here are a few additional practices to consider in conjunction with ONTAP.

1. **Use ONTAP tools for VMware vSphere's UI extensions or REST APIs to provision vVols datastores and Protocol Endpoints.**
   While it's possible to create vVols datastores with the general vSphere interface, using ONTAP tools will automatically create protocol endpoints as needed, and creates FlexVol volumes using ONTAP best practices and in compliance with your defined storage capability profiles. Simply right click on the host/cluster/datacenter, then select *ONTAP tools* and *Provision datastore*. From there simply choose the desired vVols options in the wizard.
2. **Never store the ONTAP tools appliance or vCenter Server Appliance (VCSA) on a vVols datastore that they are managing.**
   This can result in a "chicken and egg situation" if you need to reboot the appliances because they won't be able to rebind their own vVols while they are rebooting. You may store them on a vVols datastore managed by a different ONTAP tools and vCenter deployment.
3. **Avoid vVols operations across different ONTAP releases.**
   Supported storage capabilities such as QoS, personality and more have changed in various releases of the VASA Provider, and some are dependent on ONTAP release. Using different releases in an ONTAP cluster or moving vVols between clusters with different releases can result in unexpected behavior or compliance alarms.
4. **Zone your Fibre Channel fabric before using NVMe/FC or FCP for vVols.**
   The ONTAP tools VASA provider takes care of managing FCP and iSCSI igroups as well as NVMe subsystems in ONTAP based on discovered initiators of managed ESXi hosts. However, it does not integrate with Fibre Channel switches to manage zoning. Zoning must be done according to best practices before any provisioning can take place. The following is an example of single initiator zoning to four ONTAP systems:

   Single initiator zoning:

   Refer to the following documents for more best practices:

   TR-4080 Best practices for modern SAN ONTAP 9

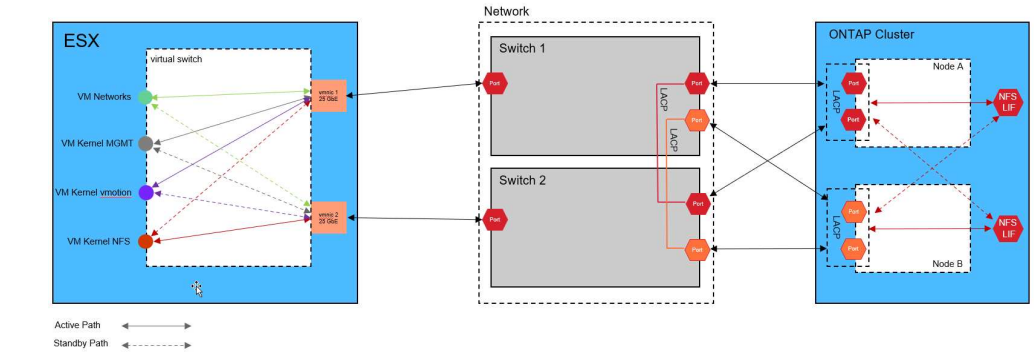
   TR-4684 Implementing and configuring modern SANs with NVMe-oF

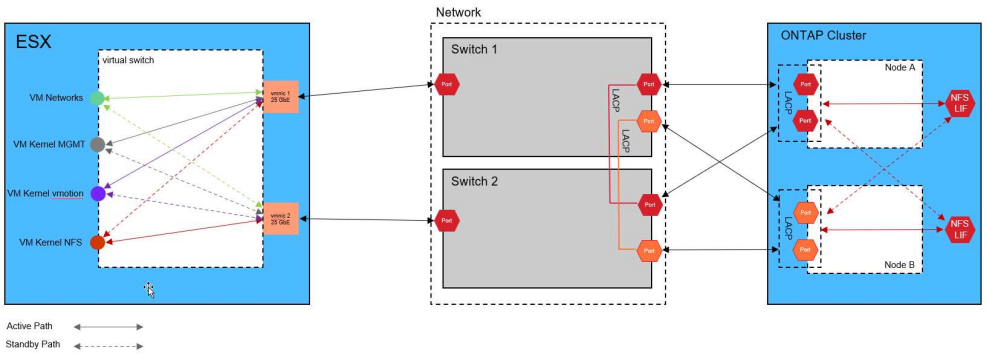
5. **Plan your backing FlexVols according to your needs.**
   It can be desirable to add several backing volumes to your vVols datastore to distribute workload across

the ONTAP cluster, to support different policy options, or to increase the number of allowed LUNs or files. However, if maximum storage efficiency is required, then place all your backing volumes on a single aggregate. Or if maximum cloning performance is required, then consider using a single FlexVol volume and keeping your templates or content library in the same volume. The VASA Provider offloads many vVols storage operations to ONTAP, including migration, cloning and snapshots. When this is done within a single FlexVol volume, space efficient file clones are used and are almost instantly available. When this is done across FlexVol volumes, the copies are quickly available and use inline deduplication and compression, but maximum storage efficiency may not be recovered until background jobs run on volumes using background deduplication and compression. Depending on the source and destination, some efficiency may be degraded.

6. **Keep Storage Capability Profiles (SCPs) simple.**
   Avoid specifying capabilities that aren't required by setting them to Any. This will minimize problems when selecting or creating FlexVol volumes. For example, with VASA Provider 7.1 and earlier, if compression is left at the default SCP setting of No, it will attempt to disable compression, even on an AFF system.
7. **Use the default SCPs as example templates to create your own.**
   The included SCPs are suitable for most general-purpose uses, but your requirements may be different.
8. **Consider using Max IOPS to control unknown or test VMs.**
   First available in VASA Provider 7.1, Max IOPS can be used to limit IOPS to a specific vVol for an unknown workload to avoid impact on other, more critical workloads. See Table 4 for more on performance management.
9. **Ensure you have sufficient data LIFs.**
   Create at least two LIFs per node per HA pair. More may be required based on your workload.
10. **Follow all protocol best practices.**
    Refer to NetApp and VMware's other best practice guides specific to the protocol you've selected. In general, there are not any changes other than those already mentioned.

    Example network configuration using vVols over NFS v3:





Deploying vVols Storage

There are several steps to creating vVols storage for your VMs.

The first two steps may not be needed for an existing vSphere environment that uses ONTAP for traditional datastores. You may already be using ONTAP tools for managing, automating, and reporting your VMFS or traditional NFSv3 based storage. These steps are covered in more detail in the following section.

1. Create the SVM (protocol configuration, either NVMe/FC, NFSv3, iSCSI, FCP, or a mix of those options) using either ONTAP System Manager wizards, or command line.
    - At least one LIF per node for each switch/fabric connection. Preferably two or more per node for SAN protocols.
    - Volumes may be created at this time, but it is simpler to let the *Provision Datastore* wizard create them. The only exception to this rule is if you plan to use vVols replication with VMware Site Recovery Manager. This is easier to set up with pre-existing FlexVol volumes with existing SnapMirror relationships. Be mindful to not enable QoS on any volumes to be used for vVols as this is intended to be managed by SPBM and ONTAP tools.
2. Deploy ONTAP tools for VMware vSphere using the OVA downloaded from the NetApp Support Site.
3. Configure ONTAP tools for your environment.
    - Add the ONTAP cluster to ONTAP tools under *Storage Systems*
        - While ONTAP tools and SRA support both cluster-level and SVM-level credentials, the VASA Provider supports only cluster-level credentials for storage systems. Therefore, if you plan to use vVols, you must add your ONTAP clusters using cluster scoped credentials.
    - If your ONTAP data LIFs are on different subnets from your VMkernel adapters, then you must add the VMkernel adapter subnets to the selected subnets list in the settings menu of ONTAP tools. By default, ONTAP tools will secure your storage traffic by only allowing local subnet access.
    - The ONTAP tools comes with several pre-defined policies that may be used or see Section 3.3 for guidance on creating SCPs.
4. Use the *ONTAP tools* menu in vCenter to start the *Provision datastore* wizard.
5. Provide a meaningful name and select the desired protocol. You may provide a description of the datastore as well.
6. Select one or more SCPs to be supported by the vVols datastore. This will filter out any ONTAP systems which are unable to match the profile. From the resulting list, select your desired cluster and SVM.
7. Use the wizard to create new FlexVol volumes for each of the specified SCPs or use existing volumes by selecting the appropriate radio button.
8. Create VM policies for each SCP that will be used in the datastore from the *Policies and Profiles* menu in the vCenter UI.
9. Choose the "NetApp.clustered.Data.ONTAP.VP.vvol" storage rule set. The "NetApp.clustered.Data.ONTAP.VP.VASA10" storage rule set is for SPBM support with non-vVols datastores
10. You will specify the Storage Capability Profile by name when creating a VM Storage Policy. While at this step, you may also configure SnapMirror policy matching by using the replication tab, and tag-based matching using the tags tab. Note that tags must already be created in order to be selectable.
11. Create your VMs, selecting the VM Storage Policy and compatible datastore under Select storage.

Migrating VMs from Traditional Datastores to vVols

Migration of VMs from traditional datastores to a vVols datastore is as simple as moving VMs between traditional datastores. Simply select the VM(s), then select Migrate from the list of Actions, and select a migration type of *change storage only*. Migration copy operations will be offloaded with vSphere 6.0 and later for SAN VMFS to vVols migrations, but not from NAS VMDKs to vVols.

Managing VMs with Policies

To automate storage provisioning with policy-based management, we need to:

- Define the capabilities of the storage (ONTAP node and FlexVol volume) with Storage Capability Profiles (SCPs).
- Create VM storage policies that map to the defined SCPs.

NetApp has simplified the capabilities and mapping beginning with VASA Provider 7.2 with continuing improvements throughout later versions. This section focuses on this new approach. Earlier releases supported a greater number of capabilities and allowed them to be mapped individually to storage policies, but this approach is no longer supported. Table 3 compares capabilities across releases.

Storage Capability Profile capabilities by ONTAP tools release

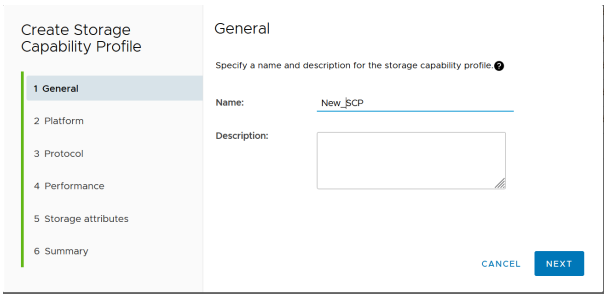
SCP Capability	Capability Values	Release Supported	Notes
Compression	Yes, No, Any	All	Mandatory for AFF in 7.2 and later.
Deduplication	Yes, No, Any	All	Mandatory for AFF in 7.2 and later.
Encryption	Yes, No, Any	7.2 and later	Selects/creates encrypted FlexVol volume.. ONTAP license required.
Max IOPS	<number>	7.1 and later, but differences	Listed under QoS Policy Group for 7.2 and later. See Table 4 for more information.
Personality	AFF, FAS	7.2 and later	FAS also includes other non-AFF systems, such as ONTAP Select. AFF includes ASA.
Protocol	NFS, NFS 4.1, iSCSI, FCP, NVMe/FC, Any	7.1 and earlier, 9.10 and later	7.2-9.8 is effectively “Any”. Beginning again in 9.10 where NFS 4.1 and NVMe/FC were added to the original list.
Space Reserve (Thin Provisioning)	Thin, Thick, (Any)	All, but differences	Called Thin Provisioning in 7.1 and earlier, which also allowed value of Any. Called Space Reserve in 7.2. All releases default to Thin.

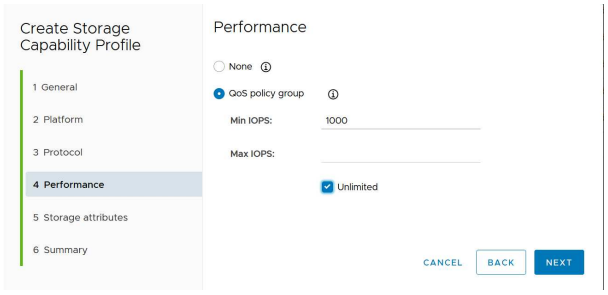
SCP Capability	Capability Values	Release Supported	Notes
Tiering Policy	Any, None, Snapshot, Auto	7.2 and later	Used for FabricPool® – requires AFF or ASA with ONTAP 9.4 or later. Only Snapshot is recommended unless using an on-premise S3 solution like NetApp StorageGRID.

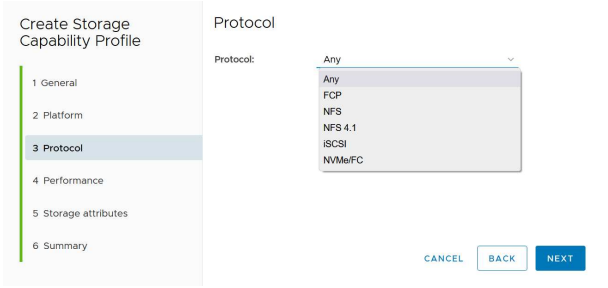
Creating Storage Capability Profiles

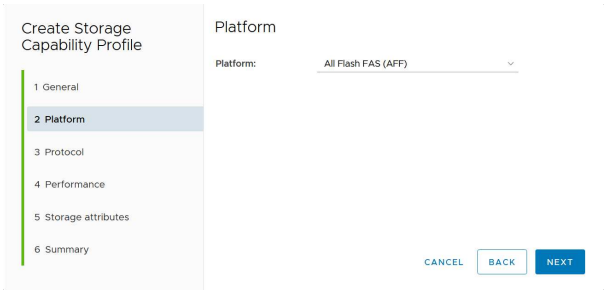
The NetApp VASA Provider comes with several pre-defined SCPs. New SCPs may be created manually, using the vCenter UI, or via automation using REST APIs. By specifying capabilities in a new profile, cloning an existing profile, or by auto-generating profile(s) from existing traditional datastores. This is done using the menus under ONTAP tools. Use *Storage Capability Profiles* to create or clone a profile, and *Storage Mapping* to auto-generate a profile.

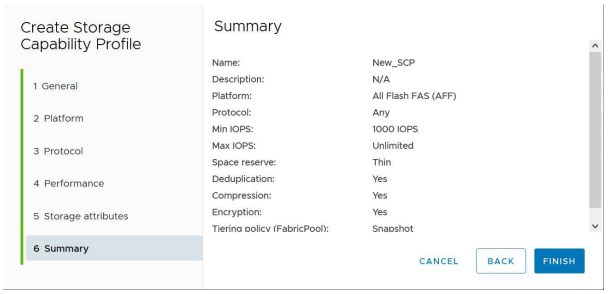
Storage Capabilities for ONTAP tools 9.10 and later

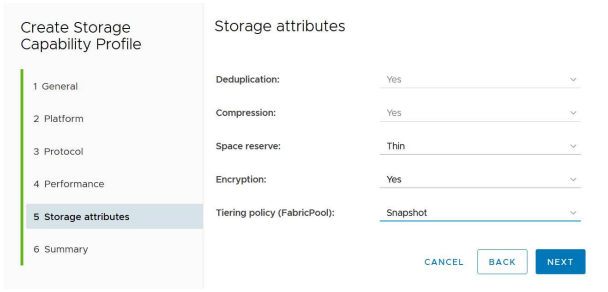












Creating vVols Datastores

Once the necessary SCPs have been created, they may be used to create the vVols datastore (and optionally, FlexVol volumes for the datastore). Right-click on the host, cluster, or datacenter on which you want to create the vVols datastore, then select *ONTAP tools* > *Provision Datastore*. Select one or more SCPs to be supported by the datastore, then select from existing FlexVol volumes and/or provision new FlexVol volumes for the datastore. Finally, specify the default SCP for the datastore, which will be used for VMs that do not have an SCP specified by policy, as well as for swap vVols (these do not require high performance storage).

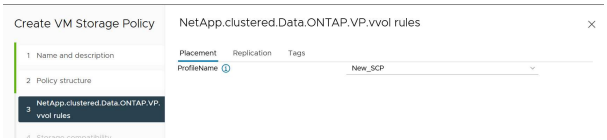
Creating VM Storage Policies

VM Storage Policies are used in vSphere to manage optional features such as Storage I/O Control or vSphere Encryption. They are also used with vVols to apply specific storage capabilities to the VM. Use the “NetApp.clustered.Data.ONTAP.VP.vvol” storage type and “ProfileName” rule to apply a specific SCP to VMs through use of the Policy. See Figure 6 for an example of this with the ONTAP tools VASA Provider. Rules for “NetApp.clustered.Data.ONTAP.VP.VASA10” storage are to be used with non-vVols based datastores.

Earlier releases are similar, but as mentioned in Table 3, your options will vary.

Once the storage policy has been created, it can be used when provisioning new VMs as shown in Figure 1. Guidelines for using performance management capabilities with VASA Provider 7.2 are covered in Table 4.

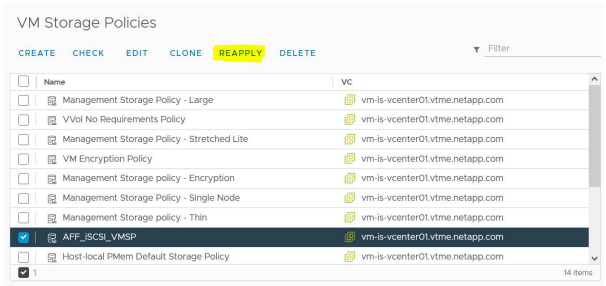
VM Storage Policy creation with ONTAP tools VASA Provider 9.10



Performance management with ONTAP tools 9.10 and later

- ONTAP tools 9.10 uses its own balanced placement algorithm to place a new vVol in the best FlexVol volume within a vVols datastore. Placement is based on the specified SCP and matching FlexVol volumes. This makes sure that the datastore and backing storage can meet the specified performance requirements.
- Changing Performance capabilities such as Min and Max IOPS requires some attention to the specific configuration.
  - **Min and Max IOPS** may be specified in an SCP and used in a VM Policy.
    - Changing the IOPS in the SCP will not change QoS on the vVols until the VM Policy is edited, and then reapplied to the VMs that use it (see Figure 7). Or create a new SCP with the desired IOPS and change the policy to use it (and reapply to VMs). Generally it is recommended to simply define separate SCPs and VM storage policies for different tiers of service and simply change the VM storage policy on the VM.
    - AFF and FAS personalities have different IOPs settings. Both Min and Max are available on AFF. However non-AFF systems can only use Max IOPs settings.
- In some cases, a vVol may need to be migrated after a policy change (either manually, or automatically by VASA Provider and ONTAP):
  - Some changes require no migration (such as changing Max IOPS, which can be applied immediately to the VM as outlined above).
  - If the policy change cannot be supported by the current FlexVol volume that stores the vVol (for example, the platform does not support the encryption or tiering policy requested), you will need to manually migrate the VM in vCenter.
- ONTAP tools creates individual non-shared QoS policies with currently supported versions of ONTAP. Therefore, each individual VMDK will receive its own allocation of IOPs.

Reapplying VM Storage Policy



Protecting vVols

VASA Provider High Availability

The NetApp VASA Provider runs as part of the virtual appliance together with the vCenter plugin and REST API server (formerly known as the Virtual Storage Console [VSC]) and Storage Replication Adapter. If the VASA Provider is not available, VMs using vVols will continue to run. However, new vVols datastores cannot be created, and vVols cannot be created or bound by vSphere. This means that VMs using vVols cannot be powered on as vCenter will not be able to request creation of the swap vVol. And running VMs cannot use

vMotion for migration to another host because the vVols cannot be bound to the new host.

VASA Provider 7.1 and later support new capabilities to make sure the services are available when needed. It includes new watchdog processes that monitor VASA Provider and integrated database services. If it detects a failure, it updates the log files and then restarts the services automatically.

Further protection must be configured by the vSphere administrator using the same availability features used to protect other mission critical VMs from faults in software, host hardware and network. No additional configuration is required on the virtual appliance to use these features; simply configure them using standard vSphere approaches. They have been tested and are supported by NetApp.

vSphere High Availability is easily configured to restart a VM on another host in the host cluster in the event of failure. vSphere Fault Tolerance provides higher availability by creating a secondary VM that is continuously replicated and can take over at any point. Additional information on these features is available in the ONTAP tools for VMware vSphere documentation (Configure high availability for ONTAP tools), as well as VMware vSphere documentation (look for vSphere Availability under ESXi and vCenter Server).

The ONTAP tools VASA Provider automatically backs up the vVols configuration in real time to managed ONTAP systems where the vVols information is stored within FlexVol volume metadata. In the event that the ONTAP tools appliance becomes unavailable for any reason, you can easily and quickly deploy a new one and import the configuration. Refer to this KB article for more information on VASA Provider recovery steps:

How to perform a VASA Provider Disaster Recovery - Resolution Guide

vVols Replication

Many ONTAP customers replicate their traditional datastores to secondary storage systems using NetApp SnapMirror, and then use the secondary system to recover individual VMs or an entire site in the event of a disaster. In most cases, customers use a software tool to manage this, such as a backup software product like the NetApp SnapCenter plugin for VMware vSphere or a disaster recovery solution such as VMware's Site Recovery Manager (together with the Storage Replication Adapter in ONTAP tools).

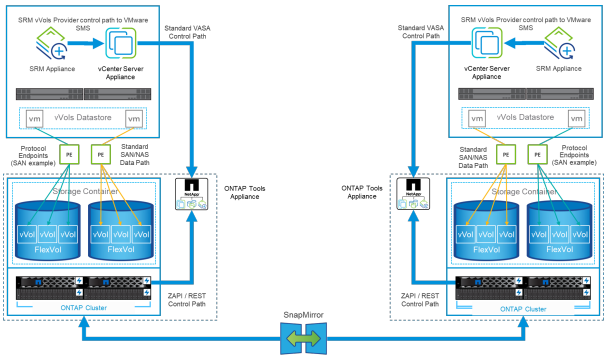
This requirement for a software tool is even more important to manage vVols replication. While some aspects can be managed by native capabilities (for example, VMware managed snapshots of vVols are offloaded to ONTAP which uses quick, efficient file or LUN clones), in general orchestration is needed to manage replication and recovery. Metadata about vVols is protected by ONTAP as well as the VASA Provider, but additional processing is needed to use them at a secondary site.

ONTAP tools 9.7.1 in conjunction with the VMware Site Recovery Manager (SRM) 8.3 release added support for disaster recovery and migration workflow orchestration taking advantage of NetApp SnapMirror technology.

In the initial release of SRM support with ONTAP tools 9.7.1 it was a requirement to pre-create FlexVols and enable SnapMirror protection before using them as backing volumes for a vVols datastore. Beginning in ONTAP tools 9.10 that process is no longer required. You can now add SnapMirror protection to existing backing volumes and update your VM storage policies to take advantage of policy-based management with disaster recovery and migration orchestration and automation integrated with SRM.

Currently, VMware SRM is the only disaster recovery and migration automation solution for vVols supported by NetApp, and ONTAP tools will check for the existence of an SRM 8.3 or later server registered with your vCenter before allowing you to enable vVols replication, although it is possible to leverage the ONTAP tools REST APIs to create your own services.

vVols replication with SRM



MetroCluster Support

Although ONTAP tools is not capable of triggering a MetroCluster switchover, it does support NetApp MetroCluster systems for vVols backing volumes in a uniform vSphere Metro Storage Cluster (vMSC) configuration. Switchover of a MetroCluster system is handled in the normal manner.

While NetApp SnapMirror Business Continuity (SM-BC) can also be used as the basis for a vMSC configuration, it is not currently supported with vVols.

Refer to these guides for more information on NetApp MetroCluster:

TR-4689 MetroCluster IP Solution architecture and design

TR-4705 NetApp MetroCluster Solution architecture and design

VMware KB 2031038 VMware vSphere Support with NetApp MetroCluster

vVols Backup Overview

There are several approaches to protecting VMs such as using in-guest backup agents, attaching VM data files to a backup proxy, or using defined APIs such as VMware VADP. vVols may be protected using the same mechanisms and many NetApp partners support VM backups, including vVols.

As mentioned earlier, VMware vCenter managed snapshots are offloaded to space efficient and fast ONTAP file/LUN clones. These may be used for quick, manual backups, but are limited by vCenter to a maximum of 32 snapshots. You may use vCenter to take snapshots and revert as needed.

Beginning with SnapCenter Plugin for VMware vSphere (SCV) 4.6 when used in conjunction with ONTAP tools 9.10 and later adds support for crash consistent backup and recovery of vVols based VMs leveraging ONTAP FlexVol volume snapshots with support for SnapMirror and SnapVault replication. Up to 1023 snapshots are supported per volume. SCV can also store more snapshots with longer retention on secondary volumes using SnapMirror with a mirror-vault policy.

vSphere 8.0 support was introduced with SCV 4.7, which used an isolated local plugin architecture. vSphere 8.0U1 support was added to SCV 4.8 which fully transitioned to the new remote plugin architecture.

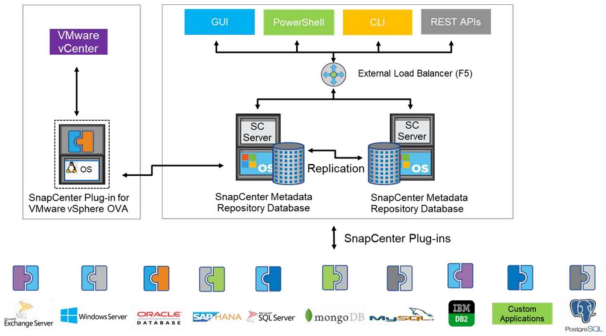
vVols Backup with SnapCenter plugin for VMware vSphere

With NetApp SnapCenter you can now create resource groups for vVols based on tags and/or folders to automatically take advantage of ONTAP's FlexVol based snapshots for vVols based VMs. This allows you to define backup and recovery services which will protect VMs automatically as they get dynamically provisioned within your environment.

SnapCenter plugin for VMware vSphere is deployed as a standalone appliance registered as a vCenter

extension, managed through the vCenter UI or via REST APIs for backup and recovery service automation.

SnapCenter architecture



Since the other SnapCenter plugins don't yet support vVols at the time of this writing, we will focus on the standalone deployment model in this document.

Because SnapCenter uses ONTAP FlexVol snapshots there is no overhead placed on vSphere, nor is there any performance penalty as one might see with traditional VMs using vCenter managed snapshots. Furthermore, because SCV's functionality is exposed via REST APIs, it makes it easy to create automated workflows using tools like VMware Aria Automation, Ansible, Terraform, and virtually any other automation tool that is capable of using standard REST APIs.

For information on SnapCenter REST APIs, see Overview of REST APIs

For information on SnapCenter Plug-in for VMware vSphere REST APIs, see SnapCenter Plug-in for VMware vSphere REST APIs

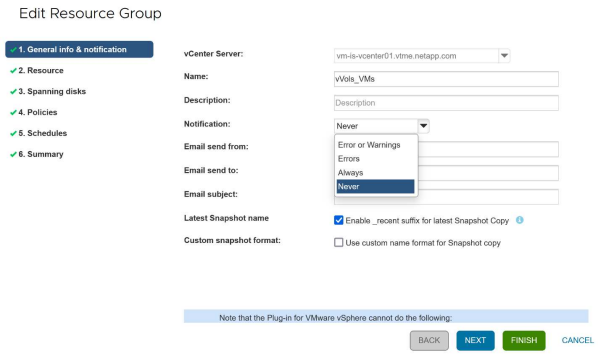
Best Practices

The following best practices can help you get the most out of your SnapCenter deployment.

1. SCV supports both vCenter Server RBAC and ONTAP RBAC and includes predefined vCenter roles which are automatically created for you when the plugin is registered. You can read more about the supported types of RBAC here.
    - Use the vCenter UI to assign least privileged account access using the predefined roles described here.
    - If you use SCV with SnapCenter Server, you must assign the *SnapCenterAdmin* role.
    - ONTAP RBAC refers to the user account used to add and manage the storage systems used by SCV. ONTAP RBAC doesn't apply to vVols based backups. Read more about ONTAP RBAC and SCV here.
2. Replicate your backup datasets to a second system using SnapMirror for complete replicas of source volumes. As previously mentioned, you may also use mirror-vault policies for longer term retention of backup data independent of source volume snapshot retention settings. Both mechanisms are supported with vVols.
3. Because SCV also requires ONTAP tools for VMware vSphere for vVols functionality, always check the NetApp Interoperability Matrix Tool (IMT) for specific version compatibility
4. If you are using vVols replication with VMware SRM, be mindful of your policy RPO and backup schedule
5. Design your backup policies with retention settings that meet your organizations defined recovery point objectives (RPOs)
6. Configure notification settings on your resource groups to be notified of the status when backups run (see

figure 10 below)

Resource group notification options



Get started with SCV using these documents

Learn about SnapCenter Plug-in for VMware vSphere

Deploy SnapCenter Plug-in for VMware vSphere

Troubleshooting

There are several troubleshooting resources available with additional information.

NetApp Support Site

In addition to a variety of Knowledgebase articles for NetApp virtualization products, the NetApp Support site also offers a convenient landing page for the ONTAP tools for VMware vSphere product. This portal provides links to articles, downloads, technical reports, and VMware Solutions Discussions on NetApp Community. It is available at:

NetApp Support Site

Additional solution documentation is available here:

NetApp Solutions for Virtualization

Product Troubleshooting

The various components of ONTAP tools, such as the vCenter plugin, VASA Provider, and Storage Replication Adapter are all documented together in the NetApp documents repository. However, each has a separate subsection of the Knowledge Base and may have specific troubleshooting procedures. These address the most common issues that may be encountered with the VASA Provider.

VASA Provider UI Problems

Occasionally the vCenter vSphere Web Client encounters problems with the Serenity components, causing the VASA Provider for ONTAP menu items not to display. See Resolving VASA Provider registration issues in the Deployment Guide, or this Knowledgebase article.

vVols Datastore Provisioning Fails

Occasionally vCenter services may time out when creating the vVols datastore. To correct it, restart the vmware-sps service, and re-mount the vVols datastore using the vCenter menus (Storage > New Datastore). This is covered under vVols datastore provisioning fails with vCenter Server 6.5 in the Administration Guide.

Upgrading Unified Appliance Fails to Mount ISO

Due to a bug in vCenter, the ISO used to upgrade the Unified Appliance from one release to the next may fail to mount. If the ISO is able to be attached to the appliance in vCenter, follow the process in this Knowledgebase article to resolve.

TR-4900: VMware Site Recovery Manager with NetApp ONTAP 9

Chance Bingen, NetApp

ONTAP for vSphere

NetApp ONTAP has been a leading storage solution for VMware vSphere environments since its introduction into the modern datacenter in 2002, and it continues to add innovative capabilities to simplify management while reducing costs. This document introduces the ONTAP solution for VMware Site Recovery Manager (SRM), VMware's industry leading disaster recovery (DR) software, including the latest product information and best practices to streamline deployment, reduce risk, and simplify ongoing management.

Best practices supplement other documents such as guides and compatibility tools. They are developed based on lab testing and extensive field experience by NetApp engineers and customers. In some cases, recommended best practices might not be the right fit for your environment; however, they are generally the simplest solutions that meet the needs of the most customers.

This document is focused on capabilities in recent releases of ONTAP 9 when used in conjunction with ONTAP tools for VMware vSphere 9.12 (which includes the NetApp Storage Replication Adapter [SRA] and VASA Provider [VP]), as well as VMware Site Recovery Manager 8.7.

Why use ONTAP with SRM?

NetApp data management platforms powered by ONTAP software are some of the most widely adopted storage solutions for SRM. The reasons are plentiful: A secure, high performance, unified protocol (NAS and SAN together) data management platform that provides industry defining storage efficiency, multitenancy, quality of service controls, data protection with space-efficient Snapshot copies and replication with SnapMirror. All leveraging native hybrid multi-cloud integration for the protection of VMware workloads and a plethora of automation and orchestration tools at your fingertips.

When you use SnapMirror for array-based replication, you take advantage of one of ONTAP's most proven and mature technologies. SnapMirror gives you the advantage of secure and highly efficient data transfers, copying only changed file system blocks, not entire VMs or datastores. Even those blocks take advantage of space savings, such as deduplication, compression, and compaction. Modern ONTAP systems now use version-independent SnapMirror, allowing you flexibility in selecting your source and destination clusters. SnapMirror has truly become one of the most powerful tools available for disaster recovery.

Whether you are using traditional NFS, iSCSI, or Fibre Channel- attached datastores (now with support for vVols datastores), SRM provides a robust first party offering that leverages the best of ONTAP capabilities for disaster recovery or datacenter migration planning and orchestration.

How SRM leverages ONTAP 9

SRM leverages the advanced data management technologies of ONTAP systems by integrating with ONTAP tools for VMware vSphere, a virtual appliance that includes three primary components:

- The vCenter plug-in, formerly known as Virtual Storage Console (VSC), simplifies storage management and efficiency features, enhances availability, and reduces storage costs and operational overhead, whether you are using SAN or NAS. It uses best practices for provisioning datastores and optimizes ESXi host settings for NFS and block storage environments. For all these benefits, NetApp recommends this plug-in when using vSphere with systems running ONTAP software.
- The VASA Provider for ONTAP supports the VMware vStorage APIs for Storage Awareness (VASA) framework. VASA Provider connects vCenter Server with ONTAP to aid in provisioning and monitoring VM storage. It enables VMware Virtual Volumes (vVols) support and the management of storage capability profiles (including vVols replication capabilities) and individual VM vVols performance. It also provides alarms for monitoring capacity and compliance with the profiles. When used in conjunction with SRM, the VASA Provider for ONTAP enables support for vVols- based virtual machines without requiring the installation of an SRA adapter on the SRM server.
- The SRA is used together with SRM to manage the replication of VM data between production and disaster recovery sites for traditional VMFS and NFS datastores and also for the nondisruptive testing of DR replicas. It helps automate the tasks of discovery, recovery, and reprotection. It includes both an SRA server appliance and SRA adapters for the Windows SRM server and the SRM appliance.

After you have installed and configured the SRA adapters on the SRM server for protecting non-vVols datastores and/or enabled vVols replication in the VASA Provider settings, you can begin the task of configuring your vSphere environment for disaster recovery.

The SRA and VASA Provider deliver a command-and-control interface for the SRM server to manage the ONTAP FlexVols that contain your VMware Virtual Machines (VMs), as well as the SnapMirror replication protecting them.

Starting with SRM 8.3, a new SRM vVols Provider control path was introduced into the SRM server, allowing it to communicate with the vCenter server and, through it, to the VASA Provider without needing an SRA. This enabled the SRM server to leverage much deeper control over the ONTAP cluster than was possible before, because VASA provides a complete API for closely coupled integration.

SRM can test your DR plan nondisruptively using NetApp's proprietary FlexClone technology to make nearly instantaneous clones of your protected datastores at your DR site. SRM creates a sandbox to safely test so that your organization, and your customers, are protected in the event of a true disaster, giving you confidence in your organizations ability to execute a failover during a disaster.

In the event of a true disaster or even a planned migration, SRM allows you to send any last-minute changes to the dataset via a final SnapMirror update (if you choose to do so). It then breaks the mirror and mounts the datastore to your DR hosts. At that point, your VMs can be automatically powered up in any order according to your pre-planned strategy.

SRM with ONTAP and other use cases: hybrid cloud and migration

Integrating your SRM deployment with ONTAP advanced data management capabilities allows for vastly improved scale and performance when compared with local storage options. But more than that, it brings the flexibility of the hybrid cloud. The hybrid cloud enables you to save money by tiering unused data blocks from your high-performance array to your preferred hyperscaler using FabricPool, which could be an on-premises S3 store such as NetApp StorageGRID. You can also use SnapMirror for edge-based systems with software-defined ONTAP Select or cloud-based DR using Cloud Volumes ONTAP (CVO) or NetApp Private Storage in Equinix for Amazon Web Services (AWS), Microsoft Azure, and Google Cloud Platform (GCP) to create a fully

integrated storage, networking, and compute- services stack in the cloud.

You could then perform test failover inside a cloud service provider's datacenter with near-zero storage footprint thanks to FlexClone. Protecting your organization can now cost less than ever before.

SRM can also be used to execute planned migrations by leveraging SnapMirror to efficiently transfer your VMs from one datacenter to another or even within the same datacenter, whether your own, or via any number of NetApp partner service providers.

New features with SRM and ONTAP Tools

With the transition from the legacy virtual appliance, ONTAP tools brings a wealth of new features, higher limits, and new vVols support.

Latest versions of vSphere and Site Recovery Manager

With the release of SRM 8.7 and later and the 9.12 and later releases of ONTAP tools, you are now able to protect VMs running on VMware vSphere 8 update 1.

NetApp has shared a deep partnership with VMware for nearly two decades and strives to provide support for the latest releases as soon as possible. Always check the NetApp Interoperability Matrix Tool (IMT) for the latest qualified combinations of software.

The NetApp IMT can be found here.

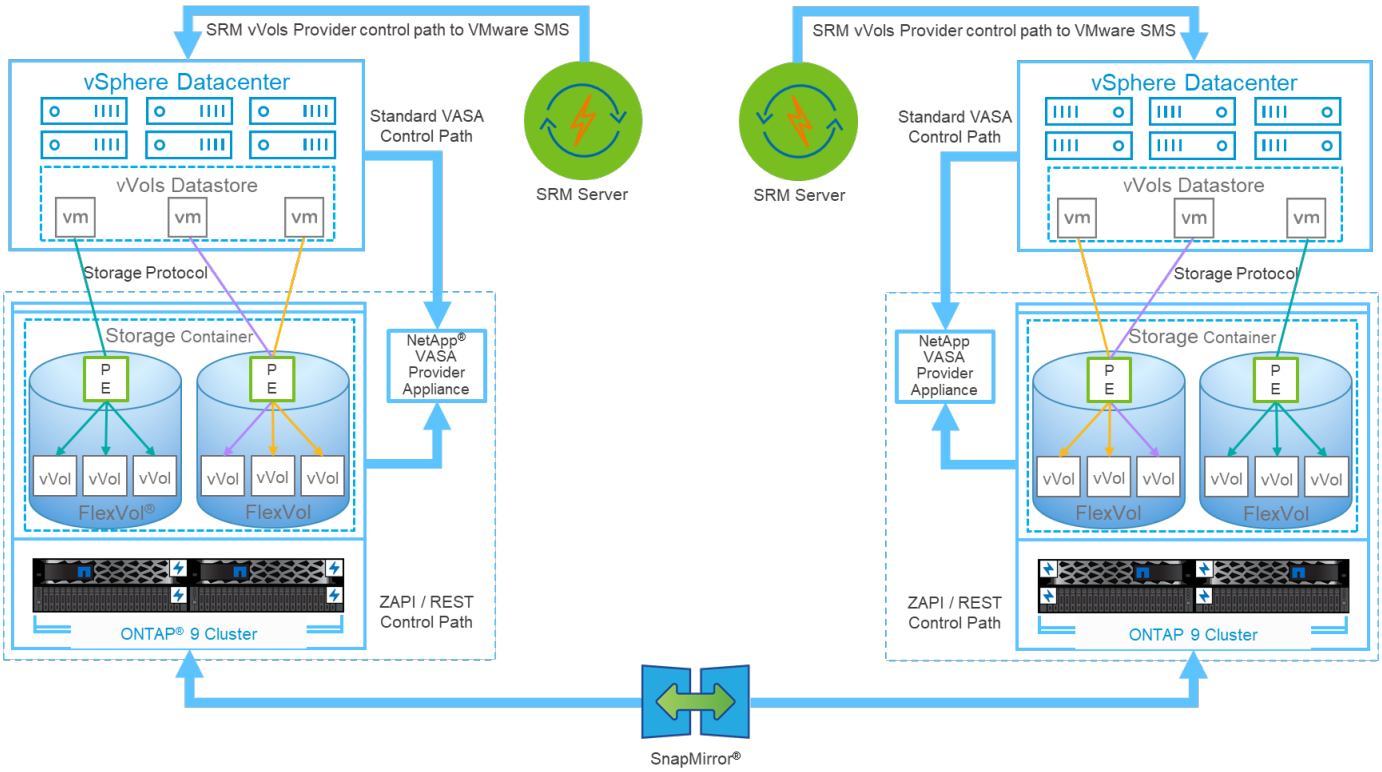
vVols support (and why SPBM matters, even with SRM)

Starting with the 8.3 release, SRM now supports storage policy-based management (SPBM) of replication leveraging vVols and array-based replication for datastores using iSCSI, FCP, and NFS v3. To accomplish this, the SRM server was updated to include a new SRM vVols provider service, which communicates to the vCenter server's SMS service for VASA related tasks.

One advantage to this architecture is that an SRA is no longer needed since everything is handled using VASA.

SPBM is a powerful tool in the vSphere toolbox, allow simplified, predictable, and consistent storage services for consumption by automation frameworks in private and hybrid cloud environments. Fundamentally, SPBM allows you to define classes of service that meet the needs of your diverse customer base. SRM now allows you to expose replication capabilities to your customers for critical workloads requiring robust industry-standard disaster- recovery orchestration and automation.

vVols Architecture example with FCP or iSCSI:



Support for appliance-based SRM servers

Photon OS-based SRM servers are now supported, in addition to legacy Windows-based platforms.

You can now install SRA adapters regardless of your preferred SRM server type.

Support for IPv6

IPv6 is now supported with the following limitations:

- vCenter 6.7 or later
- Not supported with SRM 8.2 (8.1, 8.3, and 8. 4 are supported)
- Check the Interoperability Matrix Tool for the latest qualified versions.

Improved performance

Operational performance is a key requirement for SRM task execution. To meet the requirements of modern RTOs and RPOs, the SRA with ONTAP tools has added three new improvements.

- **Support for concurrent reprotect operations.** First introduced in SRA 9.7.1, enabling this feature allows you to run reprotect on two or more recovery plans concurrently, thus reducing the time required to reprotect datastores after a failover or migration and remain within your RTO and RPO parameters.
- **ONTAP Tools 9.8 adds a new NAS- only optimized mode.** When you use SVM- scoped accounts and connections to ONTAP clusters with only NFS based datastores, you can enable NAS-only optimized mode for peak performance in supported environments.
- **ONTAP Tools 9.12 added support for ONTAP's SnapMirror quick resync feature.** This enables rapid resyncronization of mirrors at the exense of having to recalculate storage efficency savings post process. This feature is not used by default, but can be enabled in large scale environments where traditional resync takes too long or is timing out.

Greater scale

The ONTAP tools SRA can now support up to 500 protection groups (PGs) when used with SRM 8.3 and later.

Synchronous replication

A long awaited and much anticipated new feature is SnapMirror Synchronous (SM-S) with ONTAP 9.5 and later which delivers a volume granular zero RPO data replication solution for your mission-critical applications. SM-S requires ONTAP tools 9.8 or later.

REST API support

SRA server configuration can now be managed by REST APIs. A Swagger UI has been added to assist in building your automation workflows and can be found on your ONTAP tools appliance at `https://<appliance>:8143/api/rest/swagger-ui.html#/`.

Deployment best practices

SVM layout and segmentation for SMT

With ONTAP, the concept of the storage virtual machine (SVM) provides strict segmentation in secure multitenant environments. SVM users on one SVM cannot access or manage resources from another. In this way, you can leverage ONTAP technology by creating separate SVMs for different business units who manage their own SRM workflows on the same cluster for greater overall storage efficiency.

Consider managing ONTAP using SVM-scoped accounts and SVM management LIFs to not only improve security controls, but also improve performance. Performance is inherently greater when using SVM-scoped connections because the SRA is not required to process all the resources in an entire cluster, including physical resources. Instead, it only needs to understand the logical assets that are abstracted to the particular SVM.

When using NAS protocols only (no SAN access), you can even leverage the new NAS optimized mode by setting the following parameter (note that the name is such because SRA and VASA use the same backend services in the appliance):

1. Log into the control panel at `https://<IP address>:9083` and click Web based CLI interface.
2. Run the command `vp updateconfig -key=enable.qtree.discovery -value=true`.
3. Run the command `vp updateconfig -key=enable.optimised.sra -value=true`.
4. Run the command `vp reloadconfig`.

Deploy ONTAP tools and considerations for vVols

If you intend to use SRM with vVols, you must manage the storage using cluster- scoped credentials and a cluster management LIF. This is because the VASA Provider must understand the underlying physical architecture to satisfy the policy requires for VM storage policies. For example, if you have a policy that requires all- flash storage, the VASA Provider must be able to see which systems are all flash.

Another deployment best practice is to never store your ONTAP tools appliance on a vVols datastore that it is managing. This could lead to a situation whereby you cannot power on the VASA Provider because you cannot create the swap vVol for the appliance because the appliance is offline.

Best practices for managing ONTAP 9 systems

As previously mentioned, you can manage ONTAP clusters using either cluster or SVM scoped credentials and management LIFs. For optimum performance, you may want to consider using SVM- scoped credentials whenever you aren't using vVols. However, in doing so, you should be aware of some requirements, and that you do lose some functionality.

- The default vsadmin SVM account does not have the required access level to perform ONTAP tools tasks. Therefore, you need to create a new SVM account.
- If you are using ONTAP 9.8 or later, NetApp recommends creating an RBAC least privileged user account using ONTAP System Manager's users menu together with the JSON file available on your ONTAP tools appliance at `https://<IP address>:9083/vsc/config/`. Use your administrator password to download the JSON file. This can be used for SVM or cluster scoped accounts.

  If you are using ONTAP 9.6 or earlier, you should use the RBAC User Creator (RUC) tool available in the NetApp Support Site Toolchest.

- Because the vCenter UI plugin, VASA Provider, and SRA server are all fully integrated services, you must add storage to the SRA adapter in SRM the same way you add storage in the vCenter UI for ONTAP tools. Otherwise, the SRA server might not recognize the requests being sent from SRM via the SRA adapter.
- NFS path checking is not performed when using SVM-scoped credentials. This is because the physical location is logically abstracted from the SVM. This is not a cause for concern though, as modern ONTAP systems no longer suffer any noticeable performance decline when using indirect paths.
- Aggregate space savings due to storage efficiency might not be reported.
- Where supported, load-sharing mirrors cannot be updated.
- EMS logging might not be performed on ONTAP systems managed with SVM scoped credentials.

Operational best practices

Datastores and protocols

If possible, always use ONTAP tools to provision datastores and volumes. This makes sure that volumes, junction paths, LUNs, igroups, export policies, and other settings are configured in a compatible manner.

SRM supports iSCSI, Fibre Channel, and NFS version 3 with ONTAP 9 when using array-based replication through SRA. SRM does not support array-based replication for NFS version 4.1 with either traditional or vVols datastores.

To confirm connectivity, always verify that you can mount and unmount a new test datastore at the DR site from the destination ONTAP cluster. Test each protocol you intend to use for datastore connectivity. A best practice is to use ONTAP tools to create your test datastore, since it is doing all the datastore automation as directed by SRM.

SAN protocols should be homogeneous for each site. You can mix NFS and SAN, but the SAN protocols should not be mixed within a site. For example, you can use FCP in site A, and iSCSI in site B. You should not use both FCP and iSCSI at site A. The reason for this is that the SRA does not create mixed igroups at the recovery site and SRM does not filter the initiator list given to the SRA.

Previous guides advised to create LIF to data locality. That is to say, always mount a datastore using a LIF located on the node that physically owns the volume. That is no longer a requirement in modern versions of ONTAP 9. Whenever possible, and if given cluster scoped credentials, ONTAP tools will still choose to load balance across LIFs local to the data, but it is not a requirement for high availability or performance.

NetApp ONTAP 9 can be configured to automatically remove Snapshot copies to preserve uptime in the event of an out-of-space condition when autosize is not able to supply sufficient emergency capacity. The default setting for this capability does not automatically delete the Snapshot copies that are created by SnapMirror. If SnapMirror Snapshot copies are deleted, then the NetApp SRA cannot reverse and resynchronize replication for the affected volume. To prevent ONTAP from deleting SnapMirror Snapshot copies, configure the Snapshot autodelete capability to try.

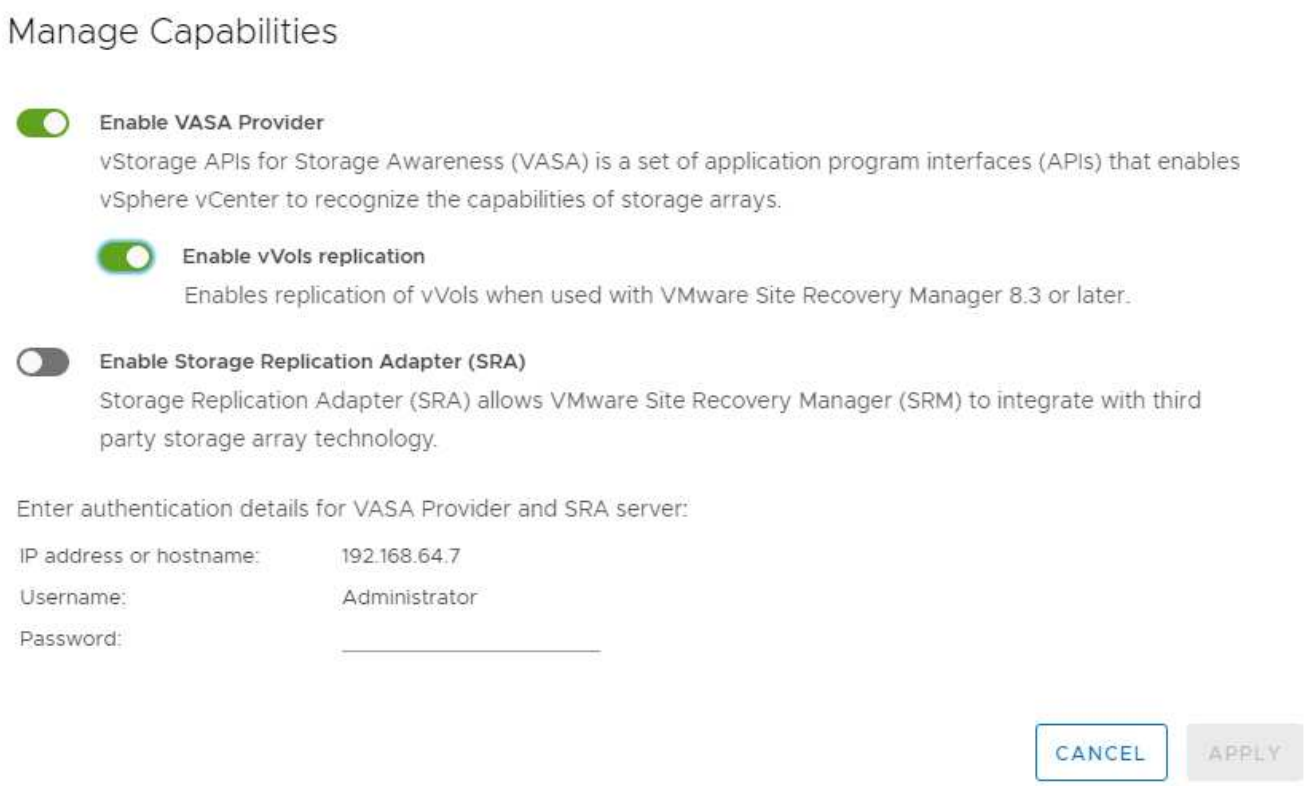
```
snap autodelete modify –volume -commitment try
```

Volume autosize should be set to `grow` for volumes containing SAN datastores and `grow_shrink` for NFS datastores. Refer to the ONTAP 9 Documentation Center for specific syntax.

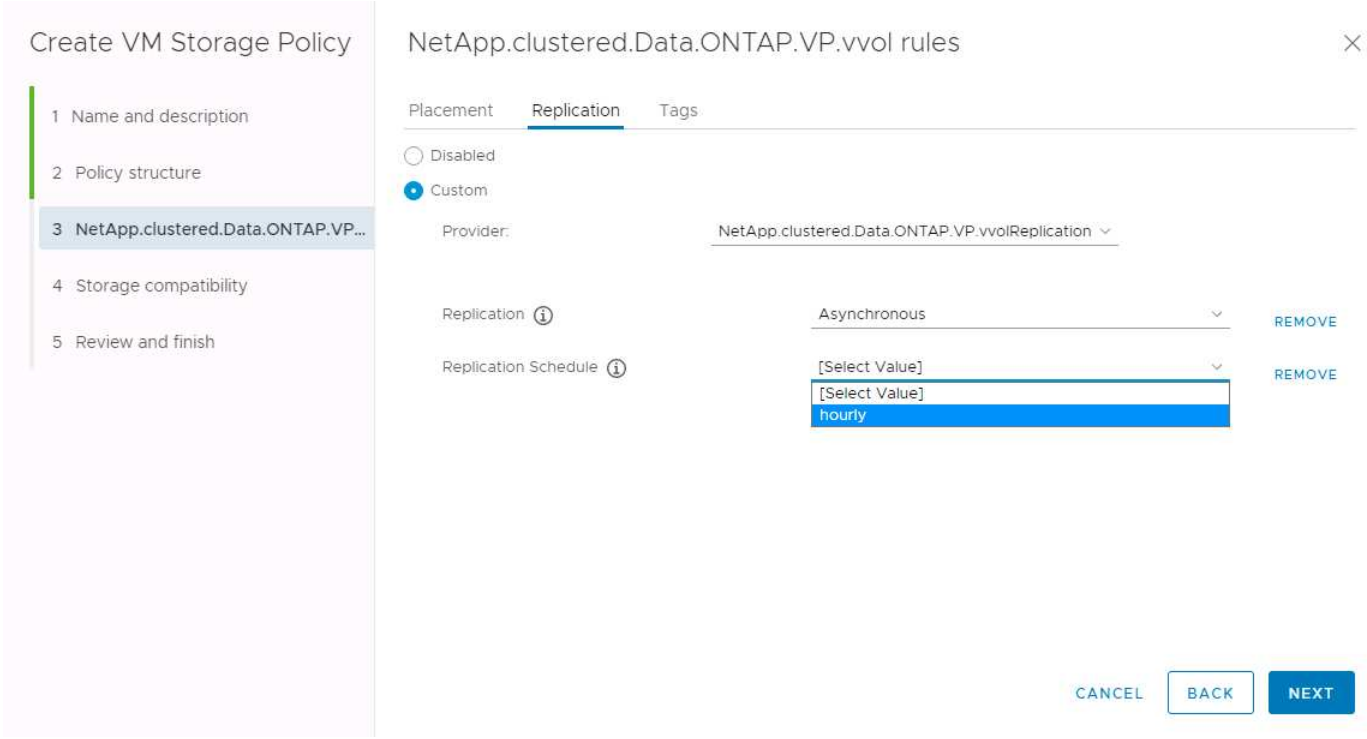
SPBM and vVols

Starting with SRM 8.3, protection of VMs using vVols datastores is supported. SnapMirror schedules are exposed to VM storage policies by the VASA Provider when vVols replication is enabled in the ONTAP tools settings menu, as shown in the following screenshots.

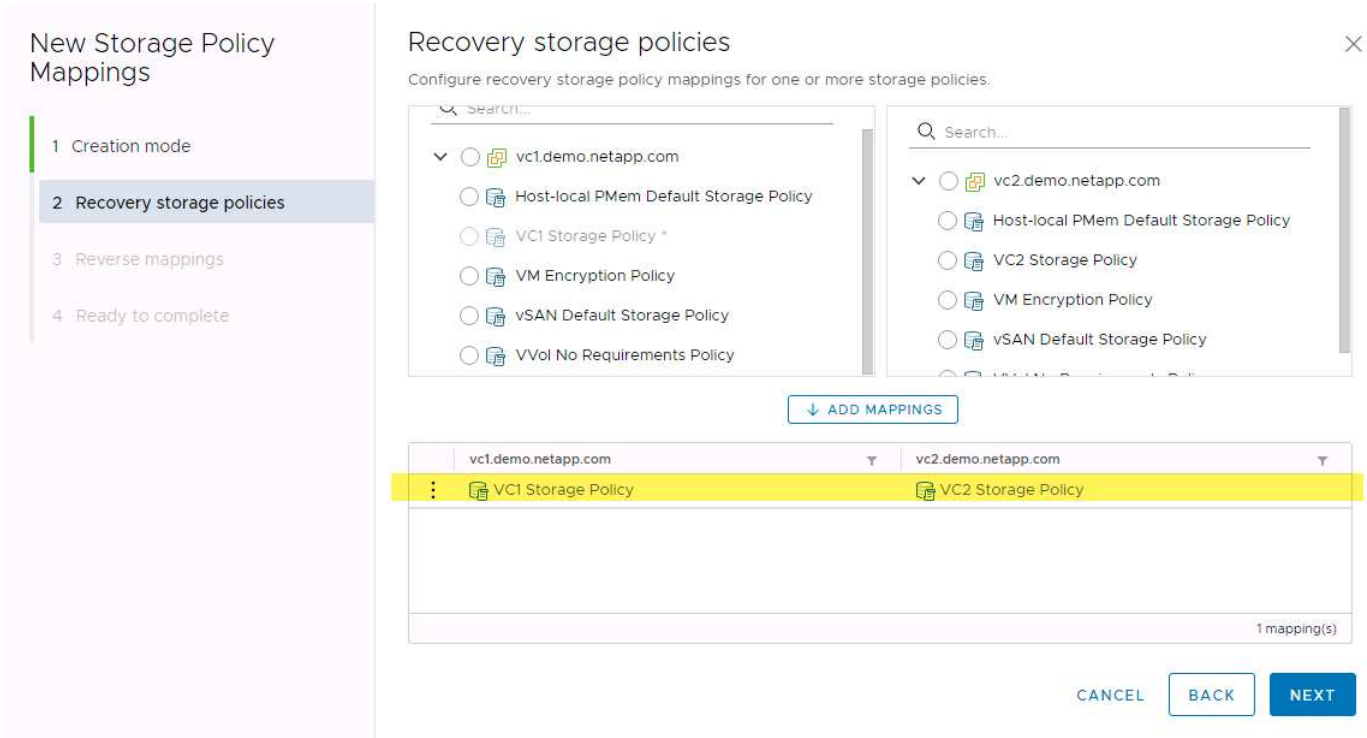
The following example show the enablement of vVols replication.



The following screenshot provides an example of SnapMirror schedules displayed in the Create VM Storage Policy wizard.



The ONTAP VASA Provider supports failover to dissimilar storage. For example, the system can fail over from ONTAP Select at an edge location to an AFF system in the core datacenter. Regardless of storage similarity, you must always configure storage policy mappings and reverse mappings for replication-enabled VM storage policies to make sure that services provided at the recovery site meet expectations and requirements. The following screenshot highlights a sample policy mapping.



Create replicated volumes for vVols datastores

Unlike previous vVols datastores, replicated vVols datastores must be created from the start with replication enabled, and they must use volumes that were pre-created on the ONTAP systems with SnapMirror

relationships. This requires pre-configuring things like cluster peering and SVM peering. These activities should be performed by your ONTAP administrator, because this facilitates a strict separation of responsibilities between those who manage the ONTAP systems across multiple sites and those who are primarily responsible for vSphere operations.

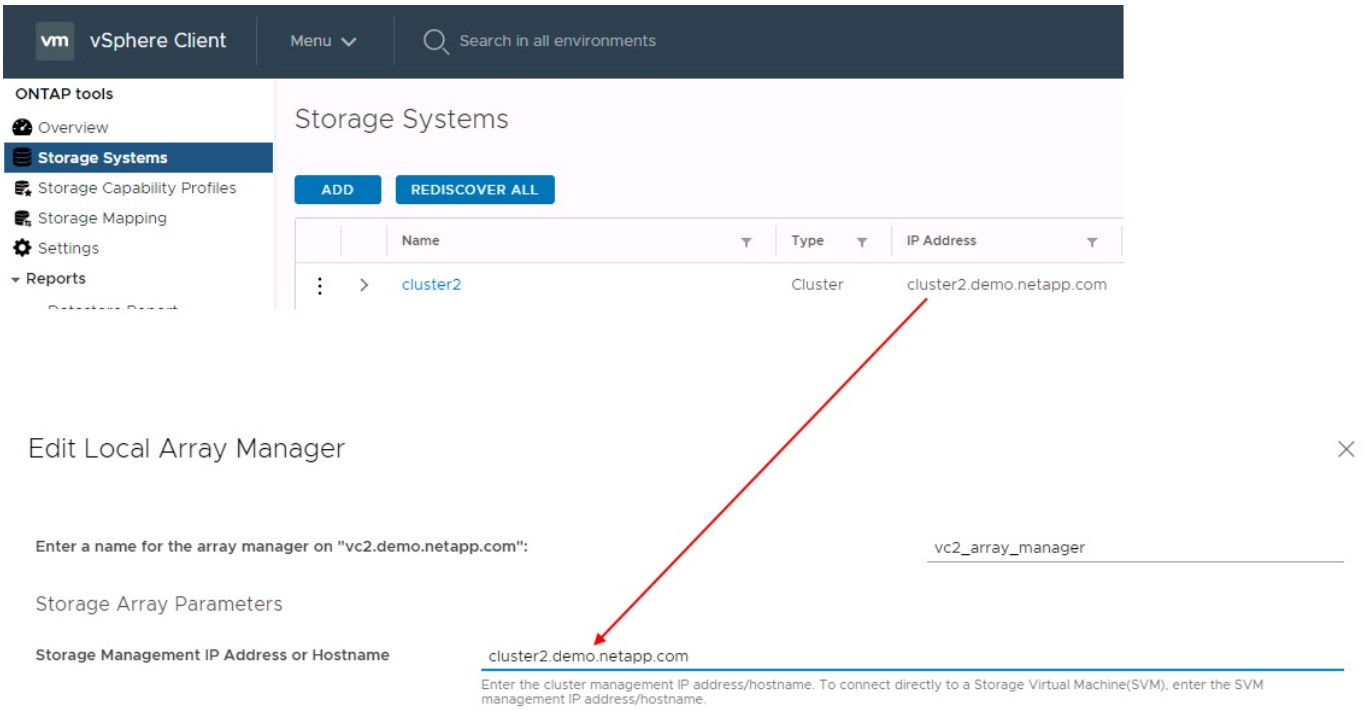
This does come with a new requirement on behalf of the vSphere administrator. Because volumes are being created outside the scope of ONTAP tools, it is unaware of the changes your ONTAP administrator has made until the regularly scheduled rediscovery period. For that reason, it is a best practice to always run rediscovery whenever you create a volume or SnapMirror relationship to be used with vVols. Simply right click on the host or cluster and select NetApp ONTAP tools > Update Host and Storage Data, as shown in the following screenshot.

One caution should be taken when it comes to vVols and SRM. Never mix protected and unprotected VMs in the same vVols datastore. The reason for this is that when you use SRM to failover to your DR site, only those VMs that are part of the protection group are brought online in DR. Therefore, when you reprotect (reverse the SnapMirror from DR back to production again), you may overwrite the VMs that were not failed over and could contain valuable data.

About array pairs

An array manager is created for each array pair. With SRM and ONTAP tools, each array pairing is done with the scope of an SVM, even if you are using cluster credentials. This allows you to segment DR workflows between tenants based on which SVMs they have been assigned to manage. You can create multiple array managers for a given cluster, and they can be asymmetric in nature. You can fan out or fan in between different ONTAP 9 clusters. For example, you can have SVM-A and SVM-B on Cluster-1 replicating to SVM-C on Cluster-2, SVM-D on Cluster-3, or vice-versa.

When configuring array pairs in SRM, you should always add them in SRM the same way as you added them to ONTAP Tools, meaning, they must use the same username, password, and management LIF. This requirement ensures that SRA communicates properly with the array. The following screenshot illustrates how a cluster might appear in ONTAP Tools and how it might be added to an array manager.



About replication groups

Replication groups contain logical collections of virtual machines that are recovered together. The ONTAP tools VASA Provider automatically creates replication groups for you. Because ONTAP SnapMirror replication occurs at the volume level, all VMs in a volume are in the same replication group.

There are several factors to consider with replication groups and how you distribute VMs across FlexVol volumes. Grouping similar VMs in the same volume can increase storage efficiency with older ONTAP systems that lack aggregate- level deduplication, but grouping increases the size of the volume and reduces volume I/O concurrency. The best balance of performance and storage efficiency can be achieved in modern ONTAP systems by distributing VMs across FlexVol volumes in the same aggregate, thereby leveraging aggregate level deduplication and gaining greater I/O parallelization across multiple volumes. You can recover VMs in the volumes together because a protection group (discussed below) can contain multiple replication groups. The downside to this layout is that blocks might be transmitted over the wire multiple times because volume SnapMirror doesn't take aggregate deduplication into account.

One final consideration for replication groups is that each one is by its nature a logical consistency group (not to be confused with SRM consistency groups). This is because all VMs in the volume are transferred together using the same snapshot. So if you have VMs that must be consistent with each other, consider storing them in the same FlexVol.

About protection groups

Protection groups define VMs and datastores in groups that are recovered together from the protected site. The protected site is where the VMs that are configured in a protection group exist during normal steady-state operations. It is important to note that even though SRM might display multiple array managers for a protection group, a protection group cannot span multiple array managers. For this reason, you should not span VM files across datastores on different SVMs.

About recovery plans

Recovery plans define which protection groups are recovered in the same process. Multiple protection groups can be configured in the same recovery plan. Also, to enable more options for the execution of recovery plans,

a single protection group can be included in multiple recovery plans.

Recovery plans allow SRM administrators to define recovery workflows by assigning VMs to a priority group from 1 (highest) to 5 (lowest), with 3 (medium) being the default. Within a priority group, VMs can be configured for dependencies.

For example, your company could have a tier-1 business critical application that relies on a Microsoft SQL server for its database. So, you decide to place your VMs in priority group 1. Within priority group 1, you begin planning the order to bring up services. You probably want your Microsoft Windows domain controller to boot up before your Microsoft SQL server, which would need to be online before your application server, and so on. You would add all these VMs to the priority group and then set the dependencies, because dependencies only apply within a given priority group.

NetApp strongly recommends working with your application teams to understand the order of operations required in a failover scenario and to construct your recovery plans accordingly.

Test failover

As a best practice, always perform a test failover whenever a change is made to the configuration of a protected VM storage. This ensures that, in the event of a disaster, you can trust that Site Recovery Manager is able to restore services within the expected RTO target.

NetApp also recommends confirming in-guest application functionality occasionally, especially after reconfiguring VM storage.

When a test recovery operation is performed, a private test bubble network is created on the ESXi host for the VMs. However, this network is not automatically connected to any physical network adapters and therefore does not provide connectivity between the ESXi hosts. To allow communication among VMs that are running on different ESXi hosts during DR testing, a physical private network is created between the ESXi hosts at the DR site. To verify that the test network is private, the test bubble network can be separated physically or by using VLANs or VLAN tagging. This network must be segregated from the production network because as the VMs are recovered, they cannot be placed on the production network with IP addresses that could conflict with actual production systems. When a recovery plan is created in SRM, the test network that was created can be selected as the private network to connect the VMs to during the test.

After the test has been validated and is no longer required, perform a cleanup operation. Running cleanup returns the protected VMs to their initial state and resets the recovery plan to the Ready state.

Failover considerations

There are several other considerations when it comes to failing over a site in addition to the order of operations mentioned in this guide.

One issue you might have to contend with is networking differences between sites. Some environments might be able to use the same network IP addresses at both the primary site and the DR site. This ability is referred to as a stretched virtual LAN (VLAN) or stretched network setup. Other environments might have a requirement to use different network IP addresses (for example, in different VLANs) at the primary site relative to the DR site.

VMware offers several ways to solve this problem. For one, network virtualization technologies like VMware NSX-T Data Center abstract the entire networking stack from layers 2 through 7 from the operating environment, allowing for more portable solutions. You can read more about NSX-T options with SRM here.

SRM also gives you the ability to change the network configuration of a VM as it is recovered. This reconfiguration includes settings such as IP addresses, gateway address, and DNS server settings. Different

network settings, which are applied to individual VMs as they are recovered, can be specified in the property's settings of a VM in the recovery plan.

To configure SRM to apply different network settings to multiple VMs without having to edit the properties of each one in the recovery plan, VMware provides a tool called the dr-ip-customizer. For information on how to use this utility, refer to VMware's documentation here.

Reprotect

After a recovery, the recovery site becomes the new production site. Because the recovery operation broke the SnapMirror replication, the new production site is not protected from any future disaster. A best practice is to protect the new production site to another site immediately after a recovery. If the original production site is operational, the VMware administrator can use the original production site as a new recovery site to protect the new production site, effectively reversing the direction of protection. Reprotection is available only in non-catastrophic failures. Therefore, the original vCenter Servers, ESXi servers, SRM servers, and corresponding databases must be eventually recoverable. If they are not available, a new protection group and a new recovery plan must be created.

Failback

A failback operation is fundamentally a failover in a different direction than before. As a best practice, you verify that the original site is back to acceptable levels of functionality before attempting to failback, or, in other words, failover to the original site. If the original site is still compromised, you should delay failback until the failure is sufficiently remediated.

Another failback best practice is to always perform a test failover after completing reprotect and before doing your final failback. This verifies that the systems in place at the original site can complete the operation.

Reprotecting the original site

After failback, you should confirm with all stake holders that their services have been returned to normal before running reprotect again,

Running reprotect after failback essentially puts the environment back in the state it was in at the beginning, with SnapMirror replication again running from the production site to the recovery site.

Replication topologies

In ONTAP 9, the physical components of a cluster are visible to cluster administrators, but they are not directly visible to the applications and hosts that use the cluster. The physical components provide a pool of shared resources from which the logical cluster resources are constructed. Applications and hosts access data only through SVMs that contain volumes and LIFs.

Each NetApp SVM is treated as an array in VMware vCenter Site Recovery Manager. SRM supports certain array-to-array (or SVM-to-SVM) replication layouts.

A single VM cannot own data—Virtual Machine Disk (VMDK) or RDM—on more than one SRM array for the following reasons:

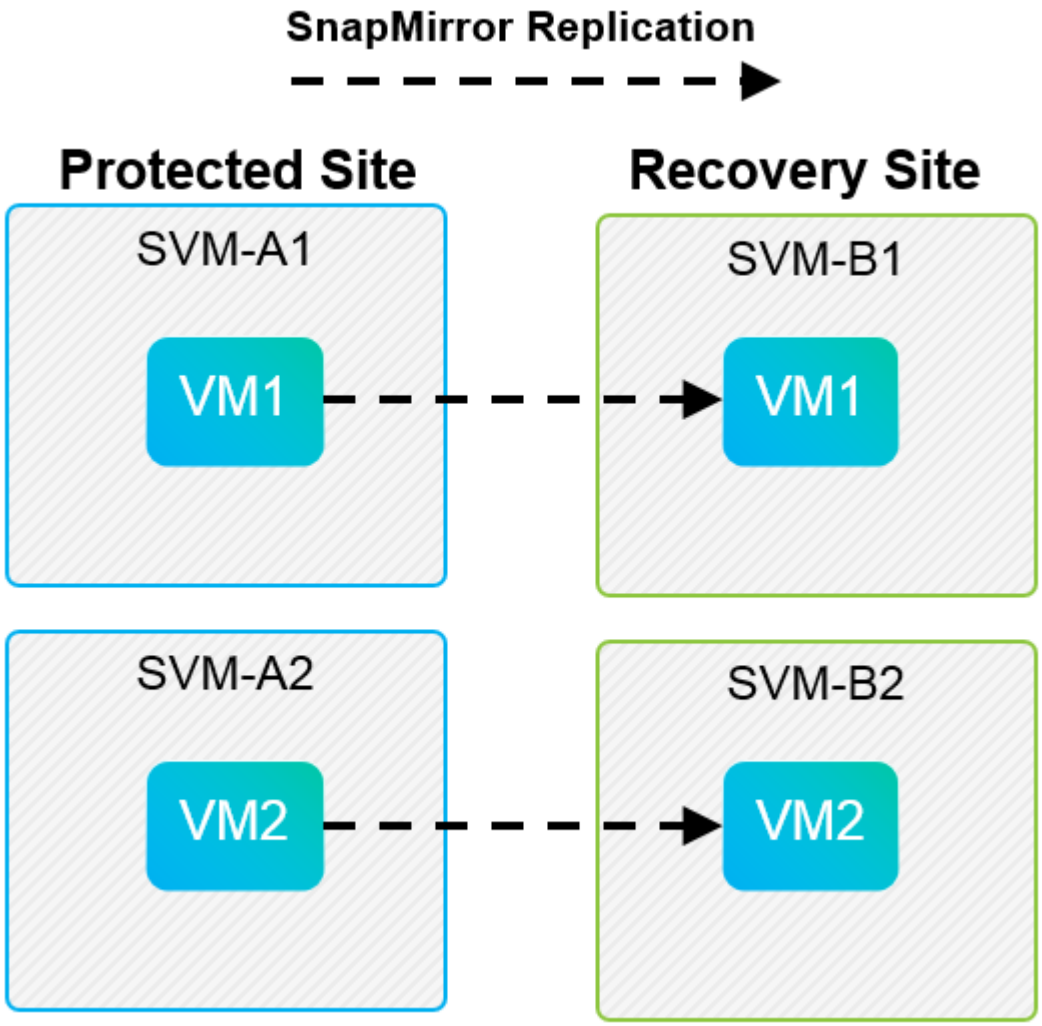
- SRM sees only the SVM, not an individual physical controller.
- An SVM can control LUNs and volumes that span multiple nodes in a cluster.

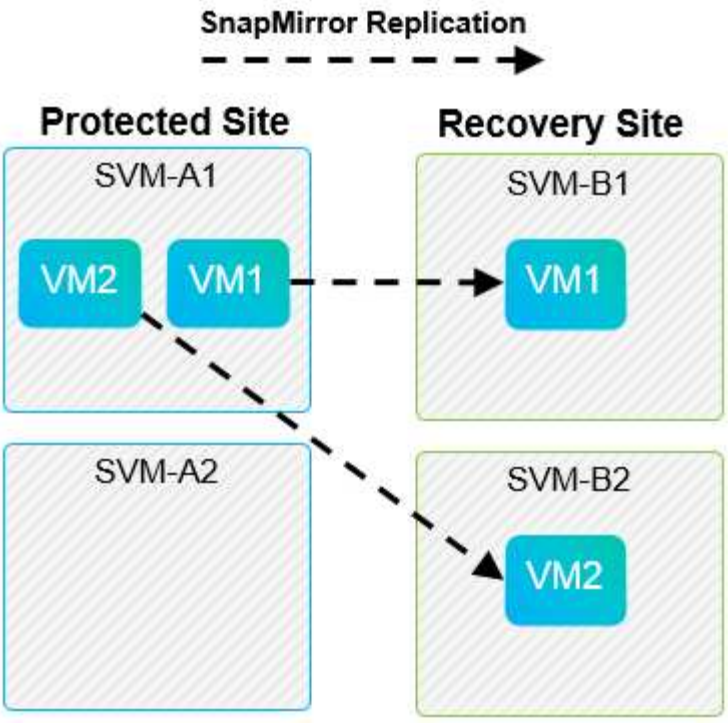
Best Practice

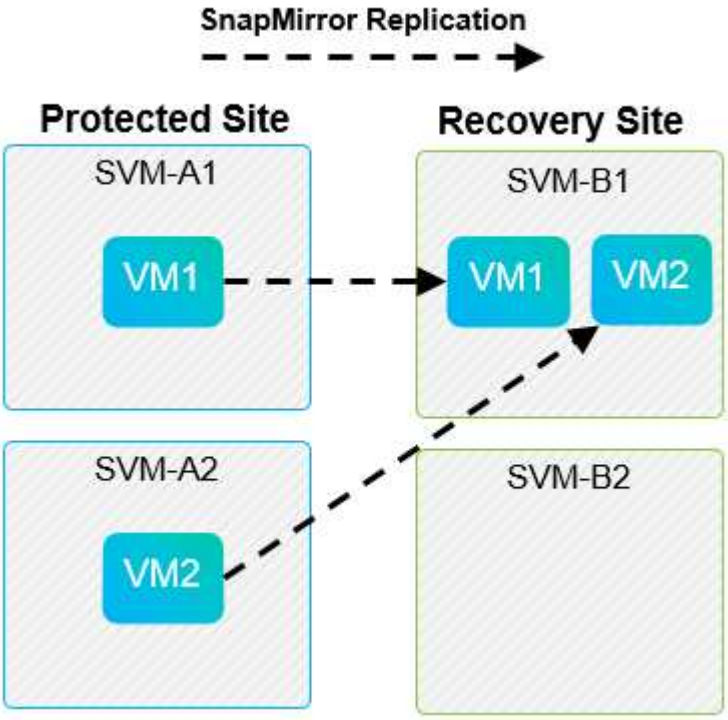
1. To determine supportability, keep this rule in mind: to protect a VM by using SRM and the NetApp SRA, all parts of the VM must exist on only one SVM. This rule applies at both the protected site and the recovery site.

Supported SnapMirror layouts

The following figures show the SnapMirror relationship layout scenarios that SRM and SRA support. Each VM in the replicated volumes owns data on only one SRM array (SVM) at each site.




SnapMirror Replication
Protected Site
Recovery Site
SVM-A1
SVM-B1
VM2
VM1
VM1
SVM-A2
SVM-B2
VM2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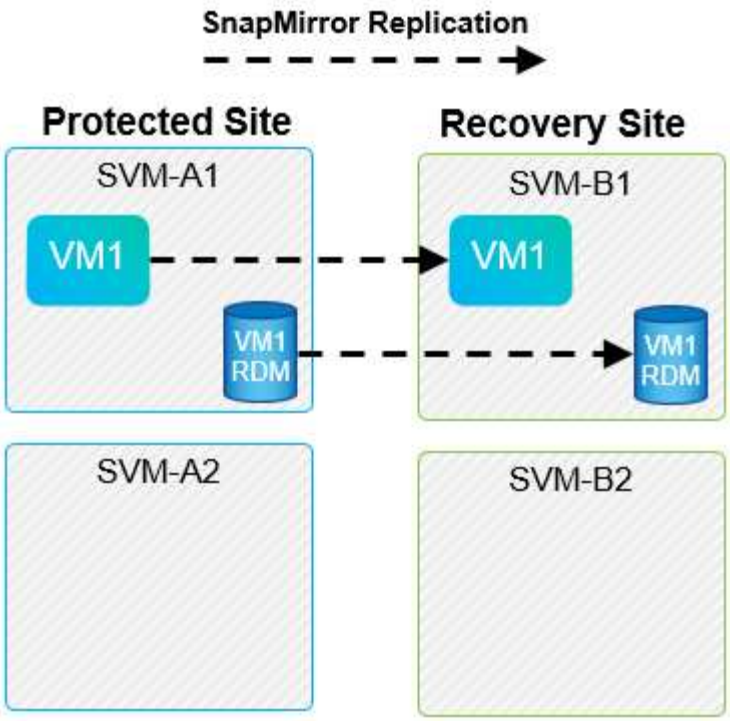
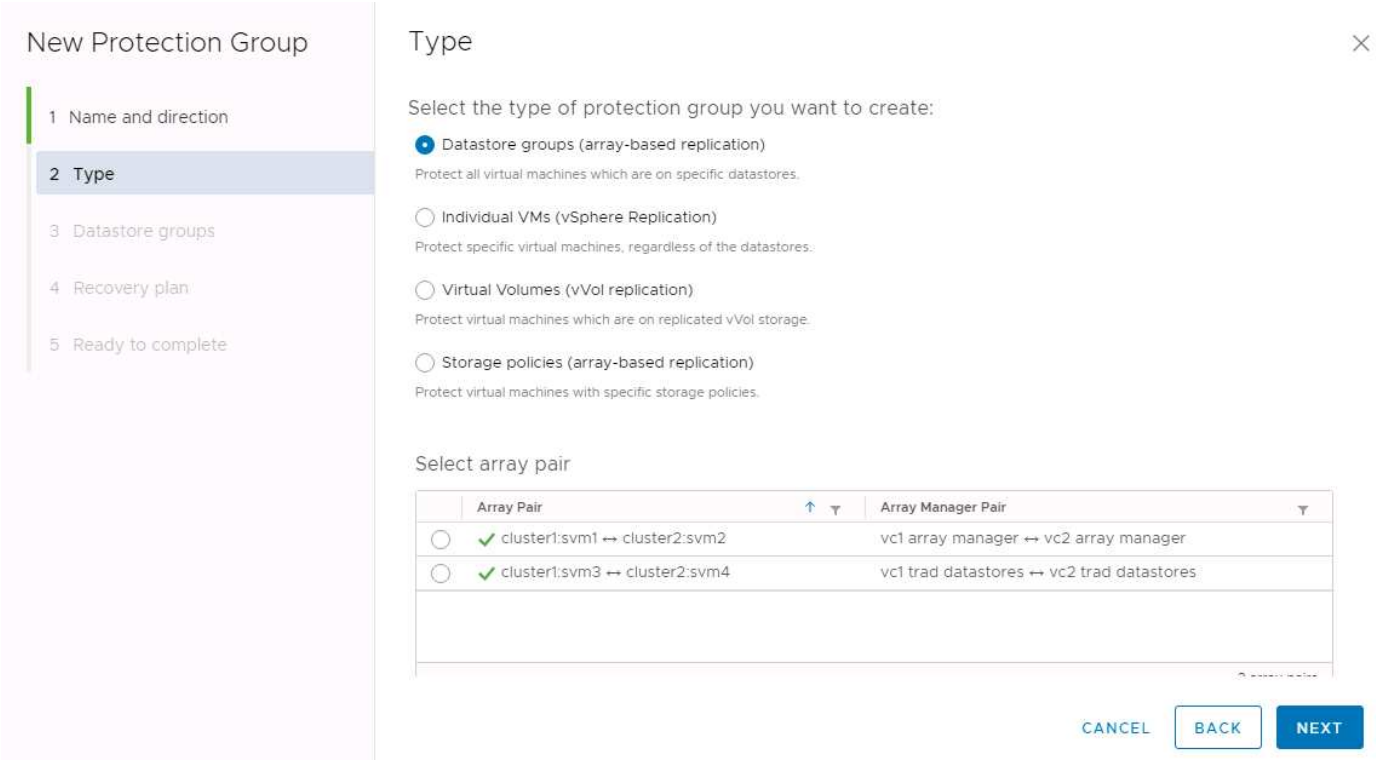


Supported Array Manager layouts

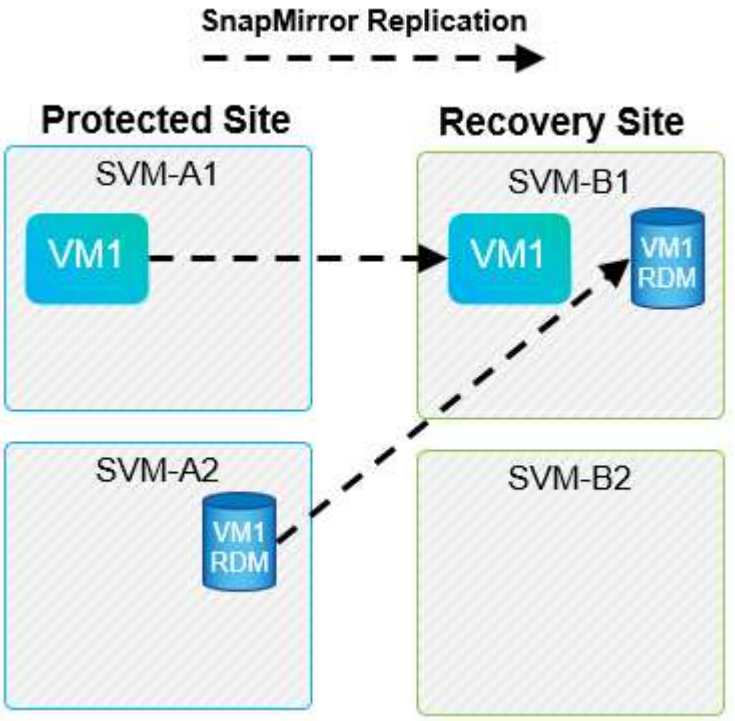
When you use array-based replication (ABR) in SRM, protection groups are isolated to a single array pair, as shown in the following screenshot. In this scenario, `SVM1` and `SVM2` are peered with `SVM3` and `SVM4` at the recovery site. However, you can select only one of the two array pairs when you create a protection group.

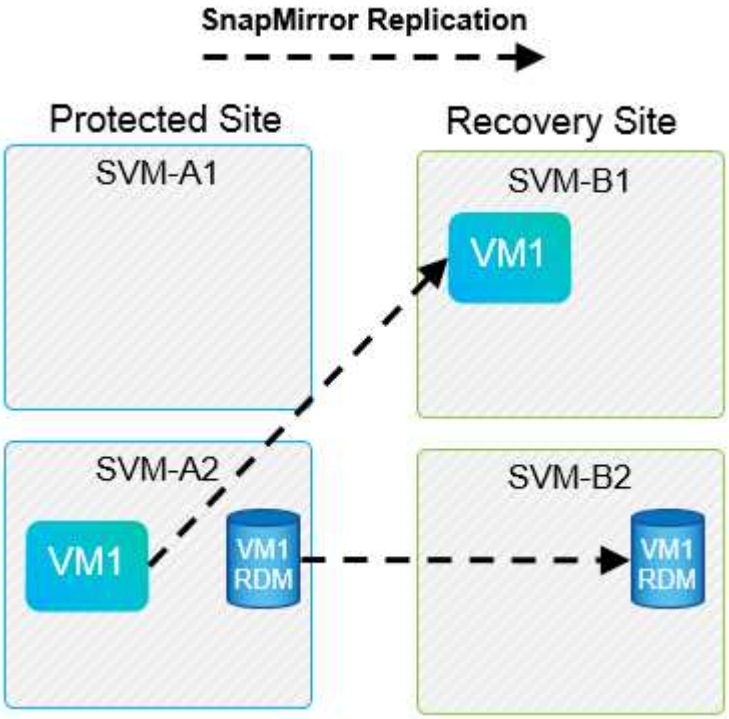


Unsupported layouts

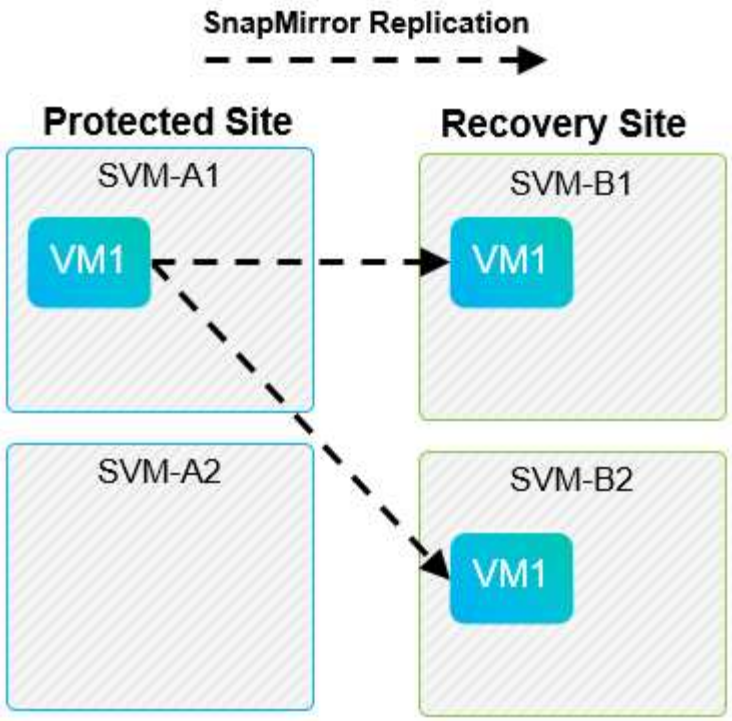
Unsupported configurations have data (VMDK or RDM) on multiple SVMs that is owned by an individual VM. In

the examples shown in the following figures, `VM1` cannot be configured for protection with SRM because `VM1` has data on two SVMs.



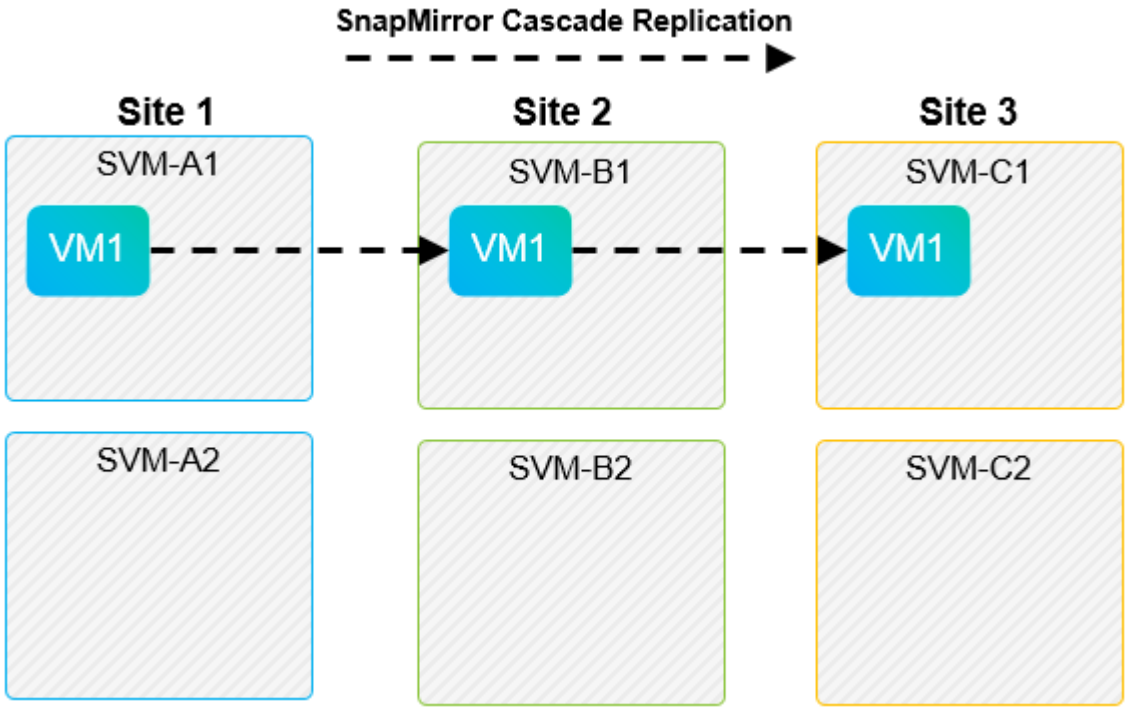


Any replication relationship in which an individual NetApp volume is replicated from one source SVM to multiple destinations in the same SVM or in different SVMs is referred to as SnapMirror fan-out. Fan-out is not supported with SRM. In the example shown in the following figure, `VM1` cannot be configured for protection in SRM because it is replicated with SnapMirror to two different locations.



SnapMirror cascade

SRM does not support cascading of SnapMirror relationships, in which a source volume is replicated to a destination volume and that destination volume is also replicated with SnapMirror to another destination volume. In the scenario shown in the following figure, SRM cannot be used for failover between any sites.



SnapMirror and SnapVault

NetApp SnapVault software enables disk-based backup of enterprise data between NetApp storage systems. SnapVault and SnapMirror can coexist in the same environment; however, SRM supports the failover of only

the SnapMirror relationships.

> The NetApp SRA supports the `mirror-vault` policy type.

SnapVault was rebuilt from the ground up for ONTAP 8.2. Although former Data ONTAP 7-Mode users should find similarities, major enhancements have been made in this version of SnapVault. One major advance is the ability to preserve storage efficiencies on primary data during SnapVault transfers.

An important architectural change is that SnapVault in ONTAP 9 replicates at the volume level as opposed to at the qtree level, as is the case in 7-Mode SnapVault. This setup means that the source of a SnapVault relationship must be a volume, and that volume must replicate to its own volume on the SnapVault secondary system.

In an environment in which SnapVault is used, specifically named Snapshot copies are created on the primary storage system. Depending on the configuration implemented, the named Snapshot copies can be created on the primary system by a SnapVault schedule or by an application such as NetApp Active IQ Unified Manager. The named Snapshot copies that are created on the primary system are then replicated to the SnapMirror destination, and from there they are vaulted to the SnapVault destination.

A source volume can be created in a cascade configuration in which a volume is replicated to a SnapMirror destination in the DR site, and from there it is vaulted to a SnapVault destination. A source volume can also be created in a fan-out relationship in which one destination is a SnapMirror destination and the other destination is a SnapVault destination. However, SRA does not automatically reconfigure the SnapVault relationship to use the SnapMirror destination volume as the source for the vault when SRM failover or replication reversal occurs.

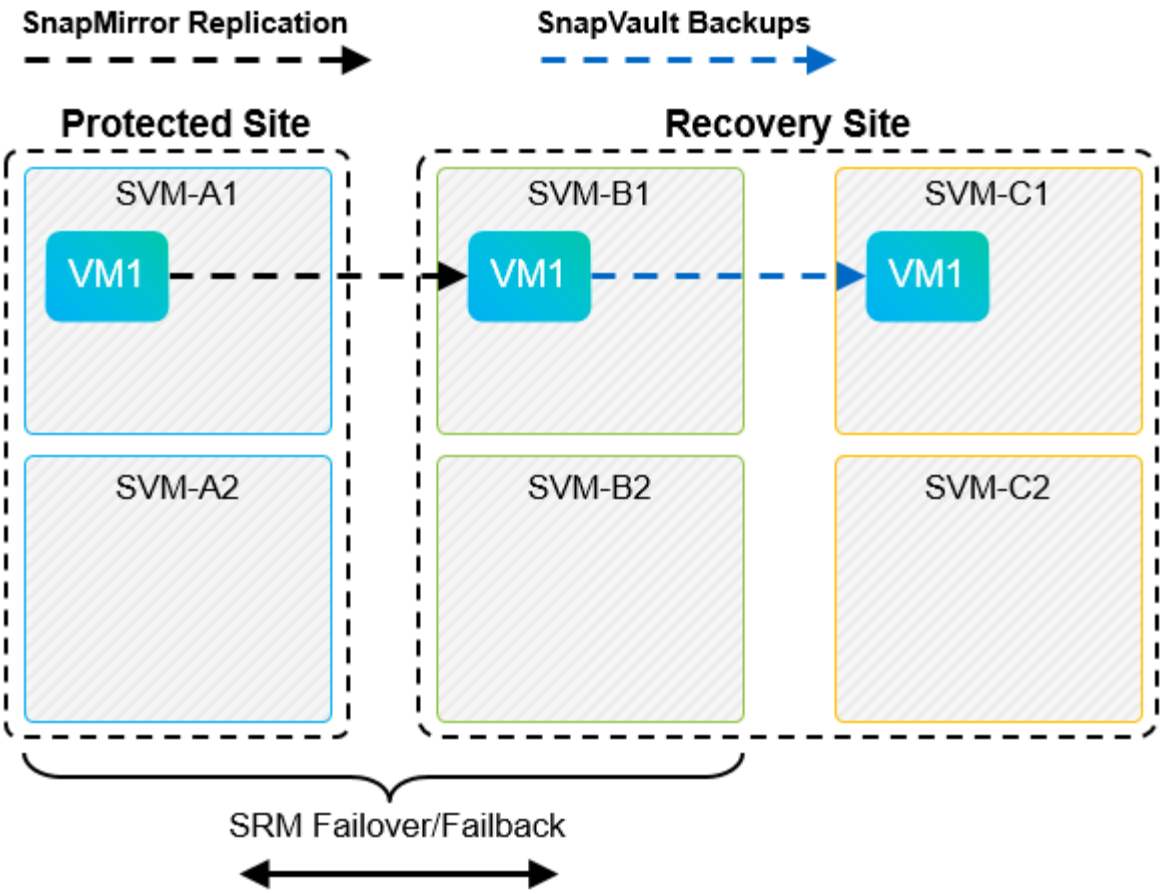
For the latest information about SnapMirror and SnapVault for ONTAP 9, see TR-4015 SnapMirror Configuration Best Practice Guide for ONTAP 9.

Best Practice

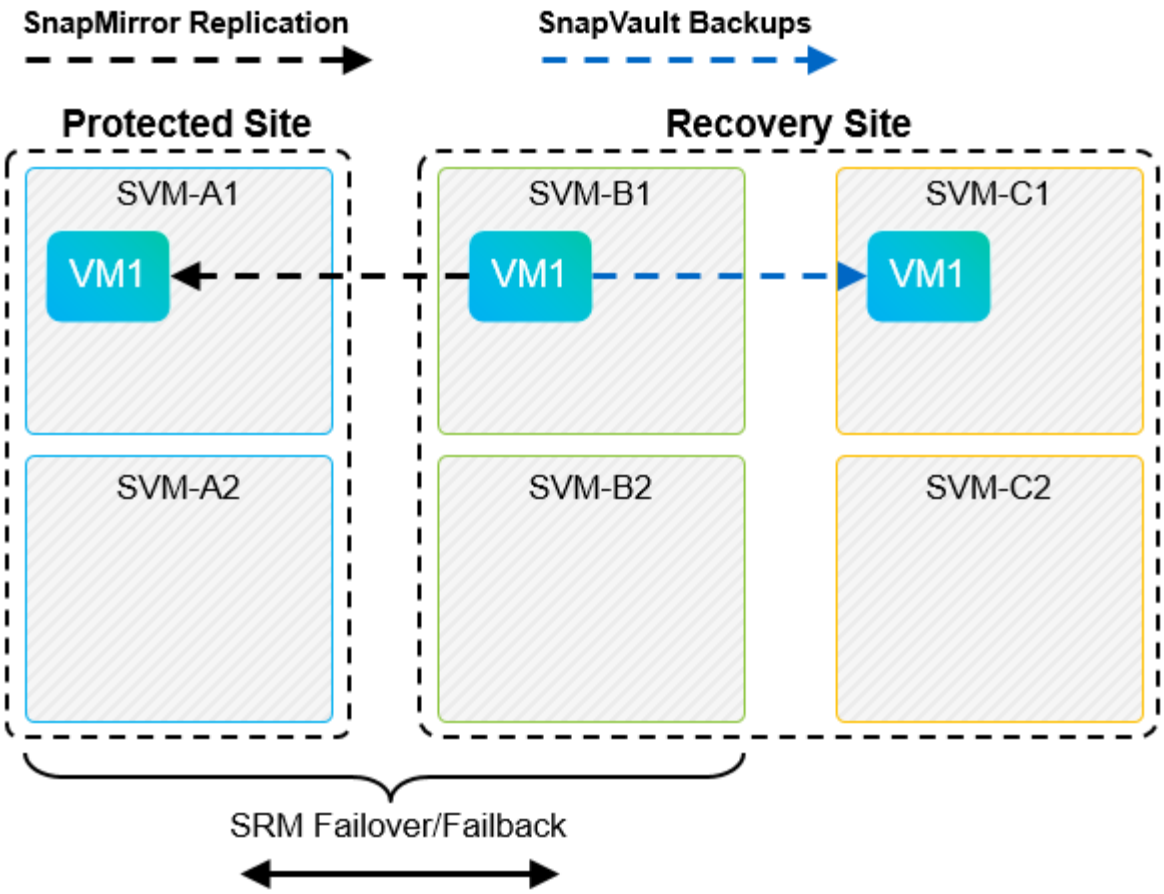
1. If SnapVault and SRM are used in the same environment, NetApp recommends using a SnapMirror to SnapVault cascade configuration in which SnapVault backups are normally performed from the SnapMirror destination at the DR site. In the event of a disaster, this configuration makes the primary site inaccessible. Keeping the SnapVault destination at the recovery site allows SnapVault backups to be reconfigured after failover so that SnapVault backups can continue while operating at the recovery site.

In a VMware environment, each datastore has a universal unique identifier (UUID), and each VM has a unique managed object ID (MOID). These IDs are not maintained by SRM during failover or failback. Because datastore UUIDs and VM MOIDs are not maintained during failover by SRM, any applications that depend on these IDs must be reconfigured after SRM failover. An example application is NetApp Active IQ Unified Manager, which coordinates SnapVault replication with the vSphere environment.

The following figure depicts a SnapMirror to SnapVault cascade configuration. If the SnapVault destination is at the DR site or at a tertiary site that is not affected by an outage at the primary site, the environment can be reconfigured to allow backups to continue after failover.



The following figure depicts the configuration after SRM has been used to reverse SnapMirror replication back to the primary site. The environment has also been reconfigured such that SnapVault backups are occurring from what is now the SnapMirror source. This setup is a SnapMirror SnapVault fan-out configuration.



After SRM performs failback and a second reversal of the SnapMirror relationships, the production data is back at the primary site. This data is now protected in the same way that it was before the failover to the DR site—through SnapMirror and SnapVault backups.

Use of Qtrees in Site Recovery Manager environments

Qtrees are special directories that allow the application of file system quotas for NAS. ONTAP 9 allows the creation of qtrees, and qtrees can exist in volumes that are replicated with SnapMirror. However, SnapMirror does not allow replication of individual qtrees or qtree-level replication. All SnapMirror replication is at the volume level only. For this reason, NetApp does not recommend the use of qtrees with SRM.

Mixed FC and iSCSI environments

With the supported SAN protocols (FC, FCoE, and iSCSI), ONTAP 9 provides LUN services—that is, the ability to create and map LUNs to attached hosts. Because the cluster consists of multiple controllers, there are multiple logical paths that are managed by multipath I/O to any individual LUN. Asymmetric logical unit access (ALUA) is used on the hosts so that the optimized path to a LUN is selected and is made active for data transfer. If the optimized path to any LUN changes (for example, because the containing volume is moved), ONTAP 9 automatically recognizes and nondisruptively adjusts for this change. If the optimized path becomes unavailable, ONTAP can nondisruptively switch to any other available path.

VMware SRM and NetApp SRA support the use of the FC protocol at one site and the iSCSI protocol at the other site. It does not support having a mix of FC-attached datastores and iSCSI-attached datastores in the same ESXi host or in different hosts in the same cluster, however. This configuration is not supported with SRM because, during the SRM failover or test failover, SRM includes all FC and iSCSI initiators in the ESXi hosts in the request.

Best Practice

1. SRM and SRA support mixed FC and iSCSI protocols between the protected and recovery sites. However, each site should be configured with only one protocol, either FC or iSCSI, not both protocols at the same site. If a requirement exists to have both FC and iSCSI protocols configured at the same site, NetApp recommends that some hosts use iSCSI and other hosts use FC. NetApp also recommends in this case that SRM resource mappings be set up so that the VMs are configured to fail over into one group of hosts or the other.

Troubleshooting SRM when using vVols replication

The workflow within SRM is significantly different when using vVols replication from what is used with SRA and traditional datastores. For example, there is no array manager concept. As such, `discoverarrays` and `discoverdevices` commands are never seen.

When troubleshooting, it is beneficial to understand the new workflows, which are listed below:

1. queryReplicationPeer: Discovers the replication agreements between two fault domains.
2. queryFaultDomain: Discovers fault domain hierarchy.
3. queryReplicationGroup: Discovers the replication groups present in the source or target domains.
4. syncReplicationGroup: Synchronizes the data between source and target.
5. queryPointInTimeReplica: Discovers the point in time replicas on a target.
6. testFailoverReplicationGroupStart: Begins test failover.
7. testFailoverReplicationGroupStop: Ends test failover.
8. promoteReplicationGroup: Promotes a group currently in test to production.
9. prepareFailoverReplicationGroup: Prepares for a disaster recovery.
10. failoverReplicationGroup: Executes disaster recovery.
11. reverseReplicateGroup: Initiates reverse replication.
12. queryMatchingContainer: Finds containers (along with Hosts or Replication Groups) that might satisfy a provisioning request with a given policy.
13. queryResourceMetadata: Discovers the metadata of all resources from the VASA provider, the resource utilization can be returned as an answer to the queryMatchingContainer function.

The most common error seen when configuring vVols replication is a failure to discover the SnapMirror relationships. This occurs because the volumes and SnapMirror relationships are created outside of the purview of ONTAP Tools. Therefore, it is a best practice to always make sure your SnapMirror relationship is fully initialized and that you have run a rediscovery in ONTAP Tools at both sites before attempting to create a replicated vVols datastore.

Conclusion

VMware vCenter Site Recovery Manager is a disaster recovery offering that provides automated orchestration and nondisruptive testing of centralized recovery plans to simplify disaster recovery management for all virtualized applications.

By deploying Site Recovery Manager on NetApp ONTAP systems, you can dramatically lower the cost and complexity of disaster recovery. With high-performance, easy-to-manage, and scalable storage appliances and robust software offerings, NetApp offers flexible storage and data management solutions to support vSphere

environments.

The best practices and recommendations that are provided in this guide are not a one-size-fits-all solution. This document contains a collection of best practices and recommendations that provide guidelines to plan, deploy, and manage SRM DR plans. Consult with a local NetApp VMware expert when you plan and deploy VMware vCenter Site Recovery environments onto NetApp storage. NetApp VMware experts can quickly identify the needs and demands of any vSphere environment and can adjust the storage solution accordingly.

Additional Information

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

- TR-4597: VMware vSphere for ONTAP
  https://docs.netapp.com/us-en/netapp-solutions/virtualization/vsphere_ontap_ontap_for_vsphere.html
- TR-4400: VMware vSphere Virtual Volumes with ONTAP
  https://www.netapp.com/pdf.html?item=/media/13555-tr4400.pdf
- TR-4015 SnapMirror Configuration Best Practice Guide for ONTAP 9
  https://www.netapp.com/media/17229-tr4015.pdf?v=127202175503P
- RBAC User Creator for ONTAP
  https://mysupport.netapp.com/site/tools/tool-eula/rbac
- ONTAP tools for VMware vSphere Resources
  https://mysupport.netapp.com/site/products/all/details/otv/docsandkb-tab
- VMware Site Recovery Manager Documentation
  https://docs.vmware.com/en/Site-Recovery-Manager/index.html

Refer to the Interoperability Matrix Tool (IMT) on the NetApp Support site to validate that the exact product and feature versions described in this document are supported for your specific environment. The NetApp IMT defines the product components and versions that can be used to construct configurations that are supported by NetApp. Specific results depend on each customer's installation in accordance with published specifications.

WP-7353: ONTAP tools for VMware vSphere - Product Security

Chance Bingen, Dan Tulledge, Jenn Schrie, NetApp

This document describes the techniques and technology used to secure ONTAP tools for VMware vSphere 9.X from both existing and emerging threats in product environments.

Secure development activities

Software engineering with NetApp ONTAP Tools for VMware vSphere employs the following secure development activities:

- **Threat modeling.** The purpose of threat modelling is to discover security flaws in a feature, component, or product early in the software development life cycle. A threat model is a structured representation of all the information that affects the security of an application. In essence, it is a view of the application and its environment through the lens of security.
- **Dynamic Application Security Testing (DAST).** This technology is designed to detect vulnerable conditions on applications in their running state. DAST tests the exposed HTTP and HTML interfaces of web-enable applications.

- **Third-party code currency.** As part of software development with open-source software (OSS), you must address security vulnerabilities that might be associated with any OSS incorporated into your product. This is a continuing effort because a new OSS version might have a newly discovered vulnerability reported at any time.
- **Vulnerability scanning.** The purpose of vulnerability scanning is to detect common and known security vulnerabilities in NetApp products before they are released to customers.
- **Penetration testing.** Penetration testing is the process of evaluating a system, web application, or network to find security vulnerabilities that could be exploited by an attacker. Penetration tests (pen tests) at NetApp are conducted by a group of approved and trusted third-party companies. Their testing scope includes the launching of attacks against an application or software similar to hostile intruders or hackers using sophisticated exploitation methods or tools.

Product security features

NetApp ONTAP tools for VMware vSphere includes the following security features in each release.

- **Login banner.** SSH is disabled by default and only allows one-time logins if enabled from the VM console. The following login banner is shown after the user enters a username in the login prompt:

  WARNING: Unauthorized access to this system is forbidden and will be prosecuted by law. By accessing this system, you agree that your actions may be monitored if unauthorized usage is suspected.

  After the user completes login through the SSH channel, the following text is displayed:

```
Linux vsc1 4.19.0-12-amd64 #1 SMP Debian 4.19.152-1 (2020-10-18) x86_64
The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.
Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
```

- **Role-based access control (RBAC).** Two kinds of RBAC controls are associated with ONTAP tools:
  - Native vCenter Server privileges
  - vCenter plug-in specific privileges. For details, see this link.
- **Encrypted communications channels.** All external communication happens over HTTPS using version 1.2 of TLS.
- **Minimal port exposure.** Only the necessary ports are open on the firewall.

  The following table describes the open port details.

TCP v4/v6 port #	Direction	Function
8143	inbound	HTTPS connections for REST API
8043	inbound	HTTPS connections

TCP v4/v6 port #	Direction	Function
9060	inbound	HTTPS connections Used for SOAP over https connections This port must be opened to allow a client to connect to the ONTAP tools API server.
22	inbound	SSH (Disabled by default)
9080	inbound	HTTPS connections - VP and SRA - Internal connections from loopback only
9083	inbound	HTTPS connections - VP and SRA Used for SOAP over https connections
1162	inbound	VP SNMP trap packets
1527	internal only	Derby database port, only between this computer and itself, external connections not accepted — Internal connections only
443	bi-directional	Used for connections to ONTAP clusters

- **Support for certificate authority (CA) signed certificates.** ONTAP tools for VMware vSphere supports CA signed certificates. See this kb article for more information.
- **Audit logging.** Support bundles can be downloaded and are extremely detailed. ONTAP tools logs all user login and logout activity in a separate log file. VASA API calls are logged in a dedicated VASA audit log (local cxf.log).
- **Password policies.** The following password policies are followed:
  - Passwords are not logged in any log files.
  - Passwords are not communicated in plain text.
  - Passwords are configured during the installation process itself.
  - Password history is a configurable parameter.
  - Minimum password age is set to 24 hours.
  - Auto complete for the password fields are disabled.
  - ONTAP tools encrypts all stored credential information using SHA256 hashing.

WP-7355: SnapCenter Plug-in for VMware vSphere - Product security

Chance Bingen, NetApp

This document describes the techniques and technology used to secure the NetApp SnapCenter Plug-in for VMware vSphere 4.X from both existing and emerging threats in product environments.

Secure development activities

This document describes the techniques and technology used to secure the NetApp SnapCenter Plug-in for VMware vSphere 4.X from both existing and emerging threats in product environments.

NetApp SnapCenter Plug-in for VMware vSphere software engineering uses the following secure development activities:

- **Threat modeling.** The purpose of threat modelling is to discover security flaws in a feature, component, or product early in the software development life cycle. A threat model is a structured representation of all the information that affects the security of an application. In essence, it is a view of the application and its environment through the lens of security.
- **Dynamic application security testing (DAST).** Technologies that are designed to detect vulnerable conditions on applications in their running state. DAST tests the exposed HTTP and HTML interfaces of web-enable applications.
- **Third-party code currency.** As part of developing software and using open-source software (OSS), it is important to address security vulnerabilities that might be associated with OSS that has been incorporated into your product. This is a continuous effort as the version of the OSS component may have a newly discovered vulnerability reported at any time.
- **Vulnerability scanning.** The purpose of vulnerability scanning is to detect common and known security vulnerabilities in NetApp products before they are released to customers.
- **Penetration testing.** Penetration testing is the process of evaluating a system, web application or network to find security vulnerabilities that could be exploited by an attacker. Penetration tests (pen tests) at NetApp are conducted by a group of approved and trusted third-party companies. Their testing scope includes the launching of attacks against an application or software like hostile intruders or hackers using sophisticated exploitation methods or tools.
- **Product Security Incident Response activity.** Security vulnerabilities are discovered both internally and externally to the company and can pose a serious risk to NetAppâ€™s reputation if they are not addressed in a timely manner. To facilitate this process, a Product Security Incident Response Team (PSIRT) reports and tracks the vulnerabilities.

Product security features

NetApp SnapCenter Plug-in for VMware vSphere includes the following security features in each release:

- **Restricted shell access.** SSH is disabled by default, and one-time logins are only allowed if they are enabled from the VM console.
- **Access warning in login banner.** The following login banner is shown after the user enters a user name in the login prompt:

  WARNING: Unauthorized access to this system is forbidden and will be prosecuted by law. By accessing this system, you agree that your actions may be monitored if unauthorized usage is suspected.

  After the user completes login through the SSH channel, the following output displays:

```
Linux vsc1 4.19.0-12-amd64 #1 SMP Debian 4.19.152-1 (2020-10-18) x86_64
The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.
Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
```

- **Role-based access control (RBAC).** Two kinds of RBAC controls are associated with NetApp ONTAP tools:
  - Native vCenter Server privileges.

    - VMware vCenter plug-in specific privileges. For more information, see Role-Based Access Control (RBAC).
- **Encrypted communications channels.** All external communication happens over HTTPS by using TLS.
- **Minimal port exposure.** Only the necessary ports are open on the firewall.

The following table provides the open port details.

TCP v4/v6 port number	Function
8144	HTTPS connections for REST API
8080	HTTPS connections for OVA GUI
22	SSH (disabled by default)
3306	MySQL (internal connections only; external connections disabled by default)
443	Nginx (data protection services)

- **Support for Certificate Authority (CA) signed certificates.** SnapCenter Plug-in for VMware vSphere supports the feature of CA signed certificates. See How to create and/or import an SSL certificate to SnapCenter Plug-in for VMware vSphere (SCV).
- **Password policies.** The following password policies are in effect:
    - Passwords are not logged in any log files.
    - Passwords are not communicated in plain text.
    - Passwords are configured during the installation process itself.
    - All credential information is stored using SHA256 hashing.
- **Base operating system image.** The product ships with Debian Base OS for OVA with restricted access and shell access disabled. This reduces the attack footprint. Every SnapCenter release base operating system is updated with latest security patches available for maximum security coverage.

NetApp develops software features and security patches with regards to SnapCenter Plug-in for VMware vSphere appliance and then releases them to customers as a bundled software platform. Because these appliances include specific Linux sub-operating system dependencies as well as our proprietary software, NetApp recommends that you do not make changes to the sub-operating system because this has a high potential to affect the NetApp appliance. This could affect the ability of NetApp to support the appliance. NetApp recommends testing and deploying our latest code version for appliances because they are released to patch any security-related issues.

Introduction to automation for ONTAP and vSphere

VMware automation

Automation has been an integral part of managing VMware environments since the first days of VMware ESX. The ability to deploy infrastructure as code and extend practices to private cloud operations helps to alleviate concerns surrounding scale, flexibility, self-provisioning, and efficiency.

Automation can be organized into the following categories:

- **Virtual infrastructure deployment**

- **Guest machine operations**
- **Cloud operations**

There are many options available to administrators with respect to automating their infrastructure. Whether through using native vSphere features such as Host Profiles or Customization Specifications for virtual machines to available APIs on the VMware software components, operating systems, and NetApp storage systems; there is significant documentation and guidance available.

Data ONTAP 8.0.1 and later supports certain VMware vSphere APIs for Array Integration (VAAI) features when the ESX host is running ESX 4.1 or later. VAAI is a set of APIs that enable communication between VMware vSphere ESXi hosts and storage devices. These features help offload operations from the ESX host to the storage system and increase network throughput. The ESX host enables the features automatically in the correct environment. You can determine the extent to which your system is using VAAI features by checking the statistics contained in the VAAI counters.

The most common starting point for automating the deployment of a VMware environment is provisioning block or file-based datastores. It is important to map out the requirements of the actual tasks prior to developing the corresponding automation.

For more information concerning the automation of VMware environments, see the following resources:

- The NetApp Pub. NetApp configuration management and automation.
- The Ansible Galaxy Community for VMware. A collection of Ansible resources for VMware.
- VMware {code} Resources. Resources needed to design solutions for the software-defined data center, including forums, design standards, sample code, and developer tools.

vSphere traditional block storage provisioning with ONTAP

VMware vSphere supports the following VMFS datastore options with ONTAP SAN protocol support indicated.

VMFS datastore options	ONTAP SAN protocol support
Fibre Channel (FC)	yes
Fibre Channel over Ethernet (FCoE)	yes
iSCSI	yes
iSCSI Extensions for RDMA (iSER)	no
NVMe over Fabric with FC (NVMe/FC)	yes
NVMe over Fabric with RDMA over Converged Ethernet (NVMe/RoCE)	no

If iSER or NVMe/RoCE VMFS is required, check SANtricity-based storage systems.

vSphere VMFS datastore - Fibre Channel storage backend with ONTAP

About this task

This section covers the creation of a VMFS datastore with ONTAP Fibre Channel (FC) storage.

For automated provisioning, use one of these scripts: [PowerShell], Ansible Playbook, or [Terraform].

What you need

- The basic skills necessary to manage a vSphere environment and ONTAP
- An ONTAP storage system (FAS/AFF/CVO/ONTAP Select/ASA) running ONTAP 9.8 or later
- ONTAP credentials (SVM name, userID, and password)
- ONTAP WWPN of host, target, and SVM and LUN information
- The completed FC configuration worksheet
- vCenter Server credentials
- vSphere host(s) information
  - vSphere 7.0 or later
- Fabric switch(es)
  - With connected ONTAP FC data ports and vSphere hosts
  - With the N_port ID virtualization (NPIV) feature enabled
  - Create a single initiator single target zone.
    - Create one zone for each initiator (single initiator zone).
    - For each zone, include a target that is the ONTAP FC logical interface (WWPN) for the SVMs. There should be at least two logical interfaces per node per SVM. Do not use the WWPN of the physical ports.
- An ONTAP Tool for VMware vSphere deployed, configured, and ready to consume.

Provisioning a VMFS datastore

To provision a VMFS datastore, complete the following steps:

1. Check compatability with the Interoperability Matrix Tool (IMT)
2. Verify that the FCP Configuration is supported.

ONTAP tasks

1. Verify that you have an ONTAP license for FCP.
   a. Use the `system license show` command to check that FCP is listed.
   b. Use `licen se add -license-code <license code>` to add the license.
2. Make sure that the FCP protocol is enabled on the SVM.
   a. Verify the FCP on an existing SVM.
   b. Configure the FCP on an existing SVM.
   c. Create s new SVM with the FCP.
3. Make sure that FCP logical interfaces are available on an SVM.

a. Use `Network Interface show` to verify the FCP adapter.

b. When an SVM is created with the GUI, logical interfaces are a part of that process.

c. To rename network interfaces, use `Network Interface modify`.

4. Create and Map a LUN. Skip this step if you are using ONTAP tools for VMware vSphere.

VMware vSphere tasks

1. Verfiy that HBA drivers are installed. VMware supported HBAs have drivers deployed out of the box and should be visible in the Storage Adapter Information.
2. Provision a VMFS datastore with ONTAP Tools.

vSphere VMFS Datastore - Fibre Channel over Ethernet storage protocol with ONTAP

About this task

This section covers the creation of a VMFS datastore with the Fibre Channel over Ethernet (FCoE) transport protocol to ONTAP storage.

For automated provisioning, use one of these scripts: [PowerShell], Ansible Playbook, or [Terraform].

What you need

- The basic skills necessary to manage a vSphere environment and ONTAP
- An ONTAP storage system (FAS/AFF/CVO/ONTAP Select) running ONTAP 9.8 or later
- ONTAP credentials (SVM name, userID, and password)
- A supported FCoE combination
- A completed configuration worksheet
- vCenter Server credentials
- vSphere host(s) information
  - vSphere 7.0 or later
- Fabric switch(es)
  - With either ONTAP FC data ports or vSphere hosts connected
  - With the N_port ID virtualization (NPIV) feature enabled
  - Create a single initiator single target zone.
  - FC/FCoE zoning configured
- Network switch(es)
  - FCoE support
  - DCB support
  - Jumbo frames for FCoE
- ONTAP Tool for VMware vSphere deployed, configured, and ready to consume

Provision a VMFS datastore

- Check compatibility with the Interoperability Matrix Tool (IMT).

- Verify that the FCoE configuration is supported.

ONTAP tasks

1. Verify the ONTAP license for FCP.
   a. Use the `system license show` command to verify that the FCP is listed.
   b. Use `license add -license-code <license code>` to add a license.
2. Verify that the FCP protocol is enabled on the SVM.
   a. Verify the FCP on an existing SVM.
   b. Configure the FCP on an existing SVM.
   c. Create a new SVM with the FCP.
3. Verify that FCP logical interfaces are available on the SVM.
   a. Use `Network Interface show` to verify the FCP adapter.
   b. When the SVM is created with the GUI, logical interfaces are a part of that process.
   c. To rename the network interface, use `Network Interface modify`.
4. Create and map a LUN; skip this step if you are using ONTAP tools for VMware vSphere.

VMware vSphere tasks

1. Verify that HBA drivers are installed. VMware-supported HBAs have drivers deployed out of the box and should be visible in the storage adapter information.
2. Provision a VMFS datastore with ONTAP Tools.

vSphere VMFS Datastore - iSCSI Storage backend with ONTAP

About this task

This section covers the creation of a VMFS datastore with ONTAP iSCSI storage.

For automated provisioning, use one of these scripts: [PowerShell], Ansible Playbook, or [Terraform].

What you need

- The basic skills necessary to manage a vSphere environment and ONTAP.
- An ONTAP storage system (FAS/AFF/CVO/ONTAP Select/ASA) running ONTAP 9.8 or later
- ONTAP credentials (SVM name, userID, and password)
- ONTAP network port, SVM, and LUN information for iSCSI
- A completed iSCSI configuration worksheet
- vCenter Server credentials
- vSphere host(s) information
  - vSphere 7.0 or later
- iSCSI VMKernel adapter IP informattion
- Network switch(es)

- With ONTAP system network data ports and connected vSphere hosts
- VLAN(s) configured for iSCSI
- (Optional) link aggregation configured for ONTAP network data ports

- ONTAP Tool for VMware vSphere deployed, configured, and ready to consume

Steps

1. Check compatibility with the Interoperability Matrix Tool (IMT).
2. Verify that the iSCSI configuration is supported.
3. Complete the following ONTAP and vSphere tasks.

ONTAP tasks

1. Verify the ONTAP license for iSCSI.
   a. Use the `system license show` command to check if iSCSI is listed.
   b. Use `license add -license-code <license code>` to add the license.
2. Verify that the iSCSI protocol is enabled on the SVM.
3. Verify that iSCSI network logical interfaces are available on the SVM.

   When an SVM is created using the GUI, iSCSI network interfaces are also created.

4. Use the `Network interface` command to view or make changes to the network interface.

   Two iSCSI network interfaces per node are recommended.

5. Create an iSCSI network interface. You can use the default-data-blocks service policy.
6. Verify that the data-iscsi service is included in the service policy. You can use `network interface service-policy show` to verify.
7. Verify that jumbo frames are enabled.
8. Create and map the LUN. Skip this step if you are using ONTAP tools for VMware vSphere. Repeat this step for each LUN.

VMware vSphere tasks

1. Verify that at least one NIC is available for the iSCSI VLAN. Two NICs are preferred for better performance and fault tolerance.
2. Identify the number of physical NICs available on the vSphere host.
3. Configure the iSCSI initiator. A typical use case is a software iSCSI initiator.
4. Verify that the TCPIP stack for iSCSI is available.
5. Verify that iSCSI portgroups are available.
   - We typically use a single virtual switch with multiple uplink ports.
   - Use 1:1 adapter mapping.
6. Verify that iSCSI VMKernel adapters are enabled to match the number of NICs and that IPs are assigned.

7. Bind the iSCSI software adapter to the iSCSI VMKernel adapter(s).
8. Provision the VMFS datastore with ONTAP Tools. Repeat this step for all datastores.
9. Verify hardware acceleration support.

What's next?

After these the tasks are completed, the VMFS datastore is ready to consume for provisioning virtual machines.

Ansible Playbook

```
## Disclaimer: Sample script for reference purpose only.

- hosts: '{{ vsphere_host }}'
  name: Play for vSphere iSCSI Configuration
  connection: local
  gather_facts: false
  tasks:
    # Generate Session ID for vCenter
    - name: Generate a Session ID for vCenter
      uri:
        url: "https://{{ vcenter_hostname }}/rest/com/vmware/cis/session"
        validate_certs: false
        method: POST
        user: "{{ vcenter_username }}"
       password: "{{ vcenter_password }}"
        force_basic_auth: yes
        return_content: yes
      register: vclogin

    # Generate Session ID for ONTAP tools with vCenter
    - name: Generate a Session ID for ONTAP tools with vCenter
      uri:
        url: "https://{{ ontap_tools_ip
}}:8143/api/rest/2.0/security/user/login"
        validate_certs: false
        method: POST
        return_content: yes
        body_format: json
        body:
          vcenterUserName: "{{ vcenter_username }}"
          vcenterPassword: "{{ vcenter_password }}"
      register: login

    # Get existing registered ONTAP Cluster info with ONTAP tools
    - name: Get ONTAP Cluster info from ONTAP tools
      uri:
```

```
        url: "https://{{ ontap_tools_ip
}}:8143/api/rest/2.0/storage/clusters"
        validate_certs: false
        method: Get
        return_content: yes
        headers:
          vmware-api-session-id: "{{ login.json.vmwareApiSessionId }}"
      register: clusterinfo

    - name: Get ONTAP Cluster ID
      set_fact:
        ontap_cluster_id: "{{ clusterinfo.json |
json_query(clusteridquery) }}"
      vars:
        clusteridquery: "records[?ipAddress == '{{ netapp_hostname }}' &&
type=='Cluster'].id | [0]"

    - name: Get ONTAP SVM ID
      set_fact:
        ontap_svm_id: "{{ clusterinfo.json | json_query(svmidquery) }}"
      vars:
        svmidquery: "records[?ipAddress == '{{ netapp_hostname }}' &&
type=='SVM' && name == '{{ svm_name }}'].id | [0]"

    - name: Get Aggregate detail
      uri:
        url: "https://{{ ontap_tools_ip
}}:8143/api/rest/2.0/storage/clusters/{{ ontap_svm_id }}/aggregates"
        validate_certs: false
        method: GET
        return_content: yes
        headers:
          vmware-api-session-id: "{{ login.json.vmwareApiSessionId }}"
          cluster-id: "{{ ontap_svm_id }}"
      when: ontap_svm_id != ''
      register: aggrinfo

    - name: Select Aggregate with max free capacity
      set_fact:
        aggr_name: "{{ aggrinfo.json | json_query(aggrquery) }}"
      vars:
        aggrquery: "max_by(records, &freeCapacity).name"

    - name: Convert datastore size in MB
      set_fact:
        datastoreSizeInMB: "{{ iscsi_datastore_size |
```

```
human_to_bytes/1024/1024 | int }}"

    - name: Get vSphere Cluster Info
      uri:
        url: "https://{{ vcenter_hostname }}/api/vcenter/cluster?names={{
vsphere_cluster }}"
        validate_certs: false
        method: GET
        return_content: yes
        body_format: json
        headers:
          vmware-api-session-id: "{{ vclogin.json.value }}"
      when: vsphere_cluster != ''
      register: vcenterclusterid

    - name: Create iSCSI VMFS-6 Datastore with ONTAP tools
      uri:
        url: "https://{{ ontap_tools_ip
}}:8143/api/rest/3.0/admin/datastore"
        validate_certs: false
        method: POST
        return_content: yes
        status_code: [200]
        body_format: json
        body:
          traditionalDatastoreRequest:
            name: "{{ iscsi_datastore_name }}"
            datastoreType: VMFS
            protocol: ISCSI
            spaceReserve: Thin
            clusterID:  "{{ ontap_cluster_id }}"
            svmID: "{{ ontap_svm_id }}"
            targetMoref: ClusterComputeResource:{{
vcenterclusterid.json[0].cluster }}
            datastoreSizeInMB: "{{ datastoreSizeInMB | int }}"
            vmfsFileSystem: VMFS6
            aggrName: "{{ aggr_name }}"
            existingFlexVolName: ""
            volumeStyle: FLEXVOL
            datastoreClusterMoref: ""
        headers:
          vmware-api-session-id: "{{ login.json.vmwareApiSessionId }}"
      when: ontap_cluster_id != '' and ontap_svm_id != '' and aggr_name !=
''
      register: result
      changed_when: result.status == 200
```

About this task

This section covers the creation of a VMFS datastore with ONTAP storage using NVMe/FC.

For automated provisioning, use one of these scripts: [PowerShell], Ansible Playbook, or [Terraform].

What you need

- Basic skills needed to manage a vSphere environment and ONTAP.
- Basic understanding of NVMe/FC.
- An ONTAP Storage System (FAS/AFF/CVO/ONTAP Select/ASA) running ONTAP 9.8 or later
- ONTAP credentials (SVM name, userID, and password)
- ONTAP WWPN for host, target, and SVMs and LUN information
- A completed FC configuration worksheet
- vCenter Server
- vSphere host(s) information (vSphere 7.0 or later)
- Fabric switch(es)
  - With ONTAP FC data ports and vSphere hosts connected.
  - With the N_port ID virtualization (NPIV) feature enabled.
  - Create a single initiator target zone.
  - Create one zone for each initiator (single initiator zone).
  - For each zone, include a target that is the ONTAP FC logical interface (WWPN) for the SVMs. There should be at least two logical interfaces per node per SVM. DO not use the WWPN of physical ports.

Provision VMFS datastore

1. Check compatibility with the Interoperability Matrix Tool (IMT).
2. Verify that the NVMe/FC configuration is supported.

ONTAP tasks

1. Verify the ONTAP license for FCP.
   Use the `system license show` command and check if NVMe_oF is listed.
   Use `license add -license-code <license code>` to add a license.
2. Verify that NVMe protocol is enabled on the SVM.
   a. Configure SVMs for NVMe.
3. Verify that NVMe/FC Logical Interfaces are available on the SVMs.
   a. Use `Network Interface show` to verify the FCP adapter.
   b. When an SVM is created with the GUI, logical interfaces are as part of that process.
   c. To rename the network interface, use the command `Network Interface modify`.
4. Create NVMe namespace and subsystem

VMware vSphere Tasks

1. Verify that HBA drivers are installed. VMware supported HBAs have the drivers deployed out of the box and should be visible at Storage Adapter Information
2. Perform vSphere Host NVMe driver installatioln and validation tasks
3. Create VMFS Datastore

vSphere traditional file storage provisioning with ONTAP

VMware vSphere supports following NFS protocols, both of which support ONTAP.

- NFS Version 3
- NFS Version 4.1

If you need help selecting the correct NFS version for vSphere, check this comparison of NFS client versions.

Reference

vSphere datastore and protocol features: NFS

vSphere NFS datastore - Version 3 with ONTAP

About this task

Creation of NFS version 3 datastore with ONTAP NAS storage.

For automated provisioning, use one of these scripts: [PowerShell], Ansible Playbook, or [Terraform].

What you need

- The basic skill necessary to manage a vSphere environment and ONTAP.
- An ONTAP storage system (FAS/AFF/CVO/ONTAP Select/Cloud Volume Service/Azure NetApp Files) running ONTAP 9.8 or later
- ONTAP credentials (SVM name, userID, password)
- ONTAP network port, SVM, and LUN information for NFS
  - A completed NFS configuration worksheet
- vCenter Server credentials
- vSphere host(s) information for vSphere 7.0 or later
- NFS VMKernel adapter IP information
- Network switch(es)
  - with ONTAP system network data ports and connected vSphere hosts
  - VLAN(s) configured for NFS
  - (Optional) link aggregation configured for ONTAP network data ports
- ONTAP Tool for VMware vSphere deployed, configured, and ready to consume

Steps

- Check compatibility with the Interoperability Matrix Tool (IMT)

    - Verify that the NFS configuration is supported.
- Complete the following ONTAP and vSphere tasks.

ONTAP tasks

1. Verify the ONTAP license for NFS.
    a. Use the `system license show` command and check that NFS is listed.
    b. Use `license add -license-code <license code>` to add a license.
2. Follow the NFS configuration workflow.

VMware vSphere Tasks

Follow the workflow for NFS client configuration for vSphere.

Reference

vSphere datastore and protocol features: NFS

What's next?

After these tasks are completed, the NFS datastore is ready to consume for provisioning virtual machines.

vSphere NFS Datastore - Version 4.1 with ONTAP

About this task

This section describes the creation of an NFS version 4.1 datastore with ONTAP NAS storage.

For automated provisioning, use one of these scripts: [PowerShell], Ansible Playbook, or [Terraform].

What you need

- The basic skills necessary to manage a vSphere environment and ONTAP
- ONTAP Storage System (FAS/AFF/CVO/ONTAP Select/Cloud Volume Service/Azure NetApp Files) running ONTAP 9.8 or later
- ONTAP credentials (SVM name, userID, password)
- ONTAP network port, SVM, and LUN information for NFS
- A completed NFS configuration worksheet
- vCenter Server credentials
- vSphere host(s) information vSphere 7.0 or later
- NFS VMKernel adapter IP information
- Network switch(es)
    - with ONTAP system network data ports, vSphere hosts, and connected
    - VLAN(s) configured for NFS
    - (Optional) link aggregation configured for ONTAP network data ports

- ONTAP Tools for VMware vSphere deployed, configured, and ready to consume

Steps

- Check compatability with the Interoperability Matrix Tool (IMT).
  - Verify that the NFS configuration is supported.
- Complete the ONTAP and vSphere Tasks provided below.

ONTAP tasks

1. Verify ONTAP license for NFS
   a. Usethe `system license show` command to check whether NFS is listed.
   b. Use `license add -license-code <license code>` to add a license.
2. Follow the NFS configuration workflow

VMware vSphere tasks

Follow the NFS Client Configuration for vSphere workflow.

What's next?

After these tasks are completed, the NFS datastore is ready to consume for provisioning virtual machines.

NetApp Hybrid Multicloud with VMware Solutions

VMware Hybrid Multicloud Use Cases

Use Cases for NetApp Hybrid Multicloud with VMware

An overview of the use cases of importance to IT organization when planning hybrid-cloud or cloud-first deployments.

Popular Use Cases

Use cases include:

- Disaster recovery,
- Hosting workloads during data center maintenance, * quick burst in which additional resources are required beyond what's provisioned in the local data center,
- VMware site expansion,
- Fast migration to the cloud,
- Dev/test, and
- Modernization of apps leveraging cloud supplemental technologies.

Throughout this documentation, cloud workload references will be detailed using the VMware use-cases. These use-cases are:

- Protect (includes both Disaster Recovery and Backup / Restore)
- Migrate
- Extend

Inside the IT Journey

Most organizations are on a journey to transformation and modernization. As part of this process, companies are trying use their existing VMware investments while leveraging cloud benefits and exploring ways to make the migration process as seamless as possible. This approach would make their modernization efforts very easy because the data is already in the cloud.

The easiest answer to this scenario is VMware offerings in each hyperscaler. Like NetApp® Cloud Volumes, VMware provides a way to move or extend on-premises VMware environments to any cloud, allowing you to retain existing on-premises assets, skills, and tools while running workloads natively in the cloud. This reduces risk because there will be no service breaks or a need for IP changes and provides the IT team the ability to operate the way they do on-premises using existing skills and tools. This can lead to accelerated cloud migrations and a much smoother transition to a hybrid Multicloud architecture.

Understanding the Importance of Supplemental NFS Storage Options

While VMware in any cloud delivers unique hybrid capabilities to every customer, limited supplemental NFS storage options have restricted its usefulness for organizations with storage-heavy workloads. Because storage is directly tied to hosts, the only way to scale storage is to add more hosts—and that can increase costs by 35–40 percent or more for storage intensive workloads. These workloads just need additional storage, not additional horsepower. But that means paying for additional hosts.

Let’s consider this scenario:

A customer requires just five hosts for CPU and memory, but has a lot of storage needs, and needs 12 hosts to meet the storage requirement. This requirement ends up really tipping the financial scale by having to buy the additional horsepower, when they only need to increment the storage.

When you’re planning cloud adoption and migrations, it’s always important to evaluate the best approach and take the easiest path that reduces total investments. The most common and easiest approach for any application migration is rehosting (also known as lift and shift) where there is no virtual machine (VM) or data conversion. Using NetApp Cloud Volumes with VMware software-defined data center (SDDC), while complementing vSAN, provides an easy lift-and-shift option.

Virtual Desktops

Virtual Desktop Services (VDS)

TR-4861: Hybrid Cloud VDI with Virtual Desktop Service

Suresh Thoppay, NetApp

The NetApp Virtual Desktop Service (VDS) orchestrates Remote Desktop Services (RDS) in major public clouds as well as on private clouds. VDS supports Windows Virtual Desktop (WVD) on Microsoft Azure. VDS automates many tasks that must be performed after deployment of WVD or RDS, including setting up SMB file shares (for user profiles, shared data, and the user home drive), enabling Windows features, application and agent installation, firewall, and policies, and so on.

Users consume VDS for dedicated desktops, shared desktops, and remote applications. VDS provides scripted events for automating application management for desktops and reduces the number of images to manage.

VDS provides a single management portal for handling deployments across public and private cloud environments.

Customer Value

The remote workforce explosion of 2020 has changed requirements for business continuity. IT departments are faced with new challenges to rapidly provision virtual desktops and thus require provisioning agility, remote management, and the TCO advantages of a hybrid cloud that makes it easy to provision on-premises and cloud resources. They need a hybrid-cloud solution that:

- Addresses the post-COVID workspace reality to enable flexible work models with global dynamics
- Enables shift work by simplifying and accelerating the deployment of work environments for all employees, from task workers to power users
- Mobilizes your workforce by providing rich, secure VDI resources regardless of the physical location
- Simplifies hybrid-cloud deployment
- Automates and simplifies risk reduction management

Next: Use Cases

Use Cases

Hybrid VDI with NetApp VDS allows service providers and enterprise virtual desktop administrators to easily expand resources to other cloud environment without affecting their users. Having on-premises resources provides better control of resources and offers wide selection of choices (compute, GPU, storage, and network) to meet demand.

This solution applies to the following use cases:

- Bursting into the cloud for surges in demand for remote desktops and applications
- Reducing TCO for long running remote desktops and applications by hosting them on-premises with flash storage and GPU resources
- Ease of management of remote desktops and applications across cloud environments
- Experience remote desktops and applications by using a software-as-a- service model with on-premises resources

Target Audience

The target audience for the solution includes the following groups:

- EUC/VDI architects who wants to understand the requirements for a hybrid VDS
- NetApp partners who would like to assist customers with their remote desktop and application needs
- Existing NetApp HCI customers who want to address remote desktop and application demands

Next: NetApp Virtual Desktop Service Overview

NetApp offers many cloud services, including the rapid provisioning of virtual desktop with WVD or remote applications and rapid integration with Azure NetApp Files.

Traditionally, it takes weeks to provision and deliver remote desktop services to customers. Apart from provisioning, it can be difficult to manage applications, user profiles, shared data, and group policy objects to enforce policies. Firewall rules can increase complexity and require a separate skillset and tools.

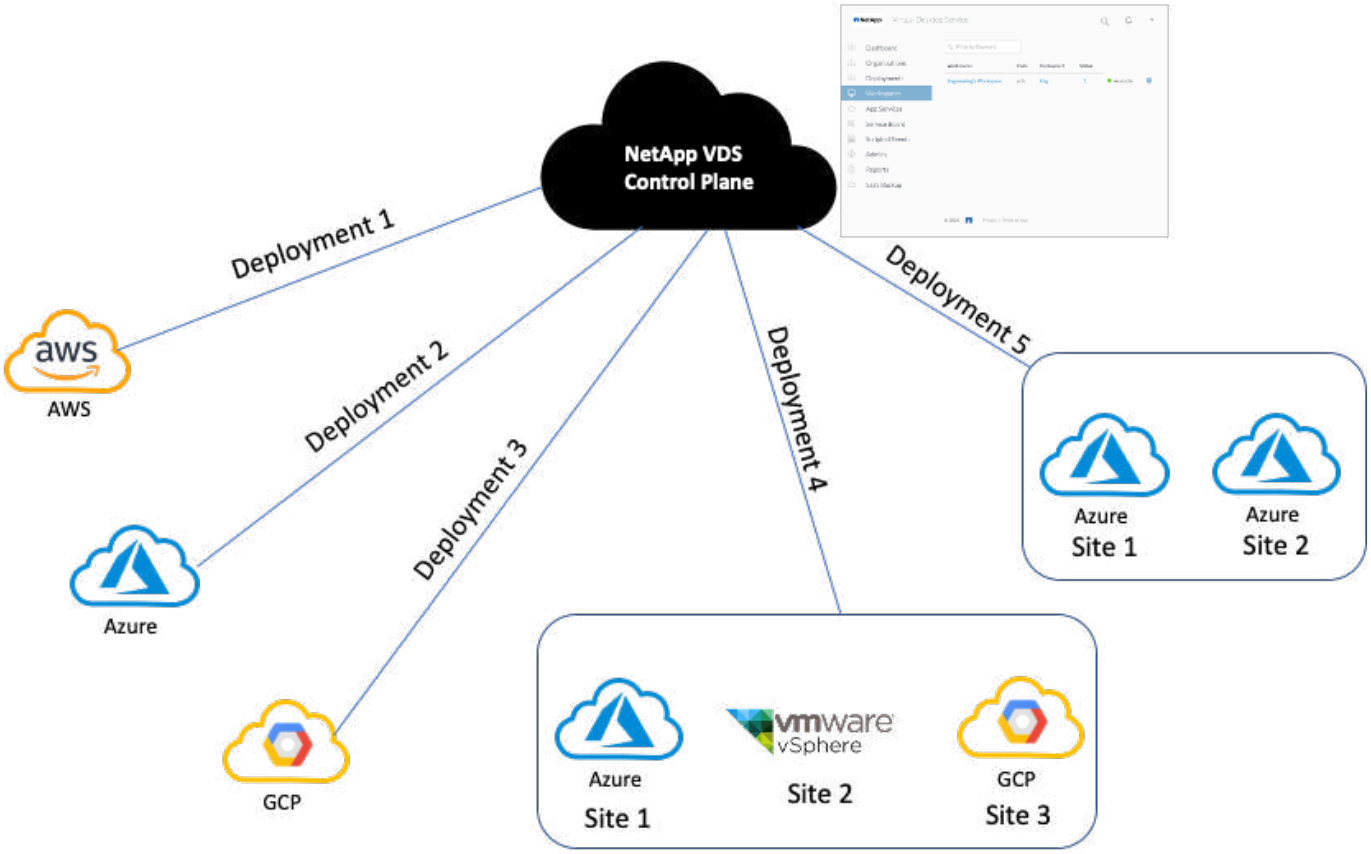
With Microsoft Azure Windows Virtual Desktop service, Microsoft takes care of maintenance for Remote Desktop Services components, allowing customers to focus on provisioning workspaces in the cloud. Customers must provision and manage the complete stack which requires special skills to manage VDI environments.

With NetApp VDS, customers can rapidly deploy virtual desktops without worrying about where to install the architecture components like brokers, gateways, agents, and so on. Customers who require complete control of their environment can work with a professional services team to achieve their goals. Customers consume VDS as a service and thus can focus on their key business challenges.

NetApp VDS is a software-as-a-service offering for centrally managing multiple deployments across AWS, Azure, GCP, or private cloud environments. Microsoft Windows Virtual Desktop is available only on Microsoft Azure. NetApp VDS orchestrates Microsoft Remote Desktop Services in other environments.

Microsoft offers multisession on Windows 10 exclusively for Windows Virtual Desktop environments on Azure. Authentication and identity are handled by the virtual desktop technology; WVD requires Azure Active Directory synced (with AD Connect) to Active Directory and session VMs joined to Active Directory. RDS requires Active Directory for user identity and authentication and VM domain join and management.

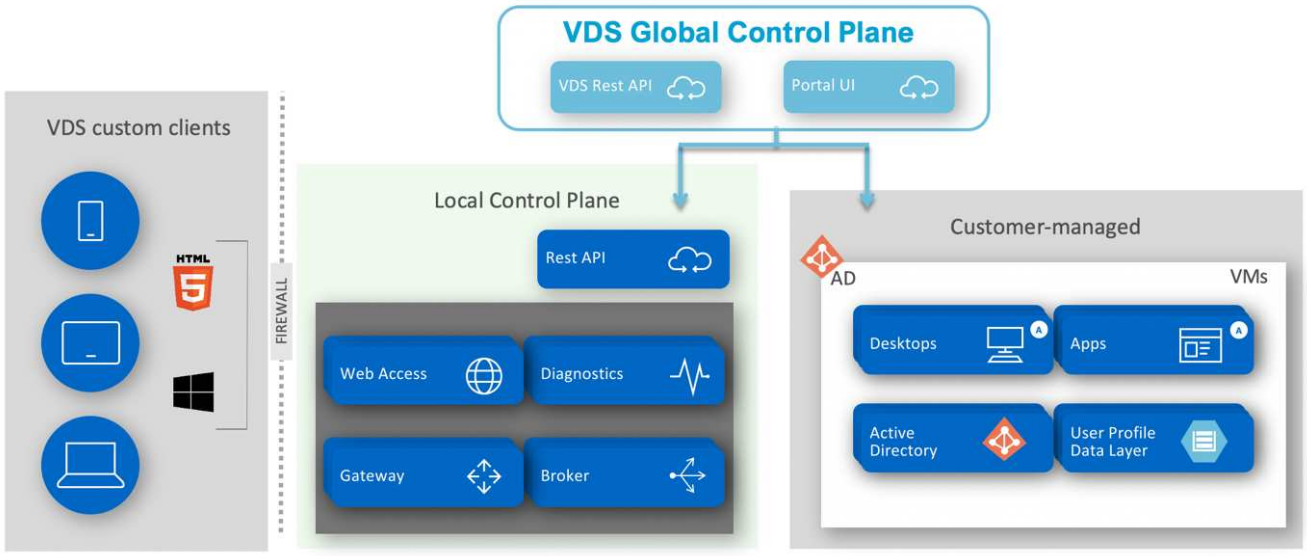
A sample deployment topology is shown in the following figure.



Each deployment is associated with an active directory domain and provides clients with an access entry point for workspaces and applications. A service provider or enterprise that has multiple active directory domains typically has more deployments. A single Active Directory domain that spans multiple regions typically has a single deployment with multiple sites.

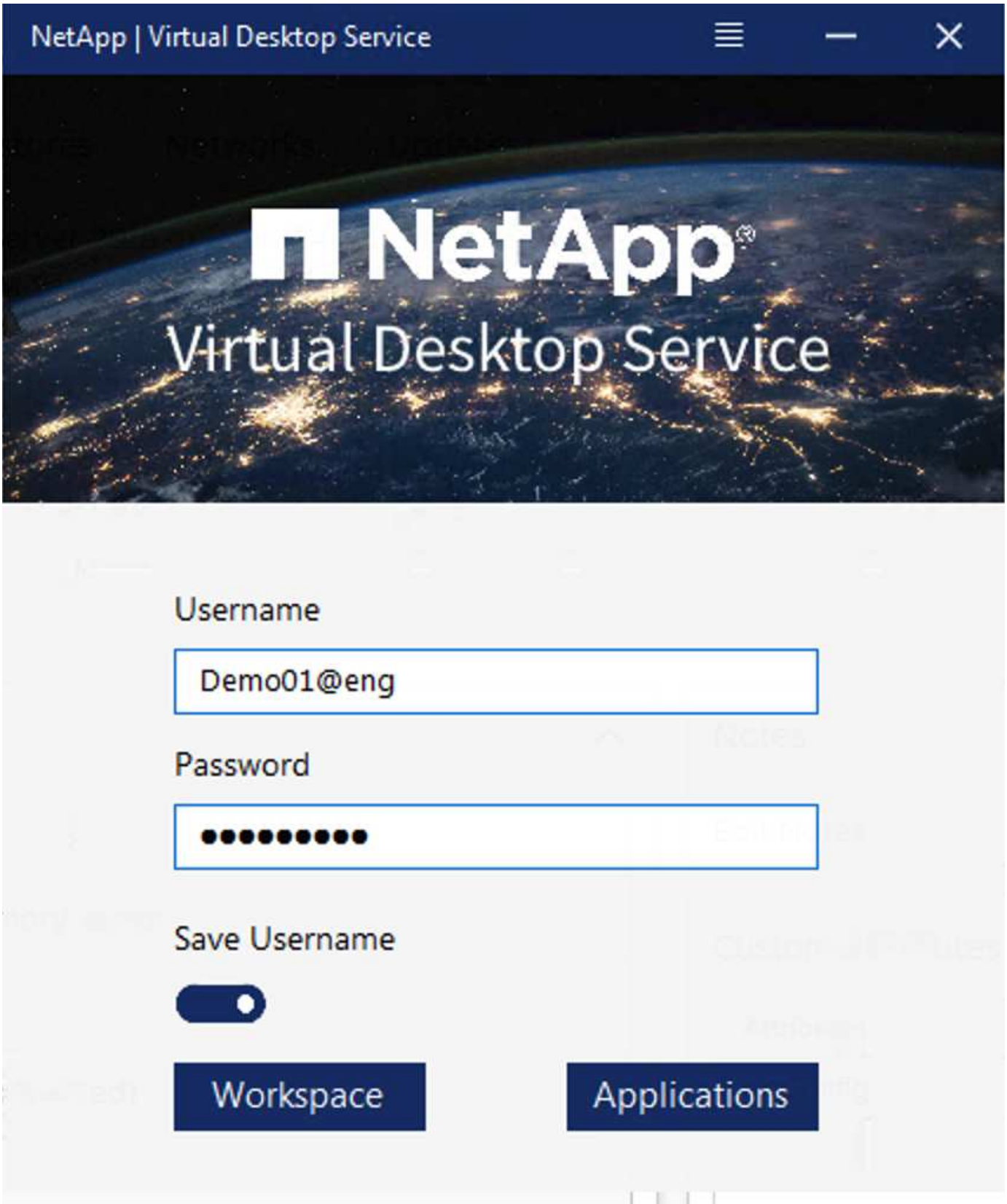
For WVD in Azure, Microsoft provides a platform-as-a-service that is consumed by NetApp VDS. For other environments, NetApp VDS orchestrates the deployment and configuration of Microsoft Remote Desktop Services. NetApp VDS supports both WVD Classic and WVD ARM and can also be used to upgrade existing versions.

Each deployment has its own platform services, which consists of Cloud Workspace Manager (REST API endpoint), an HTML 5 Gateway (connect to VMs from a VDS management portal), RDS Gateways (Access point for clients), and a Domain Controller. The following figure depicts the VDS Control Plane architecture for RDS implementation.



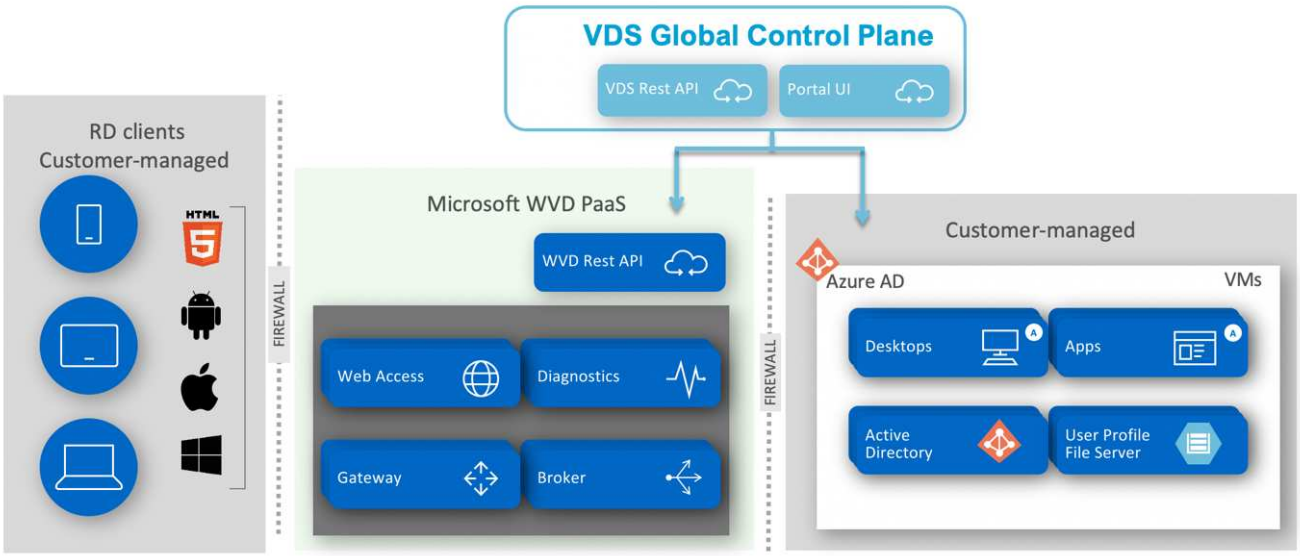
For RDS implementations, NetApp VDS can be readily accessed from Windows and browsers using client software that can be customized to include customer logo and images. Based on user credentials, it provides user access to approved workspaces and applications. There is no need to configure the gateway details.

The following figure shows the NetApp VDS client.



In the Azure WVD implementation, Microsoft handles the access entry point for the clients and can be consumed by a Microsoft WVD client available natively for various OSs. It can also be accessed from a web-based portal. The configuration of client software must be handled by the Group Policy Object (GPO) or in other ways preferred by customers.

The following figure depicts the VDS Control Plane architecture for Azure WVD implementations.



In addition to the deployment and configuration of required components, NetApp VDS also handles user management, application management, resource scaling, and optimization.

NetApp VDS can create users or grant existing user accounts access to cloud workspace or application services. The portal can also be used for password resets and the delegation of administrating a subset of components. Helpdesk administrators or Level-3 technicians can shadow user sessions for troubleshooting or connect to servers from within the portal.

NetApp VDS can use image templates that you create, or it can use existing ones from the marketplace for cloud-based provisioning. To reduce the number of images to manage, you can use a base image, and any additional applications that you require can be provisioned using the provided framework to include any command-line tools like Chocolatey, MSIX app attach, PowerShell, and so on. Even custom scripts can be used as part of machine lifecycle events.

Next: NetApp HCI Overview

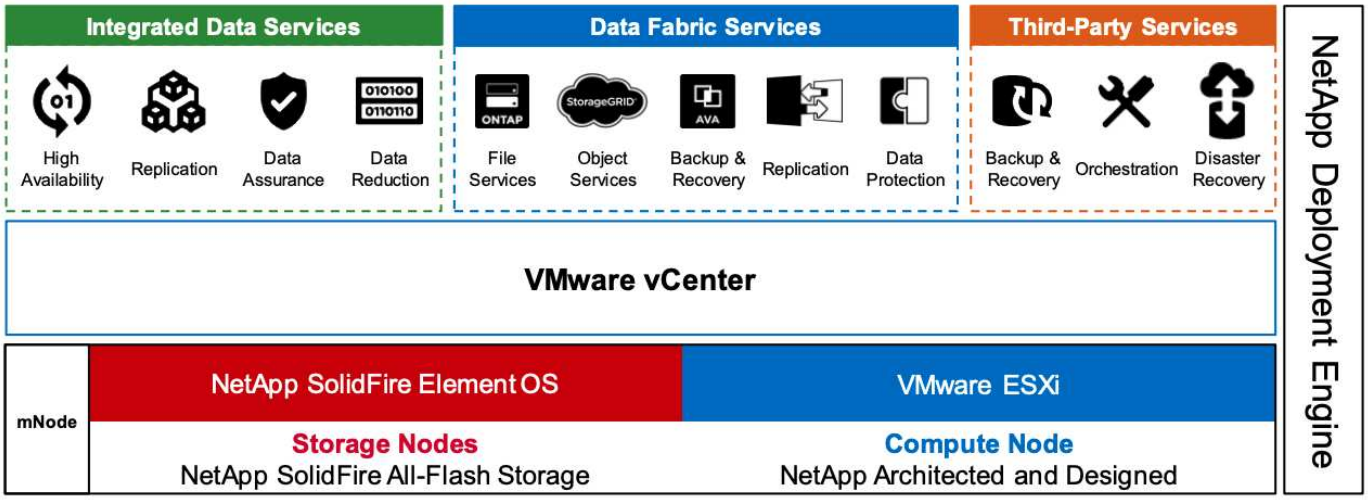
NetApp HCI Overview

NetApp HCI is a hybrid cloud infrastructure that consists of a mix of storage nodes and compute nodes. It is available as either a two-rack unit or single-rack unit, depending on the model. The installation and configuration required to deploy VMs are automated with the NetApp Deployment Engine (NDE). Compute clusters are managed with VMware vCenter, and storage clusters are managed with the vCenter Plug-in deployed with NDE. A management VM called the mNode is deployed as part of the NDE.

NetApp HCI handles the following functions:

- Version upgrades
- Pushing events to vCenter
- vCenter Plug-In management
- A VPN tunnel for support
- The NetApp Active IQ collector
- The extension of NetApp Cloud Services to on the premises, enabling a hybrid cloud infrastructure. The

following figure depicts HCI components.



Storage Nodes

Storage nodes are available as either a half-width or full-width rack unit. A minimum of four storage nodes is required at first, and a cluster can expand to up to 40 nodes. A storage cluster can be shared across multiple compute clusters. All the storage nodes contain a cache controller to improve write performance. A single node provides either 50K or 100K IOPS at a 4K block size.

NetApp HCI storage nodes run NetApp Element software, which provides minimum, maximum, and burst QoS limits. The storage cluster supports a mix of storage nodes, although one storage node cannot exceed one-third of total capacity.

Compute Nodes

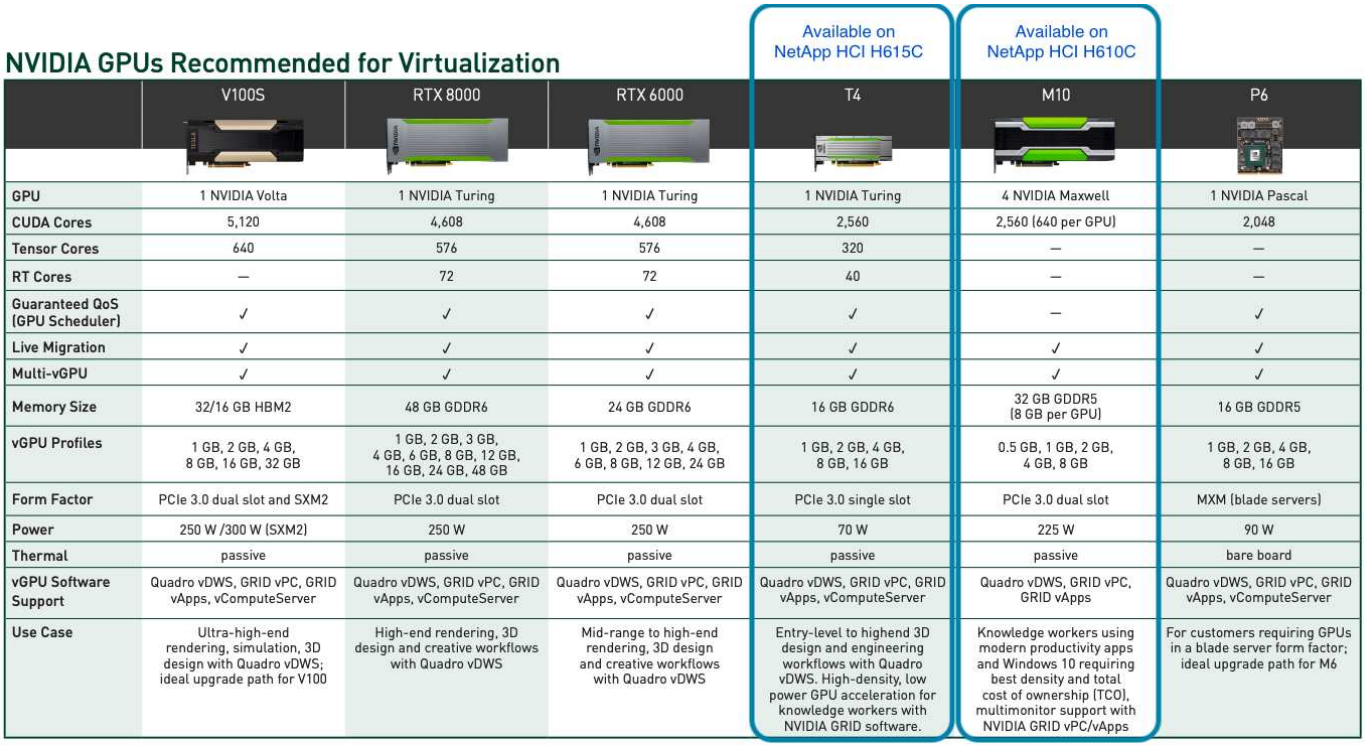
NetApp supports its storage connected to any compute servers listed in the VMware Compatability Guide.

Compute nodes are available in half-width, full-width, and two rack-unit sizes. The NetApp HCI H410C and H610C are based on scalable Intel Skylake processors. The H615C is based on second-generation scalable Intel Cascade Lake processors. There are two compute models that contain GPUs: the H610C contains two NVIDIA M10 cards and the H615C contains three NVIDIA T4 cards.

The NVIDIA T4 has 40 RT cores that provide the computation power needed to deliver real-time ray tracing. The same server model used by designers and engineers can now also be used by artists to create photorealistic imagery that features light bouncing off surfaces just as it would in real life. This RTX-capable GPU produces real-time ray tracing performance of up to five Giga Rays per second. The NVIDIA T4, when combined with Quadro Virtual Data Center Workstation (Quadro vDWS) software, enables artists to create photorealistic designs with accurate shadows, reflections, and refractions on any device from any location.

Tensor cores enable you to run deep learning inferencing workloads. When running these workloads, an NVIDIA T4 powered with Quadro vDWS can perform up to 25 times faster than a VM driven by a CPU-only server. A NetApp H615C with three NVIDIA T4 cards in one rack unit is an ideal solution for graphics and compute-intensive workloads.

The following figure lists NVIDIA GPU cards and compares their features.



NVIDIA GPUs Recommended for Virtualization

Available on NetApp HCI H615C

Available on NetApp HCI H610C

	V100S	RTX 8000	RTX 6000	T4	M10	P6
GPU	1 NVIDIA Volta	1 NVIDIA Turing	1 NVIDIA Turing	1 NVIDIA Turing	4 NVIDIA Maxwell	1 NVIDIA Pascal
CUDA Cores	5,120	4,608	4,608	2,560	2,560 (640 per GPU)	2,048
Tensor Cores	640	576	576	320	–	–
RT Cores	–	72	72	40	–	–
Guaranteed QoS (GPU Scheduler)	✓	✓	✓	✓	–	✓
Live Migration	✓	✓	✓	✓	✓	✓
Multi-vGPU	✓	✓	✓	✓	✓	✓
Memory Size	32/16 GB HBM2	48 GB GDDR6	24 GB GDDR6	16 GB GDDR6	32 GB GDDR5 (8 GB per GPU)	16 GB GDDR5
vGPU Profiles	1 GB, 2 GB, 4 GB, 8 GB, 16 GB, 32 GB	1 GB, 2 GB, 3 GB, 4 GB, 6 GB, 8 GB, 12 GB, 16 GB, 24 GB, 48 GB	1 GB, 2 GB, 3 GB, 4 GB, 6 GB, 8 GB, 12 GB, 24 GB	1 GB, 2 GB, 4 GB, 8 GB, 16 GB	0.5 GB, 1 GB, 2 GB, 4 GB, 8 GB	1 GB, 2 GB, 4 GB, 8 GB, 16 GB
Form Factor	PCIe 3.0 dual slot and SXM2	PCIe 3.0 dual slot	PCIe 3.0 dual slot	PCIe 3.0 single slot	PCIe 3.0 dual slot	MXM (blade servers)
Power	250 W /300 W (SXM2)	250 W	250 W	70 W	225 W	90 W
Thermal	passive	passive	passive	passive	passive	bare board
vGPU Software Support	Quadro vDWS, GRID vPC, GRID vApps, vComputeServer	Quadro vDWS, GRID vPC, GRID vApps, vComputeServer	Quadro vDWS, GRID vPC, GRID vApps, vComputeServer	Quadro vDWS, GRID vPC, GRID vApps, vComputeServer	Quadro vDWS, GRID vPC, GRID vApps	Quadro vDWS, GRID vPC, GRID vApps, vComputeServer
Use Case	Ultra-high-end rendering, simulation, 3D design with Quadro vDWS; ideal upgrade path for V100	High-end rendering, 3D design and creative workflows with Quadro vDWS	Mid-range to high-end rendering, 3D design and creative workflows with Quadro vDWS	Entry-level to highend 3D design and engineering workflows with Quadro vDWS. High-density, low power GPU acceleration for knowledge workers with NVIDIA GRID software.	Knowledge workers using modern productivity apps and Windows 10 requiring best density and total cost of ownership (TCO), multimonitor support with NVIDIA GRID vPC/vApps	For customers requiring GPUs in a blade server form factor; ideal upgrade path for M6

The M10 GPU remains the best TCO solution for knowledge-worker use cases. However, the T4 makes a great alternative when IT wants to standardize on a GPU that can be used across multiple use cases, such as virtual workstations, graphics performance, real-time interactive rendering, and inferencing. With the T4, IT can take advantage of the same GPU resources to run mixed workloads—for example, running VDI during the day and repurposing the resources to run compute workloads at night.

The H610C compute node is two rack units in size; the H615C is one rack unit in size and consumes less power. The H615C supports H.264 and H.265 (High Efficiency Video Coding [HEVC]) 4:4:4 encoding and decoding. It also supports the increasingly mainstrean VP9 decoder; even the WebM container package served by YouTube uses the VP9 codec for video.

The number of nodes in a compute cluster is dictated by VMware; currently, it is 96 with VMware vSphere 7.0 Update 1. Mixing different models of compute nodes in a cluster is supported when Enhanced vMotion Compatibility (EVC) is enabled.

Next: NVIDIA Licensing

NVIDIA Licensing

When using an H610C or H615C, the license for the GPU must be procured from NVIDIA partners that are authorized to resell the licenses. You can find NVIDIA partners with the partner locator. Search for competencies such as virtual GPU (vGPU) or Tesla.

NVIDIA vGPU software is available in four editions:

- NVIDIA GRID Virtual PC (GRID vPC)
- NVIDIA GRID Virtual Applications (GRID vApps)
- NVIDIA Quadro Virtual Data Center Workstation (Quadro vDWS)

- NVIDIA Virtual ComputeServer (vComputeServer)

GRID Virtual PC

This product is ideal for users who want a virtual desktop that provides a great user experience for Microsoft Windows applications, browsers, high-definition video, and multi-monitor support. The NVIDIA GRID Virtual PC delivers a native experience in a virtual environment, allowing you to run all your PC applications at full performance.

GRID Virtual Applications

GRID vApps are for organizations deploying a Remote Desktop Session Host (RDSH) or other app-streaming or session-based solutions. Designed to deliver Microsoft Windows applications at full performance, Windows Server-hosted RDSH desktops are also supported by GRID vApps.

Quadro Virtual Data Center Workstation

This edition is ideal for mainstream and high-end designers who use powerful 3D content creation applications like Dassault CATIA, SOLIDWORKS, 3Dexcite, Siemens NX, PTC Creo, Schlumberger Petrel, or Autodesk Maya. NVIDIA Quadro vDWS allows users to access their professional graphics applications with full features and performance anywhere on any device.

NVIDIA Virtual ComputeServer

Many organizations run compute-intensive server workloads such as artificial intelligence (AI), deep learning (DL), and data science. For these use cases, NVIDIA vComputeServer software virtualizes the NVIDIA GPU, which accelerates compute-intensive server workloads with features such as error correction code, page retirement, peer-to-peer over NVLink, and multi-vGPU.

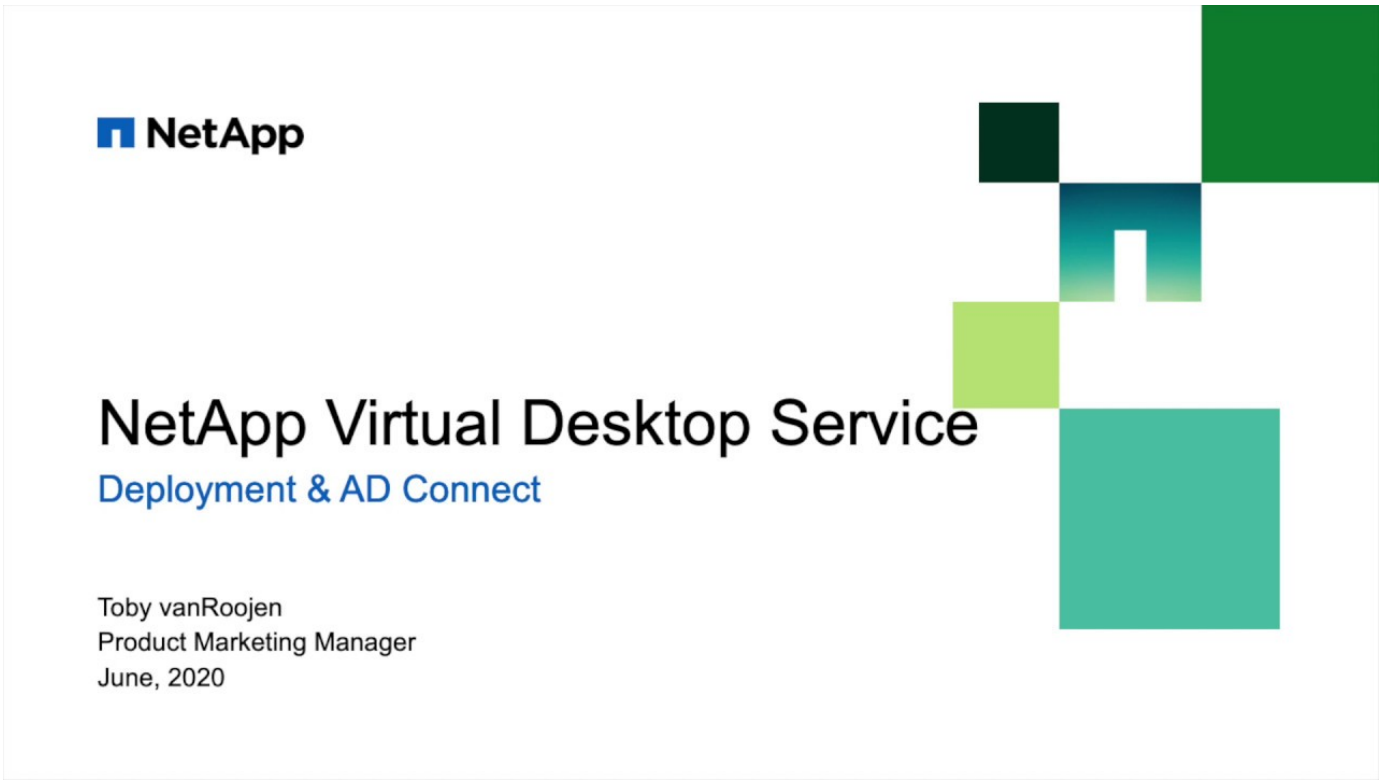
A Quadro vDWS license enables you to use GRID vPC and NVIDIA vComputeServer.

Next: Deployment

Deployment

NetApp VDS can be deployed to Microsoft Azure using a setup app available based on the required codebase. The current release is available here and the preview release of the upcoming product is available here.

See this video for deployment instructions.

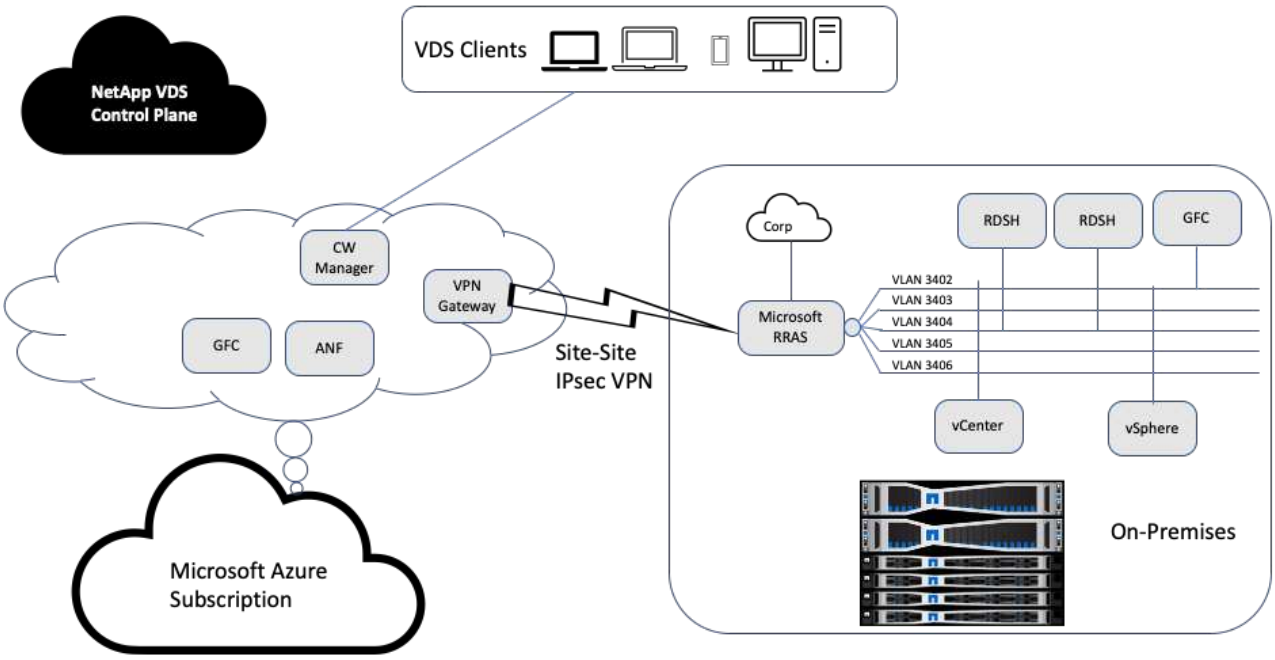


Next: Hybrid Cloud Environment

Hybrid Cloud Environment

NetApp Virtual Desktop Service can be extended to on-premises when connectivity exists between on-premises resources and cloud resources. Enterprises can establish the link to Microsoft Azure using Express Route or a site-to-site IPsec VPN connection. You can also create links to other clouds in a similar way either using a dedicated link or with an IPsec VPN tunnel.

For the solution validation, we used the environment depicted in the following figure.



On-premises, we had multiple VLANs for management, remote-desktop-session hosts, and so on. They were on the 172.21.146-150.0/24 subnet and routed to the corporate network using the Microsoft Remote Routing Access Service. We also performed the following tasks:

1. We noted the public IP of the Microsoft Routing and Remote Access Server (RRAS; identified with IPchicken.com).
2. We created a Virtual Network Gateway resource (route-based VPN) on Azure Subscription.
3. We created the connection providing the local network gateway address for the public IP of the Microsoft RRAS server.
4. We completed VPN configuration on RRAS to create a virtual interface using pre-shared authentication that was provided while creating the VPN gateway. If configured correctly, the VPN should be in the connected state. Instead of Microsoft RRAS, you can also use pfSense or other relevant tools to create the site-to-site IPsec VPN tunnel. Since it is route-based, the tunnel redirects traffic based on the specific subnets configured.

Microsoft Azure Active Directory provides identity authentication based on oAuth. Enterprise client authentications typically require NTLM or Kerberos-based authentication. Microsoft Azure Active Directory Domain Services perform password hash sync between Azure Active Directory and on-prem domain controllers using ADConnect.

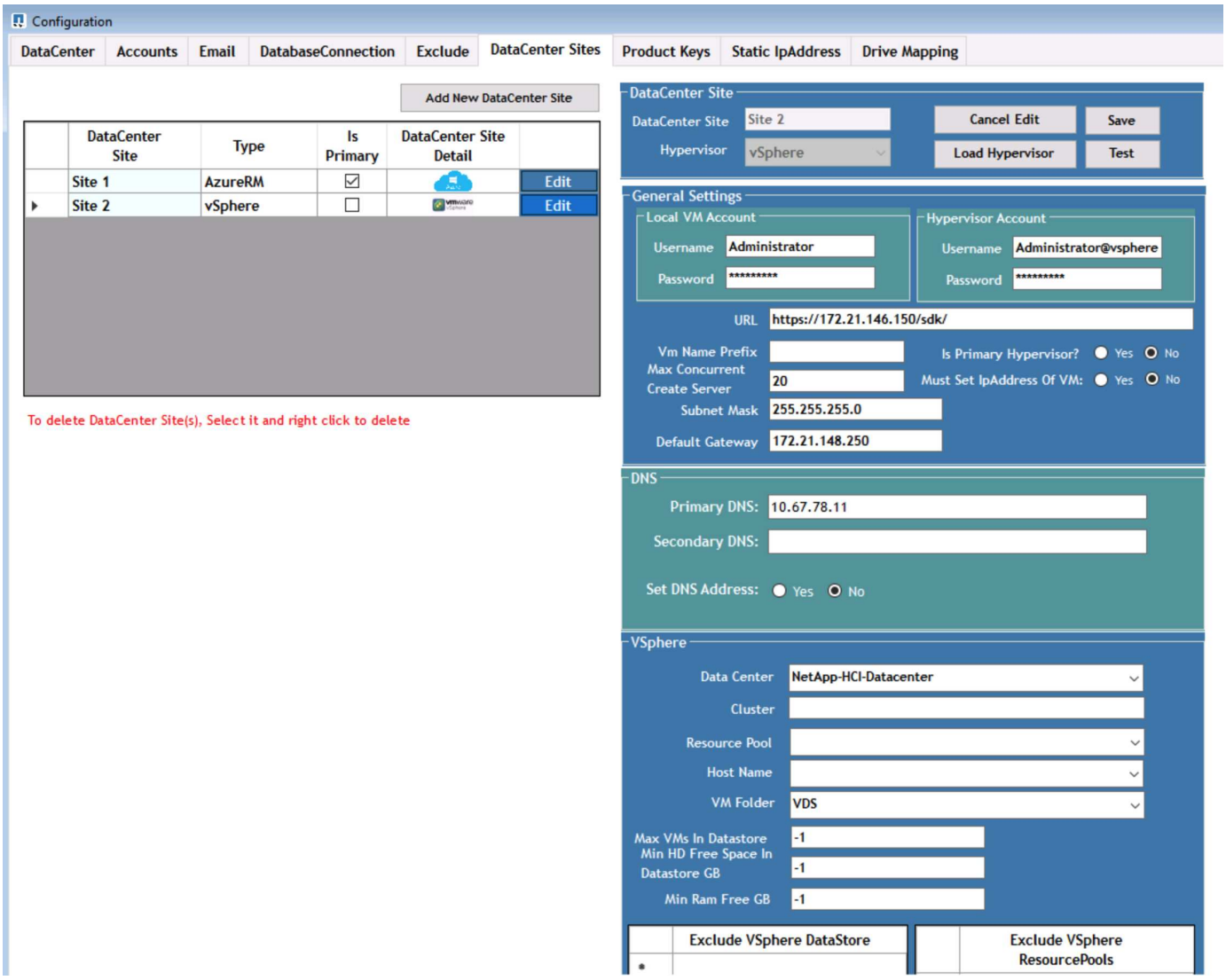
For this Hybrid VDS solution validation, we initially deployed to Microsoft Azure and added an additional site with vSphere. The advantage with this approach is that platform services were deployed to Microsoft Azure and were then readily backed up using the portal. Services can then be easily accessed from anywhere, even if the site-site VPN link is down.

To add another site, we used a tool called DCConfig. The shortcut to that application is available on the desktop of the cloud workspace manager (CWMgr) VM. After this application is launched, navigate to the DataCenter Sites tab, add the new datacenter site, and fill in the required info as shown below. The URL points to the vCenter IP. Make sure that the CWMgr VM can communicate with vCenter before adding the

configuration.

Make sure that vSphere PowerCLI 5.1 on CloudWorkspace manager is installed to enable communication with VMware vSphere environment.

The following figure depicts on- premises datacenter site configuration.



Note that there are filtering options available for compute resource based on the specific cluster, host name, or free RAM space. Filtering options for storage resource includes the minimum free space on datastores or the maximum VMs per datastore. Datastores can be excluded using regular expressions. Click Save button to save the configuration.

To validate the configuration, click the Test button or click Load Hypervisor and check any dropdown under the vSphere section. It should be populated with appropriate values. It is a best practice to keep the primary hypervisor set to yes for the default provisioning site.

The VM templates created on VMware vSphere are consumed as provisioning collections on VDS. Provisioning collections come in two forms: shared and VDI. The shared provisioning collection type is used for remote desktop services for which a single resource policy is applied to all servers. The VDI type is used for WVD instances for which the resource policy is individually assigned. The servers in a provisioning collection can be assigned one of the following three roles:

- **TSDATA.** Combination of Terminal Services and Data server role.
- **TS.** Terminal Services (Session Host).
- **DATA.** File Server or Database Server. When you define the server role, you must pick the VM template and storage (datastore). The datastore chosen can be restricted to a specific datastore or you can use the least-used option in which the datastore is chosen based on data usage.

Each deployment has VM resource defaults for the cloud resource allocation based on Active Users, Fixed, Server Load, or User Count.

Next: Single Server Load Test with Login VSI

Single server load test with Login VSI

The NetApp Virtual Desktop Service uses the Microsoft Remote Desktop Protocol to access virtual desktop sessions and applications, and the Login VSI tool determines the maximum number of users that can be hosted on a specific server model. Login VSI simulates user login at specific intervals and performs user operations like opening documents, reading and composing mails, working with Excel and PowerPoint, printing documents, compressing files, and taking random breaks. It then measures response times. User response time is low when server utilization is low and increases when more user sessions are added. Login VSI determines the baseline based on initial user login sessions and it reports the maximum user session when the user response exceeds 2 seconds from the baseline.

NetApp Virtual Desktop Service utilizes Microsoft Remote Desktop Protocol to access the Virtual Desktop session and Applications. To determine the maximum number of users that can be hosted on a specific server model, we used the Login VSI tool. Login VSI simulates user login at specific intervals and performs user operations like opening documents, reading and composing mails, working with Excel and PowerPoint, printing documents, compressing files, taking random breaks, and so on. It also measures response times. User response time is low when server utilization is low and increases when more user sessions are added. Login VSI determines the baseline based on the initial user login sessions and it reports maximum user sessions when the user response exceeds 2sec from the baseline.

The following table contains the hardware used for this validation.

Model	Count	Description
NetApp HCI H610C	4	Three in a cluster for launchers, AD, DHCP, and so on. One server for load testing.
NetApp HCI H615C	1	2x24C Intel Xeon Gold 6282 @2.1GHz. 1.5TB RAM.

The following table contains the software used for this validation.

Product	Description
NetApp VDS 5.4	Orchestration
VM Template Windows 2019 1809	Server OS for RDSH
Login VSI	4.1.32.1

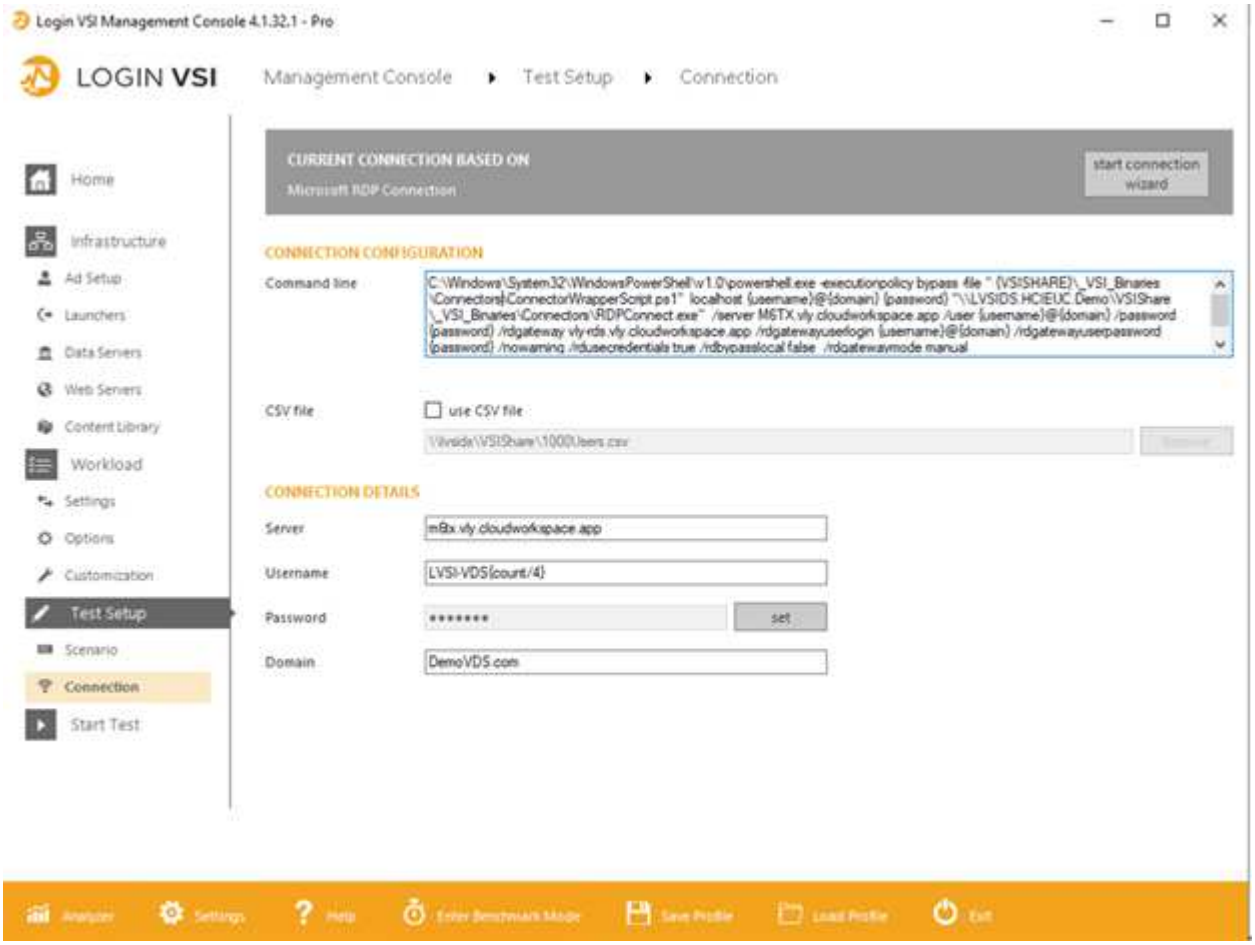
Product	Description
VMware vSphere 6.7 Update 3	Hypervisor
VMware vCenter 6.7 Update 3f	VMware management tool

The Login VSI test results are as follows:

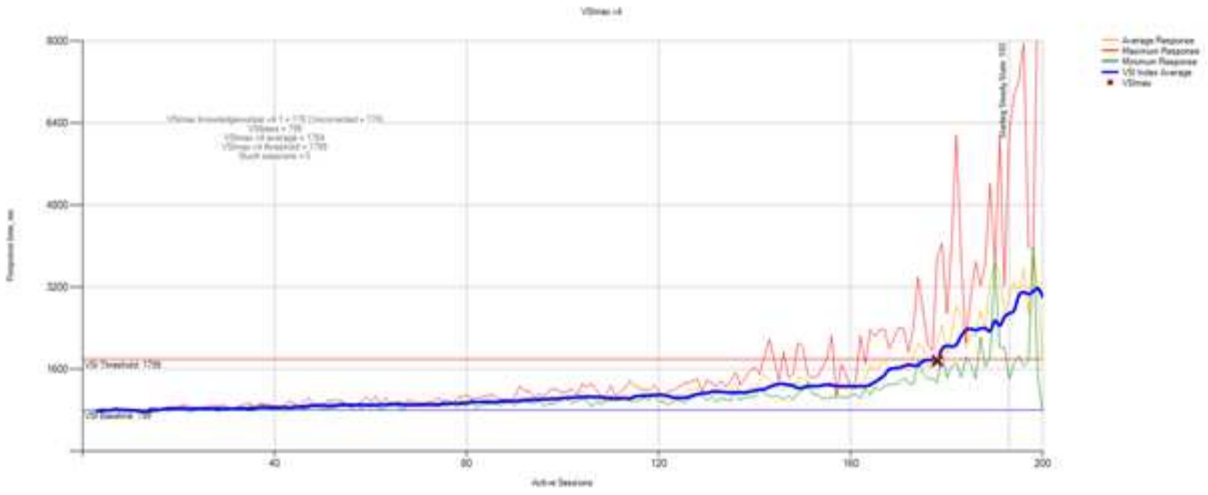
Model	VM configuration	Login VSI baseline	Login VSI Max
H610C	8 vCPU, 48GB RAM, 75GB disk, 8Q vGPU profile	799	178
H615C	12 vCPU, 128GB RAM, 75GB disk	763	272

Considering sub-NUMA boundaries and hyperthreading, the eight VMs chosen for VM testing and configuration depended on the cores available on the host.

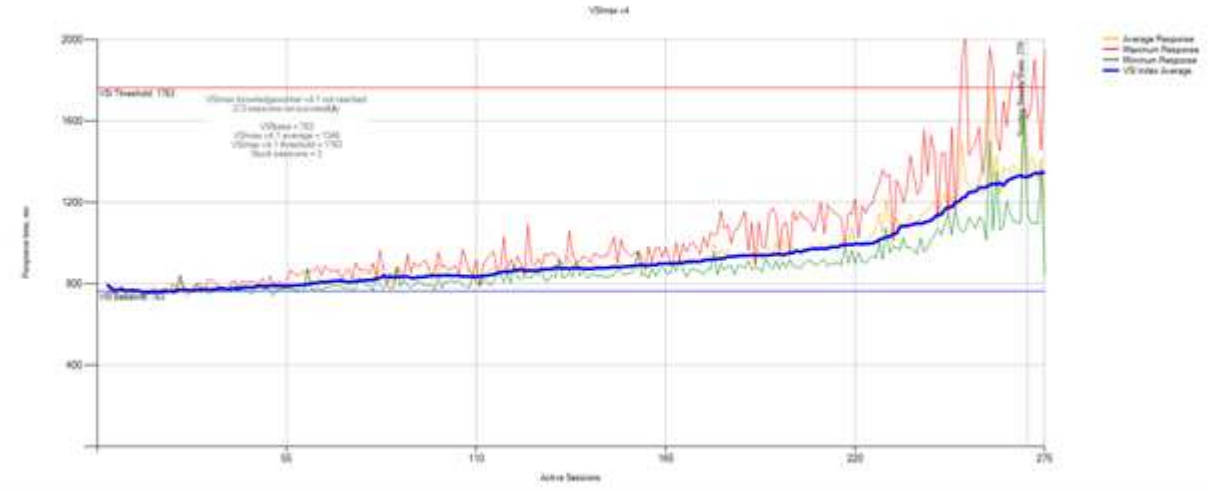
We used 10 launcher VMs on the H610C, which used the RDP protocol to connect to the user session. The following figure depicts the Login VSI connection information.



The following figure displays the Login VSI response time versus the active sessions for the H610C.



The following figure displays the Login VSI response time versus active sessions for the H615C.



The performance metrics from Cloud Insights during H615C Login VSI testing for the vSphere host and VMs are shown in the following figure.

Next: Management Portal

Management Portal

NetApp VDS Cloud Workspace Management Suite portal is available here and the upcoming version is available here.

The portal allows centralized management for various VDS deployments including one that has sites defined for on-premises, administrative users, the application catalog, and scripted events. The portal is also used by administrative users for the manual provisioning of applications if required and to connect to any machines for troubleshooting.

Service providers can use this portal to add their own channel partners and allow them to manage their own clients.

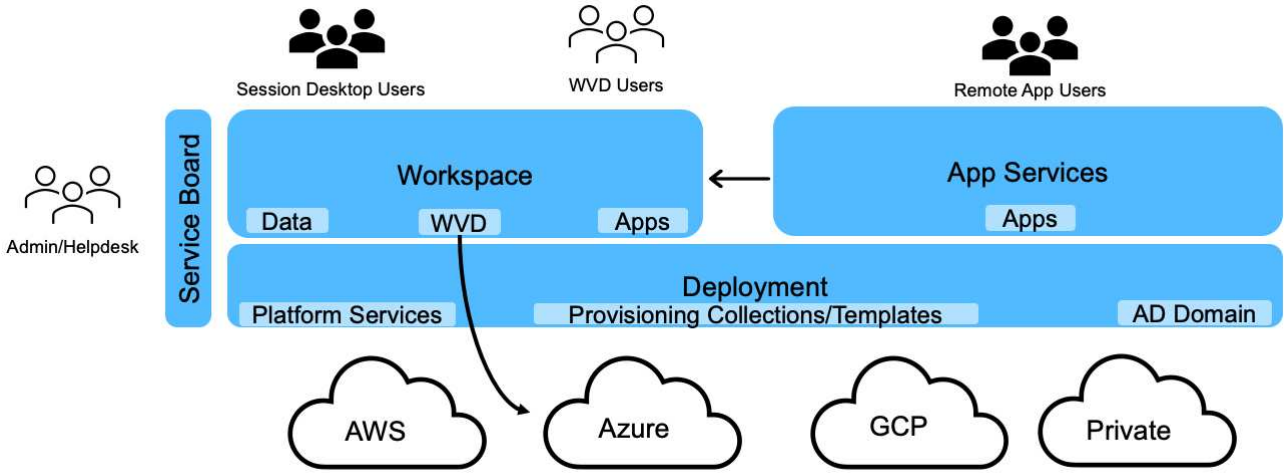
Next: User Management

User Management

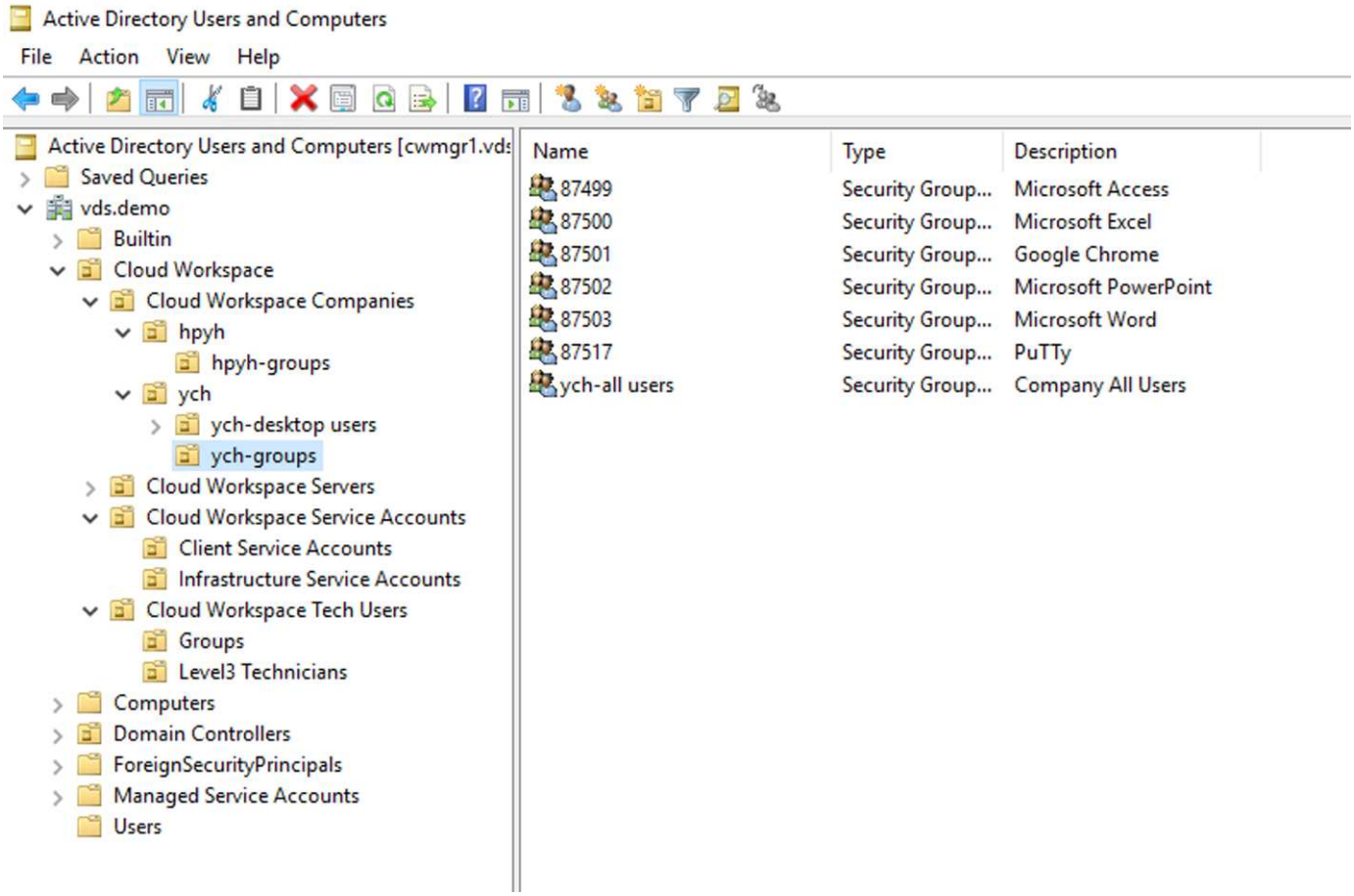
NetApp VDS uses Azure Active Directory for identity authentication and Azure Active Directory Domain Services for NTLM/Kerberos authentication. The ADConnect tool can be used to sync an on-prem Active Directory domain with Azure Active Directory.

New users can be added from the portal, or you can enable cloud workspace for existing users. Permissions for workspaces and application services can be controlled by individual users or by groups. From the management portal, administrative users can be defined to control permissions for the portal, workspaces, and so on.

The following figure depicts user management in NetApp VDS.



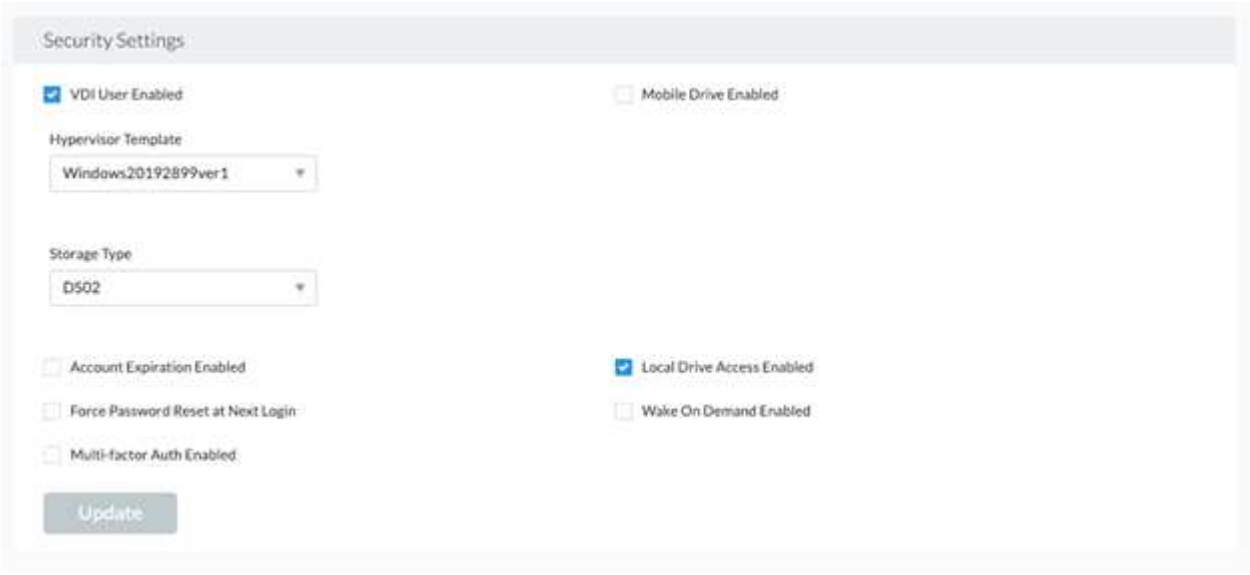
Each workspace resides in its own Active Directory organization unit (OU) under the Cloud Workspace OU as shown in the following figure.



For more info, see this video on user permissions and user management in NetApp VDS.

When an Active Directory group is defined as a CRAUserGroup using an API call for the datacenter, all the users in that group are imported into the CloudWorkspace for management using the UI. As the cloud workspace is enabled for the user, VDS creates user home folders, settings permissions, user properties updates, and so on.

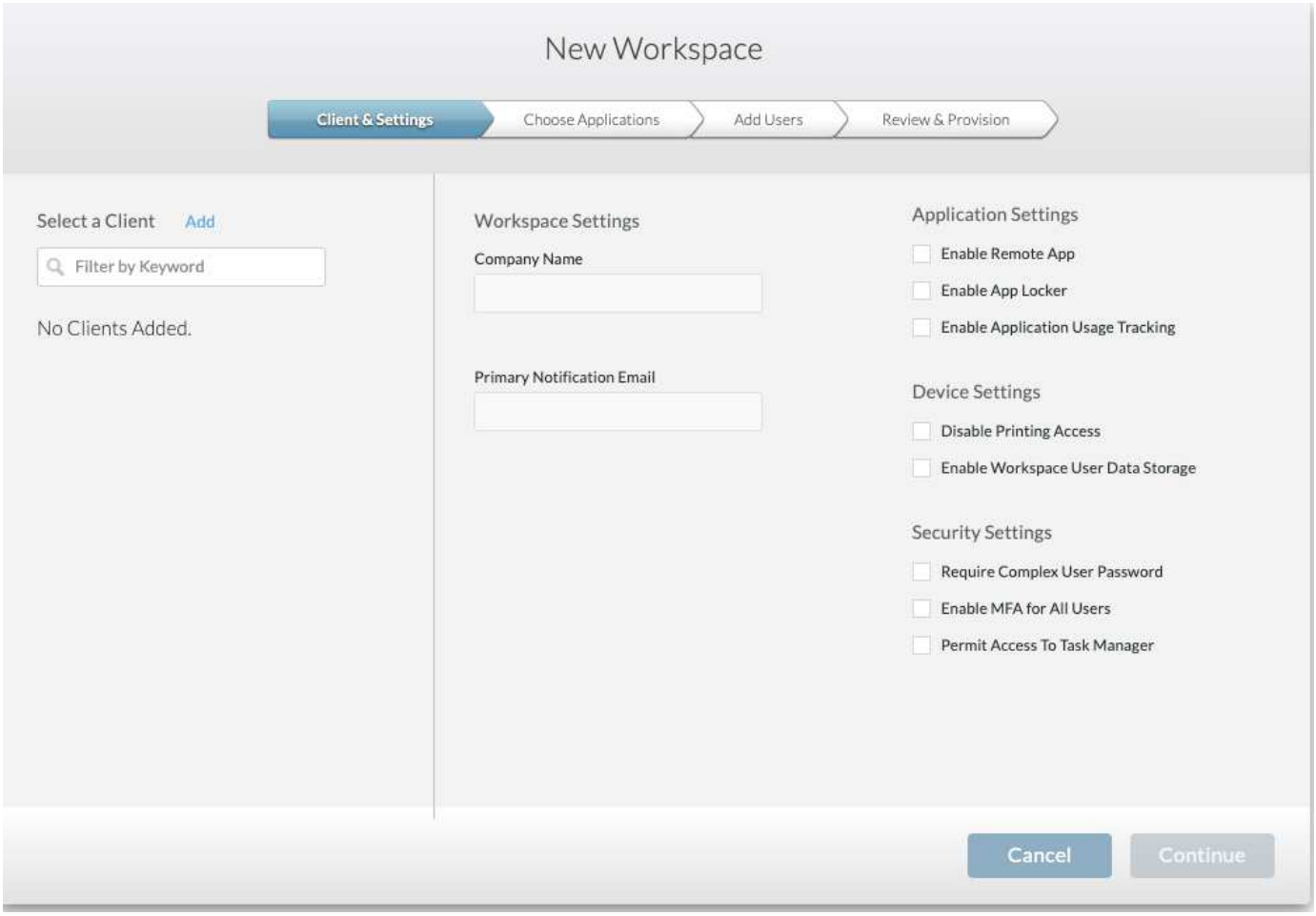
If VDI User Enabled is checked, VDS creates a single-session RDS machine dedicated to that user. It prompts for the template and the datastore to provision.



Next: Workspace Management

Workspace Management

A workspace consists of a desktop environment; this can be shared remote desktop sessions hosted on-premises or on any supported cloud environment. With Microsoft Azure, the desktop environment can be persistent with Windows Virtual Desktops. Each workspace is associated with a specific organization or client. Options available when creating a new workspace can be seen in the following figure.



Each workspace is associated with specific deployment.

Workspaces contain associated apps and app services, shared data folders, servers, and a WVD instance. Each workspace can control security options like enforcing password complexity, multifactor authentication, file audits, and so on.

Workspaces can control the workload schedule to power on extra servers, limit the number of users per server, or set the schedule for the resources available for given period (always on/off). Resources can also be configured to wake up on demand.

The workspace can override the deployment VM resource defaults if required. For WVD, WVD host pools (which contains session hosts and app groups) and WVD workspaces can also be managed from the cloud workspace management suite portal. For more info on the WVD host pool, see this video.

Next: Application Management

Application Management

Task workers can quickly launch an application from the list of applications made available to them. App services publish applications from the Remote Desktop Services session hosts. With WVD, App Groups provide similar functionality from multi-session Windows 10 host pools.

For office workers to power users, the applications that they require can be provisioned manually using a service board, or they can be auto-provisioned using the scripted events feature in NetApp VDS.

For more information, see the NetApp Application Entitlement page.

Next: ONTAP features for Virtual Desktop Service

ONTAP features for Virtual Desktop Service

The following ONTAP features make it attractive choice for use with a virtual desktop service.

- **Scale-out filesystem.** ONTAP FlexGroup volumes can grow to more than 20PB in size and can contain more than 400 billion files within a single namespace. The cluster can contain up to 24 storage nodes, each with a flexible the number of network interface cards depending on the model used.

  User's virtual desktops, home folders, user profile containers, shared data, and so on can grow based on demand with no concern for filesystem limitations.

- **File system analytics.** You can use the XCP tool to gain insights into shared data. With ONTAP 9.8+ and ActiveIQ Unified Manager, you can easily query and retrieve file metadata information and identify cold data.
- **Cloud tiering.** You can migrage cold data to an object store in the cloud or to any S3-compatible storage in your datacenter.
- **File versions.** Users can recover files protected by NetApp ONTAP Snapshot copies. ONTAP Snapshot copies are very space efficient because they only record changed blocks.
- **Global namespace.** ONTAP FlexCache technology allows remote caching of file storage making it easier to manage shared data across locations containing ONTAP storage systems.
- **Secure multi-tenancy support.** A single physical storage cluster can be presented as multiple virtual storage arrays each with its own volumes, storage protocols, logical network interfaces, identity and authentication domain, management users, and so on. Therefore, you can share the storage array across multiple business units or environments, such as test, development, and production.

  To guarantee performance, you can use adaptive QoS to set performance levels based on used or allocated space, and you can control storage capacity by using quotas.

- **VMware integration.** ONTAP tools for VMware vSphere provides a vCenter plug-in to provision datastores, implement vSphere host best practices, and monitor ONTAP resources.

  ONTAP supports vStorage APIs for Array Integration (VAAI) for offloading SCSI/file operations to the storage array. ONTAP also supports vStorage APIs for Storage Awareness (VASA) and Virtual Volumes support for both block and file protocols.

  The Snapcenter Plug-in for VMware vSphere provides an easy way to back up and restore virtual machines using the Snapshot feature on a storage array.

  ActiveIQ Unified Manager provides end-to-end storage network visibility in a vSphere environment. Administrators can easily identify any latency issues that might occur on virtual desktop environments hosted on ONTAP.

- **Security compliance.** With ActiveIQ Unified Manager, you can monitor multiple ONTAP systems with alerts for any policy violations.
- **Multi-protocol support.** ONTAP supports block (iSCSI, FC, FCoE, and NVMe/FC), file (NFSv3, NFSv4.1, SMB2.x, and SMB3.x), and object (S3) storage protocols.
- **Automation support.** ONTAP provides REST API, Ansible, and PowerShell modules to automate tasks

with the VDS Management Portal.

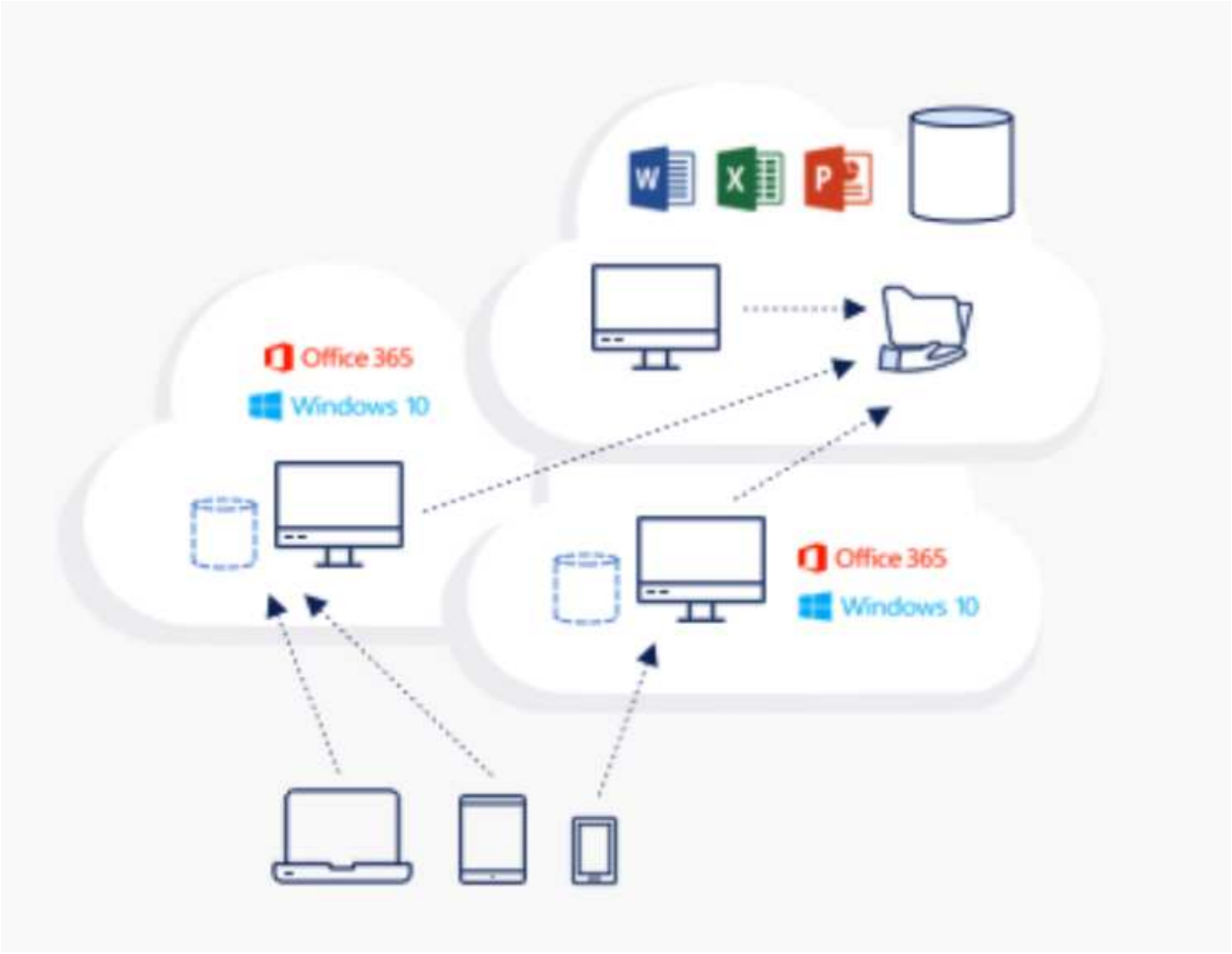
Next: Data Management

Data Management

As a part of deployment, you can choose the file-services method to host the user profile, shared data, and the home drive folder. The available options are File Server, Azure Files, or Azure NetApp Files. However, after deployment, you can modify this choice with the Command Center tool to point to any SMB share. There are various advantages to hosting with NetApp ONTAP. To learn how to change the SMB share, see Change Data Layer.

Global File Cache

When users are spread across multiple sites within a global namespace, Global File Cache can help reduce latency for frequently accessed data. Global File Cache deployment can be automated using a provisioning collection and scripted events. Global File Cache handles the read and write caches locally and maintains file locks across locations. Global File Cache can work with any SMB file servers, including Azure NetApp Files.



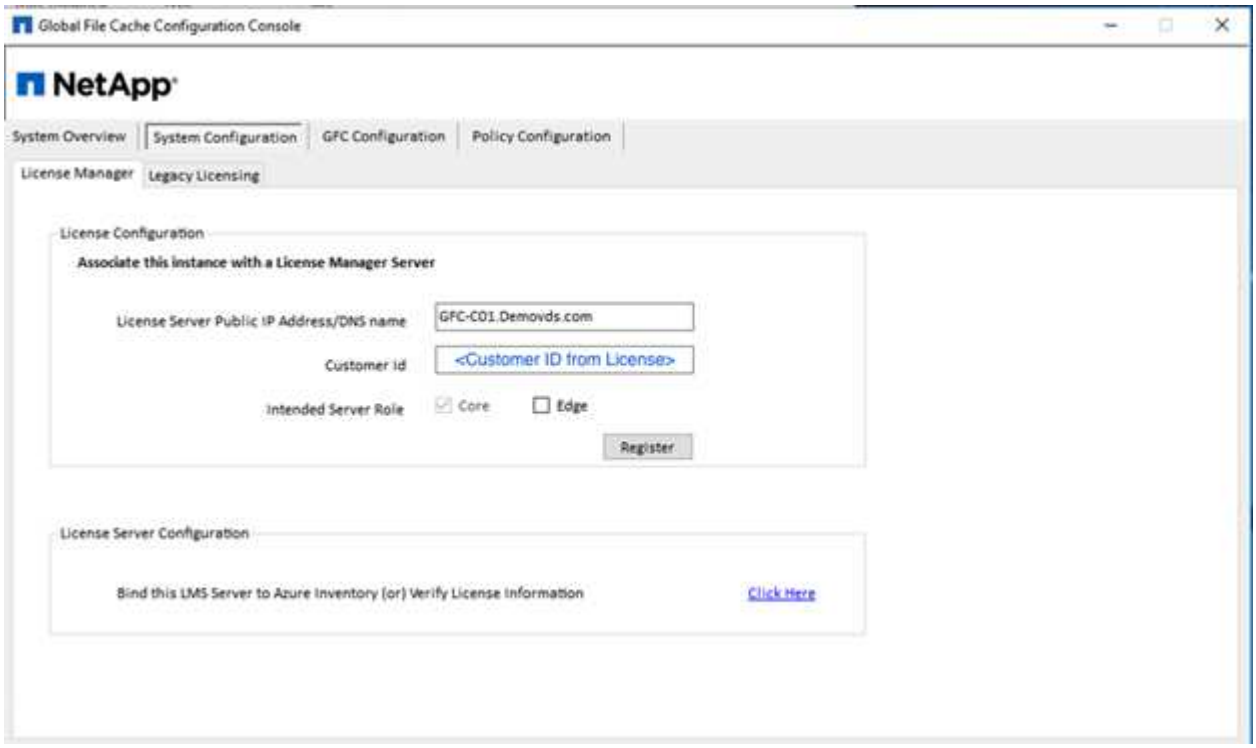
Global File Cache requires the following:

- Management server (License Management Server)
- Core
- Edge with enough disk capacity to cache the data

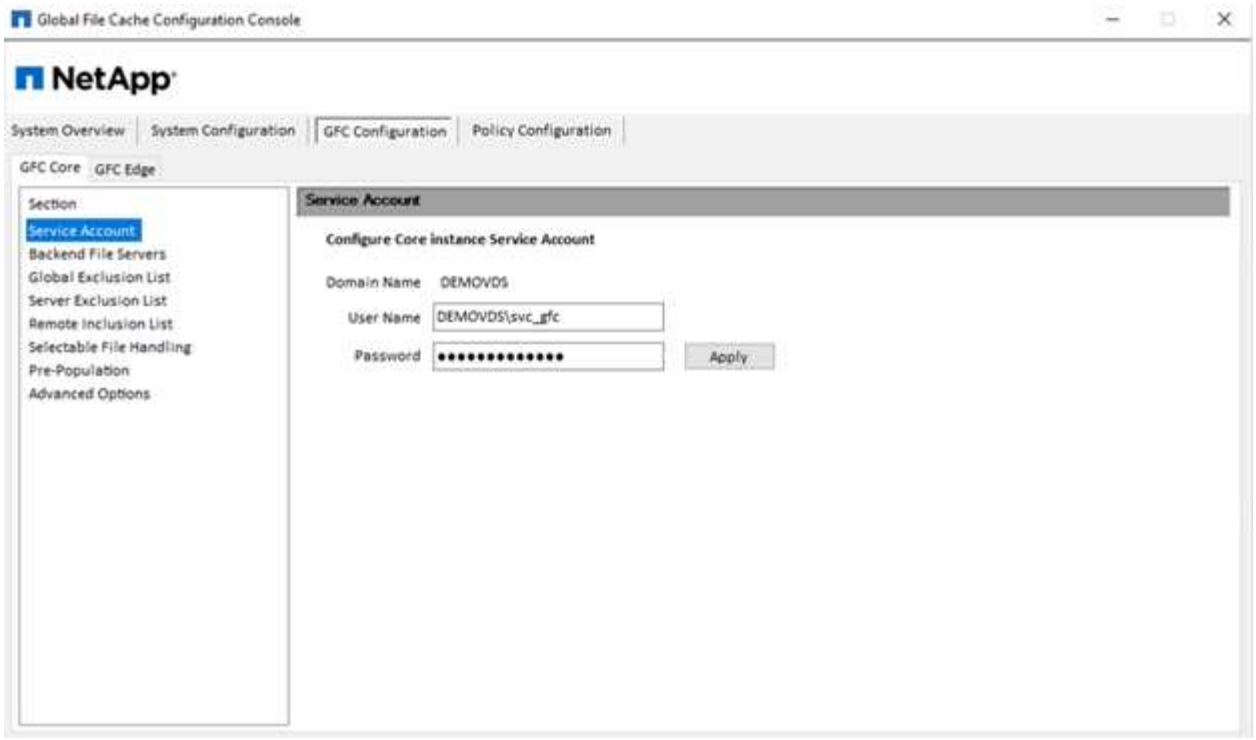
To download the software and to calculate the disk cache capacity for Edge, see the GFC documentation.

For our validation, we deployed the core and management resources on the same VM at Azure and edge resources on NetApp HCI. Please note that the core is where high-volume data access is required and the edge is a subset of the core. After the software is installed, you must activate the license activated before use. To do so, complete the following steps:

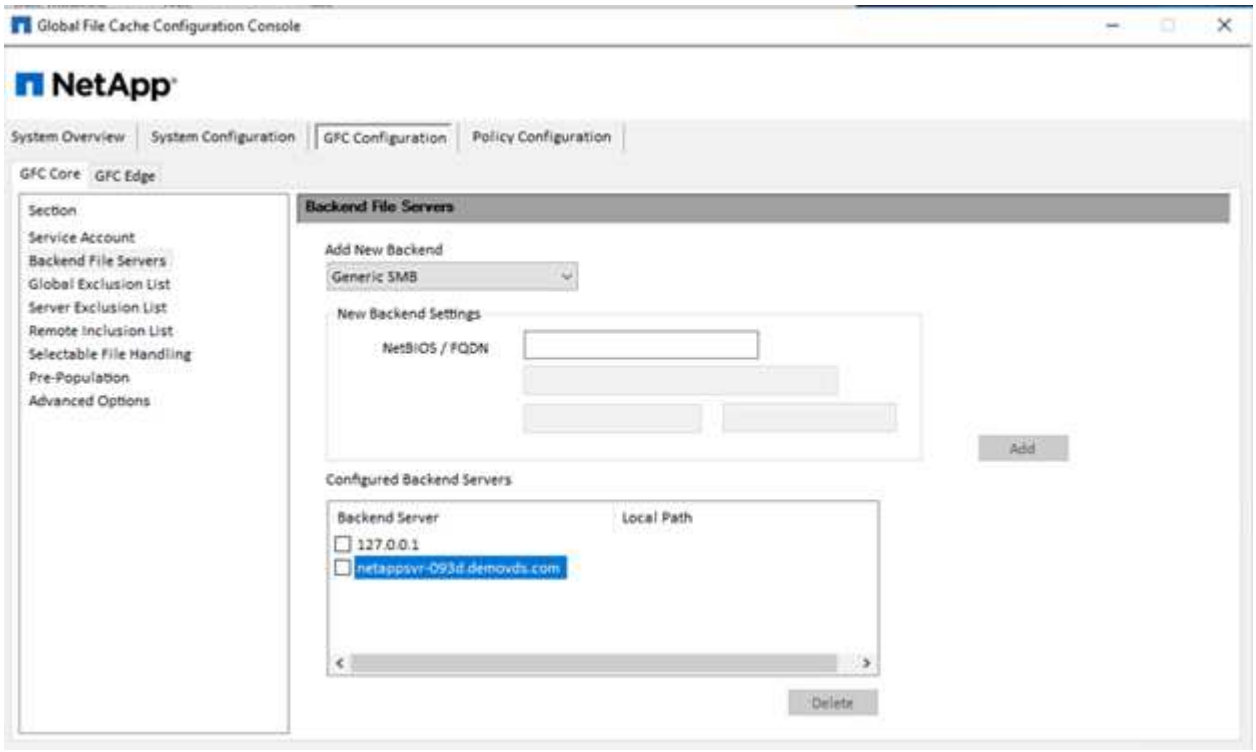
1. Under the License Configuration section, use the link Click Here to complete the license activation. Then register the core.



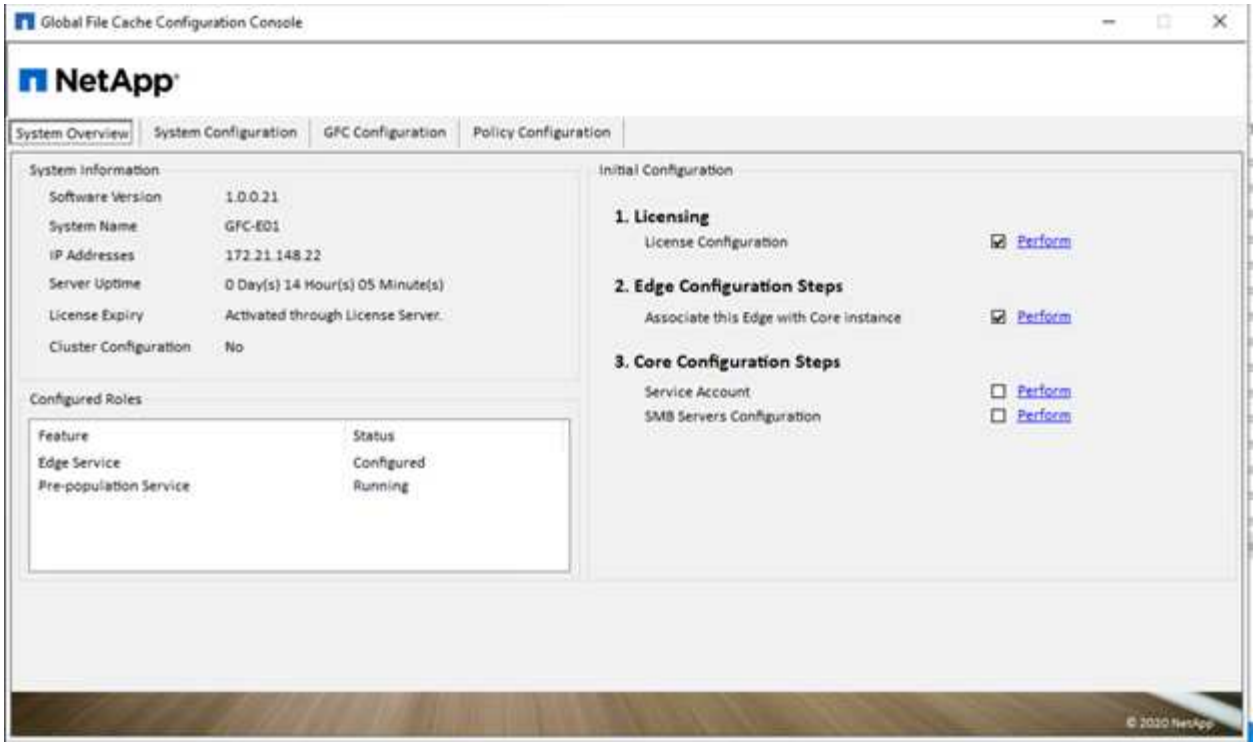
2. Provide the service account to be used for the Global File Cache. For the required permissions for this account, see the GFC documentation.



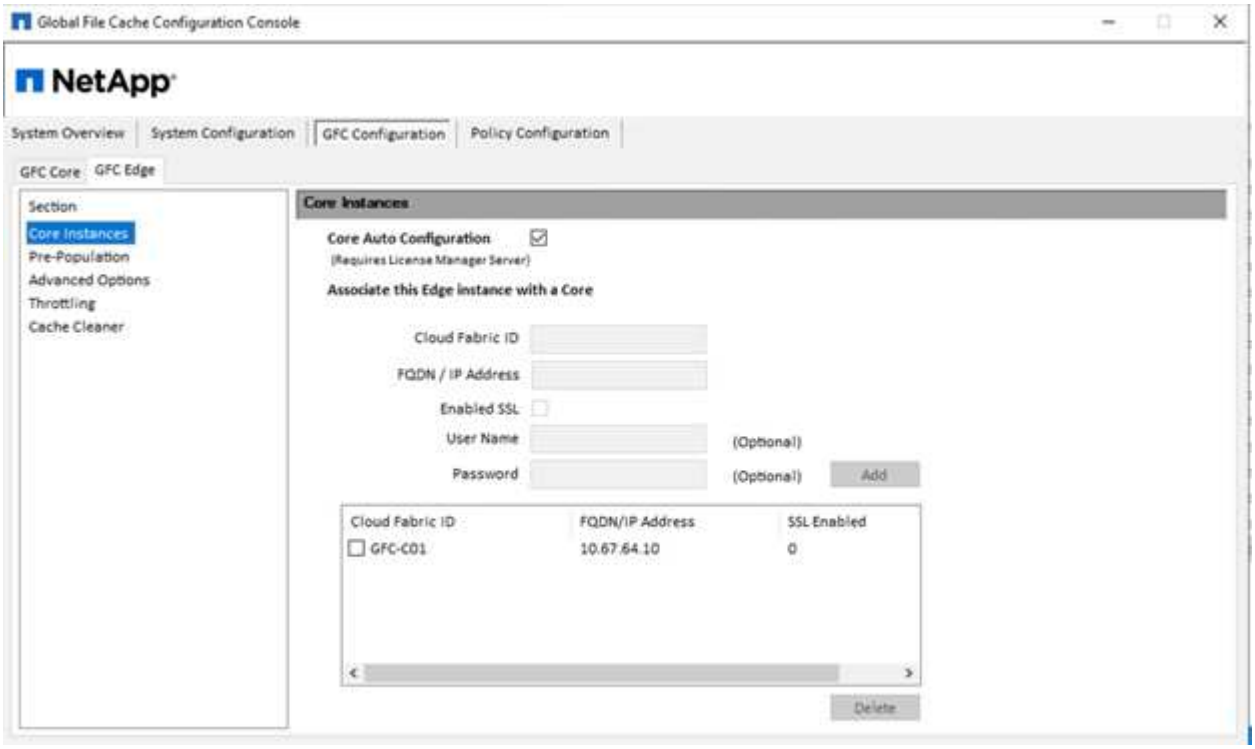
3. Add a new backend file server and provide the file server name or IP.



4. On the edge, the cache drive must have the drive letter D. If it does not, use diskpart.exe to select the volume and change drive letter. Register with the license server as edge.



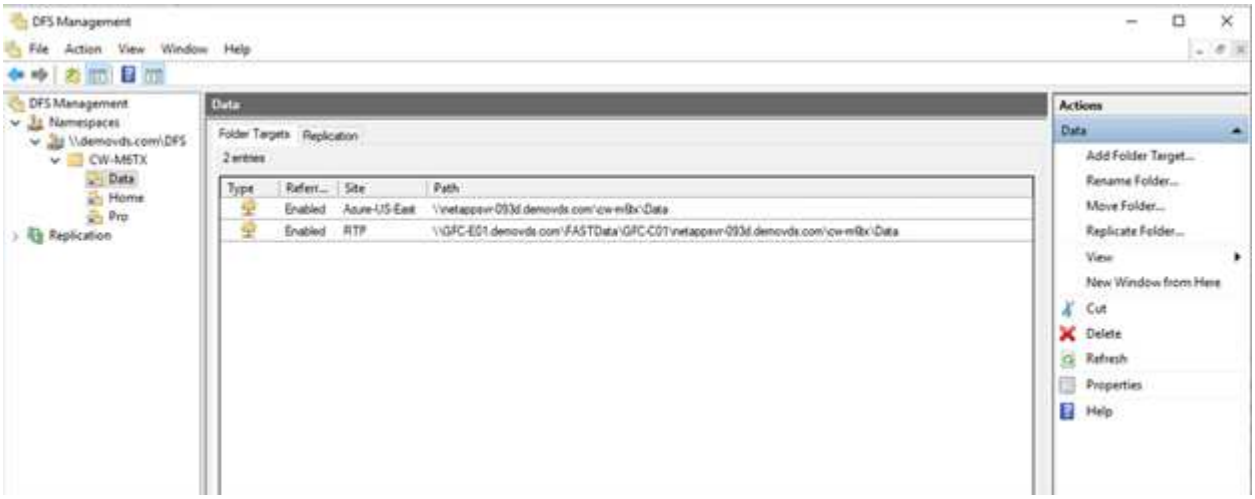
If core auto-configuration is enabled, core information is retrieved from the license management server automatically.



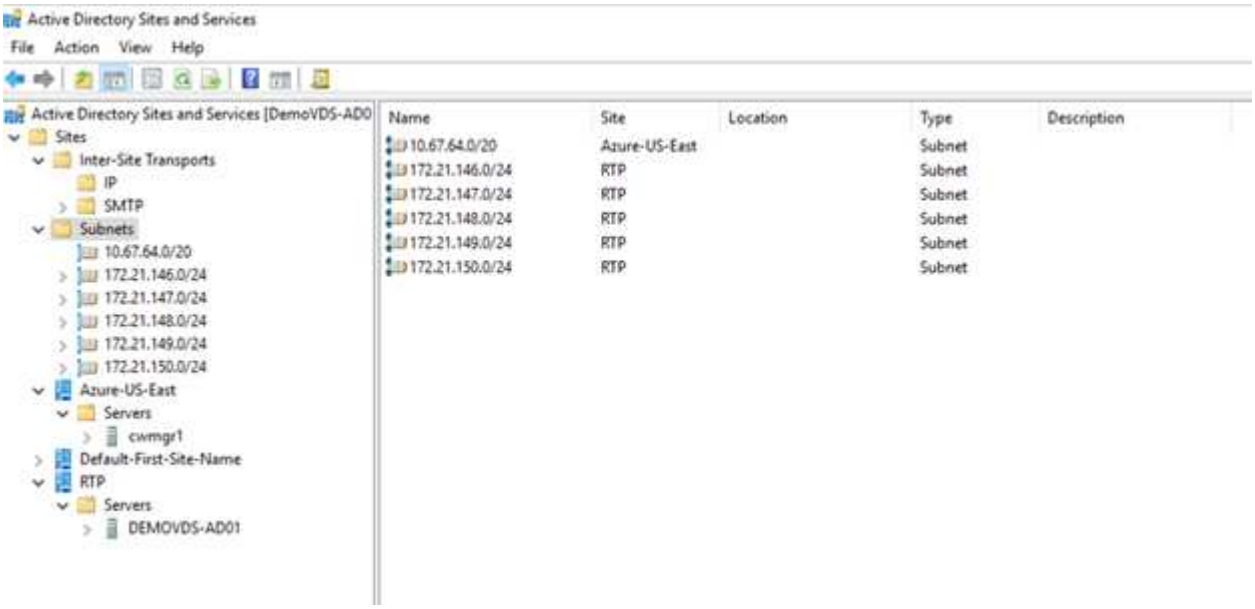
From any client machine, the administrators that used to access the share on the file server can access it with GFC edge using UNC Path `\\<edge server name>\FASTDATA\<core server name>\<backend file server name>\<share name>`. Administrators can include this path in user logonscript or GPO for users drive mapping at the edge location.

To provide transparent access for users across the globe, an administrator can setup the Microsoft Distributed

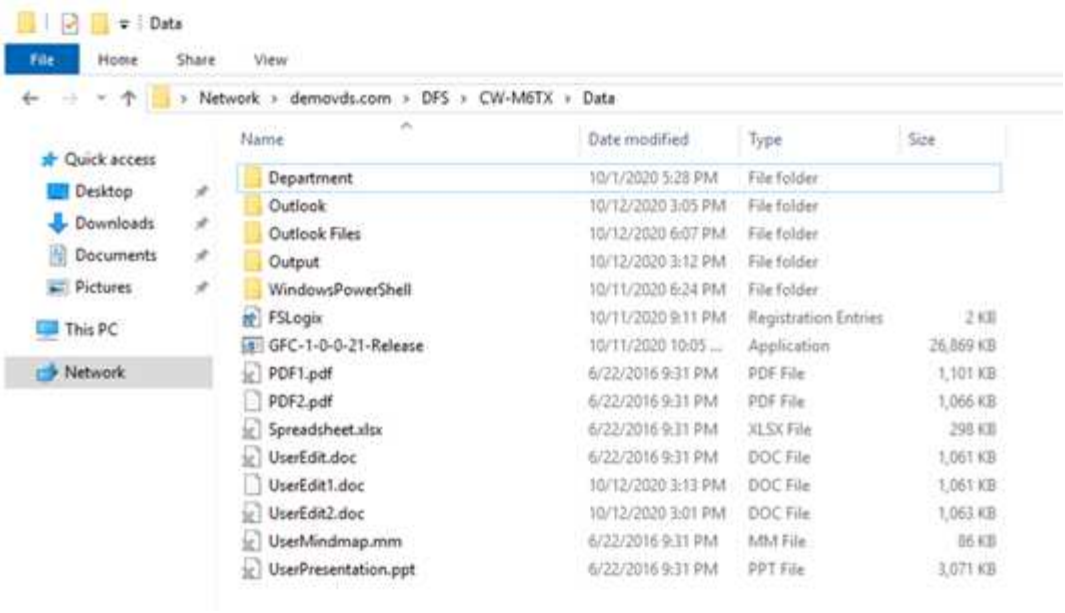
Filesystem (DFS) with links pointing to file server shares and to edge locations.



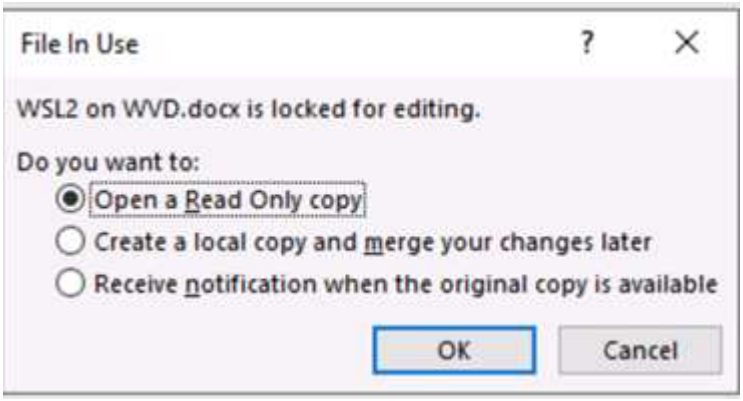
When users log in with Active Directory credentials based on the subnets associated with the site, the appropriate link is utilized by the DFS client to access the data.



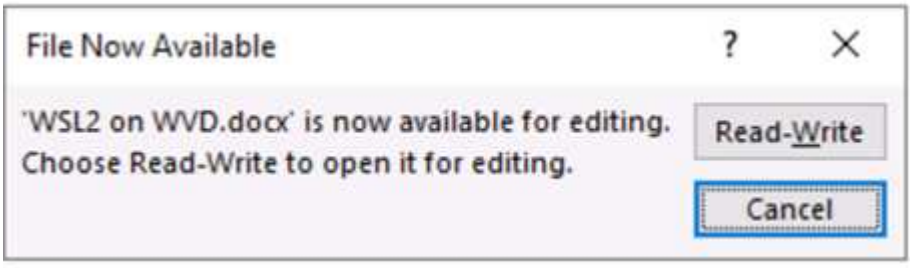
File icons change depending on whether a file is cached; files that are not cached have a grey X on the lower left corner of the icon. After a user in an edge location accesses a file, that file is cached, and the icon changes.



When a file is open and another user is trying to open the same file from an edge location, the user is prompted with the following selection:



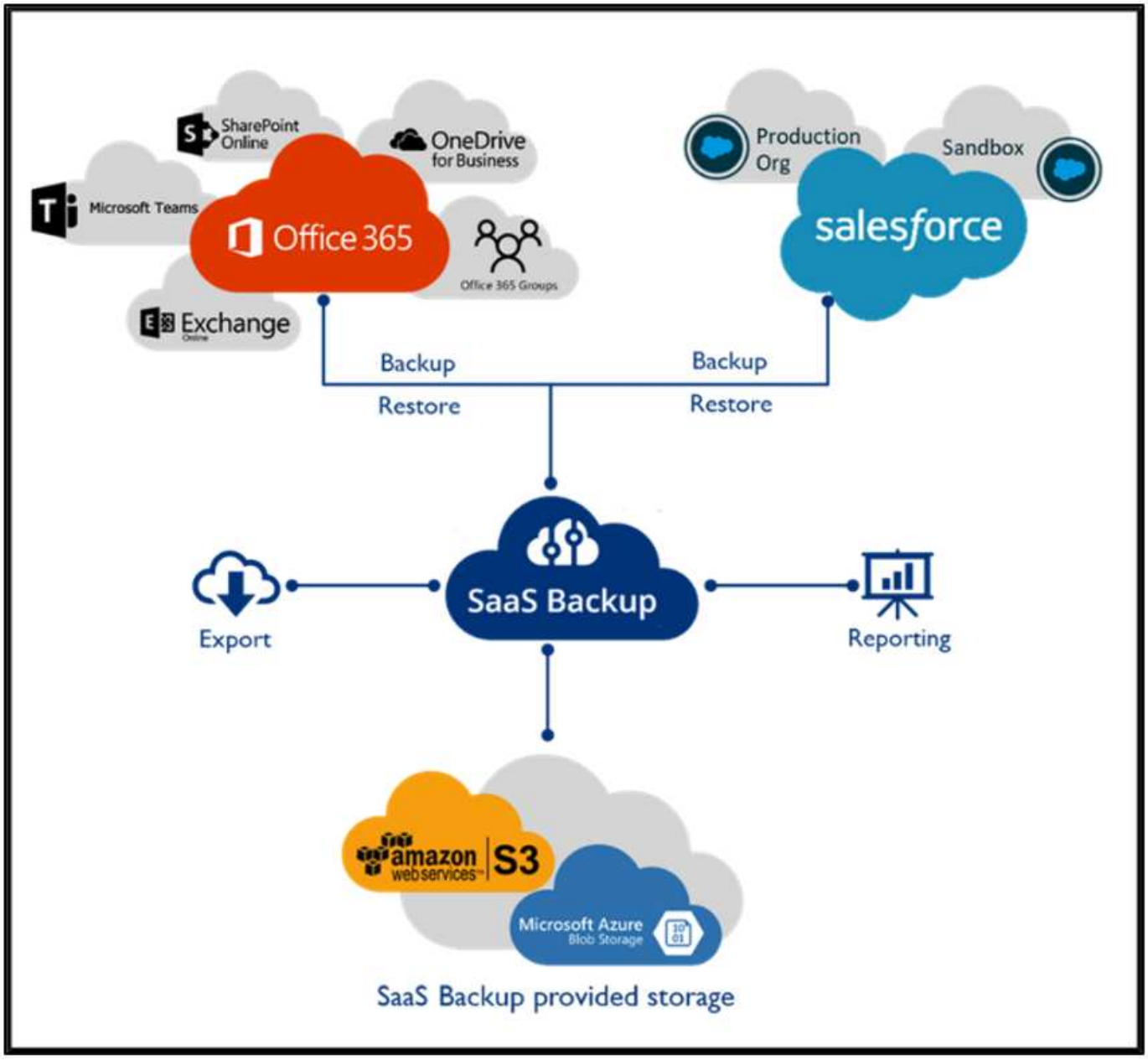
If the user selects the option to receive a notification when the original copy is available, the user is notified as follows:



For more information, see this video on Talon and Azure NetApp Files Deployment.

SaaS Backup

NetApp VDS provides data protection for Salesforce and Microsoft Office 365, including Exchange, SharePoint, and Microsoft OneDrive. The following figure shows how NetApp VDS provides SaaS Backup for these data services.



For a demonstration of Microsoft Office 365 data protection, see this video.

For a demonstration of Salesforce data protection, see this video.

Next: Operation Management

Operation management

With NetApp VDS, administrators can delegate tasks to others. They can connect to deployed servers to troubleshoot, view logs, and run audit reports. While assisting customers, helpdesk or level-3 technicians can shadow user sessions, view process lists, and kill processes if required.

For information on VDS logfiles, see the Troubleshooting Failed VDA Actions page.

For more information on the required minimum permissions, see the VDA Components and Permissions page.

If you would like to manually clone a server, see the Cloning Virtual Machines page.

To automatically increase the VM disk size, see the Auto-Increase Disk Space Feature page.

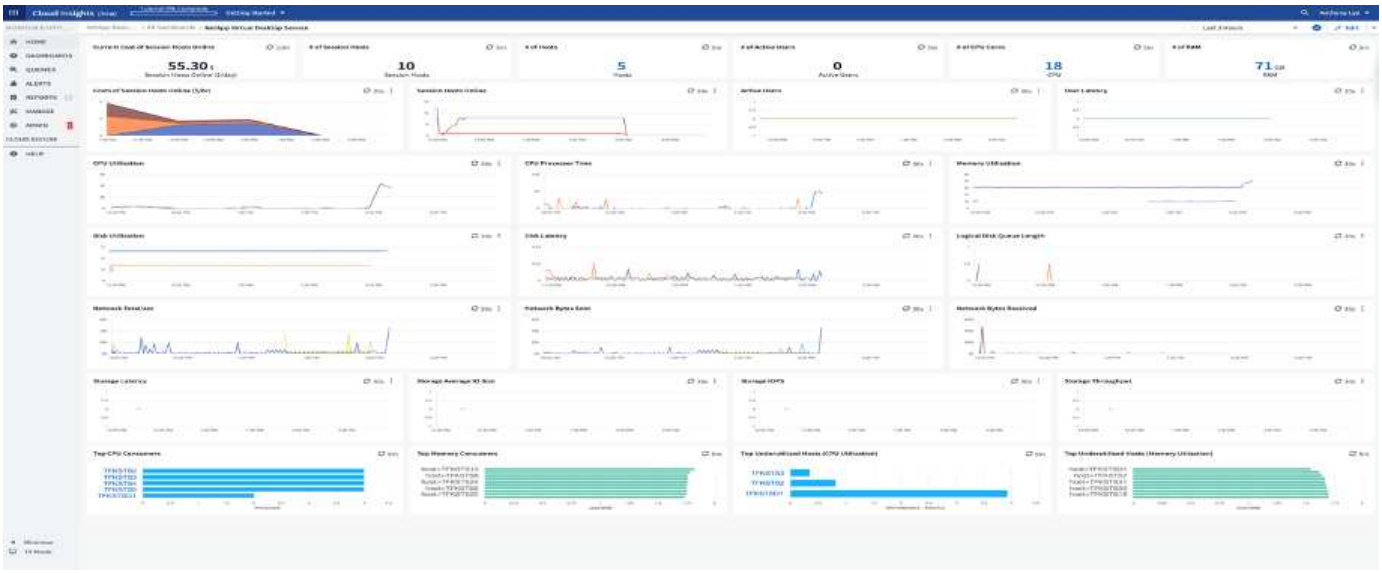
To identify the gateway address to manually configure the client, see the End User Requirements page.

Cloud Insights

NetApp Cloud Insights is a web-based monitoring tool that gives you complete visibility into infrastructure and applications running on NetApp and other third-party infrastructure components. Cloud Insights supports both private cloud and public clouds for monitoring, troubleshooting, and optimizing resources.

Only the acquisition unit VM (can be Windows or Linux) must be installed on a private cloud to collect metrics from data collectors without the need for agents. Agent-based data collectors allow you to pull custom metrics from Windows Performance Monitor or any input agents that Telegraf supports.

The following figure depicts the Cloud Insights VDS dashboard.



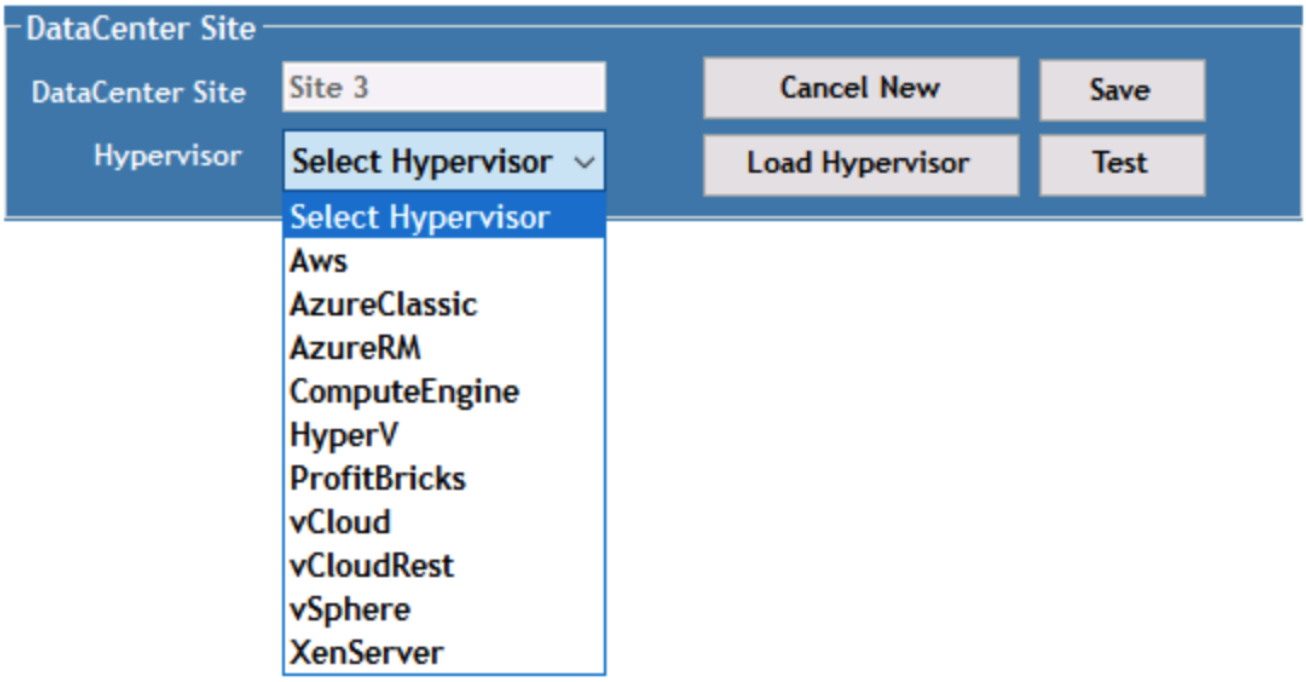
For more info on NetApp Cloud Insights, see this video.

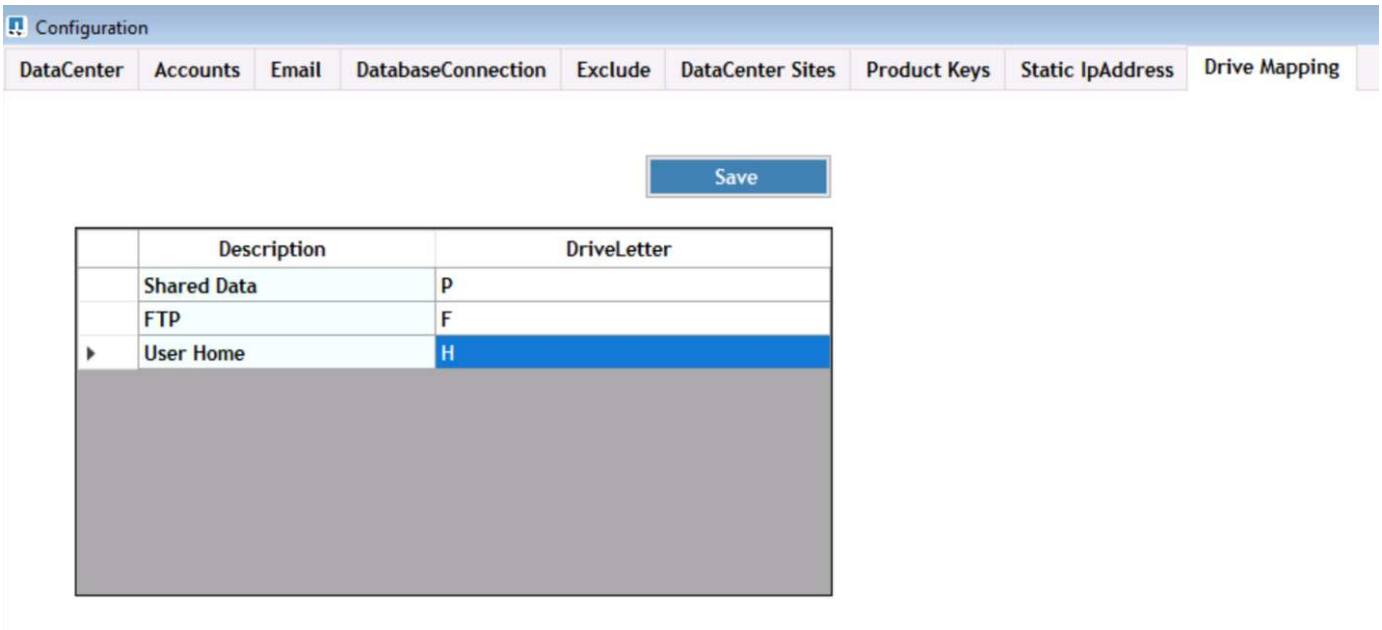
Next: Tools and logs

Tools and Logs

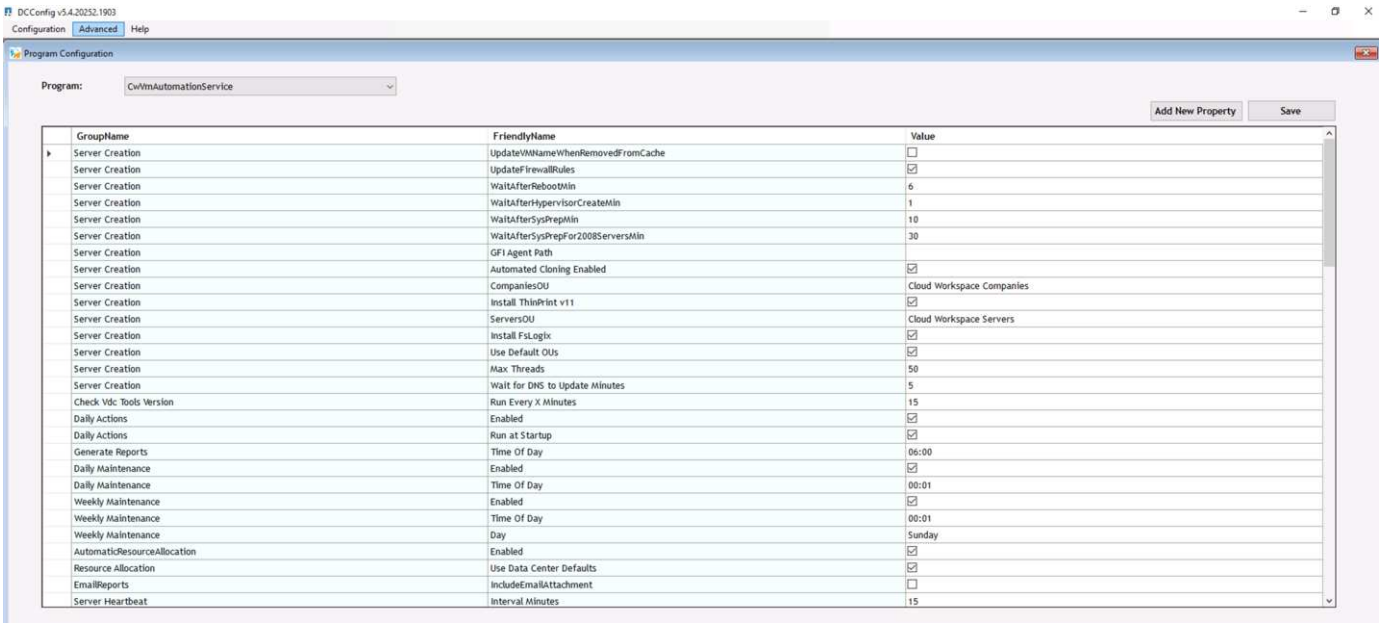
DCConfig Tool

The DCCconfig tool supports the following hypervisor options for adding a site:





Workspace-specific drive-letter mapping for shared data can be handled using GPO. Professional Services or the support team can use the advanced tab to customize settings like Active Directory OU names, the option to enable or disable deployment of FSLogix, various timeout values, and so on.



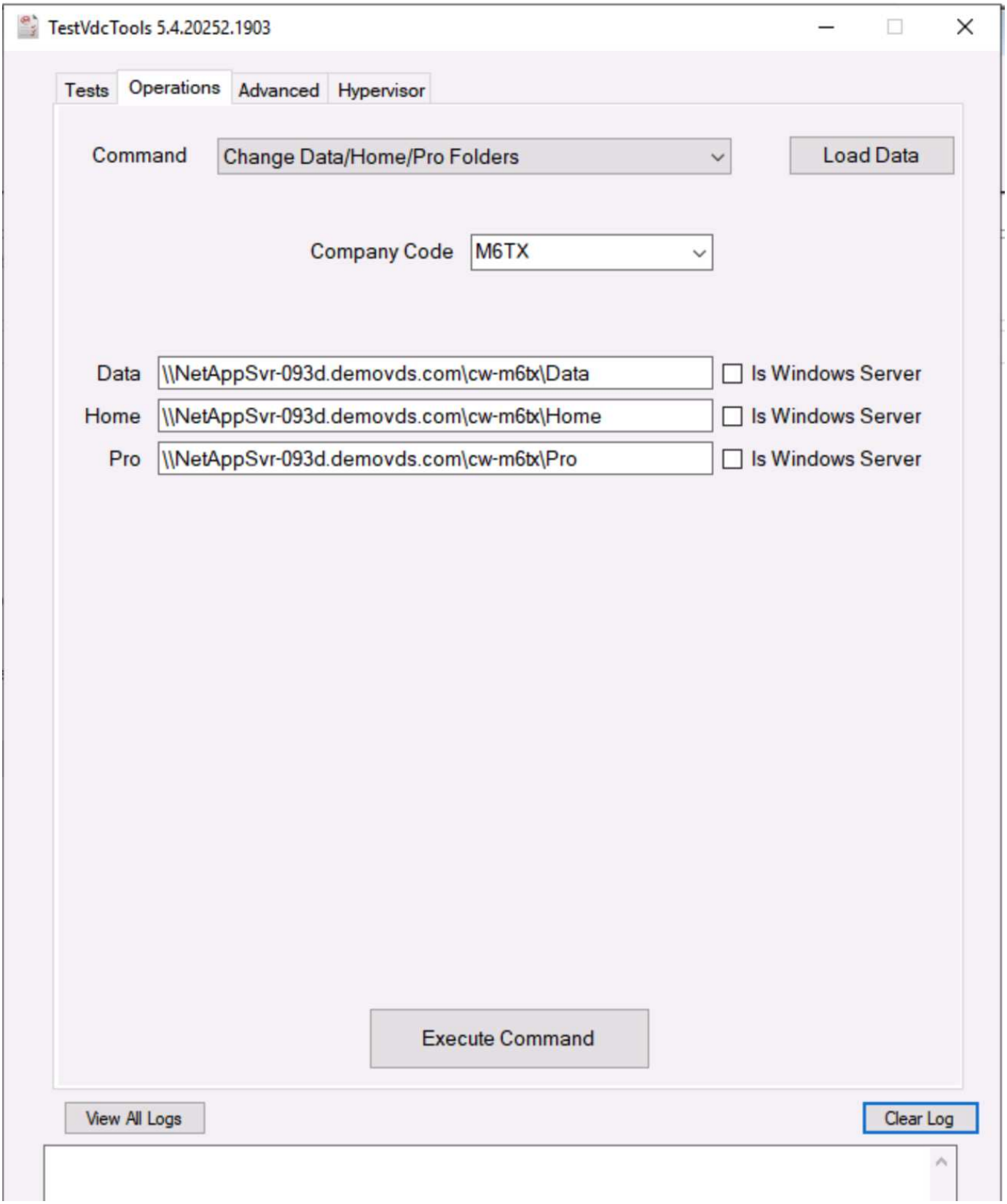
GroupName	FriendlyName	Value
Server Creation	UpdateVMNameWhenRemovedFromCache	☐
Server Creation	UpdateFirewallRules	☑
Server Creation	WaitAfterRebootMin	6
Server Creation	WaitAfterHypervisorCreateMin	1
Server Creation	WaitAfterSysPrepMin	10
Server Creation	WaitAfterSysPrepFor2008ServersMin	30
Server Creation	GFI Agent Path	
Server Creation	Automated Cloning Enabled	☑
Server Creation	CompaniesOU	Cloud Workspace Companies
Server Creation	Install ThinPrint v11	☑
Server Creation	ServersOU	Cloud Workspace Servers
Server Creation	Install FsLogix	☑
Server Creation	Use Default OUs	☑
Server Creation	Max Threads	50
Server Creation	Wait for DNS to Update Minutes	5
Check Vdc Tools Version	Run Every X Minutes	15
Daily Actions	Enabled	☑
Daily Actions	Run at Startup	☑
Generate Reports	Time Of Day	06:00
Daily Maintenance	Enabled	☑
Daily Maintenance	Time Of Day	00:01
Weekly Maintenance	Enabled	☑
Weekly Maintenance	Time Of Day	00:01
Weekly Maintenance	Day	Sunday
AutomaticResourceAllocation	Enabled	☑
Resource Allocation	Use Data Center Defaults	☑
EmailReports	IncludeEmailAttachment	☐
Server Heartbeat	Interval Minutes	15

Command Center (Previously known as TestVdc Tools)

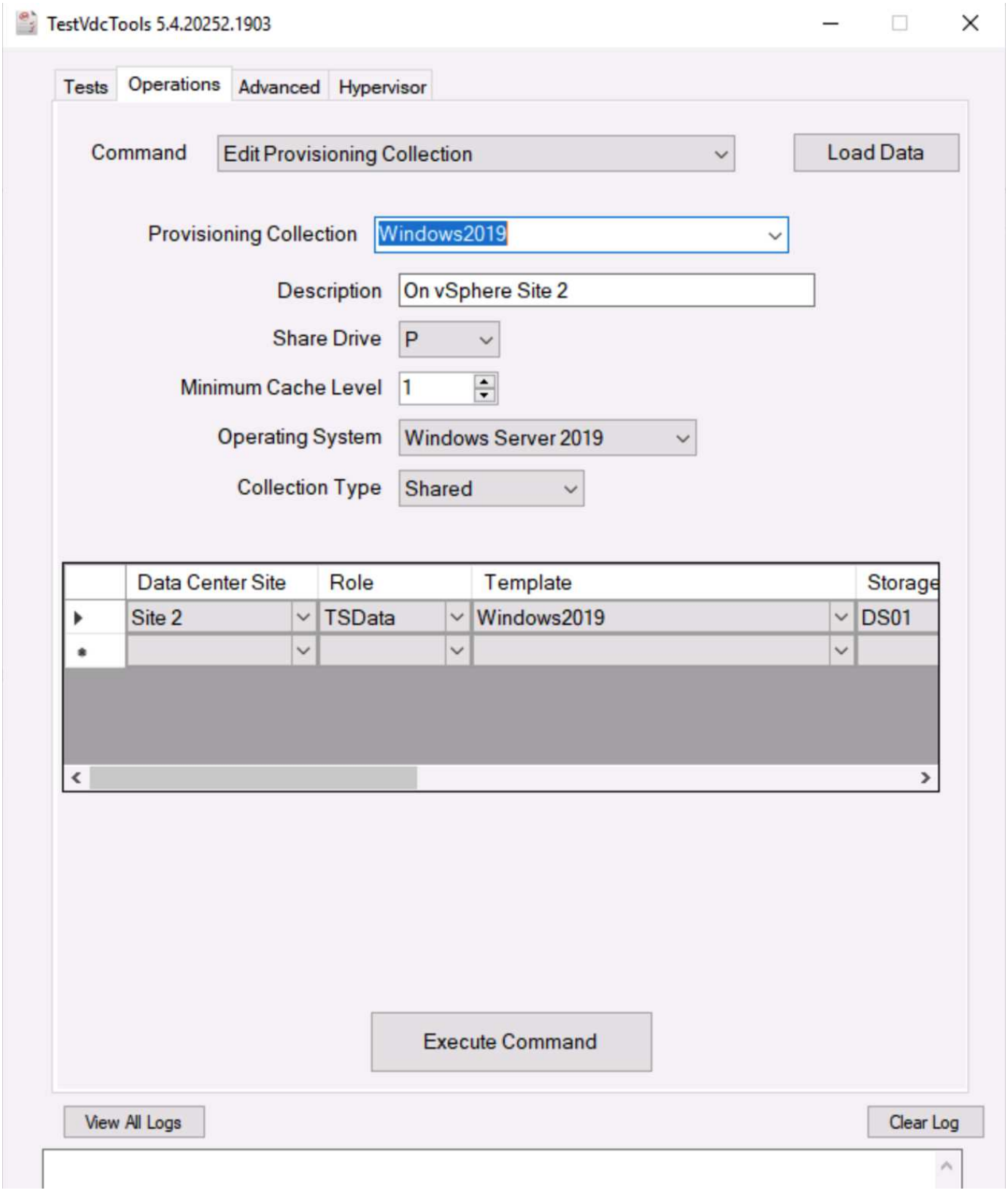
To launch Command Center and the required role, see the Command Center Overview.

You can perform the following operations:

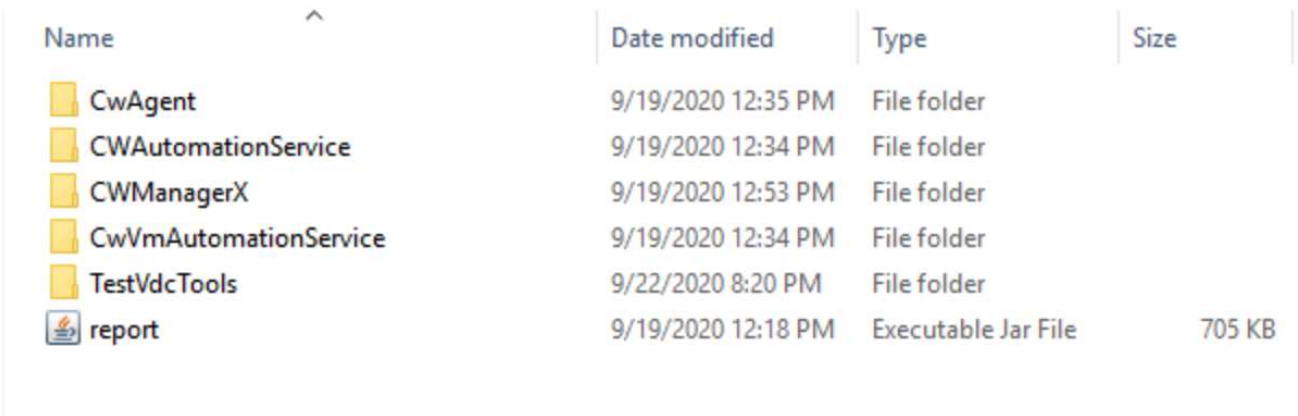
- Change the SMB Path for a workspace.



- Change the site for provisioning collection.


TestVdcTools 5.4.20252.1903
Tests
Operations
Advanced
Hypervisor
Command
Edit Provisioning Collection
Load Data
Provisioning Collection
Windows2019
Description
On vSphere Site 2
Share Drive
P
Minimum Cache Level
1
Operating System
Windows Server 2019
Collection Type
Shared
Data Center Site
Role
Template
Storage
Site 2
TSData
Windows2019
DS01
Execute Command
View All Logs
Clear Log

Log Files



Check automation logs for more info.

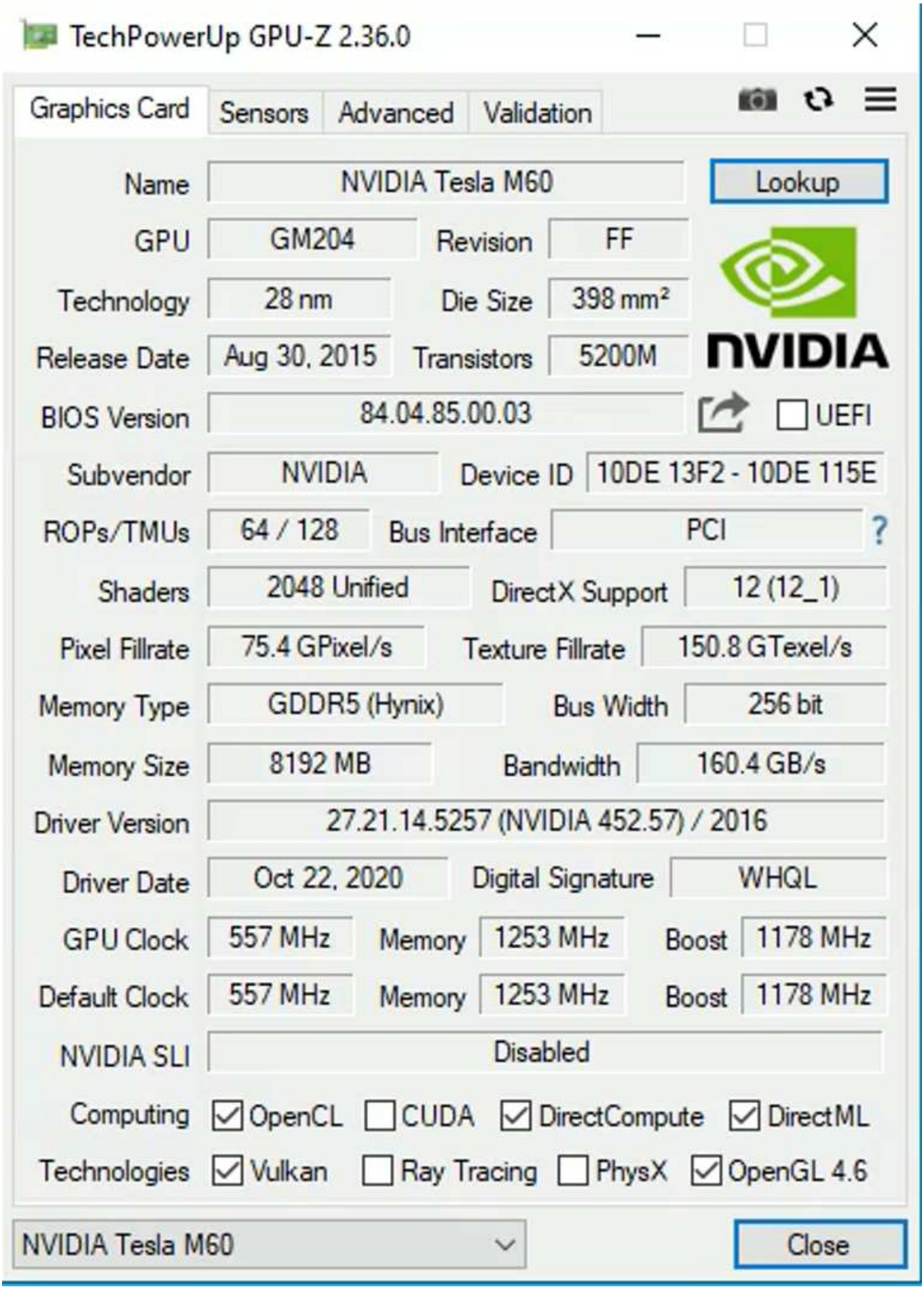
Next: Conclusion

GPU considerations

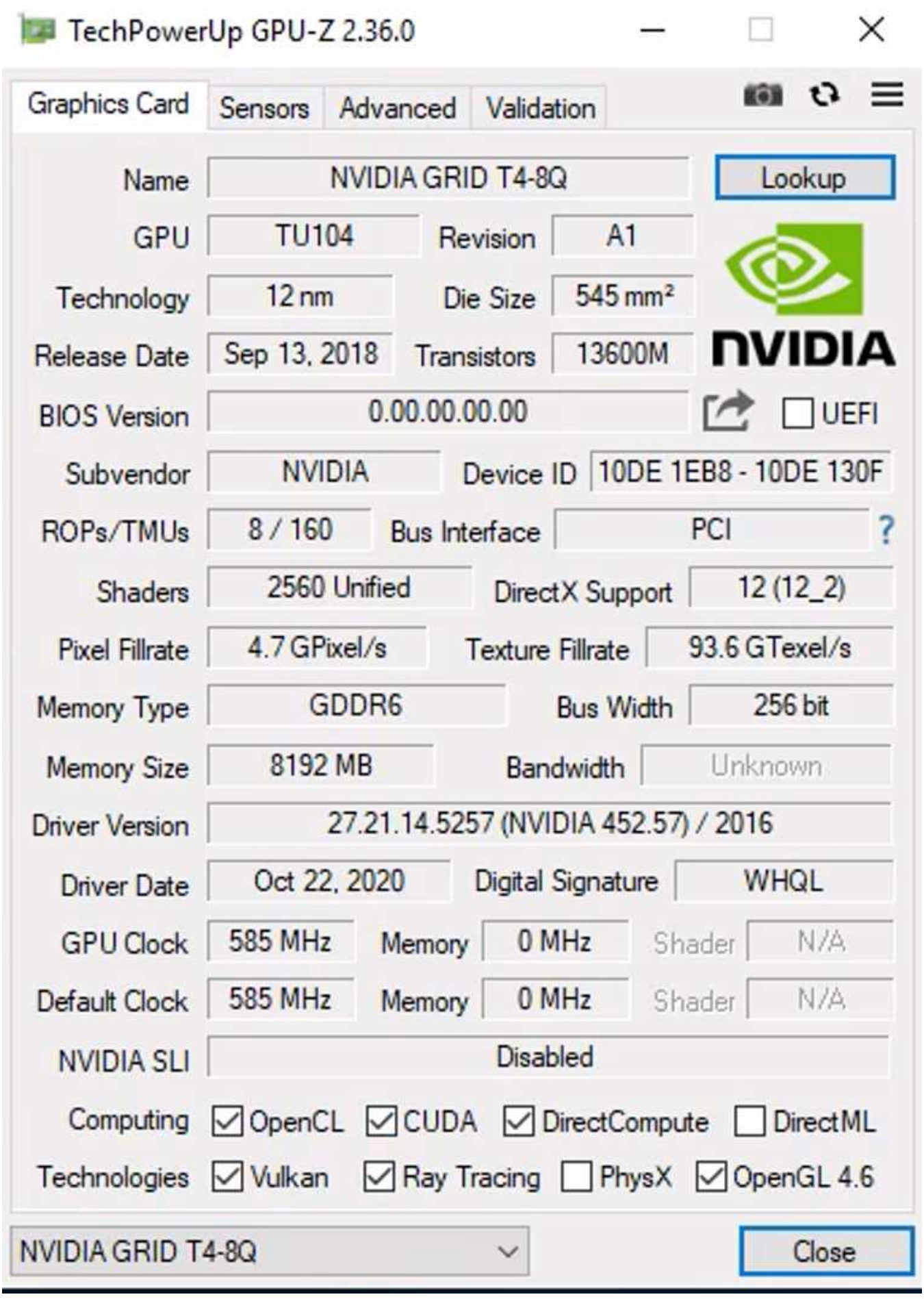
GPUs are typically used for graphic visualization (rendering) by performing repetitive arithmetic calculations. This repetitive compute capability is often used for AI and deep learning use cases.

For graphic intensive applications, Microsoft Azure offers the NV series based on the NVIDIA Tesla M60 card with one to four GPUs per VM. Each NVIDIA Tesla M60 card includes two Maxwell-based GPUs, each with 8GB of GDDR5 memory for a total of 16GB.

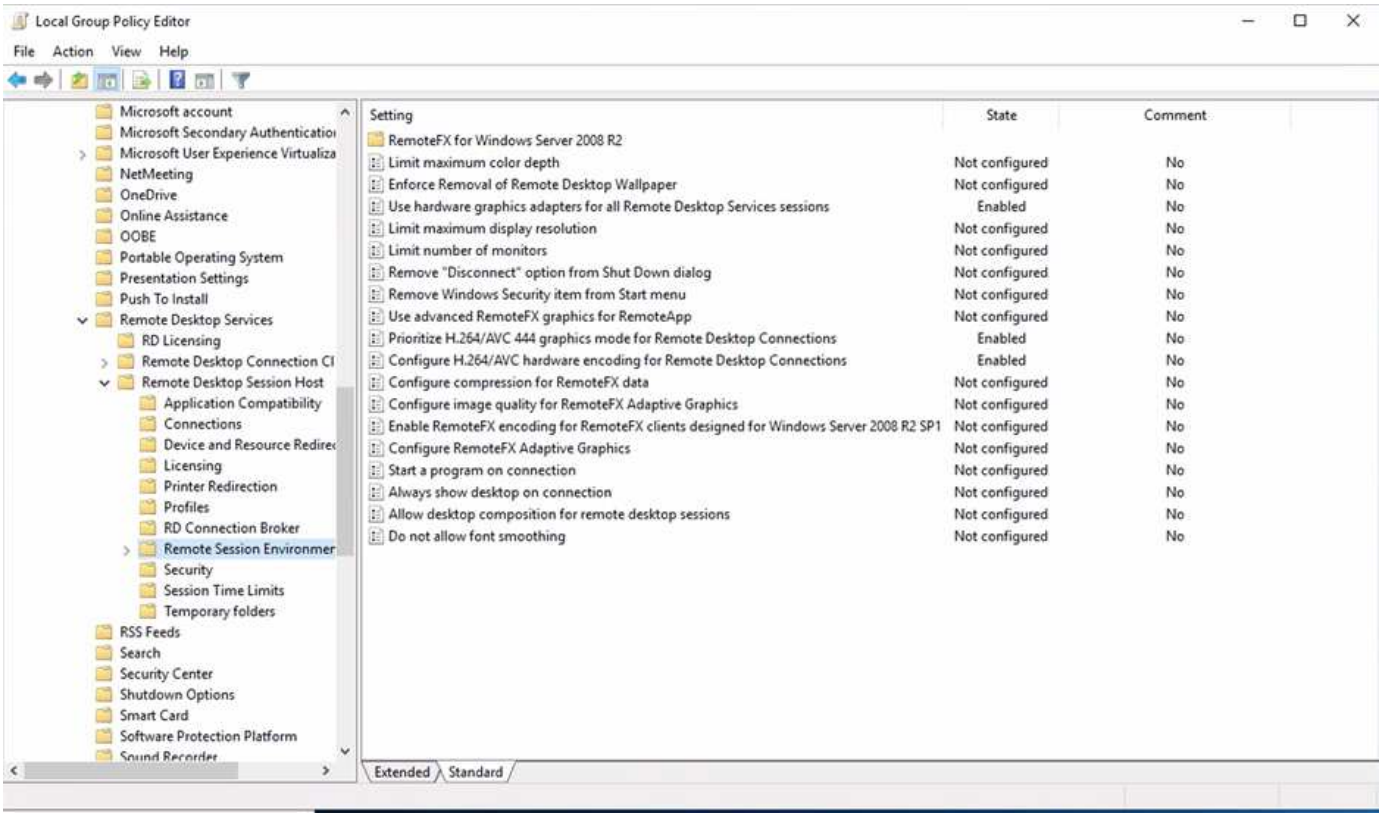
An NVIDIA license is included with the NV series.


TechPowerUp GPU-Z 2.36.0
Graphics Card
Sensors
Advanced
Validation
Name
NVIDIA Tesla M60
Lookup
GPU
GM204
Revision
FF
Technology
28 nm
Die Size
398 mm²
Release Date
Aug 30, 2015
Transistors
5200M
NVIDIA
BIOS Version
84.04.85.00.03
UEFI
Subvendor
NVIDIA
Device ID
10DE 13F2 - 10DE 115E
ROPs/TMUs
64 / 128
Bus Interface
PCI
Shaders
2048 Unified
DirectX Support
12 (12_1)
Pixel Fillrate
75.4 GPixel/s
Texture Fillrate
150.8 GTexel/s
Memory Type
GDDR5 (Hynix)
Bus Width
256 bit
Memory Size
8192 MB
Bandwidth
160.4 GB/s
Driver Version
27.21.14.5257 (NVIDIA 452.57) / 2016
Driver Date
Oct 22, 2020
Digital Signature
WHQL
GPU Clock
557 MHz
Memory
1253 MHz
Boost
1178 MHz
Default Clock
557 MHz
Memory
1253 MHz
Boost
1178 MHz
NVIDIA SLI
Disabled
Computing
OpenCL
CUDA
DirectCompute
DirectML
Technologies
Vulkan
Ray Tracing
PhysX
OpenGL 4.6
NVIDIA Tesla M60
Close

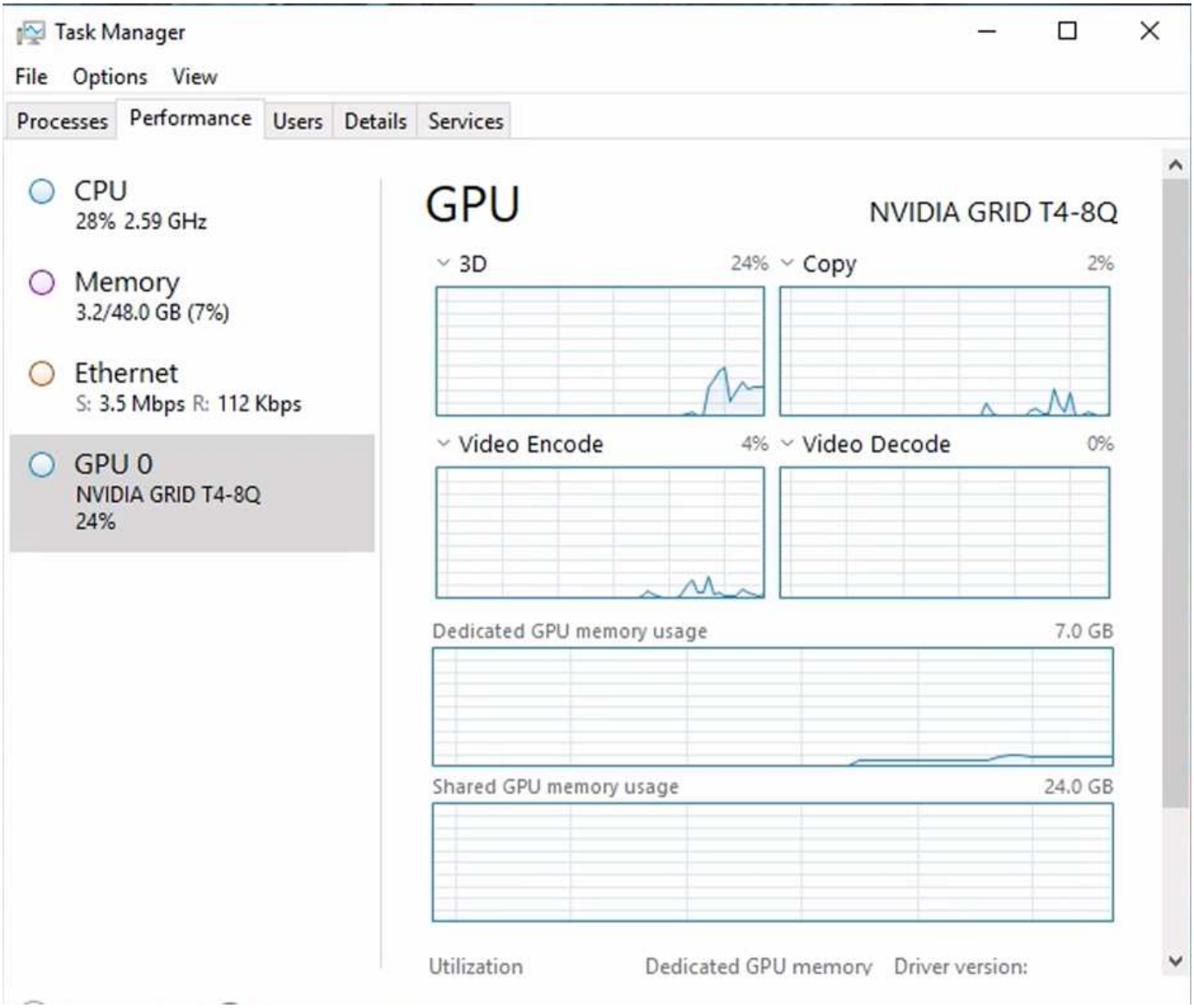
With NetApp HCI, the H615C GPU contains three NVIDIA Tesla T4 cards. Each NVIDIA Tesla T4 card has a Touring-based GPU with 16GB of GDDR6 memory. When used in a VMware vSphere environment, virtual machines are able to share the GPU, with each VM having dedicated frame buffer memory. Ray tracing is available with the GPUs on the NetApp HCI H615C to produce realistic images including light reflections. Please note that you need to have an NVIDIA license server with a license for GPU features.


TechPowerUp GPU-Z 2.36.0
Graphics Card
Sensors
Advanced
Validation
Name
NVIDIA GRID T4-8Q
Lookup
GPU
TU104
Revision
A1
Technology
12 nm
Die Size
545 mm²
Release Date
Sep 13, 2018
Transistors
13600M
NVIDIA
BIOS Version
0.00.00.00.00
UEFI
Subvendor
NVIDIA
Device ID
10DE 1EB8 - 10DE 130F
ROPs/TMUs
8 / 160
Bus Interface
PCI
Shaders
2560 Unified
DirectX Support
12 (12_2)
Pixel Fillrate
4.7 GPixel/s
Texture Fillrate
93.6 GTexel/s
Memory Type
GDDR6
Bus Width
256 bit
Memory Size
8192 MB
Bandwidth
Unknown
Driver Version
27.21.14.5257 (NVIDIA 452.57) / 2016
Driver Date
Oct 22, 2020
Digital Signature
WHQL
GPU Clock
585 MHz
Memory
0 MHz
Shader
N/A
Default Clock
585 MHz
Memory
0 MHz
Shader
N/A
NVIDIA SLI
Disabled
Computing
OpenCL
CUDA
DirectCompute
DirectML
Technologies
Vulkan
Ray Tracing
PhysX
OpenGL 4.6
NVIDIA GRID T4-8Q
Close

To use the GPU, you must install the appropriate driver, which can be downloaded from the NVIDIA license portal. In an Azure environment, the NVIDIA driver is available as GPU driver extension. Next, the group policies in the following screenshot must be updated to use GPU hardware for remote desktop service sessions. You should prioritize H.264 graphics mode and enable encoder functionality.



Validate GPU performance monitoring with Task Manager or by using the nvidia-smi CLI when running WebGL samples. Make sure that GPU, memory, and encoder resources are being consumed.



To make sure that the virtual machine is deployed to the NetApp HCI H615C with Virtual Desktop Service, define a site with the vCenter cluster resource that has H615C hosts. The VM template must have the required vGPU profile attached.

For shared multi-session environments, consider allocating multiple homogenous vGPU profiles. However, for high end professional graphics application, it is better to have each VM dedicated to a user to keep VMs isolated.

The GPU processor can be controlled by a QoS policy, and each vGPU profile can have dedicated frame buffers. However, the encoder and decoder are shared for each card. The placement of a vGPU profile on a GPU card is controlled by the vSphere host GPU assignment policy, which can emphasize performance (spread VMs) or consolidation (group VMs).

Next: Solutions for industry.

Solutions for Industry

Graphics workstations are typically used in industries such as manufacturing, healthcare, energy, media and entertainment, education, architecture, and so on. Mobility is often

limited for graphics-intensive applications.

To address the issue of mobility, Virtual Desktop Services provide a desktop environment for all types of workers, from task workers to expert users, using hardware resources in the cloud or with NetApp HCI, including options for flexible GPU configurations. VDS enables users to access their work environment from anywhere with laptops, tablets, and other mobile devices.

To run manufacturing workloads with software like ANSYS Fluent, ANSYS Mechanical, Autodesk AutoCAD, Autodesk Inventor, Autodesk 3ds Max, Dassault Systèmes SOLIDWORKS, Dassault Systèmes CATIA, PTC Creo, Siemens PLM NX, and so on, the GPUs available on various clouds (as of Jan 2021) are listed in the following table.

GPU Model	Microsoft Azure	Google Compute (GCP)	Amazon Web Services (AWS)	On-Premises (NetApp HCI)
NVIDIA M60	Yes	Yes	Yes	No
NVIDIA T4	No	Yes	Yes	Yes
NVIDIA P100	No	Yes	No	No
NVIDIA P4	No	Yes	No	No

Shared desktop sessions with other users and dedicated personal desktops are also available. Virtual desktops can have one to four GPUs or can utilize partial GPUs with NetApp HCI. The NVIDIA T4 is a versatile GPU card that can address the demands of a wide spectrum of user workloads.
Each GPU card on NetApp HCI H615C has 16GB of frame buffer memory and three cards per server. The number of users that can be hosted on single H615C server depends on the user workload.

Users/Server	Light (4GB)	Medium (8GB)	Heavy (16GB)
H615C	12	6	3

To determine the user type, run the GPU profiler tool while users are working with applications performing typical tasks. The GPU profiler captures memory demands, the number of displays, and the resolution that users require. You can then pick the vGPU profile that satisfies your requirements.

Virtual desktops with GPUs can support a display resolution of up to 8K, and the utility nView can split a single monitor into regions to work with different datasets.

With ONTAP file storage, you can realize the following benefits:

- A single namespace that can grow up to 20PB of storage with 400 billion of files, without much administrative input
- A namespace that can span the globe with a Global File Cache
- Secure multitenancy with managed NetApp storage
- The migration of cold data to object stores using NetApp FabricPool
- Quick file statistics with file system analytics
- Scaling a storage cluster up to 24 nodes increasing capacity and performance
- The ability to control storage space using quotas and guaranteed performance with QoS limits
- Securing data with encryption
- Meeting broad requirements for data protection and compliance

- Delivering flexible business continuity options

Next: Conclusion

Conclusion

The NetApp Virtual Desktop Service provides an easy-to-consume virtual desktop and application environment with a sharp focus on business challenges. By extending VDS with the on-premises ONTAP environment, you can use powerful NetApp features in a VDS environment, including rapid clone, in-line deduplication, compaction, thin provisioning, and compression. These features save storage costs and improve performance with all-flash storage. With VMware vSphere hypervisor, which minimizes server-provisioning time by using Virtual Volumes and vSphere API for Array integration. Using the hybrid cloud, customers can pick the right environment for their demanding workloads and save money. The desktop session running on-premises can access cloud resources based on policy.

Next: Where to Find Additional Information

Where to Find Additional Information

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

- NetApp Cloud
- NetApp VDS Product Documentation
- Connect your on-premises network to Azure with VPN Gateway
- Azure Portal
- Microsoft Windows Virtual Desktop
- Azure NetApp Files Registration

VMware Horizon

NVA-1132-DESIGN: VMware end-user computing with NetApp HCI

Suresh Thoppay, NetApp

VMware end-user computing with NetApp HCI is a prevalidated, best-practice data center architecture for deploying virtual desktop workloads at an enterprise scale. This document describes the architectural design and best practices for deploying the solution at production scale in a reliable and risk-free manner.

NVA-1132-DESIGN: VMware end-user computing with NetApp HCI

NVA-1129-DESIGN: VMware end-user computing with NetApp HCI and NVIDIA GPUs

Suresh Thoppay, NetApp

VMware end-user computing with NetApp HCI is a prevalidated, best-practice data center architecture for deploying virtual desktop workloads at an enterprise scale. This document describes the architectural design and best practices for deploying the solution at production scale in a reliable and risk-free manner.

NVA-1129-DESIGN: VMware end-user computing with NetApp HCI and NVIDIA GPUs

NVA-1129-DEPLOY: VMware end-user Computing with NetApp HCI and NVIDIA GPUs

Suresh Thoppay, NetApp

VMware end-user Computing with NetApp HCI is a prevalidated, best-practice, data center architecture for deploying virtual desktop workloads at an enterprise scale. This document describes how to deploy the solution at production scale in a reliable and risk-free manner

NVA-1129-DEPLOY: VMware end-user Computing with NetApp HCI and NVIDIA GPUs

NetApp HCI for virtual desktop infrastructure with VMware Horizon 7 - Empower your power users with 3D Graphics

Suresh Thoppay, NetApp

TR-4792 provides guidance on using the NetApp H615C compute node for 3D graphics workloads in a VMware Horizon environment powered by NVIDIA graphics processing units (GPUs) and virtualization software. It also provides the results from the preliminary testing of SPECviewperf 13 for the H615C.

NetApp HCI for virtual desktop infrastructure with VMware Horizon 7 - Empower your power users with 3D Graphics

FlexPod desktop virtualization solutions

Learn more about FlexPod virtualization solutions by reviewing the FlexPod design guides

Demos and Tutorials

Virtualization Videos and Demos

See the following videos and demos highlighting specific features of the hybrid cloud, virtualization, and container solutions.

NetApp ONTAP Tools for VMware vSphere

- ONTAP Tools for VMware - Overview
- VMware iSCSI Datastore Provisioning with ONTAP
- VMware NFS Datastore Provisioning with ONTAP

VMware Cloud on AWS with AWS FSx for NetApp ONTAP

- Windows Guest Connected Storage with FSx ONTAP using iSCSI
- Linux Guest Connected Storage with FSx ONTAP using NFS
- VMware Cloud on AWS TCO savings with Amazon FSx for NetApp ONTAP
- VMware Cloud on AWS supplemental datastore w/ Amazon FSx for NetApp ONTAP
- VMware HCX Deployment and Configuration Setup for VMC
- vMotion Migration Demonstration with VMware HCX for VMC and FSxN
- Cold Migration Demonstration with VMware HCX for VMC and FSxN

Azure VMware Services on Azure with Azure NetApp Files (ANF)

- Azure VMware Solution supplemental datastore overview with Azure NetApp Files
- Azure VMware Solution DR with Cloud Volumes ONTAP, SnapCenter and JetStream
- Cold Migration Demonstration with VMware HCX for AVS and ANF
- vMotion Demonstration with VMware HCX for AVS and ANF
- Bulk Migration Demonstration with VMware HCX for AVS and ANF

SnapCenter Plug-in for VMware vSphere

NetApp SnapCenter software is an easy-to-use enterprise platform to securely coordinate and manage data protection across applications, databases, and file systems.

The SnapCenter Plug-in for VMware vSphere allows you to perform backup, restore, and attach operations for VMs and backup and mount operations for datastores that are registered with SnapCenter directly within VMware vCenter.

For more information about NetApp SnapCenter Plug-in for VMware vSphere, see the NetApp SnapCenter Plug-in for VMware vSphere Overview.

SnapCenter Plug-in for VMware vSphere - Solution Pre-Requisites

SnapCenter Plug-in for VMware vSphere - Deployment

SnapCenter Plug-in for VMware vSphere - Backup Workflow

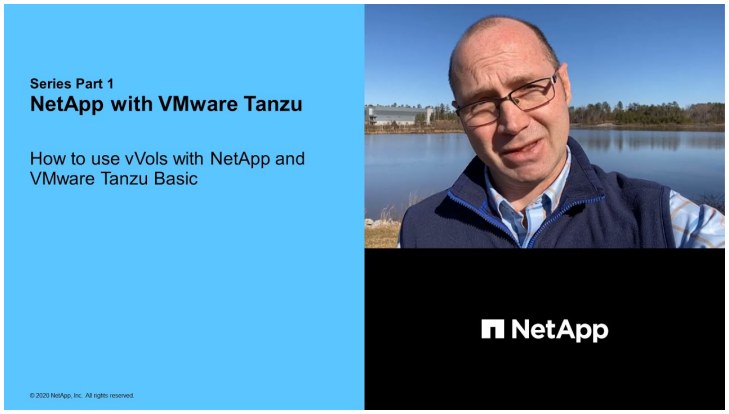
SnapCenter Plug-in for VMware vSphere - Restore Workflow

SnapCenter - SQL Restore Workflow

NetApp with VMware Tanzu

VMware Tanzu enables customers to deploy, administer, and manage their Kubernetes environment through vSphere or the VMware Cloud Foundation. This portfolio of products from VMware allows customer to manage all their relevant Kubernetes clusters from a single control plane by choosing the VMware Tanzu edition that best suits their needs.

For more information about VMware Tanzu, see the VMware Tanzu Overview. This review covers use cases, available additions, and more about VMware Tanzu.



How to use vVols with NetApp and VMware Tanzu Basic, part 1

How to use vVols with NetApp and VMware Tanzu Basic, part 2

How to use vVols with NetApp and VMware Tanzu Basic, part 3

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