Virtualization

NetApp Solutions

NetApp
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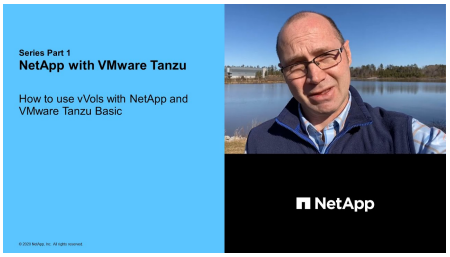

Deploying Dynamic Persistent NetApp Storage for VMware Tanzu, part 1

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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**

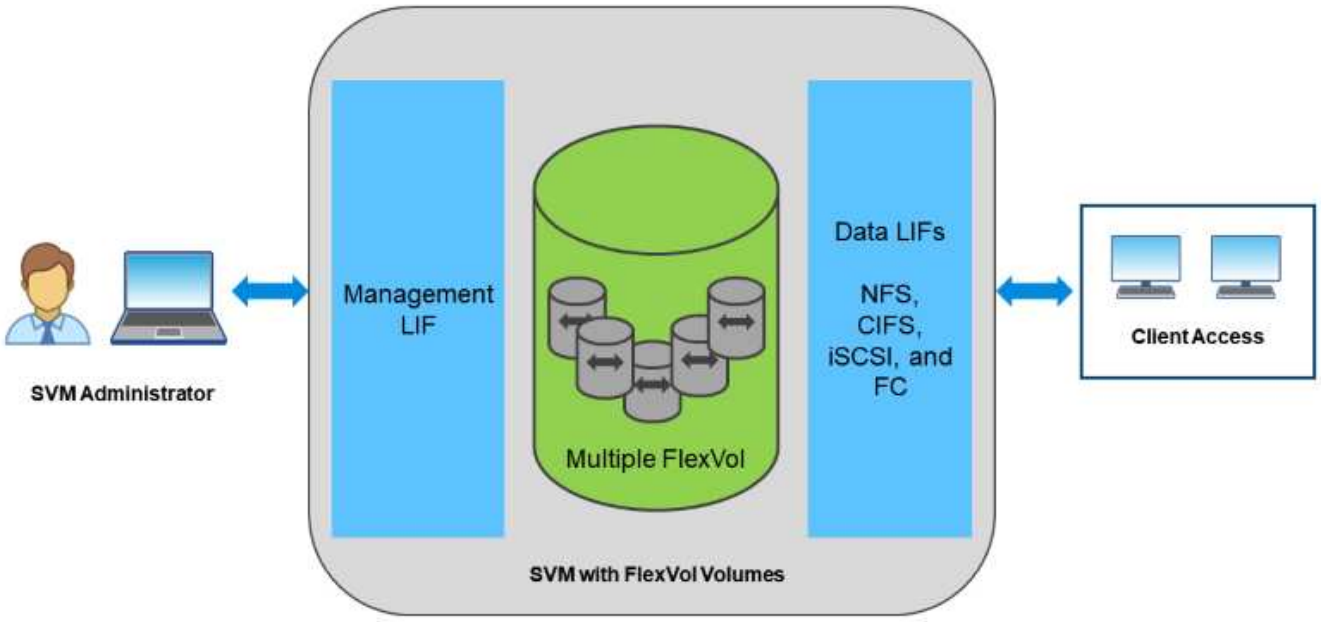
For more information regarding supported NetApp and VMware solutions, see the following resources:

- 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.

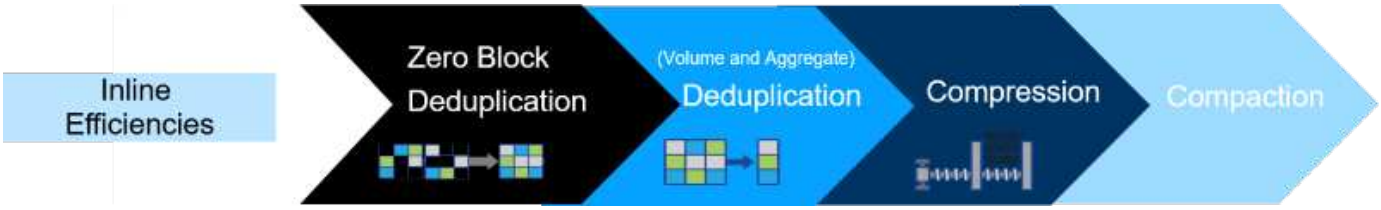
For more information on SVMs, unified storage and client access, see Storage Virtualization in the ONTAP 9 Documentation center.

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.

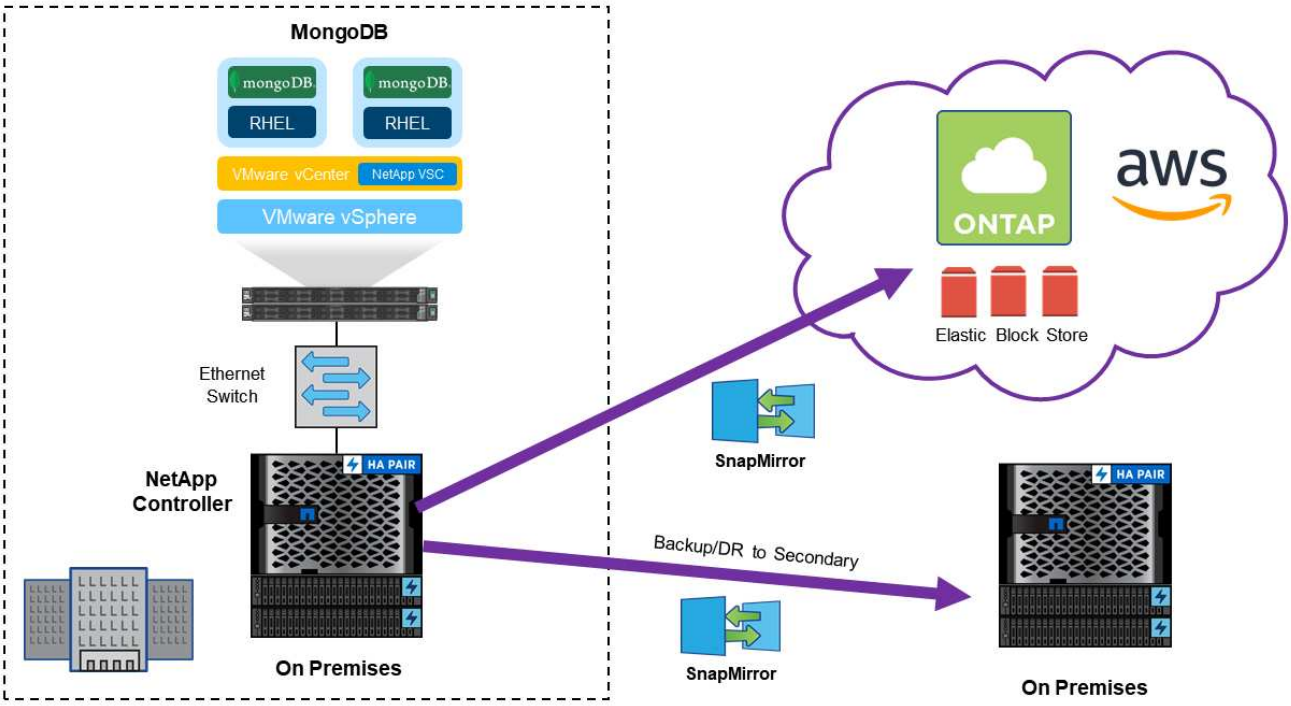
Choose from Azure, AWS, IBM, or Google clouds to optimize costs and avoid lock-in. Leverage advanced support for OpenStack and container technologies as needed.

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, augmenting 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 effect 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, 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, 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 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 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 both a server appliance and user interface extensions for vCenter.

NFS Plug-In for VMware VAAI

The NetApp NFS Plug-In for VMware 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 offload 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.

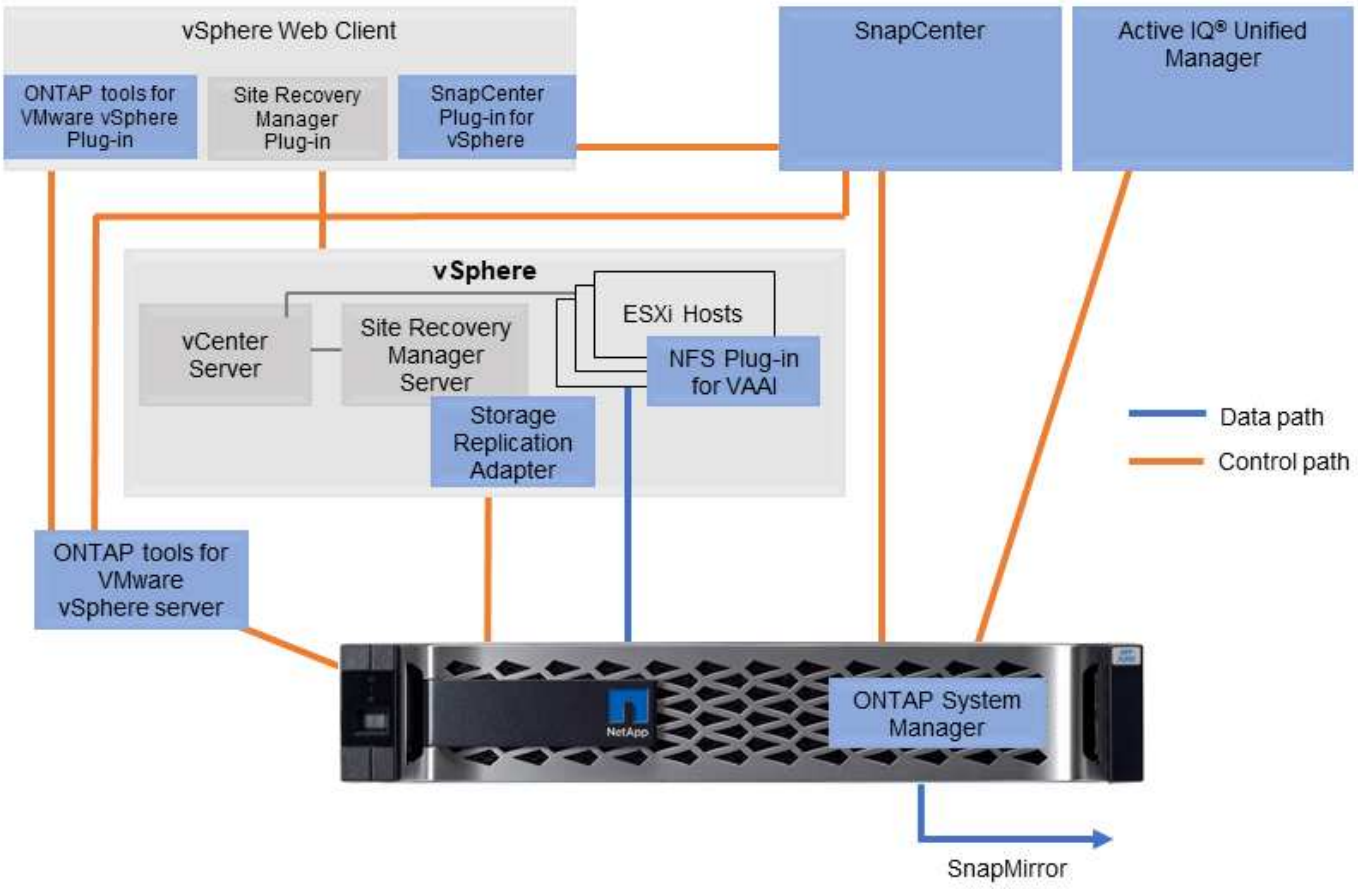
VASA Provider for ONTAP

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 SRA is supplied as part of ONTAP tools for VMware vSphere.

The following figure depicts ONTAP tools for vSphere.



Best practices

vSphere datastore and protocol features

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

- FC
- FCoE
- NVMe/FC
- iSCSI
- NFS

FC, FCoE, NVMe/FC, and iSCSI are block protocols that use the vSphere Virtual Machine File System (VMFS) to store VMs inside ONTAP LUNs or namespaces that are contained in an ONTAP 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, iSCSI, 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 7.x 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	NFS
Format	VMFS or raw device mapping (RDM)	VMFS or RDM	N/A
Maximum number of datastores or LUNs	256 targets/HBA	256 targets	256 mounts Default NFS. MaxVolumes is 8. Use ONTAP tools for VMware vSphere to increase to 256.
Maximum datastore size	64TB	64TB	100TB FlexVol volume or greater with FlexGroup volume
Maximum datastore file size (for VMDKs using vSphere version 5.5 and VMFS 5 or later)	62TB	62TB	16TB 62TB is the maximum size supported by vSphere.
Optimal queue depth per LUN or file system	64	64	N/A

The following table lists supported VMware storage-related functionalities.

Capacity/Feature	FC/FCoE	iSCSI	NFS
vMotion	Yes	Yes	Yes
Storage vMotion	Yes	Yes	Yes
VMware HA	Yes	Yes	Yes
Storage Distributed Resource Scheduler (SDRS)	Yes	Yes	Yes
VMware vStorage APIs for Data Protection (VADP)–enabled backup software	Yes	Yes	Yes
Microsoft Cluster Service (MSCS) or failover clustering within a VM	Yes	Yes*	Not supported
Fault Tolerance	Yes	Yes	Yes
Site Recovery Manager	Yes	Yes	Yes
Thin-provisioned VMs (virtual disks)	Yes	Yes	Yes This setting is the default for all VMs on NFS when not using VAAI.
VMware native multipathing	Yes	Yes	N/A

*NetApp recommends using in-guest iSCSI for Microsoft clusters rather than multi- writer 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 multi-writer enabled VMDKs but requires a datastore presented via the FC protocol, which has clustered VMDK support enabled. Other restrictions apply. See VMware's Setup for Windows Server Failover Clustering documentation for configuration guidelines.

The following table lists supported ONTAP storage management features.

Capability/Feature	FC/FCoE	iSCSI	NFS
Data deduplication	Savings in the array	Savings in the array	Savings in the datastore
Thin provisioning	Datastore or RDM	Datastore or RDM	Datastore
Resize datastore	Grow only	Grow only	Grow, autogrow, and shrink
SnapCenter plug-ins for Windows, Linux applications (in guest)	Yes	Yes	Yes
Monitoring and host configuration using ONTAP tools for VMware vSphere	Yes	Yes	Yes
Provisioning using ONTAP tools for VMware vSphere	Yes	Yes	Yes

The following table lists supported backup features.

Capability/Feature	FC/FCoE	iSCSI	NFS
ONTAP Snapshot copies	Yes	Yes	Yes
SRM supported by replicated backups	Yes	Yes	Yes
Volume SnapMirror	Yes	Yes	Yes
VMDK image access	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 and third-party applications
NDMP granularity	Datastore	Datastore	Datastore or VM

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 as it scales 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 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 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 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
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, but 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.

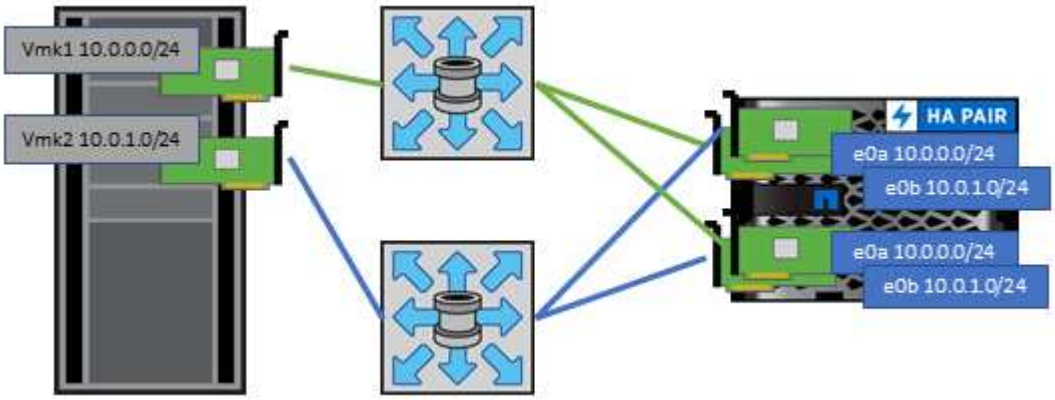
- SLM is enabled by default. Unless you are using portsets, no additional configuration is required.
- For LUNs created prior to Data ONTAP 8.3, manually apply SLM by running the `lun mapping remove-reporting-nodes` command to remove the LUN reporting nodes and restrict LUN access to the LUN-owning node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

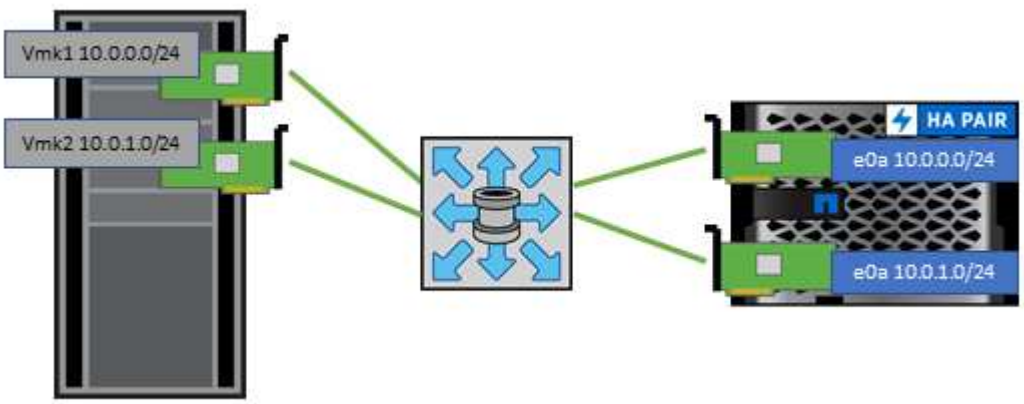
vSphere allows customers to use enterprise-class NFS arrays to provide concurrent access to datastores to all the nodes in an ESXi cluster. As mentioned in the datastore section, there are some ease of use and storage efficiency visibility benefits when using NFS with vSphere.

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
Virtual volumes	Yes	No
Hardware acceleration (VAAI)	Yes	Yes (vSphere 6.5 and later, NetApp VAAI Plug-in 1.1.2)
Kerberos authentication	No	Yes (enhanced with vSphere 6.5 and later to support AES, krb5i)
Multipathing support	No	No (ESXi 6.5 and later supports through session trunking; ONTAP supports through pNFS)

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

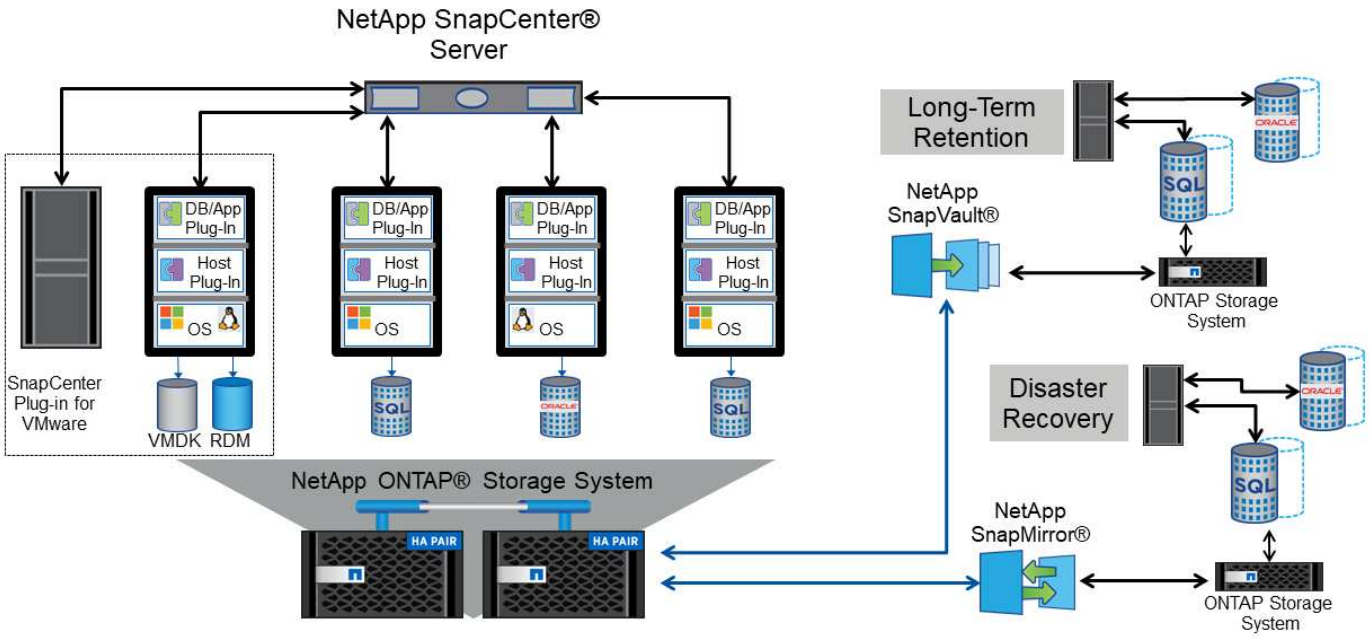
Backing up your VMs and quickly recovering them are among the great strengths of ONTAP for vSphere, and it is easy to manage this ability inside vCenter with the SnapCenter Plug-In for VMware vSphere. Use Snapshot copies to make quick copies of your VM or datastore without affecting performance, and 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.

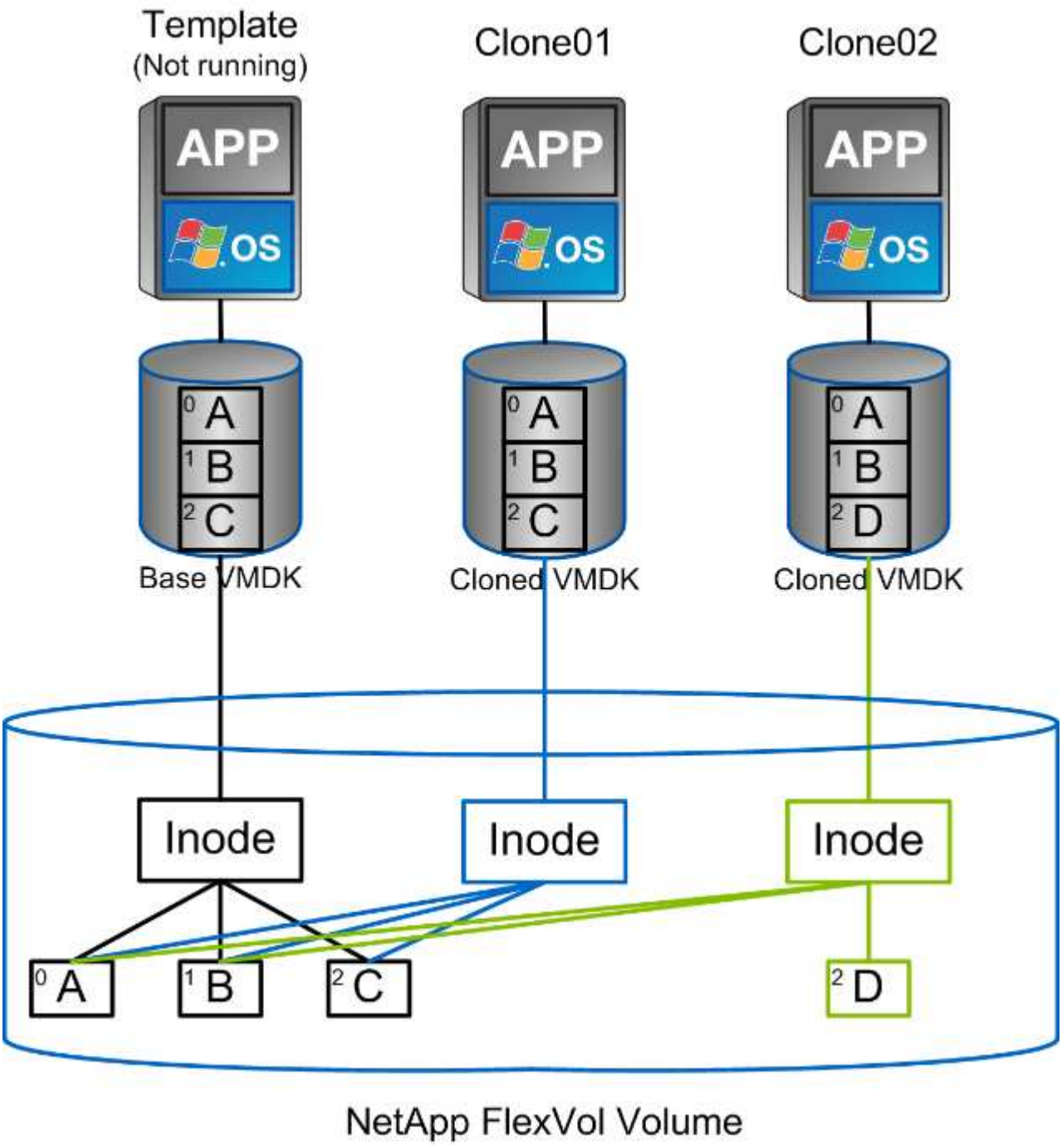
VM and datastore cloning

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.

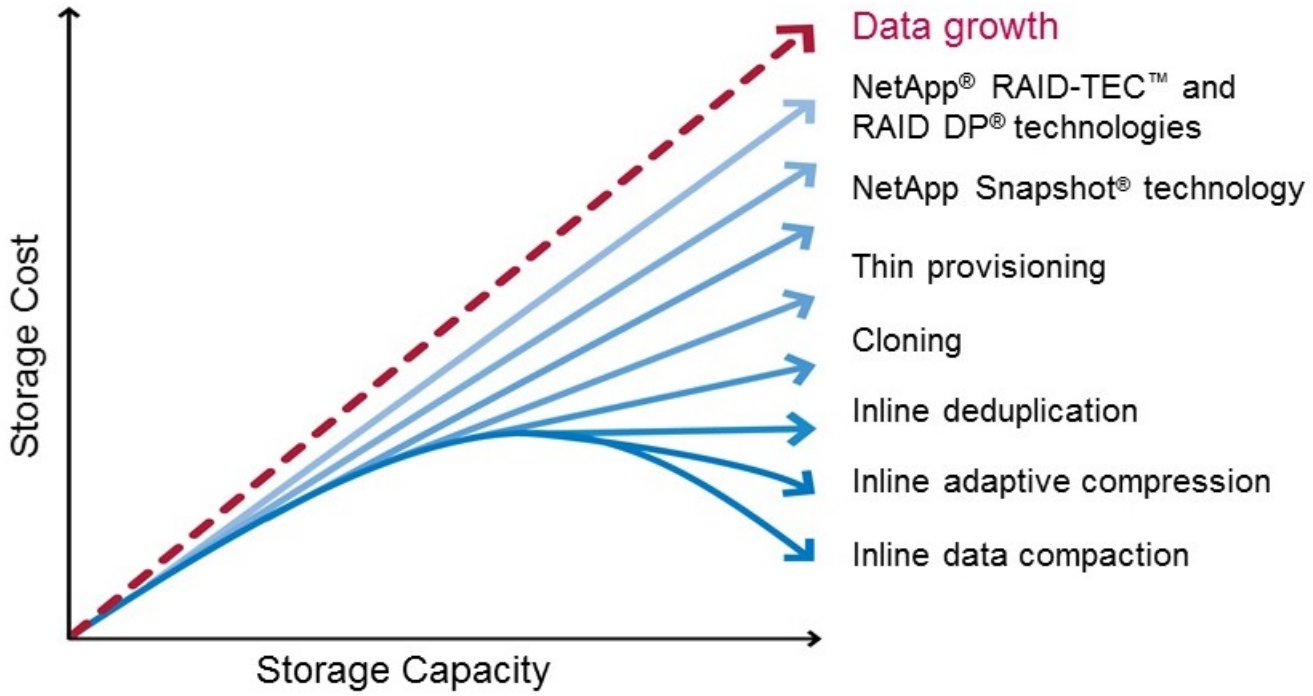
You can also clone a volume or LUN directly within ONTAP to clone a datastore. With NFS datastores, FlexClone technology can clone an entire volume, and the clone can be exported from ONTAP and mounted by ESXi as another datastore. For VMFS datastores, ONTAP can clone a LUN within a volume or a whole 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.

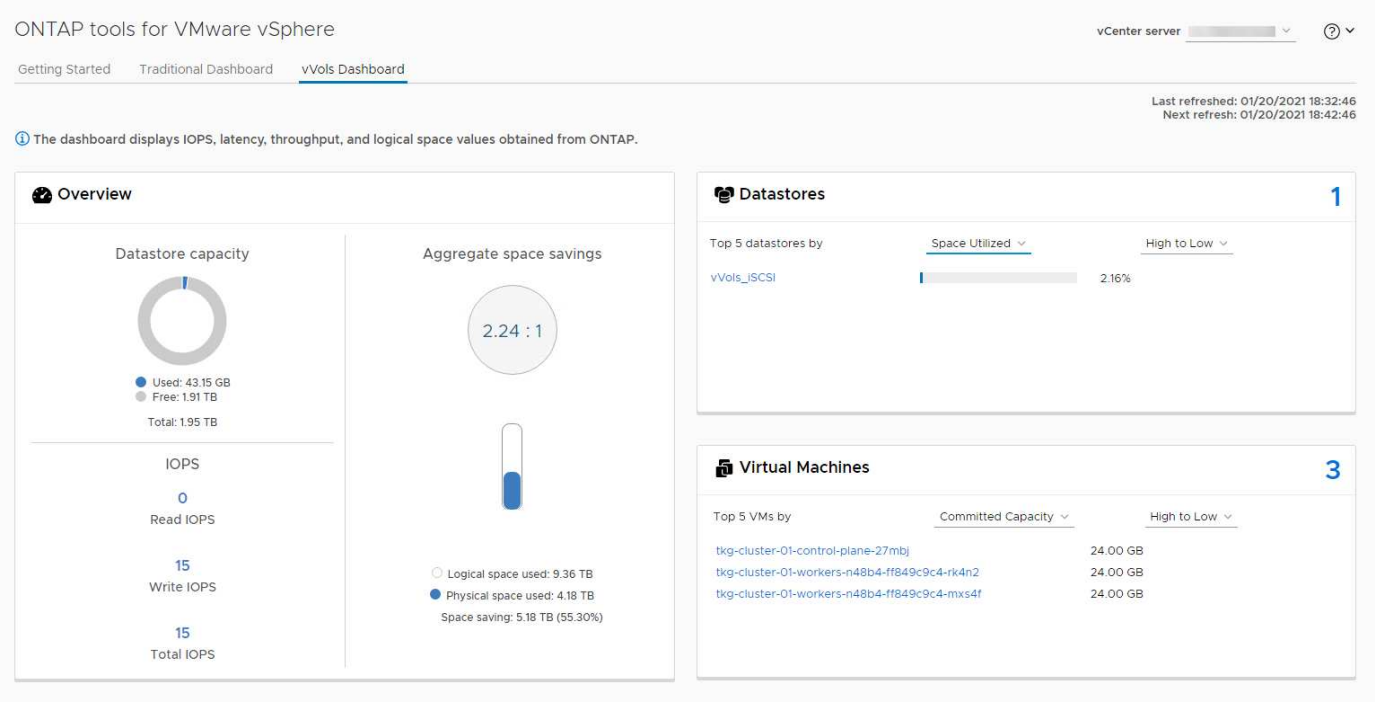
Storage policy-based management and vVols

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.

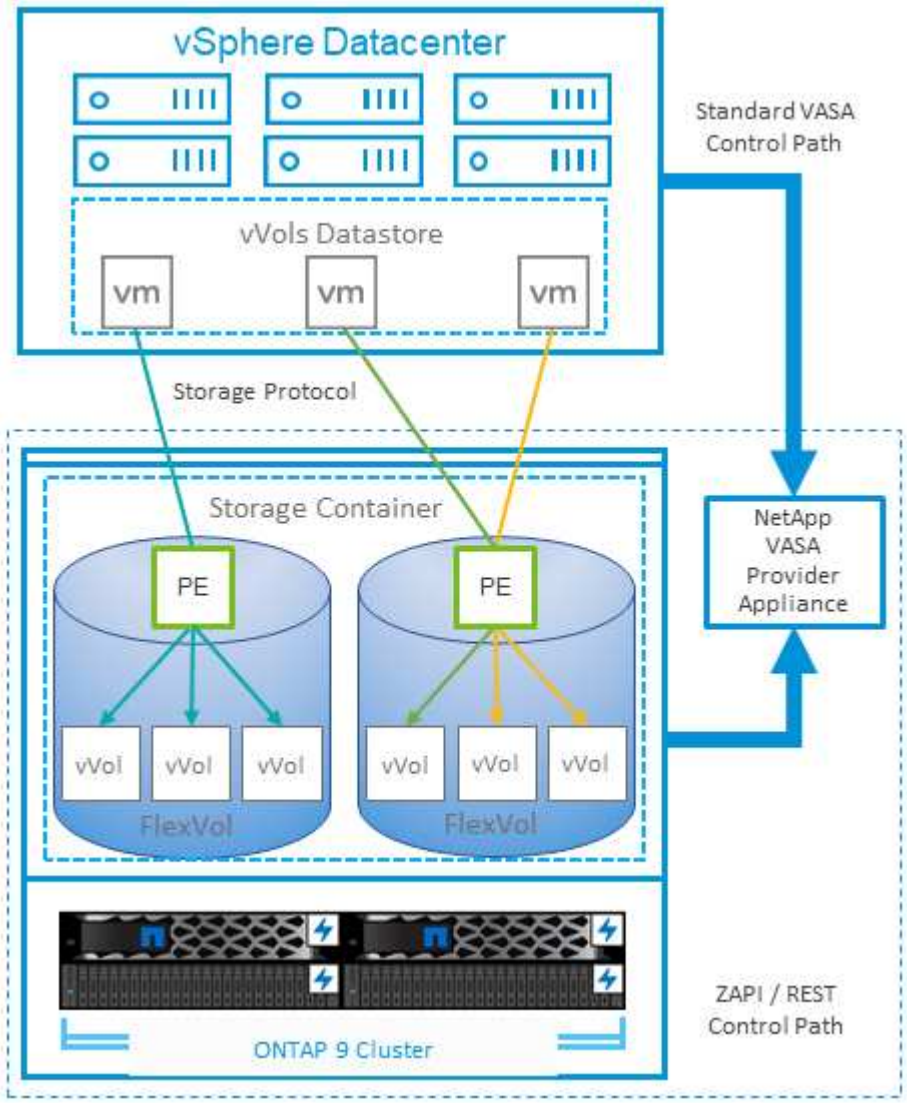
VASA provides the technology to query storage and return a set of storage capabilities to vCenter. VASA vendor providers supply the translation between the storage system APIs and constructs and the VMware APIs that are understood by vCenter. NetApp's VASA Provider for ONTAP is offered as part of the 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.

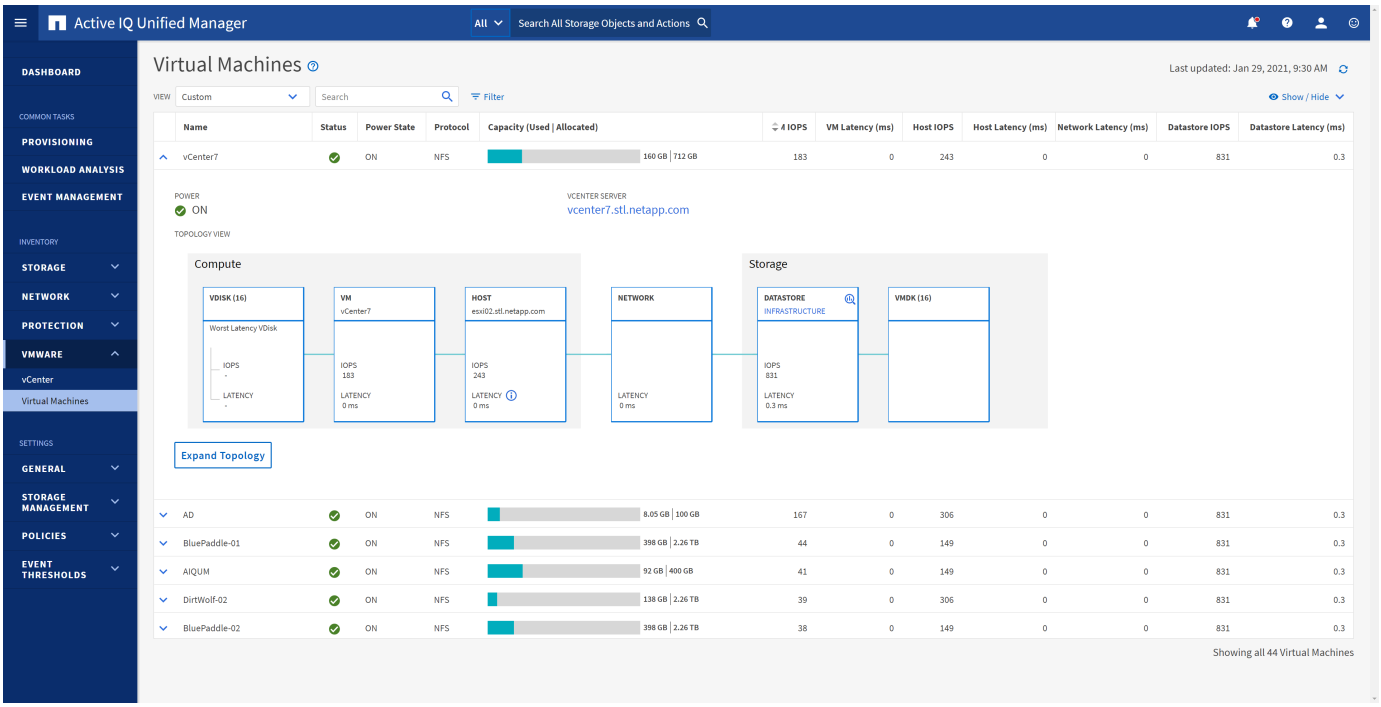
It's simple to get started with software encryption. After the license is installed, simply configure the onboard key manager by specifying a passphrase and then either create a new volume or do a storage-side volume move to enable encryption. NetApp is working to add more integrated support for encryption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

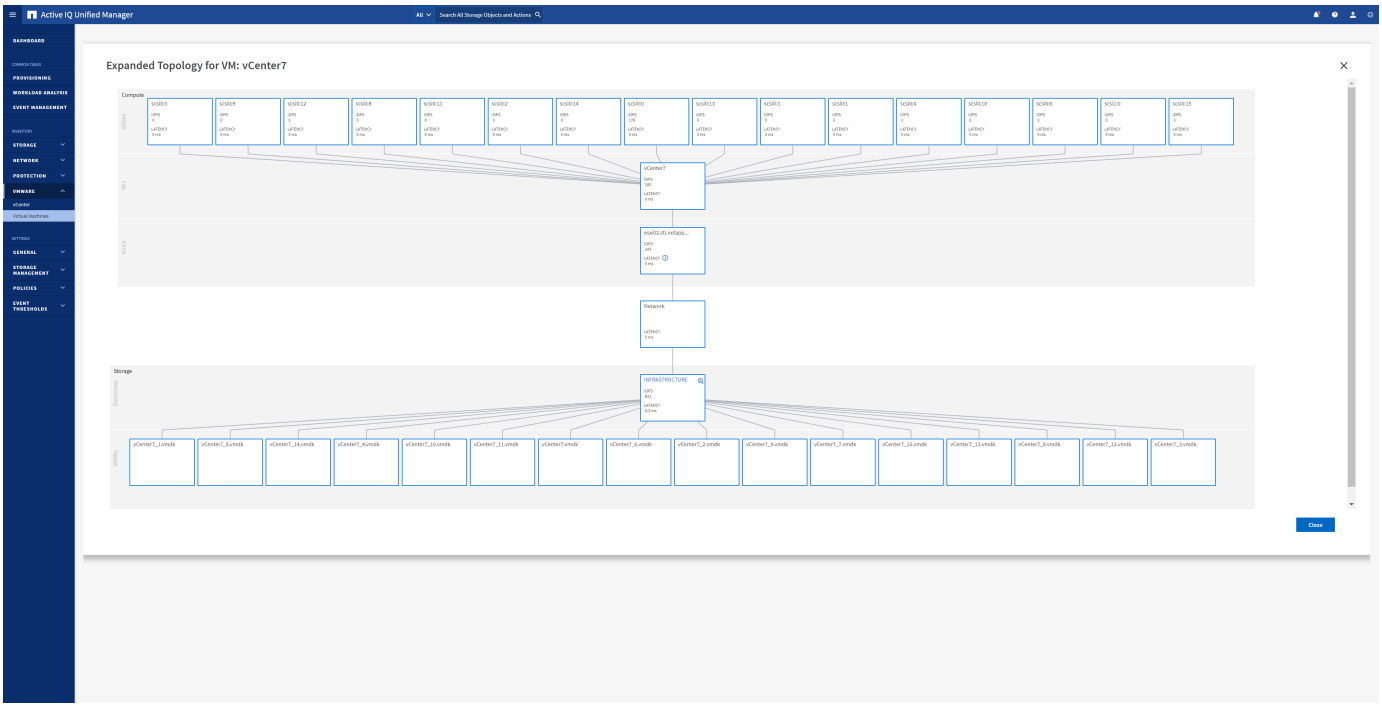
A typical virtual infrastructure deployment on ONTAP has various components that are spread across compute, network, and storage layers. Any performance lag in a VM application might occur due to a combination of latencies faced by the various components at the respective layers.

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
ESXi advanced configuration	
VMFS3.HardwareAcceleratedLocking	Leave as set (VMware default is 1).
VMFS3.EnableBlockDelete	Leave as set (VMware default is 0, but this is not needed for VMFS6). For more information, see VMware KB article 2007427.
NFS Settings	
Net.TcpipHeapSize	vSphere 6.0 or later, set to 32. All other NFS configurations, set to 30.
Net.TcpipHeapMax	Set to 1536 for vSphere 6.0 and later.
NFS.MaxVolumes	vSphere 6.0 or later, set to 256. All other NFS configurations, set to 64.
NFS41.MaxVolumes	vSphere 6.0 or later, set to 256.
NFS.MaxQueueDepth	vSphere 6.0 or later, set to 128.
NFS.HeartbeatMaxFailures	Set to 10 for all NFS configurations.
NFS.HeartbeatFrequency	Set to 12 for all NFS configurations.
NFS.HeartbeatTimeout	Set to 5 for all NFS configurations.
SunRPC.MaxConnPerIP	vSphere 7.0 or later, set to 128.
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.
Disk.QFullSampleSize	Set to 32 for all configurations. Setting this value helps prevent I/O errors.
Disk.QFullThreshold	Set to 8 for all configurations. Setting this value helps prevent I/O errors.
Emulex FC HBA timeouts	Use the default value.
QLogic FC HBA timeouts	Use the default value.
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.
Disk.QFullSampleSize	Set to 32 for all configurations. Setting this value helps prevent I/O errors.
Disk.QFullThreshold	Set to 8 for all configurations. Setting this value helps prevent I/O errors.

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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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 supported versions of ONTAP tools for VMware vSphere (which includes the NetApp Storage Replication Adapter [SRA] and VASA Provider [VP]), as well as VMware Site Recovery Manager 8. 4.

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 8.3 and later and the 9.7.1 and later releases of ONTAP tools, you are now able to protect VMs running on VMware vSphere 7.

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.

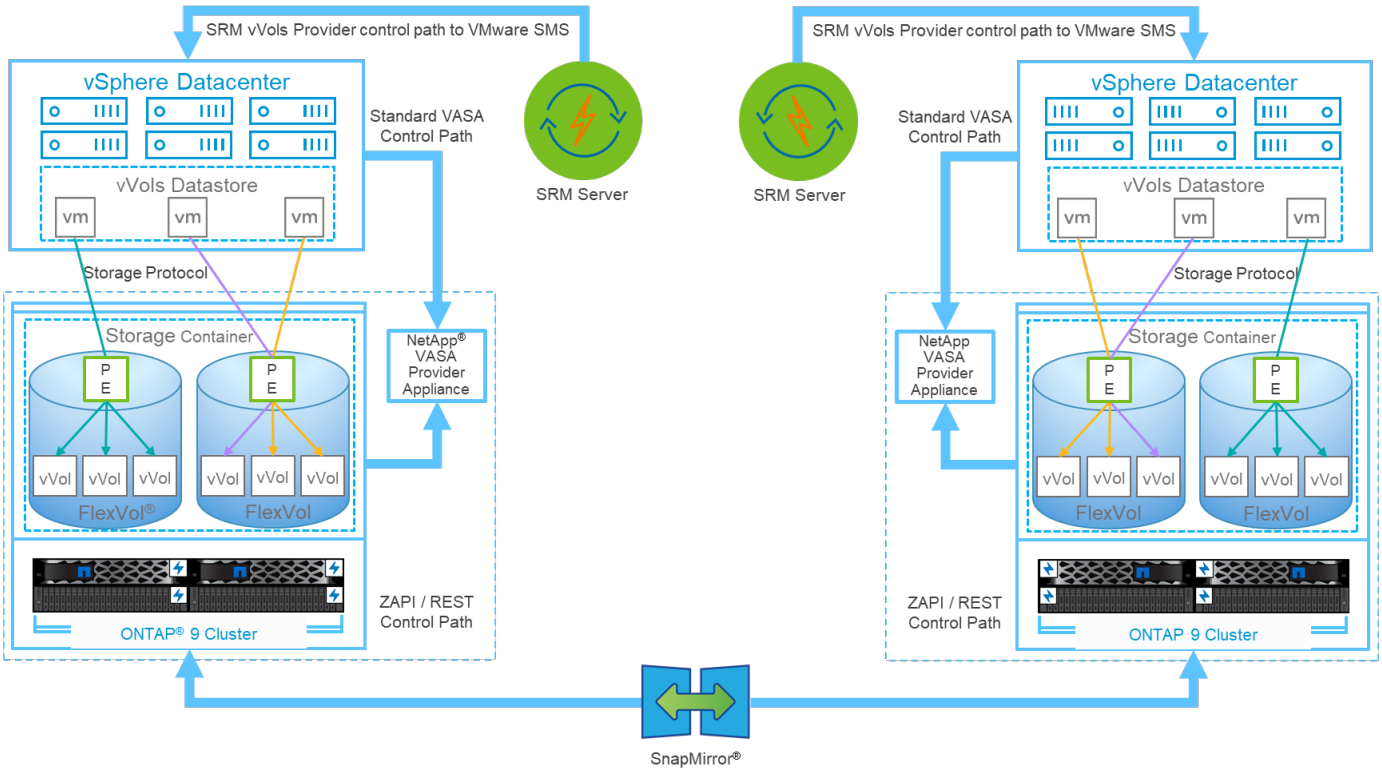
The NetApp IMT can be found here.

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. 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 2.3 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 two 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.

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.

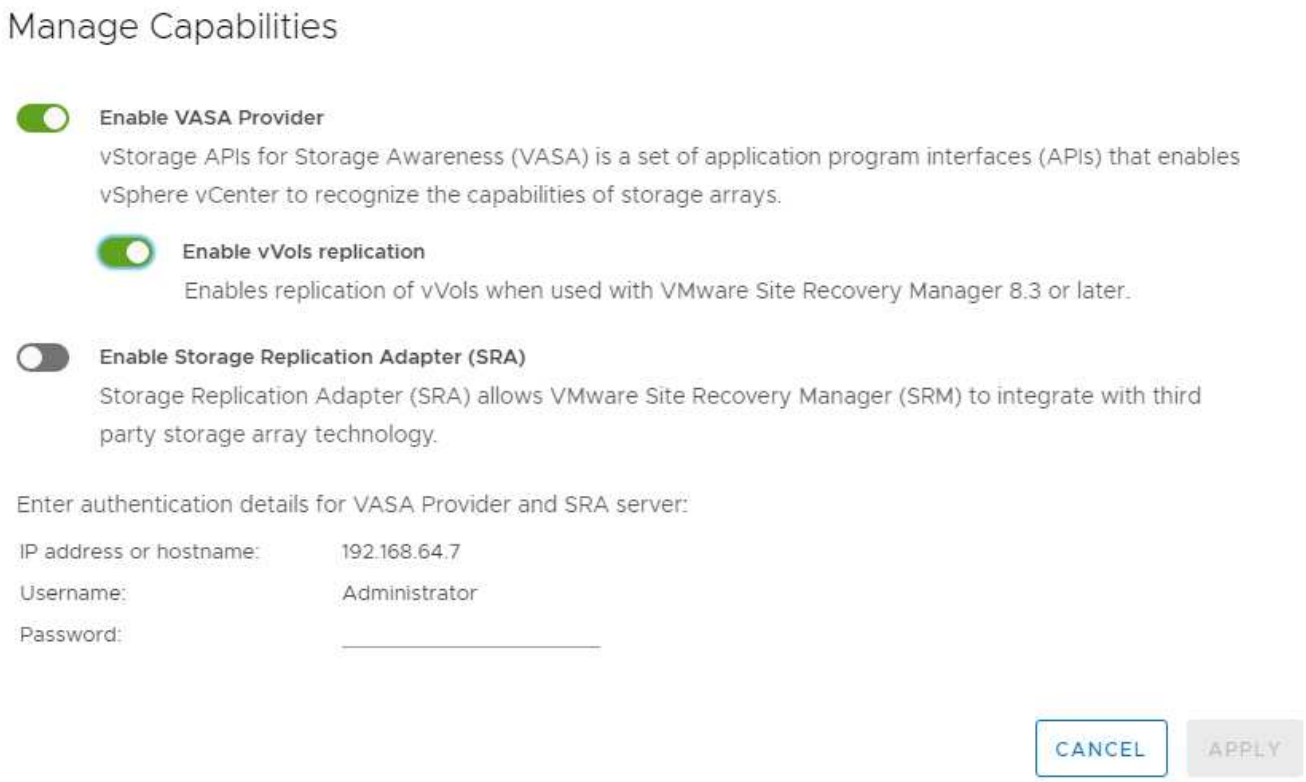
```
snap autodelete modify -volume -commitment try
```

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.

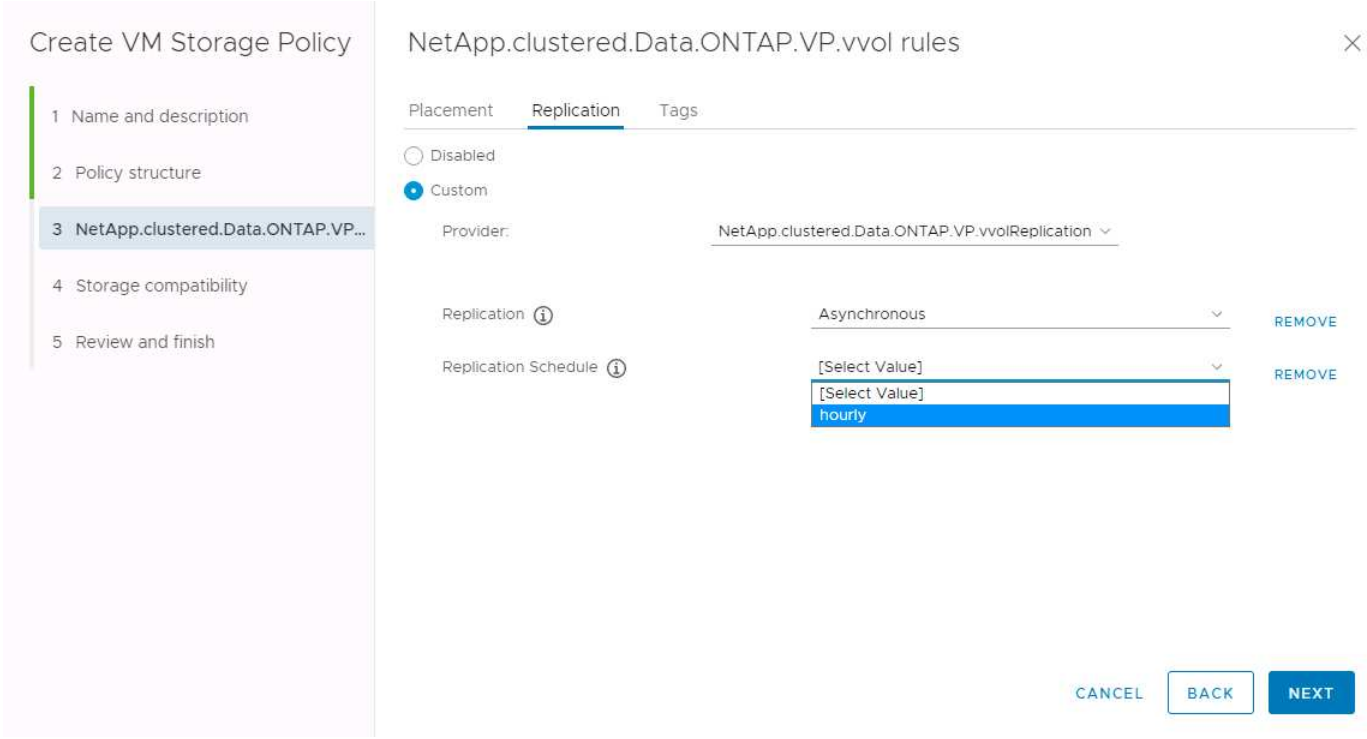
SPBM and vVols

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.

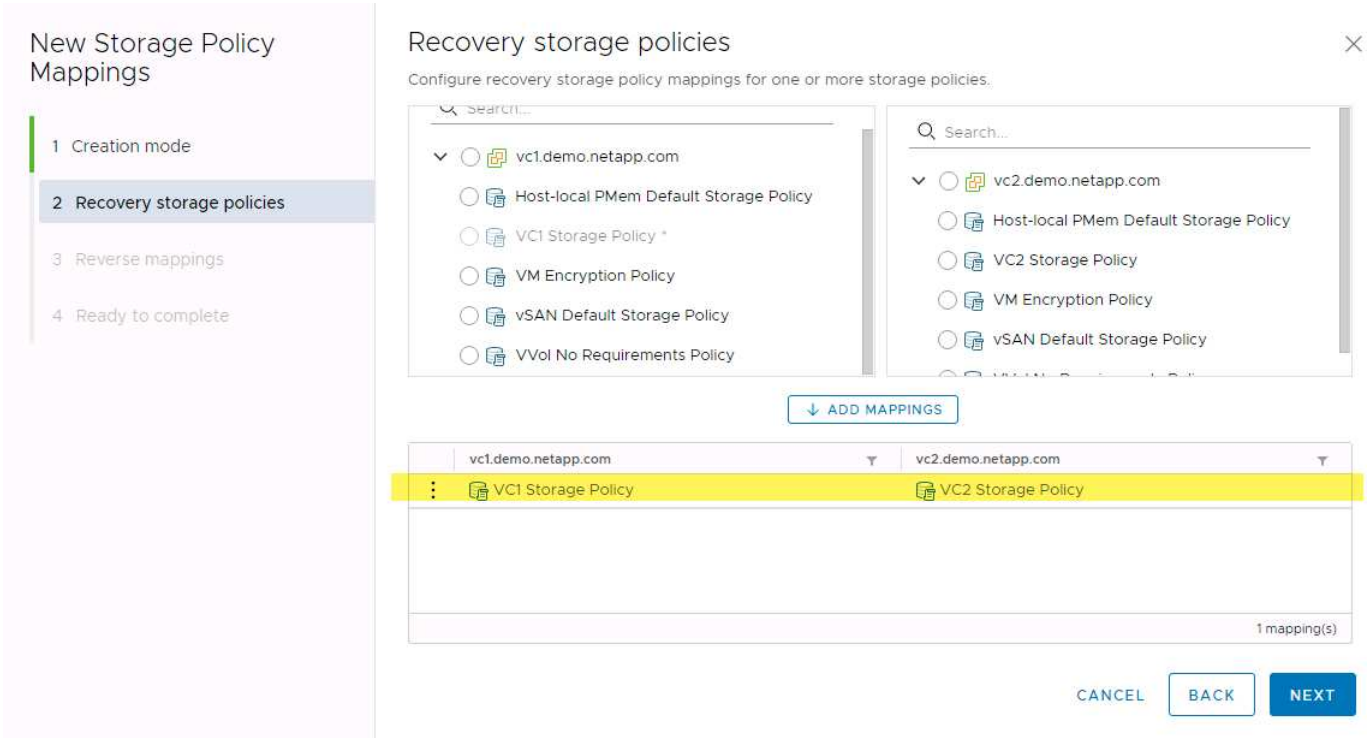
The following example show the enablement of vVols replication.



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.

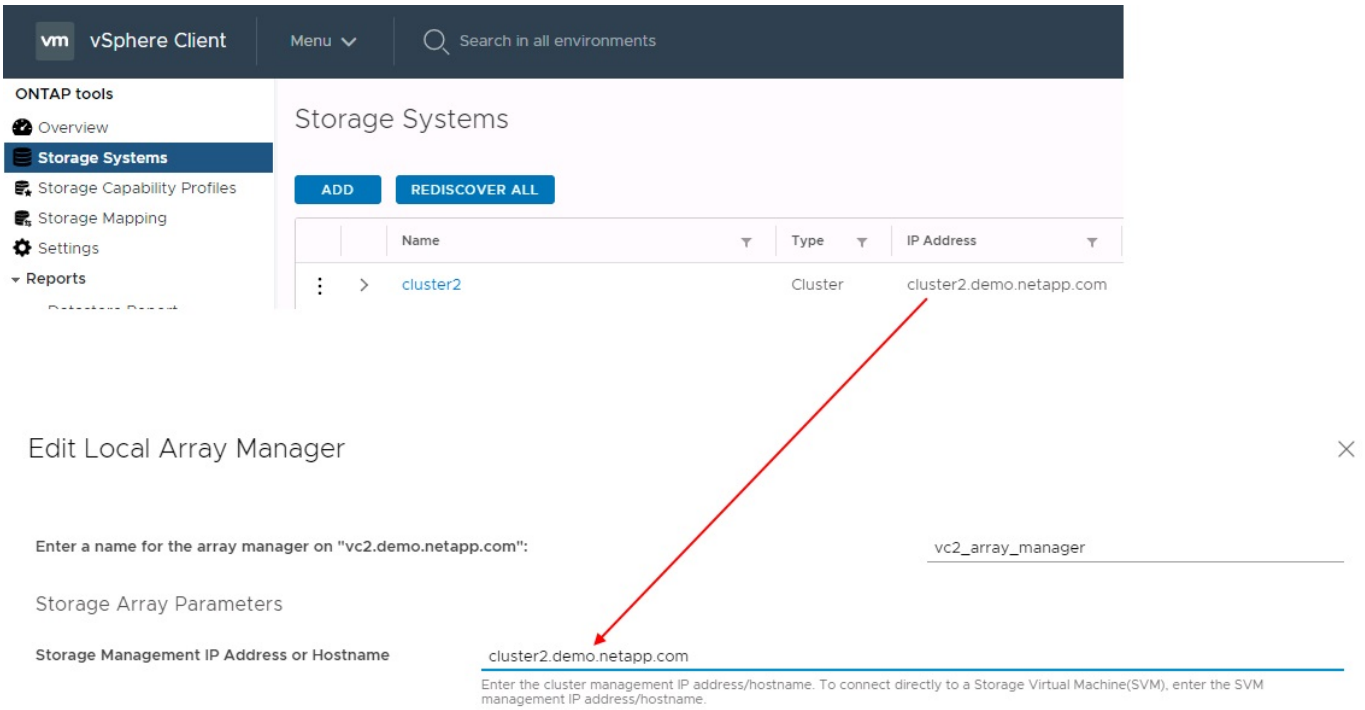
This does come with a new requirement on behalf of the vSphere administrator. Because volumes are being created outside the scope of ONTAP tools, it is unaware of the changes your ONTAP administrator has made until the regularly scheduled rediscovery period. For that reason, it is a best practice to 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.

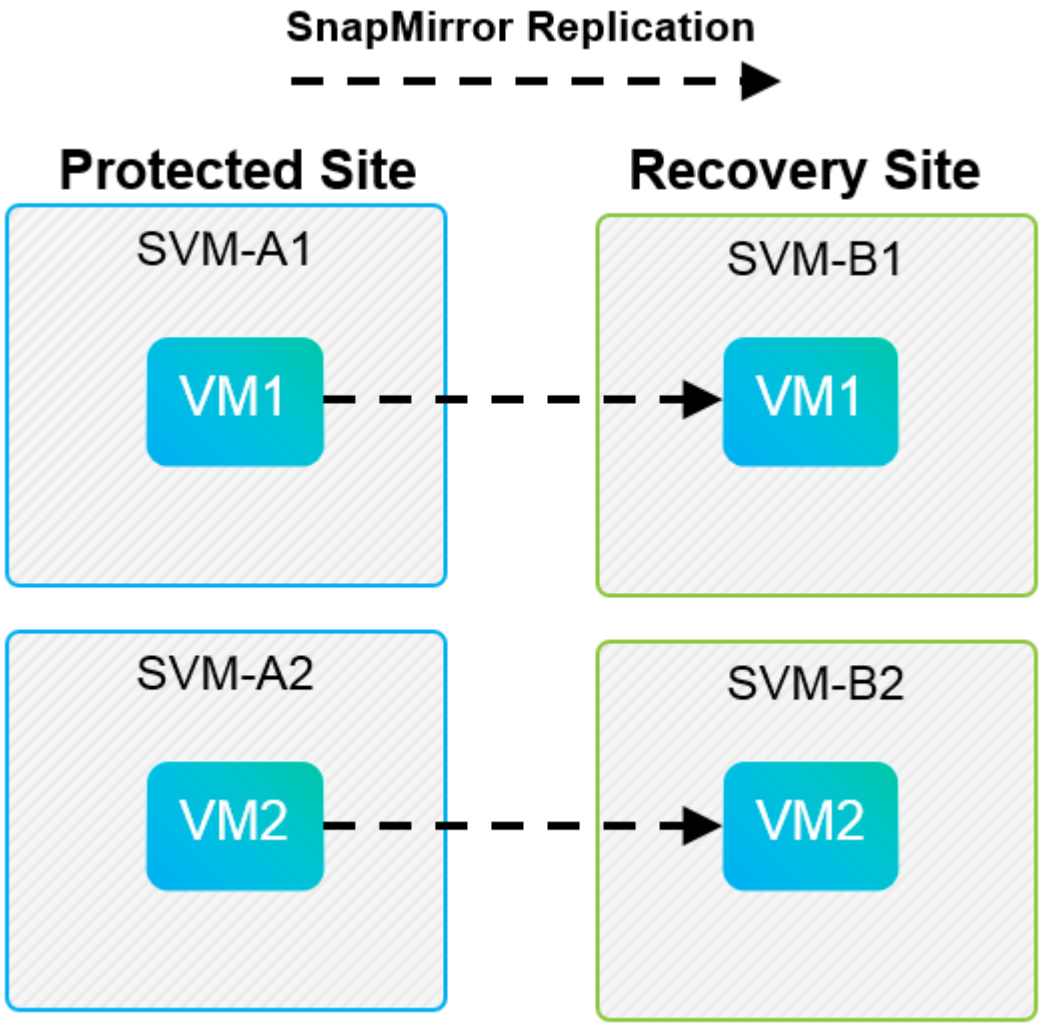
A single VM cannot own data—Virtual Machine Disk (VMDK) or RDM—on more than one SRM array for the following reasons:

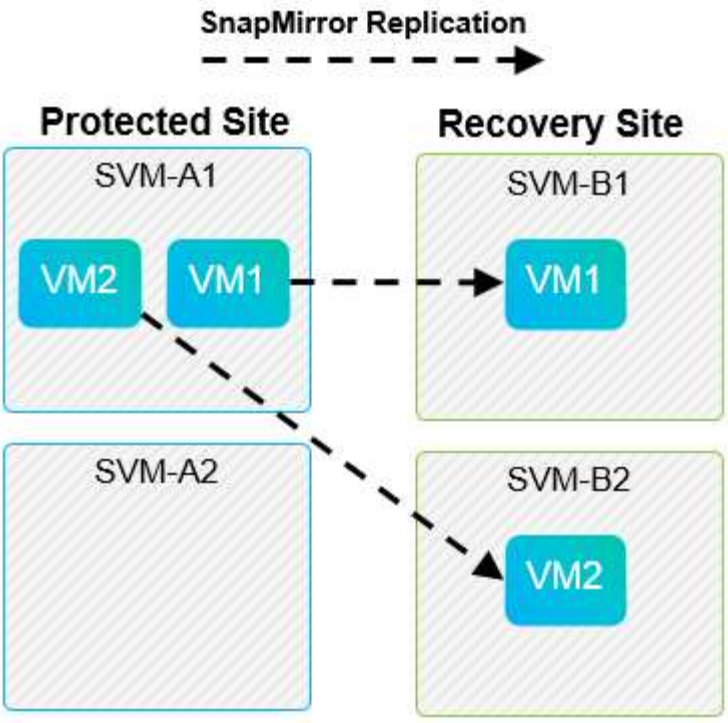
- SRM sees only the SVM, not an individual physical controller.
- An SVM can control LUNs and volumes that span multiple nodes in a cluster.

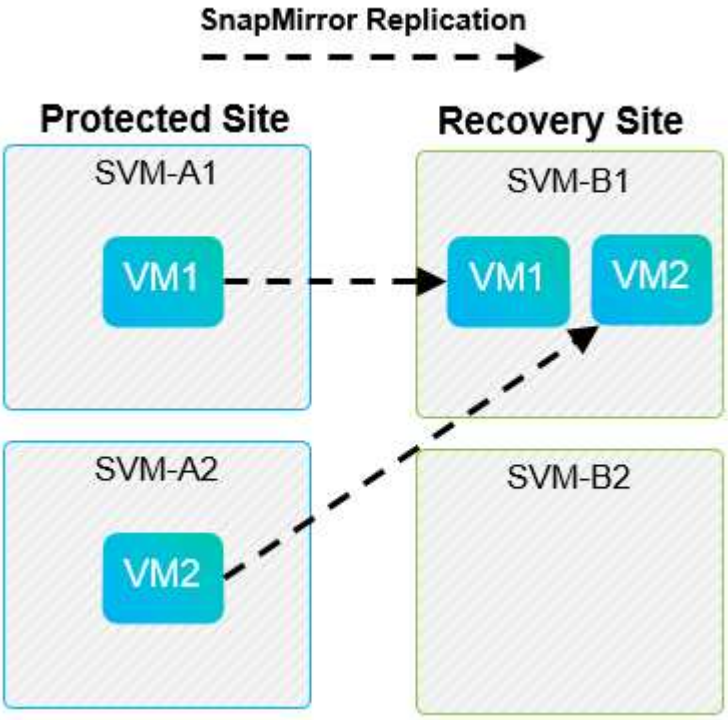
Best Practice
To determine supportability, keep this rule in mind: to protect a VM by using SRM and the NetApp SRA, all parts of the VM must exist on only one SVM. This rule applies at both the protected site and the recovery site.

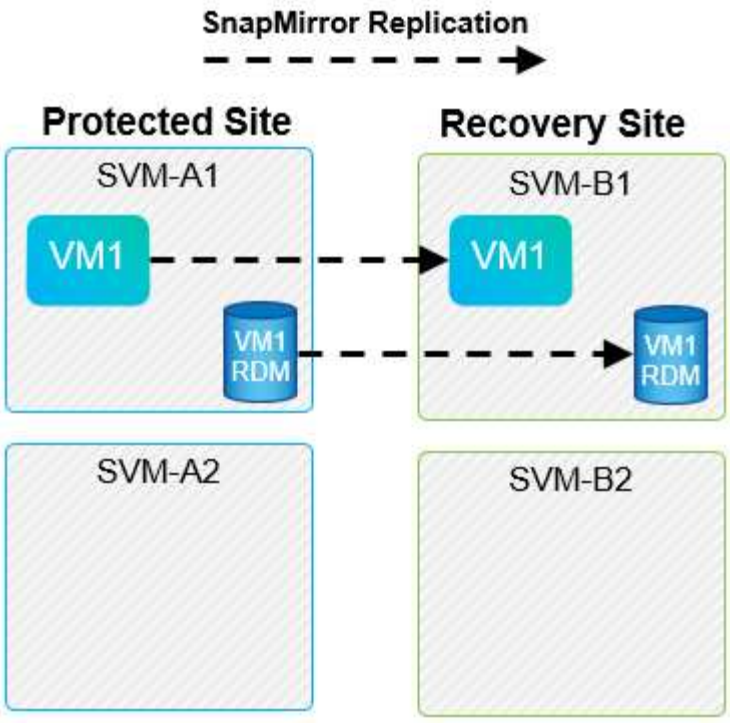
Supported SnapMirror layouts

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.



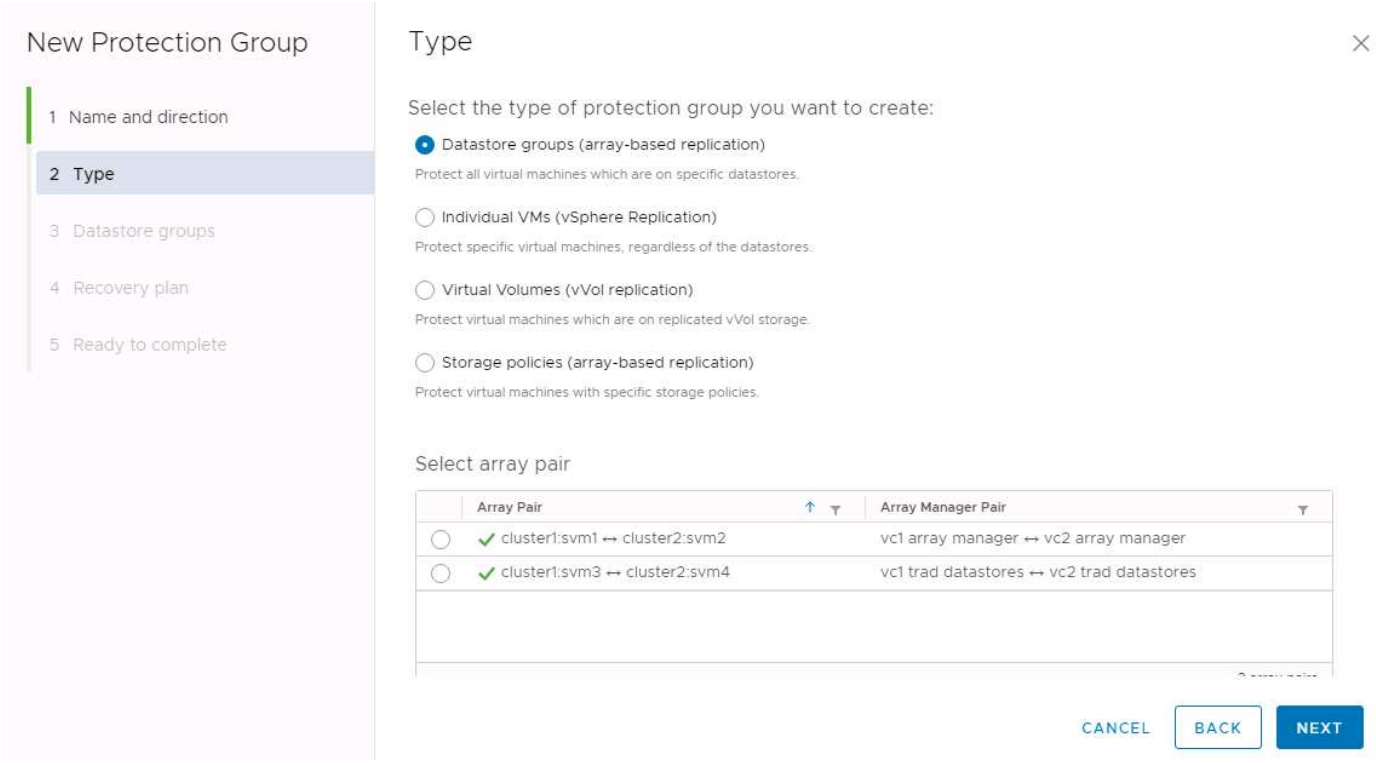

SnapMirror Replication
Protected Site
Recovery Site
SVM-A1
SVM-B1
VM2
VM1
VM1
SVM-A2
SVM-B2
VM2


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



Supported Array Manager layouts

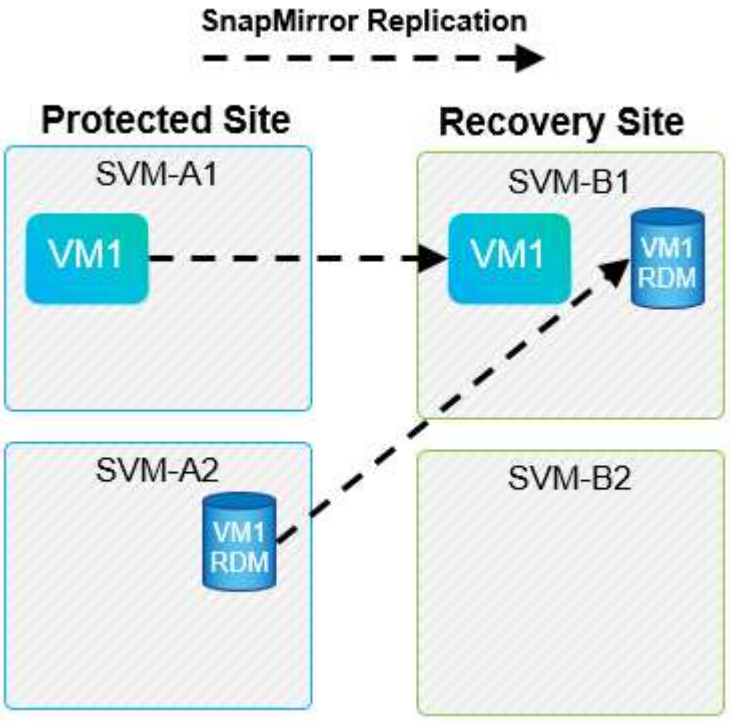
When you use array-based replication (ABR) in SRM, protection groups are isolated to a single array pair, as shown in the following screenshot. In this scenario, `SVM1` and `SVM2` are peered with `SVM3` and `SVM4` at the recovery site. However, you can select only one of the two array pairs when you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

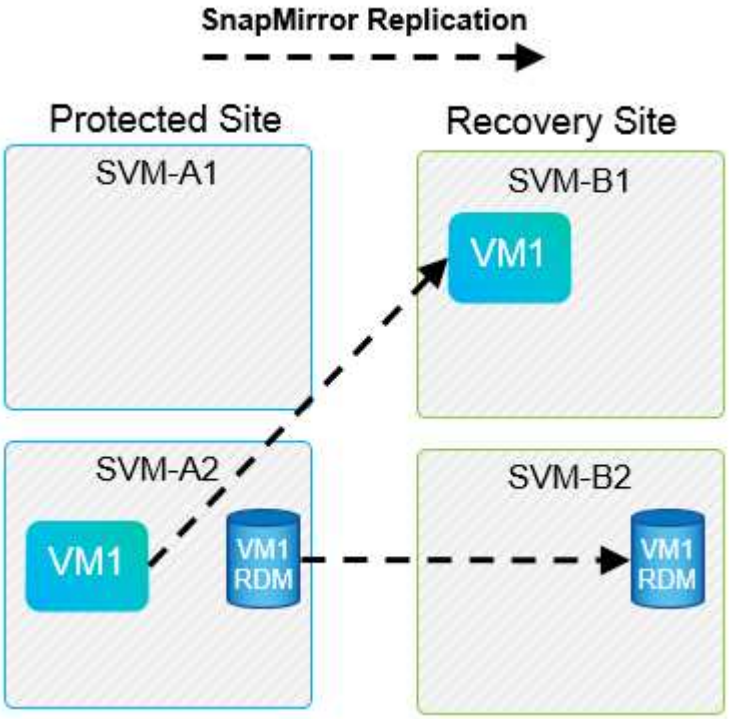


Unsupported layouts

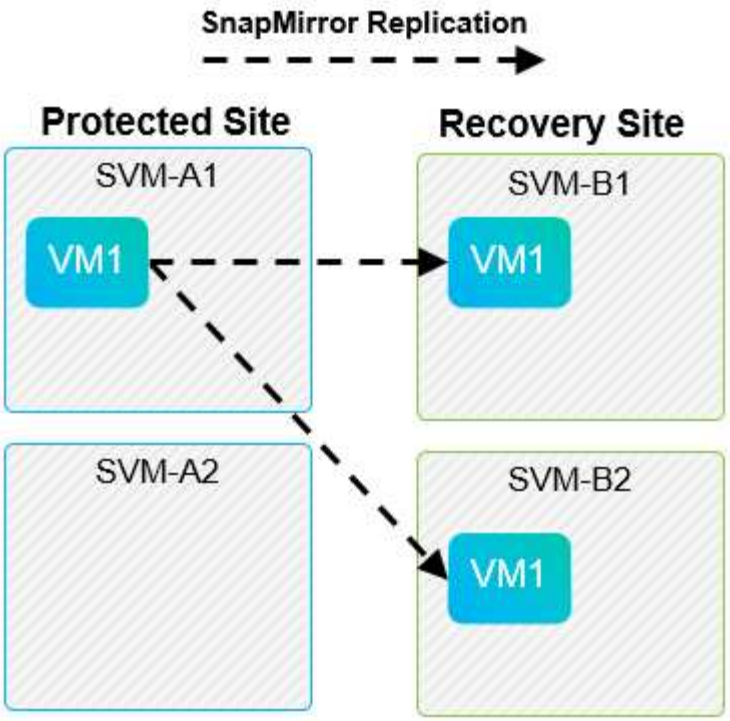
Unsupported configurations have data (VMDK or RDM) on multiple SVMs that is owned by an individual VM. In

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



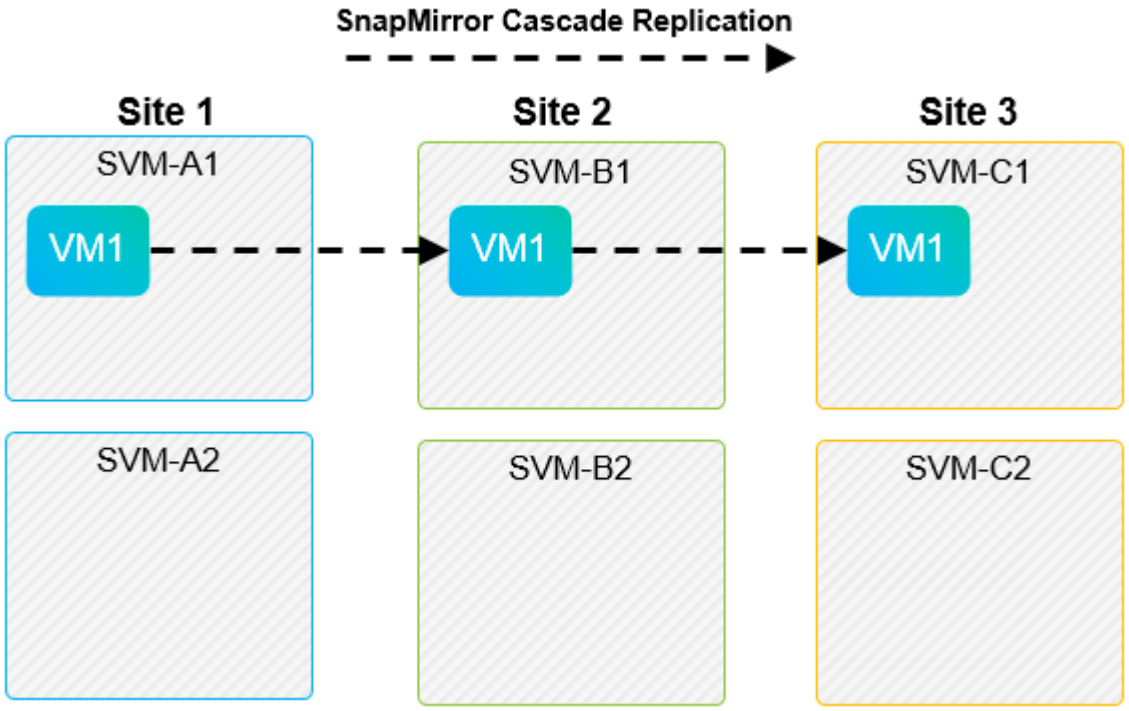


Any replication relationship in which an individual NetApp volume is replicated from one source SVM to multiple destinations in the same SVM or in different SVMs is referred to as SnapMirror fan-out. Fan-out is not supported with SRM. In the example shown in the following figure, `VM1` cannot be configured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

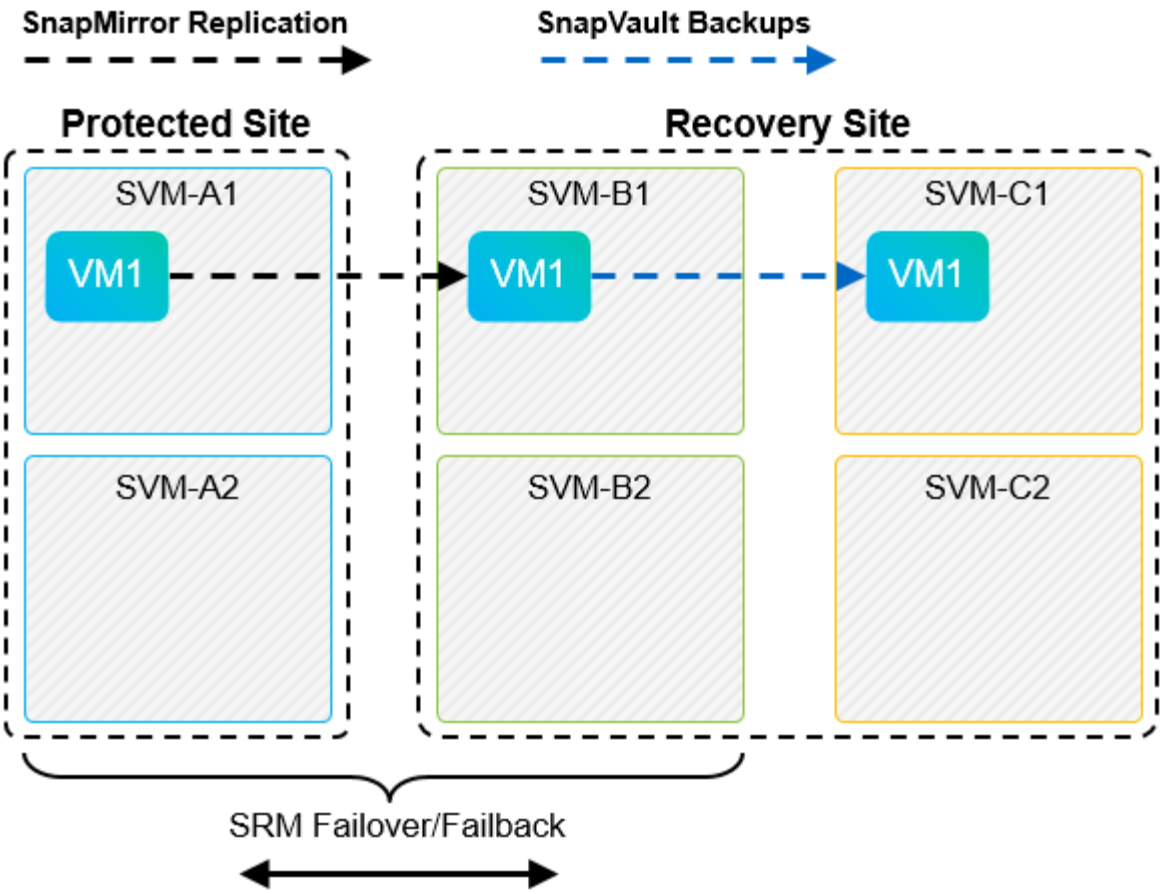
A source volume can be created in a cascade configuration in which a volume is replicated to a SnapMirror destination in the DR site, and from there it is vaulted to a SnapVault destination. A source volume can also be created in a fan-out relationship in which one destination is a SnapMirror destination 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.

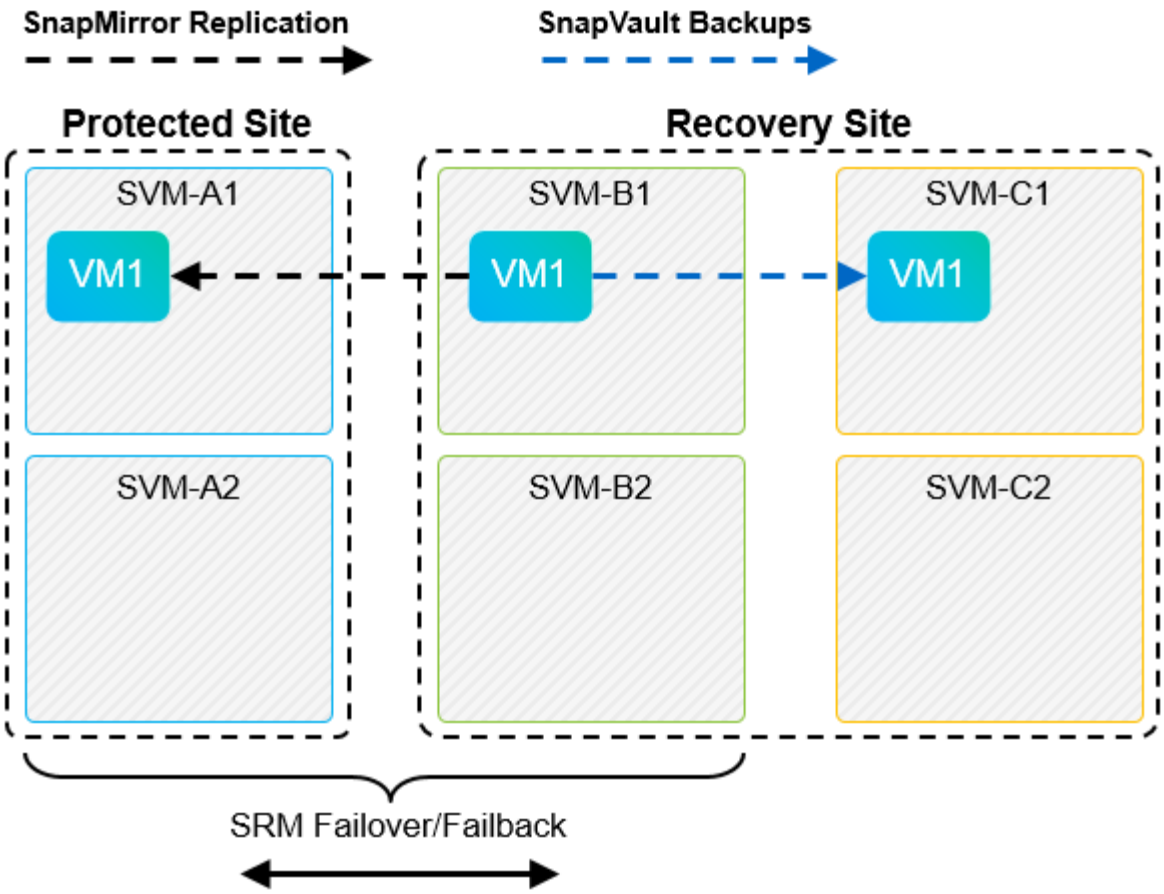
Best Practice
If SnapVault and SRM are used in the same environment, NetApp recommends using a SnapMirror to SnapVault cascade configuration in which SnapVault backups are normally performed from the SnapMirror destination at the DR site. In the event of a disaster, this configuration makes the primary 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
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

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)

TCP v4/v6 port #	Direction	Function
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.

Version history

Version	Date	Document version history
Version 1.0	November 2021	Initial release

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.

VMware for Public Cloud

Overview of NetApp Hybrid Multi-Cloud with VMware

Most IT organizations follow the hybrid cloud-first approach. These organizations are in a transformation phase and customers are evaluating their current IT landscape and then migrating their workloads to the cloud based on the assessment and discovery exercise.

The factors for customers migrating to the cloud can include elasticity and burst, data center exit, data center consolidation, end-of-life scenarios, mergers, acquisitions, and so on. The reason for this migration can vary based on each organization and their respective business priorities. When moving to the hybrid cloud, choosing the right storage in the cloud is very important in order to unleash the power of cloud deployment and elasticity.

VMware Cloud options in Public Cloud

Azure VMware Solution

Azure VMware Solution is a hybrid cloud service that allows for fully functioning VMware SDDCs within the Microsoft Azure public cloud. Azure VMware Solution is a first-party solution fully managed and supported by Microsoft, verified by VMware leveraging Azure infrastructure. This means that when Azure VMware Solution is deployed, customer's get VMware's ESXi for compute virtualization, vSAN for hyper-converged storage, and NSX for networking and security, all while taking advantage of Microsoft Azure's global presence, class-leading

data center facilities and proximity to the rich ecosystem of native Azure services and solutions.

VMware Cloud on AWS

VMware Cloud on AWS brings VMware's enterprise-class SDDC software to the AWS Cloud with optimized access to native AWS services. Powered by VMware Cloud Foundation, VMware Cloud on AWS integrates VMware's compute, storage, and network virtualization products (VMware vSphere, VMware vSAN, and VMware NSX) along with VMware vCenter Server management, optimized to run on dedicated, elastic, bare-metal AWS infrastructure.

Google Cloud VMware Engine

Google Cloud VMware Engine is an infrastructure-as-a-service (IaaS) offering built on Google Cloud's highly performant scalable infrastructure and VMware Cloud Foundation stack – VMware vSphere, vCenter, vSAN, and NSX-T. This service enables a fast path to the cloud, seamlessly migrating or extending existing VMware workloads from on-premises environments to Google Cloud Platform without the cost, effort ,or risk of rearchitecting applications or retooling operations. It is a service sold and supported by Google, working closely with VMware.

SDDC private cloud and NetApp Cloud Volumes colocation provides the best performance with minimal network latency.

Did you know?

Regardless of the cloud used, when a VMware SDDC is deployed, the initial cluster includes the following products:

- VMware ESXi hosts for compute virtualization with a vCenter Server appliance for management
- VMware vSAN hyper-converged storage incorporating the physical storage assets of each ESXi host
- VMware NSX for virtual networking and security with an NSX Manager cluster for management

Storage configuration

For customers planning to host storage-intensive workloads and scale out on any cloud-hosted VMware solution, the default hyper-converged infrastructure dictates that the expansion should be on both the compute and storage resources.

By integrating with NetApp Cloud Volumes, such as Azure NetApp Files, Amazon FSx for NetApp ONTAP, Cloud Volumes ONTAP (available in all three major hyperscalers), and Cloud Volumes Service for Google Cloud, customers now have options to independently scale their storage separately, and only add compute nodes to the SDDC cluster as needed.

Notes:

- VMware does not recommend unbalanced cluster configurations, hence expanding storage means adding more hosts, which implies more TCO.
- Only one vSAN environment is possible. Therefore, all storage traffic will compete directly with production workloads.
- There is no option to provide multiple performance tiers to align application requirements, performance, and cost.
- It is very easy to reach the limits of storage capacity of vSAN built on top of the cluster hosts. Use NetApp Cloud Volumes to scale storage to either host active datasets or tier cooler data to persistent storage.

Azure NetApp Files, Amazon FSx for NetApp ONTAP, Cloud Volumes ONTAP (available in all three major hyperscalers), and Cloud Volumes Service for Google Cloud can be used in conjunction with guest VMs. This hybrid storage architecture consists of a vSAN datastore that holds the guest operating system and application binary data. The application data is attached to the VM through a guest-based iSCSI initiator or the NFS/SMB mounts that communicate directly with Amazon FSx for NetApp ONTAP, Cloud Volume ONTAP, Azure NetApp Files and Cloud Volumes Service for Google Cloud respectively. This configuration allows you to easily overcome challenges with storage capacity as with vSAN, the available free space depends on the slack space and storage policies used.

Let's consider a three-node SDDC cluster on VMware Cloud on AWS:

- The total raw capacity for a three-node SDDC = 31.1TB (roughly 10TB for each node).
- The slack space to be maintained before additional hosts are added = 25% = (.25 x 31.1TB) = 7.7TB.
- The usable raw capacity after slack space deduction = 23.4TB
- The effective free space available depends on the storage policy applied.

  For example:

  - RAID 0 = effective free space = 23.4TB (usable raw capacity/1)
  - RAID 1 = effective free space = 11.7TB (usable raw capacity/2)
  - RAID 5 = effective free space = 17.5TB (usable raw capacity/1.33)

Thus, using NetApp Cloud Volumes as guest-connected storage would help in expanding the storage and optimizing the TCO while meeting the performance and data protection requirements.

NetApp storage as a datastore is currently available as Private preview in all of the major hyperscaler clouds. Please visit the following links for more information.

FSx ONTAP as a native datastore for AWS
Azure NetApp Files (ANF) as a native datastore for Azure
Cloud Volumes Service (CVS) as a native datastore for GCP

Points to Remember

- In hybrid storage models, place tier 1 or high priority workloads on vSAN datastore to address any specific latency requirements because they are part of the host itself and within proximity. Use in-guest mechanisms for any workload VMs for which transactional latencies are acceptable.
- Use NetApp SnapMirror® technology to replicate the workload data from the on-premises ONTAP system to Cloud Volumes ONTAP or Amazon FSx for NetApp ONTAP to ease migration using block-level mechanisms. This does not apply to Azure NetApp Files and Cloud Volumes Services. For migrating data

to Azure NetApp Files or Cloud Volumes Services, use NetApp XCP, Cloud sync, rysnc or robocopy depending on the file protocol used.

- Testing shows 2-4ms additional latency while accessing storage from the respective SDDCs. Factor this additional latency into the application requirements when mapping the storage.
- For mounting guest-connected storage during test failover and actual failover, make sure iSCSI initiators are reconfigured, DNS is updated for SMB shares, and NFS mount points are updated in fstab.
- Make sure that in-guest Microsoft Multipath I/O (MPIO), firewall, and disk timeout registry settings are configured properly inside the VM.

This applies to guest connected storage only.

Benefits of NetApp cloud storage

NetApp cloud storage offers the following benefits:

- Improves compute-to-storage density by scaling storage independently of compute.
- Allows you to reduce the host count, thus reducing the overall TCO.
- Compute node failure does not impact storage performance.
- The volume reshaping and dynamic service-level capability of Azure NetApp Files allows you to optimize cost by sizing for steady-state workloads, and thus preventing over provisioning.
- The storage efficiencies, cloud tiering, and instance-type modification capabilities of Cloud Volumes ONTAP allow optimal ways of adding and scaling storage.
- Prevents over provisioning storage resources are added only when needed.
- Efficient Snapshot copies and clones allow you to rapidly create copies without any performance impact.
- Helps address ransomware attacks by using quick recovery from Snapshot copies.
- Provides efficient incremental block transfer-based regional disaster recovery and integrated backup block level across regions provides better RPO and RTOs.

Assumptions

- SnapMirror technology or other relevant data migration mechanisms are enabled. There are many connectivity options, from on-premises to any hyperscaler cloud. Use the appropriate path and work with the relevant networking teams.
- In-guest storage was the only available option at the time this document was written.

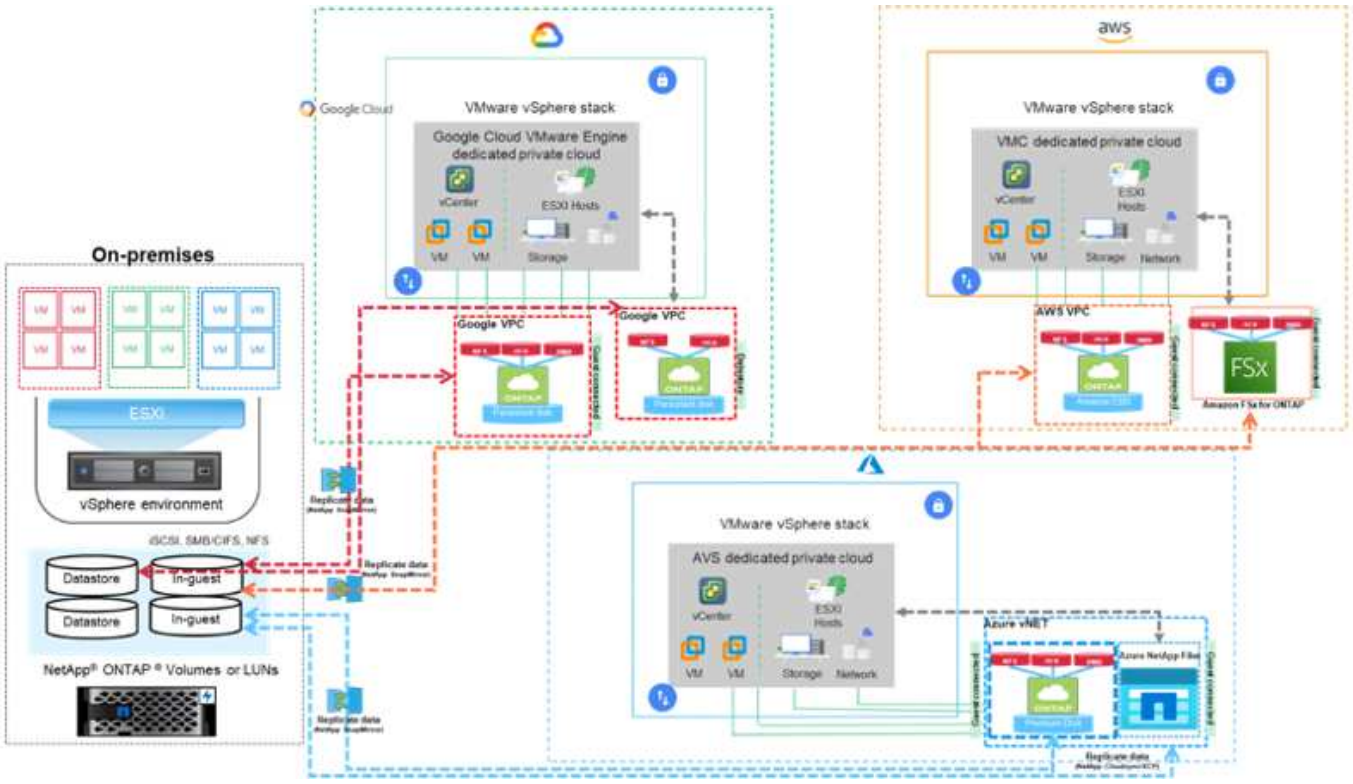
NetApp storage as a datastore is currently available as Private preview in all of the major hyperscaler clouds. Please visit the following links for more information.

FSx ONTAP as a native datastore for AWS
Azure NetApp Files (ANF) as a native datastore for Azure
Cloud Volumes Service (CVS) as a native datastore for GCP

Engage NetApp solution architects and respective hyperscaler cloud architects for planning and sizing of storage and the required number of hosts. NetApp recommends identifying the storage performance requirements before using the Cloud Volumes ONTAP sizer to finalize the storage instance type or the appropriate service level with the right throughput.

Detailed architecture

From a high-level perspective, this architecture (shown in the figure below) covers how to achieve hybrid multi-cloud connectivity and app portability across multiple cloud providers using NetApp Cloud Volumes ONTAP, Cloud Volumes Service for Google Cloud and Azure NetApp Files as an additional in-guest storage option.



NetApp Solutions for VMware in Hyperscalers

Learn more about the capabilities that NetApp brings to the three (3) primary hyperscalers - from NetApp as a guest connected storage device or a native datastore to migrating workflows, extending/bursting to the cloud, backup/restore and disaster recovery.

Pick your cloud and let NetApp do the rest!

To see the capabilities for a specific hyperscaler, click on the appropriate tab for that hyperscaler.

Jump to the section for the desired content by selecting from the following options:

- VMware in the Hyperscalers Configuration
- NetApp Storage Options
- NetApp / VMware Cloud Solutions

VMware in the Hyperscalers Configuration

As with on-premises, planning a cloud based virtualization environment is critical for a successful production-ready environment for creating VMs and migration.

AWS / VMC

This section describes how to set up and manage VMware Cloud on AWS SDDC and use it in combination with the available options for connecting NetApp storage.

> In-guest storage is the only supported method of connecting FSx ONTAP and Cloud Volumes ONTAP to AWS VMC.

The setup process can be broken down into the following steps:

- Deploy and Configure VMware Cloud for AWS
- Connect VMware Cloud to FSx ONTAP

View the detailed configuration steps for VMC.

Azure / AVS

This section describes how to set up and manage Azure VMware Solution and use it in combination with the available options for connecting NetApp storage.

> In-guest storage is the only supported method of connecting Azure NetApp Files and Cloud Volumes ONTAP to Azure VMware Solution.

The setup process can be broken down into the following steps:

- Register the resource provider and create a private cloud
- Connect to a new or existing ExpressRoute virtual network gateway
- Validate the network connectivity and access the private cloud

View the detailed configuration steps for AVS.

GCP / GCVE

This section describes how to set up and manage GCVE and use it in combination with the available options for connecting NetApp storage.

> In-guest storage is the only supported method of connecting Cloud Volumes ONTAP and Cloud Volumes Services to GCVE.

The setup process can be broken down into the following steps:

- Deploy and Configure GCVE
- Enable Private Access to GCVE

View the detailed configuration steps for GCVE.

NetApp Storage Options

NetApp storage can be utilized in several ways - either as guess connected or as a native datastore - within each of the 3 major hyperscalers.

Please visit Supported NetApp Storage Options for more information.

AWS / VMC

AWS supports NetApp storage in the following configurations:

- FSx ONTAP as guest connected storage
- Cloud Volumes ONTAP (CVO) as guest connected storage
- FSx ONTAP as a native datastore[1]

View the detailed guest connect storage options for VMC.

Read more about FSx ONTAP as a native datastore[1].

1 - Currently in Private Preview

Azure / AVS

Azure supports NetApp storage in the following configurations:

- Azure NetApp Files (ANF) as guest connected storage
- Cloud Volumes ONTAP (CVO) as guest connected storage
- Azure NetApp Files (ANF) as a native datastore[1]

View the detailed guest connect storage options for AVS.

Read more about Azure NetApp Files (ANF) as a native datastore[1].

1 - Currently in Private Preview

GCP / GCVE

Google Cloud supports NetApp storage in the following configurations:

- Cloud Volumes ONTAP (CVO) as guest connected storage
- Cloud Volumes Service (CVS) as guest connected storage
- Cloud Volumes Service (CVS) as a native datastore[1]

View the detailed guest connect storage options for GCVE.

Read more about Cloud Volumes Service (CVS) as a native datastore[1].

1 - Currently in Private Preview

NetApp / VMware Cloud Solutions

With NetApp and VMware cloud solutions, many use cases are simple to deploy in your hyperscaler of choice. VMware defines the primary cloud workload use-cases as:

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

AWS / VMC

Browse the NetApp solutions for AWS / VMC

Azure / AVS

Browse the NetApp solutions for Azure / AVS

GCP / GCVE

Browse the NetApp solutions for Google Cloud Platform (GCP) / GCVE

Supported Configurations for NetApp Hybrid Multi-Cloud with VMware

Understanding the combinations for NetApp storage support in the major hyperscalers.

	Guest Connected	Native Datastore
AWS	CVO FSx ONTAP Details	FSx ONTAP Details[1]
Azure	CVO ANF Details	ANF Details[1]
GCP	CVO CVS Details	CVS Details[1]

1 - Currently in Private Preview

Configuring the virtualization environment in the cloud provider

Details for how to configure the virtualization environment in each of the supported hyperscalers are covered here.

AWS / VMC

This section describes how to set up and manage VMware Cloud on AWS SDDC and use it in combination with the available options for connecting NetApp storage.

> In-guest storage is the only supported method of connecting FSx ONTAP and Cloud Volumes ONTAP to AWS VMC.

The setup process can be broken down into the following steps:

- Deploy and Configure VMware Cloud for AWS
- Connect VMware Cloud to FSx ONTAP

View the detailed configuration steps for VMC.

Azure / AVS

This section describes how to set up and manage Azure VMware Solution and use it in combination with the available options for connecting NetApp storage.

> In-guest storage is the only supported method of connecting Azure NetApp Files and Cloud Volumes ONTAP to Azure VMware Solution.

The setup process can be broken down into the following steps:

- Register the resource provider and create a private cloud
- Connect to a new or existing ExpressRoute virtual network gateway
- Validate the network connectivity and access the private cloud

View the detailed configuration steps for AVS.

GCP / GCVE

This section describes how to set up and manage GCVE and use it in combination with the available options for connecting NetApp storage.

> In-guest storage is the only supported method of connecting Cloud Volumes ONTAP and Cloud Volumes Services to GCVE.

The setup process can be broken down into the following steps:

- Deploy and Configure GCVE
- Enable Private Access to GCVE

View the detailed configuration steps for GCVE.

Deploy and configure the Virtualization Environment on AWS

As with on-premises, planning VMware Cloud on AWS is critical for a successful production-ready environment for creating VMs and migration.

This section describes how to set up and manage VMware Cloud on AWS SDDC and use it in combination

with the available options for connecting NetApp storage.

> In-guest storage is currently the only supported method of connecting FSx ONTAP and Cloud Volumes ONTAP to AWS VMC.

The setup process can be broken down into the following steps:

Deploy and configure VMware Cloud for AWS

VMware Cloud on AWS provides for a cloud native experience for VMware based workloads in the AWS ecosystem. Each VMware Software-Defined Data Center (SDDC) runs in an Amazon Virtual Private Cloud (VPC) and provides a full VMware stack (including vCenter Server), NSX-T software-defined networking, vSAN software-defined storage, and one or more ESXi hosts that provide compute and storage resources to your workloads.

This section describes how to set up and manage VMware Cloud on AWS and use it in combination with Amazon FSx for NetApp ONTAP and/or Cloud Volumes ONTAP on AWS with in-guest storage.

In-guest storage is the only supported method of connecting Amazon FSx for NetApp ONTAP and Cloud Volumes ONTAP to VMware Cloud on AWS.

The setup process can be broken down into three parts:

Register for an AWS Account

Register for an Amazon Web Services Account.

You need an AWS account to get started, assuming there isn't one created already. New or existing, you need administrative privileges in the account for many steps in this procedure. See this link for more information regarding AWS credentials.

Register for a My VMware Account

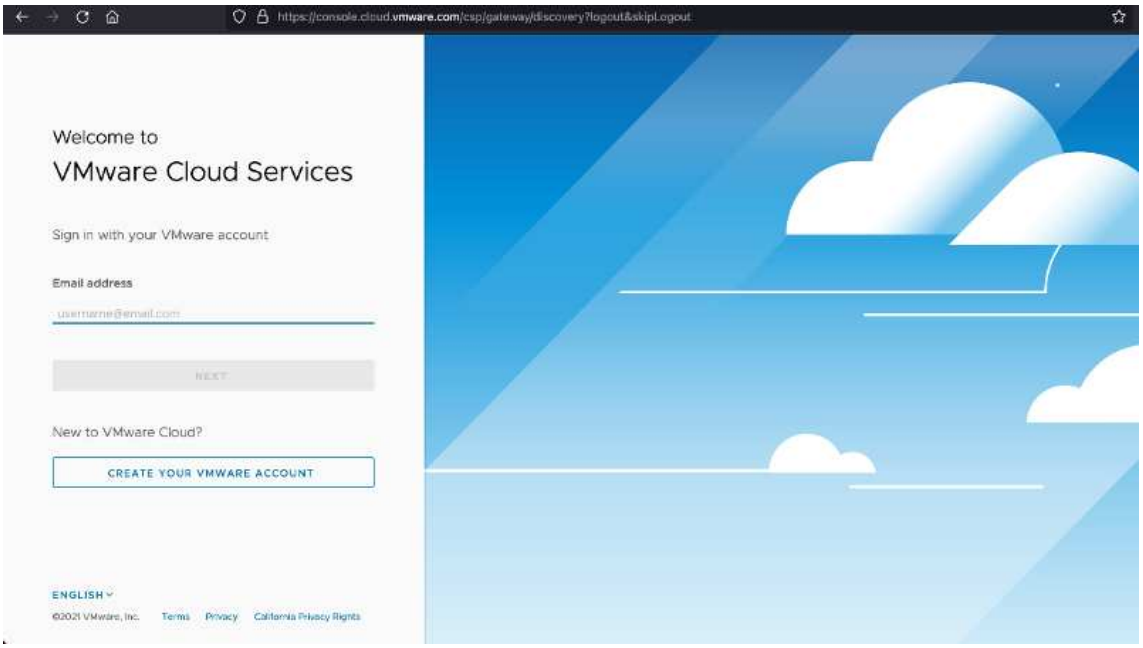
Register for a My VMware account.

For access to VMware's cloud portfolio (including VMware Cloud on AWS), you need a VMware customer account or a My VMware account. If you have not already done so, create a VMware account here.

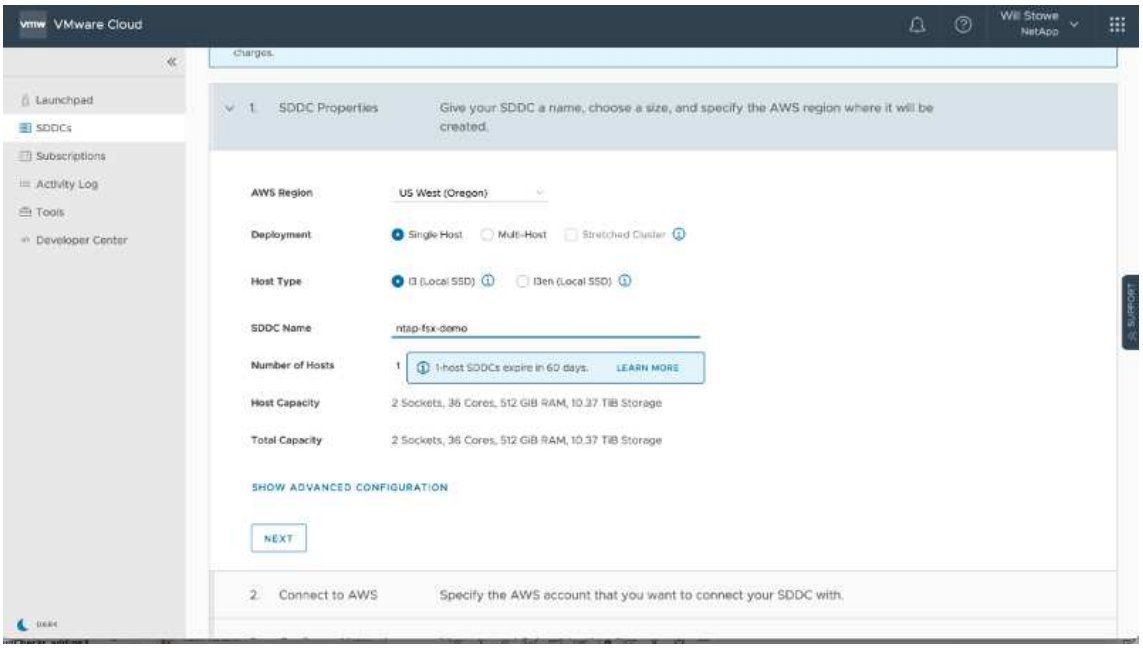
Provision SDDC in VMware Cloud

After the VMware account is configured and proper sizing is performed, deploying a Software-Defined Data Center is the obvious next step for using the VMware Cloud on AWS service. To create an SDDC, pick an AWS region to host it, give the SDDC a name, and specify how many ESXi hosts you want the SDDC to contain. If you don't already have an AWS account, you can still create a starter configuration SDDC that contains a single ESXi host.

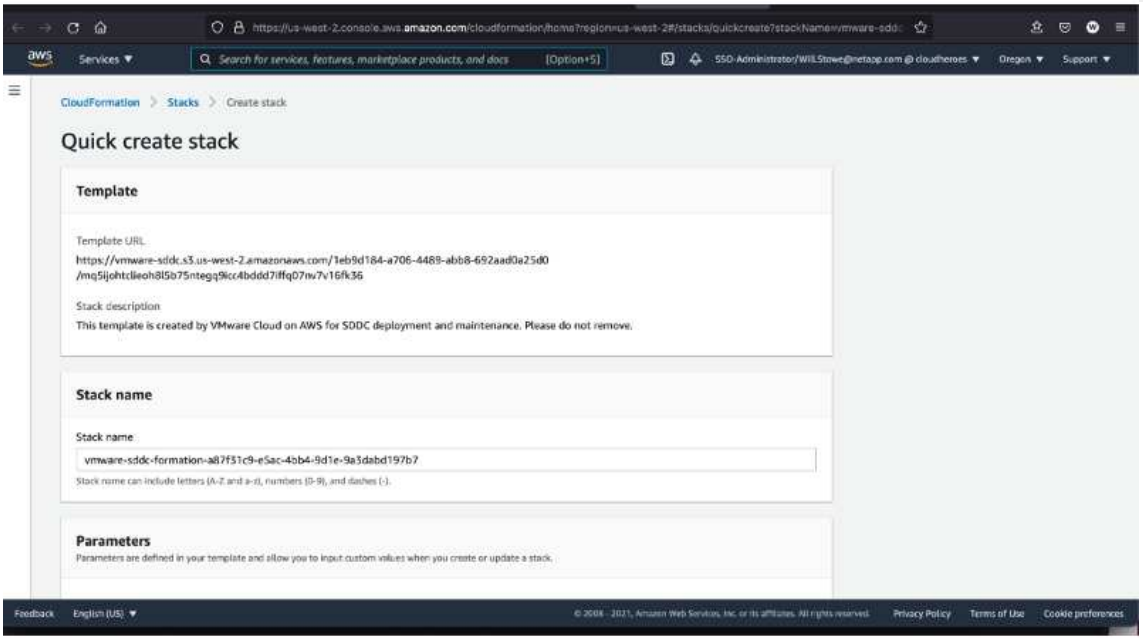
1. Log into the VMware Cloud Console using your existing or newly created VMware credentials.

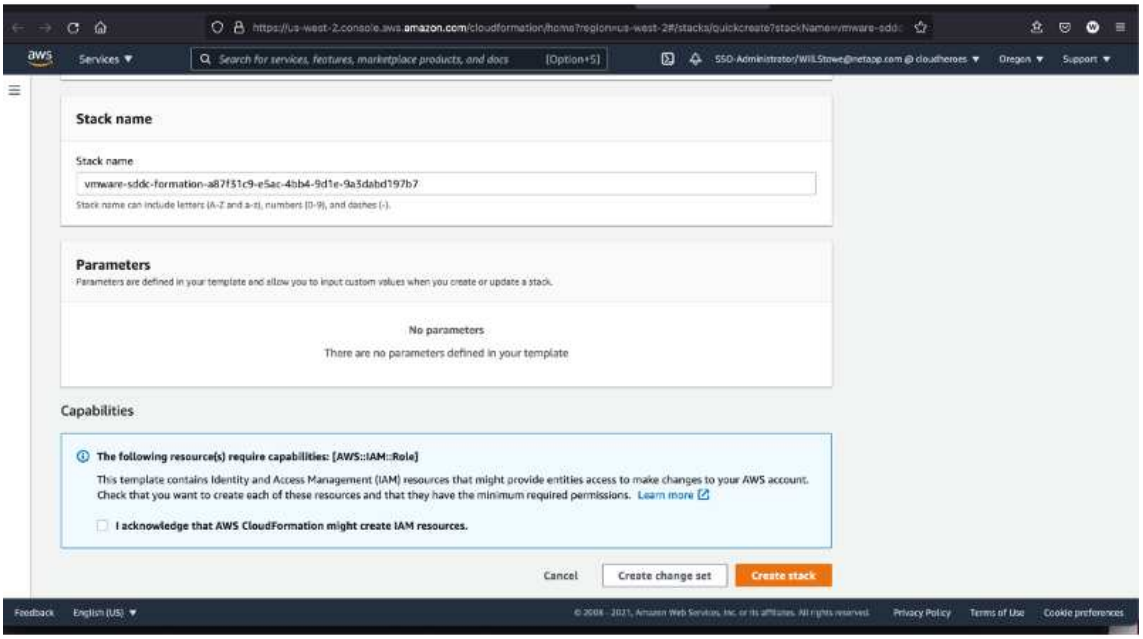


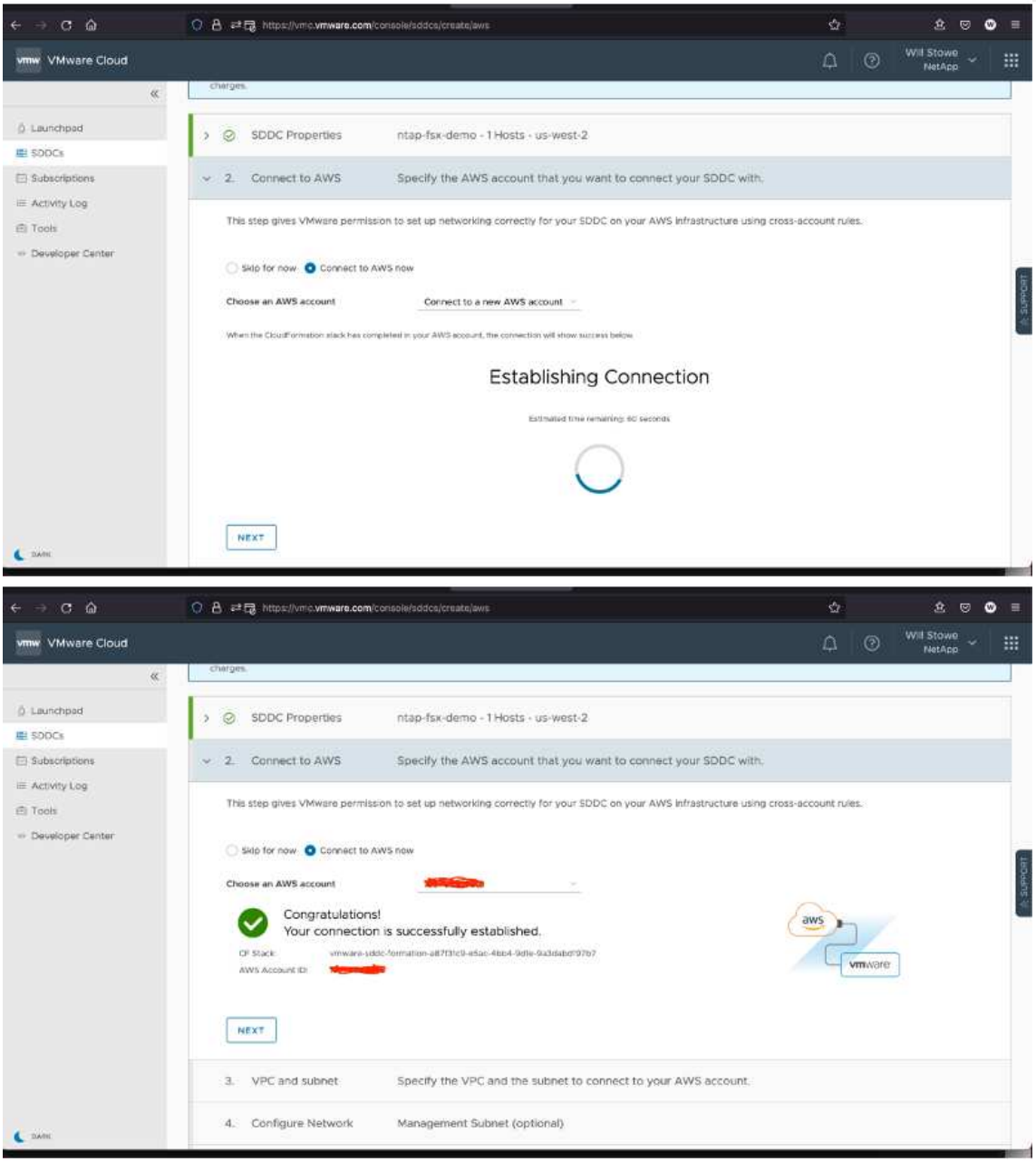
2. Configure the AWS region, deployment, and host type and the SDDC name:



3. Connect to the desired AWS account and execute the AWS Cloud Formation stack.

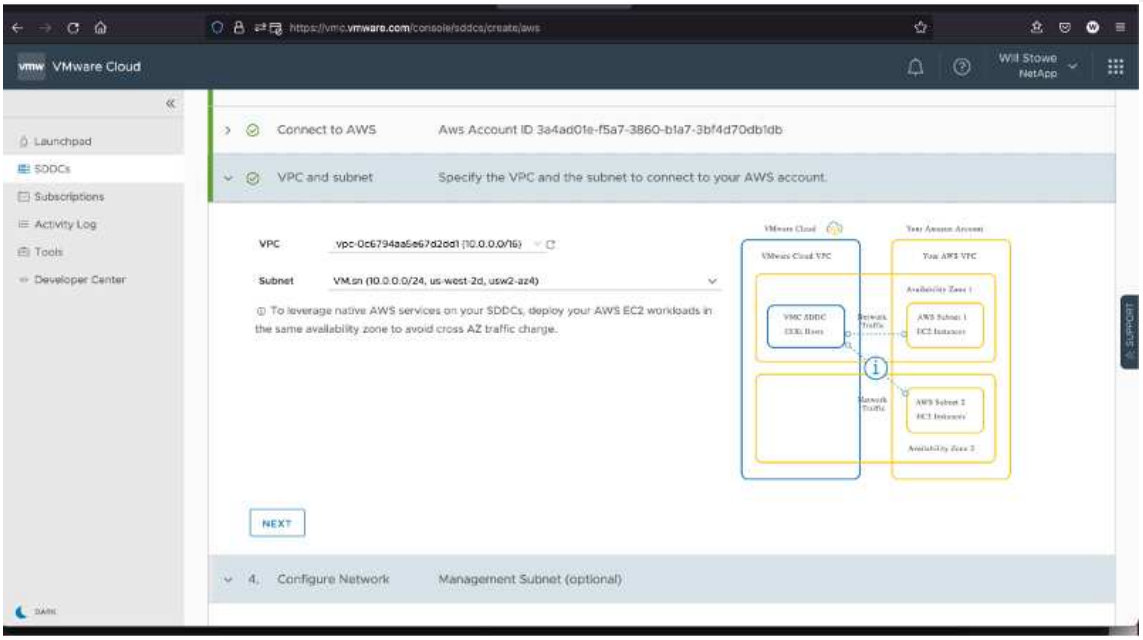

CloudFormation > Stacks > Create stack
Quick create stack
Template
Template URL
https://vmware-sddc.s3.us-west-2.amazonaws.com/1eb9d184-a706-4489-abb8-692aad0a25d0/mq5ijohtclieoh8l5b75ntegq9icc4bddd7iffq07nv7v16fk36
Stack description
This template is created by VMware Cloud on AWS for SDDC deployment and maintenance. Please do not remove.
Stack name
Stack name
vmware-sddc-formation-a87f51c9-e5ac-4bb4-9d1e-9a3dabd197b7
Parameters
Parameters are defined in your template and allow you to input custom values when you create or update a stack.


Stack name
Stack name
vmware-sddc-formation-a87f51c9-e5ac-4bb4-9d1e-9a3dabd197b7
Parameters
Parameters are defined in your template and allow you to input custom values when you create or update a stack.
No parameters
There are no parameters defined in your template
Capabilities
The following resource(s) require capabilities: [AWS::IAM::Role]
This template contains Identity and Access Management (IAM) resources that might provide entities access to make changes to your AWS account. Check that you want to create each of these resources and that they have the minimum required permissions. Learn more
I acknowledge that AWS CloudFormation might create IAM resources.
Cancel
Create change set
Create stack

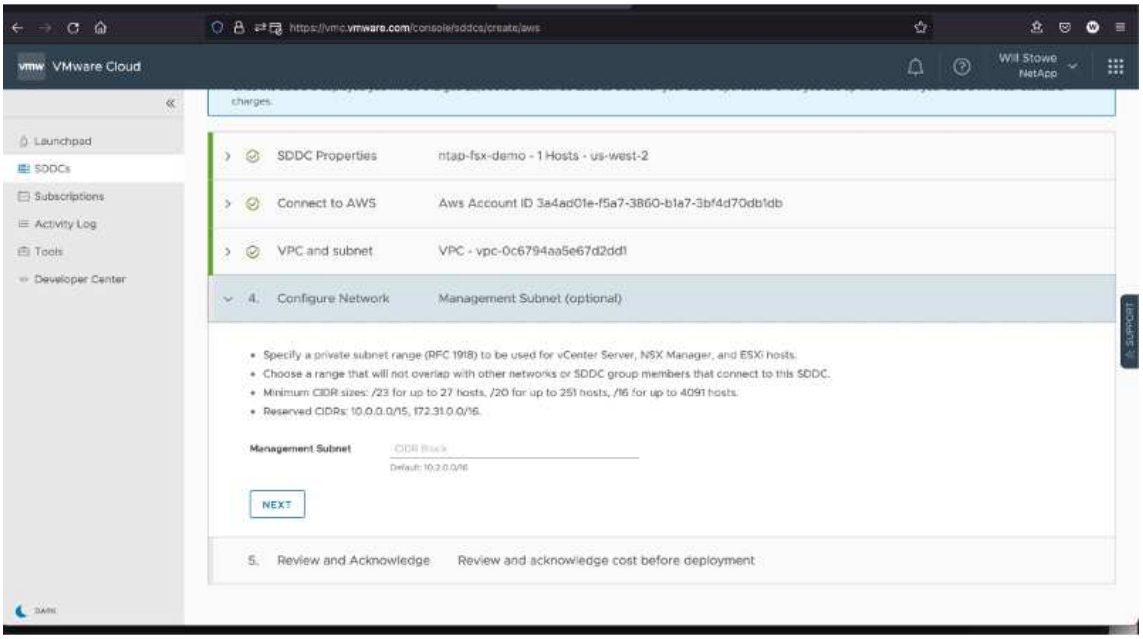


Single-host configuration is used in this validation.

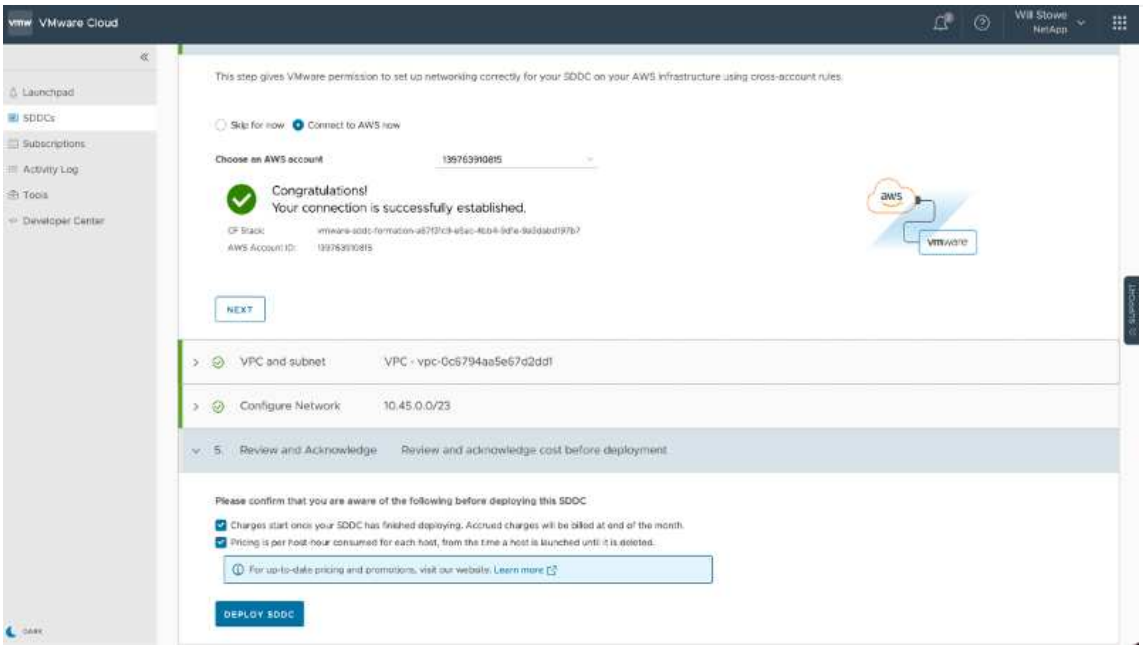
4. Select the desired AWS VPC to connect the VMC environment with.



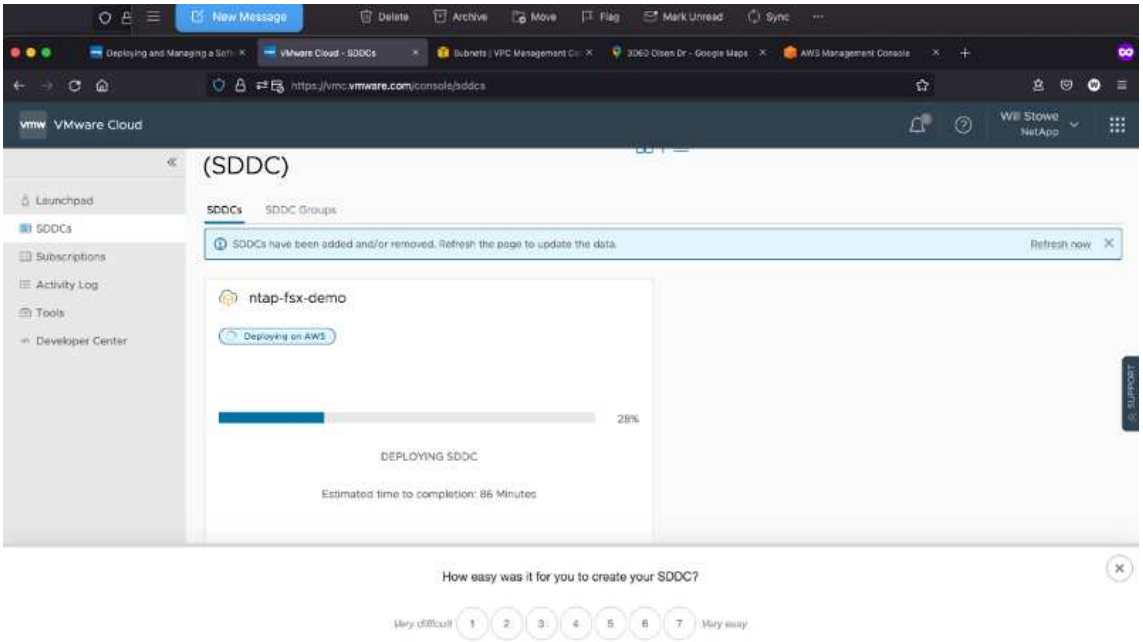
5. Configure the VMC Management Subnet; this subnet contains VMC-managed services like vCenter, NSX, and so on. Do not choose an overlapping address space with any other networks that need connectivity to the SDDC environment. Finally, follow the recommendations for CIDR size notated below.



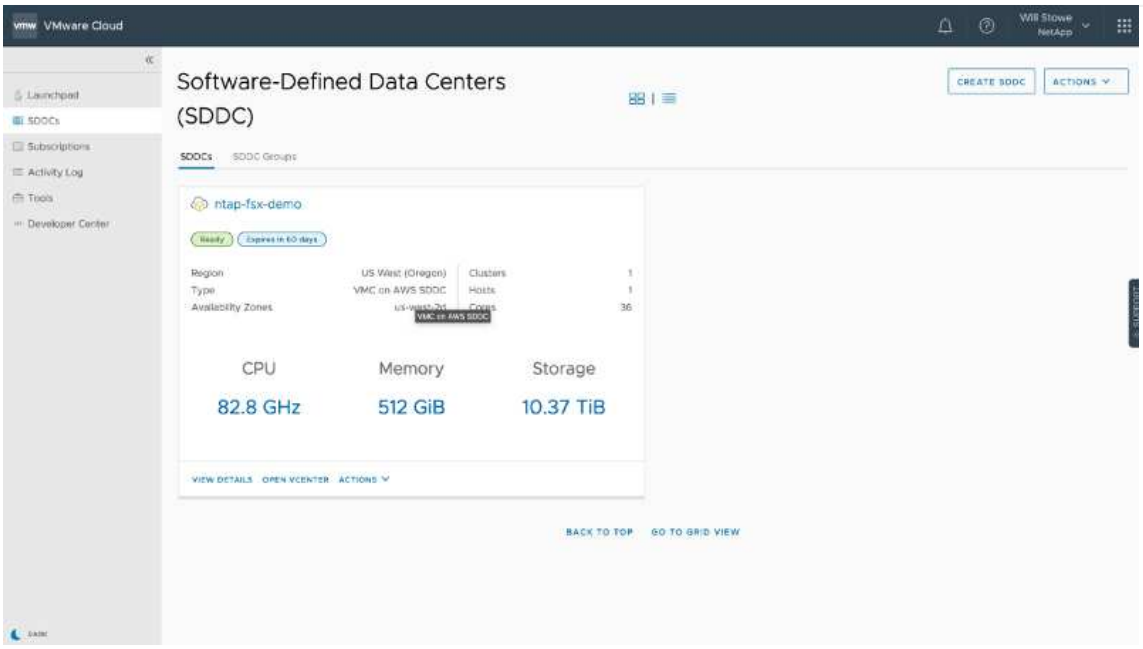
6. Review and acknowledge the SDDC configuration, and then click deploy the SDDC.



The deployment process typically takes approximately two hours to complete.



7. After completion, the SDDC is ready for use.

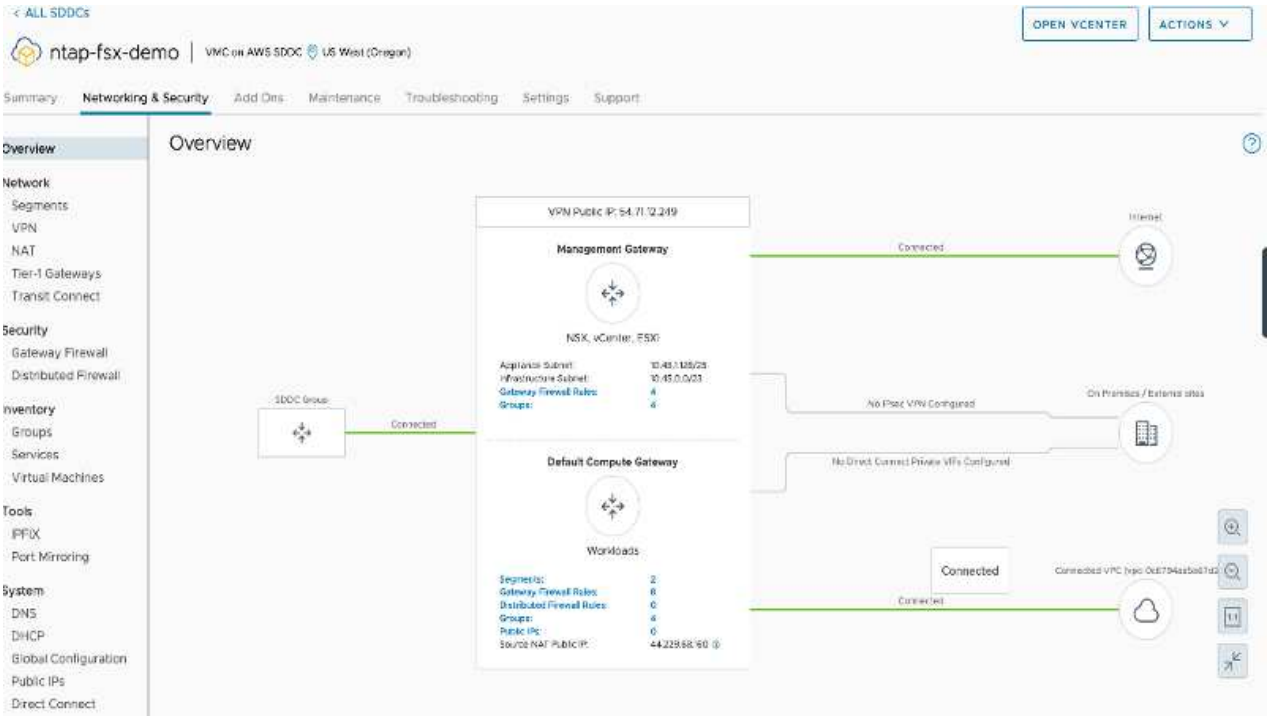


For a step-by-step guide on SDDC deployment, see Deploy an SDDC from the VMC Console.

Connect VMware Cloud to FSx ONTAP

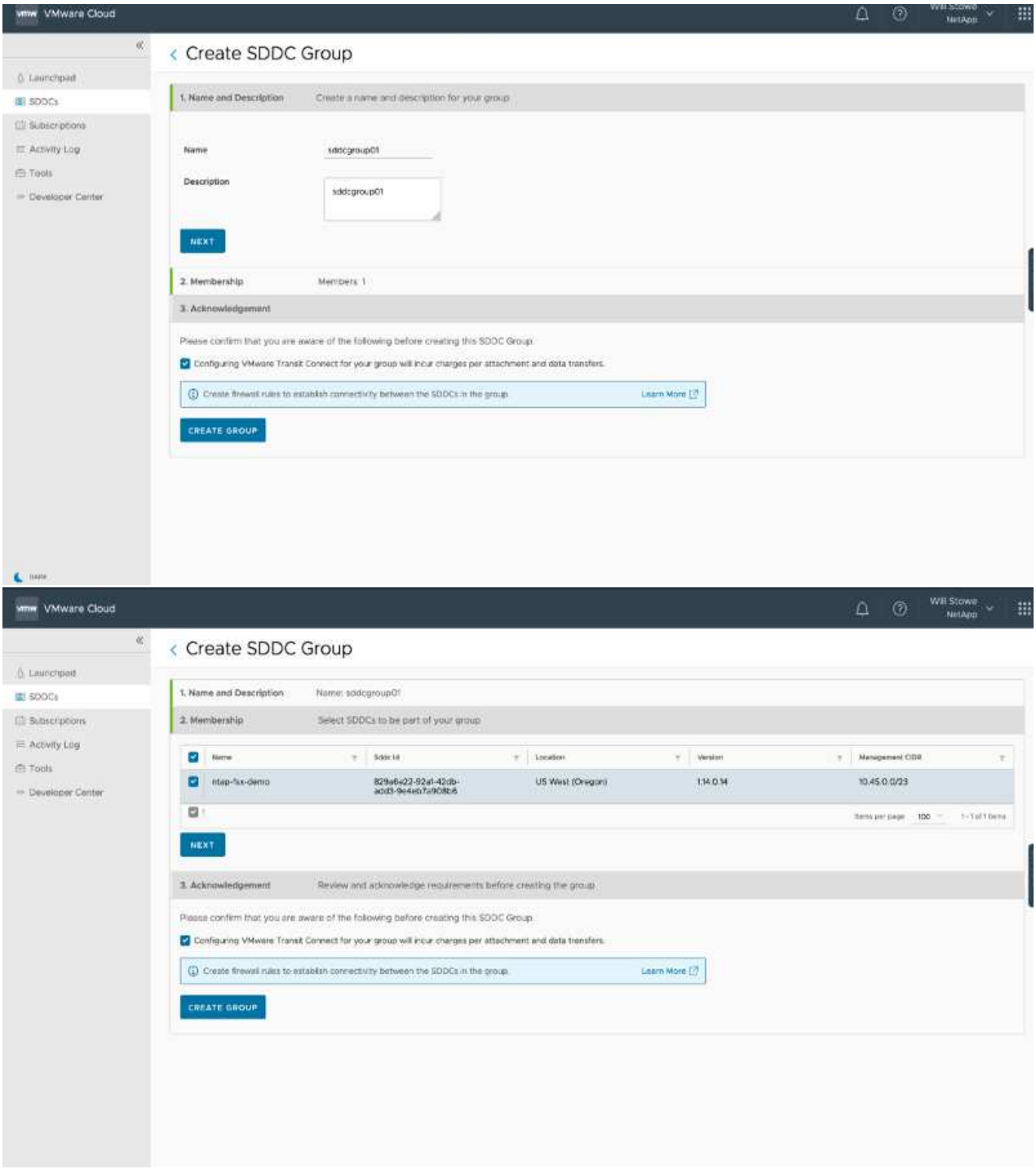
To connect VMware Cloud to FSx ONTAP, complete the following steps:

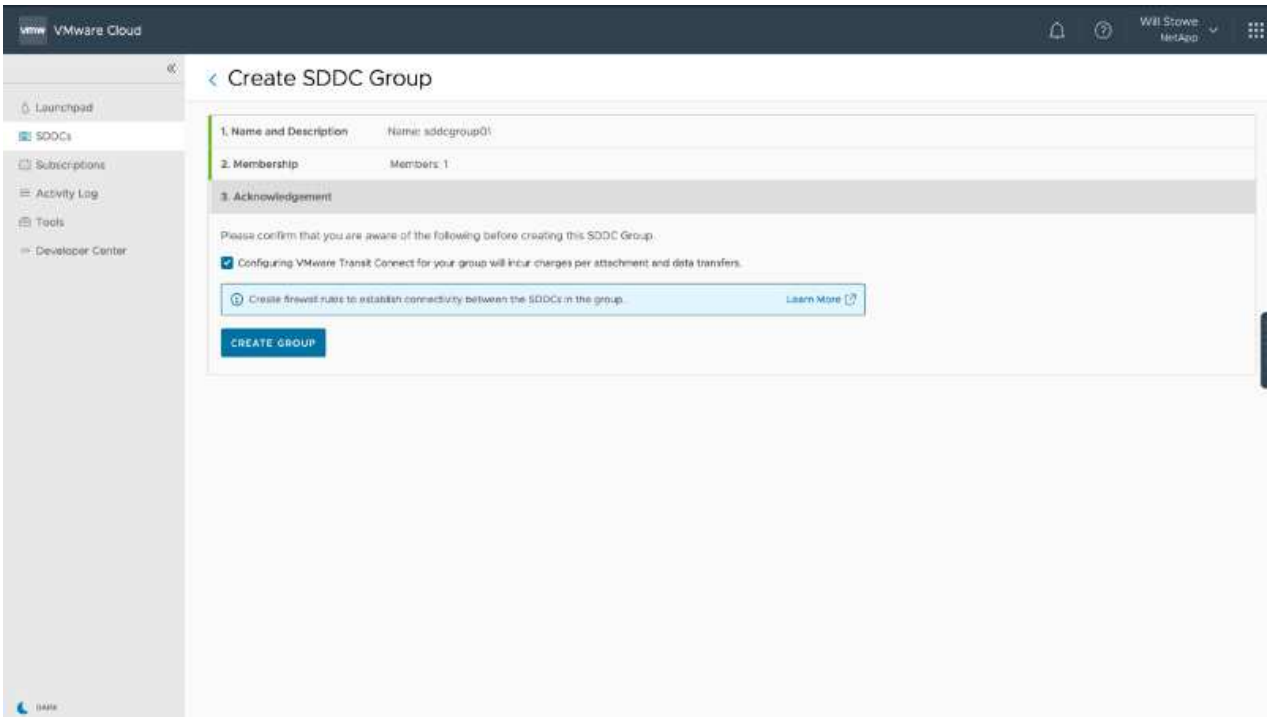
1. With VMware Cloud deployment completed and connected to AWS VPC, you must deploy Amazon FSx for NetApp ONTAP into a new VPC rather than the original connected VPC (see the screenshot below). FSx (NFS and SMB floating IPs) is not accessible if it is deployed in the connected VPC. Keep in mind that ISCSI endpoints like Cloud Volumes ONTAP work just fine from the connected VPC.



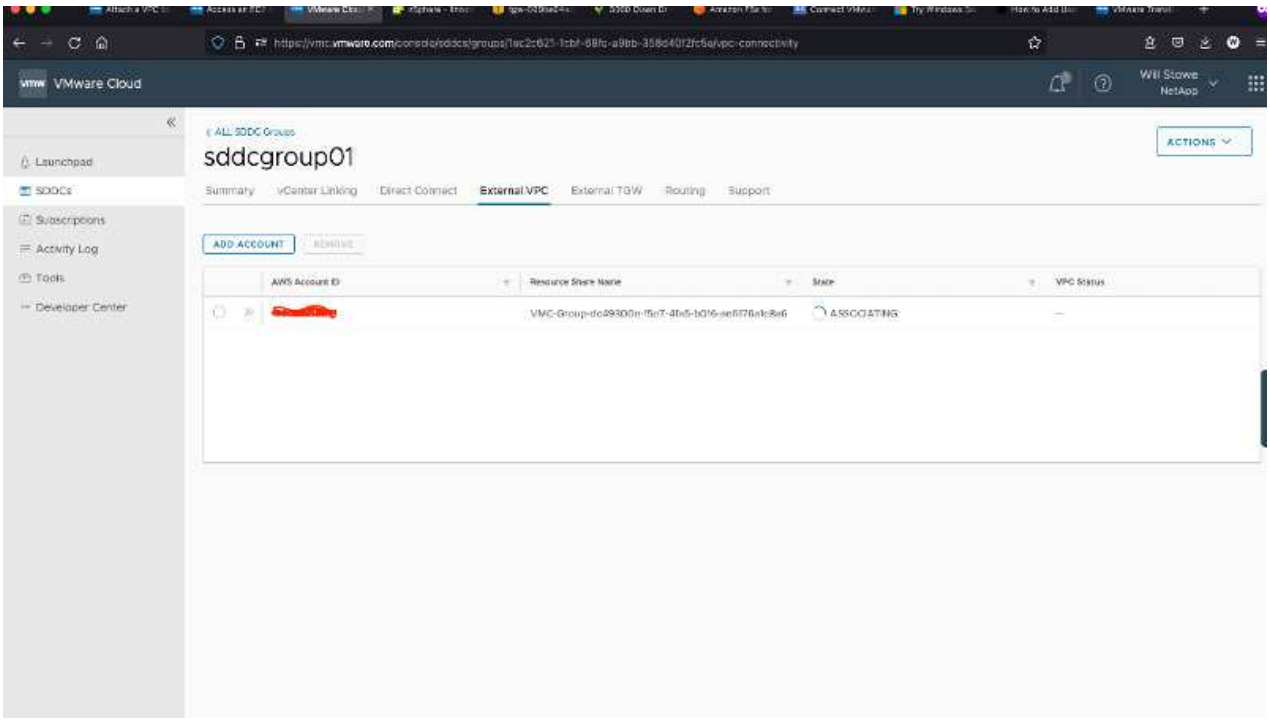
2. Deploy an additional VPC in the same region, and then deploy Amazon FSx for NetApp ONTAP into the new VPC.

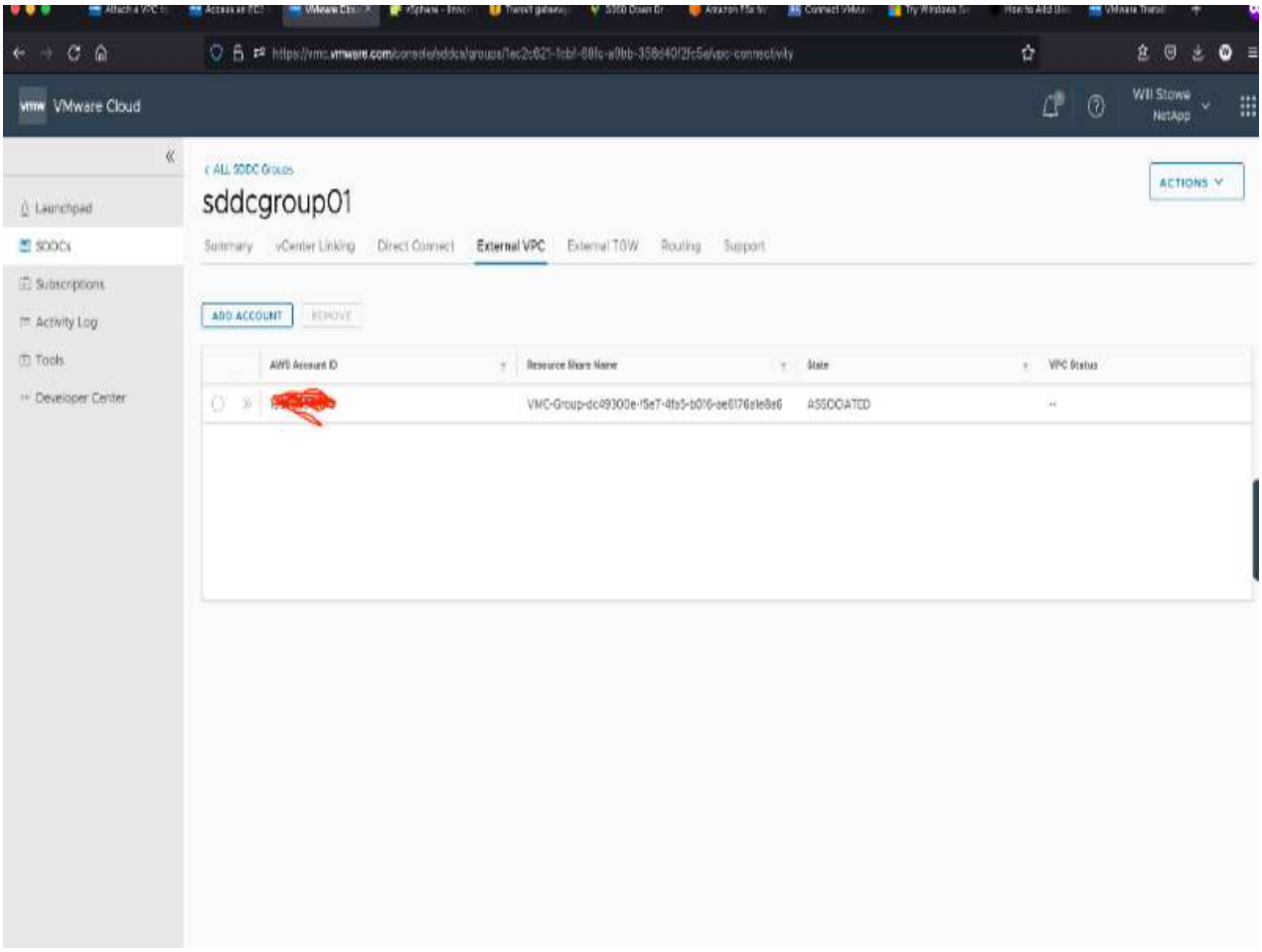
   Configuration of an SDDC group in the VMware Cloud console enables the networking configuration options required to connect to the new VPC where FSx is deployed. In step 3, verify that “Configuring VMware Transit Connect for your group will incur charges per attachment and data transfers” is checked, and then choose Create Group. The process can take a few minutes to complete.


VMware Cloud
Will Stowe
NetApp
Launchpad
SDDCs
Subscriptions
Activity Log
Tools
Developer Center
Create SDDC Group
1. Name and Description
Create a name and description for your group
Name
sddcgroup01
Description
sddcgroup01
NEXT
2. Membership
Members: 1
3. Acknowledgement
Please confirm that you are aware of the following before creating this SDDC Group.
Configuring VMware Transit Connect for your group will incur charges per attachment and data transfers.
Create firewall rules to establish connectivity between the SDDCs in the group.
Learn More
CREATE GROUP
VMware Cloud
Will Stowe
NetApp
Launchpad
SDDCs
Subscriptions
Activity Log
Tools
Developer Center
Create SDDC Group
1. Name and Description
Name: sddcgroup01
2. Membership
Select SDDCs to be part of your group
Name
Sddc Id
Location
Version
Management CIDR
ntap-fsx-demo
829a6e22-92a1-42db-acd3-9e4eb7a908b6
US West (Oregon)
1.14.0.14
10.45.0.0/23
Items per page: 100
1 - 1 of 1 items
NEXT
3. Acknowledgement
Review and acknowledge requirements before creating the group
Please confirm that you are aware of the following before creating this SDDC Group.
Configuring VMware Transit Connect for your group will incur charges per attachment and data transfers.
Create firewall rules to establish connectivity between the SDDCs in the group.
Learn More
CREATE GROUP

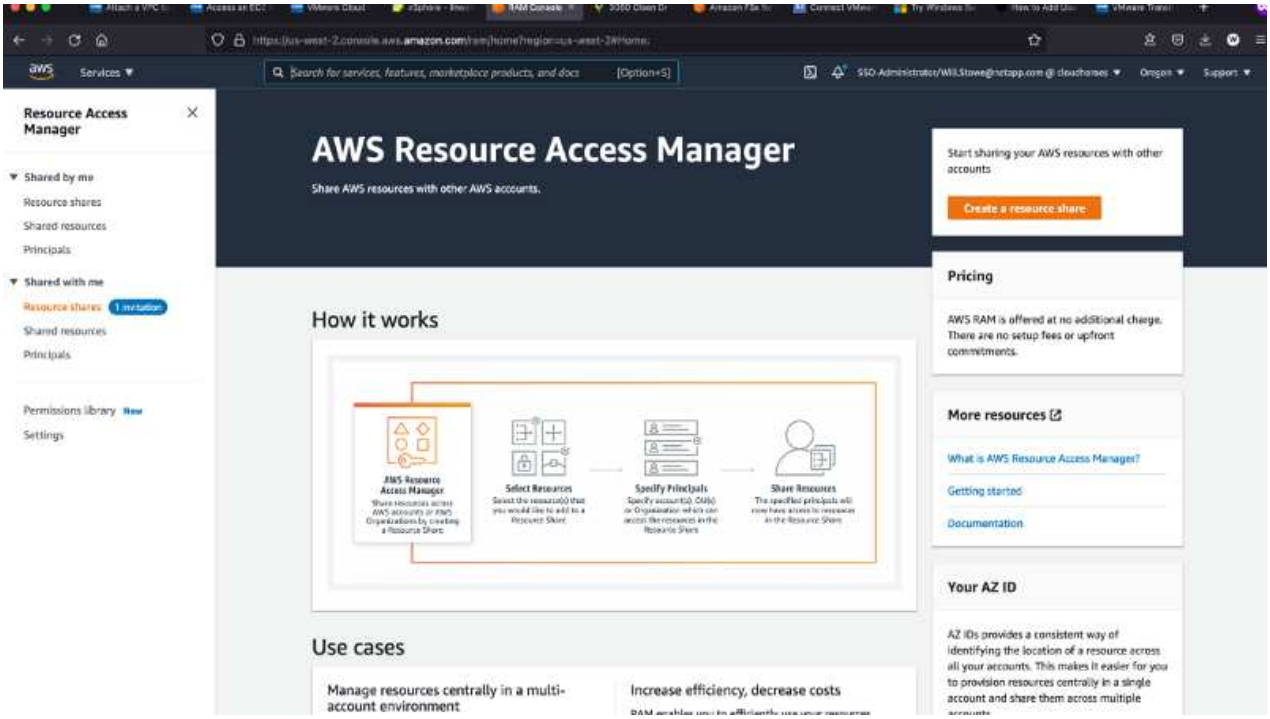


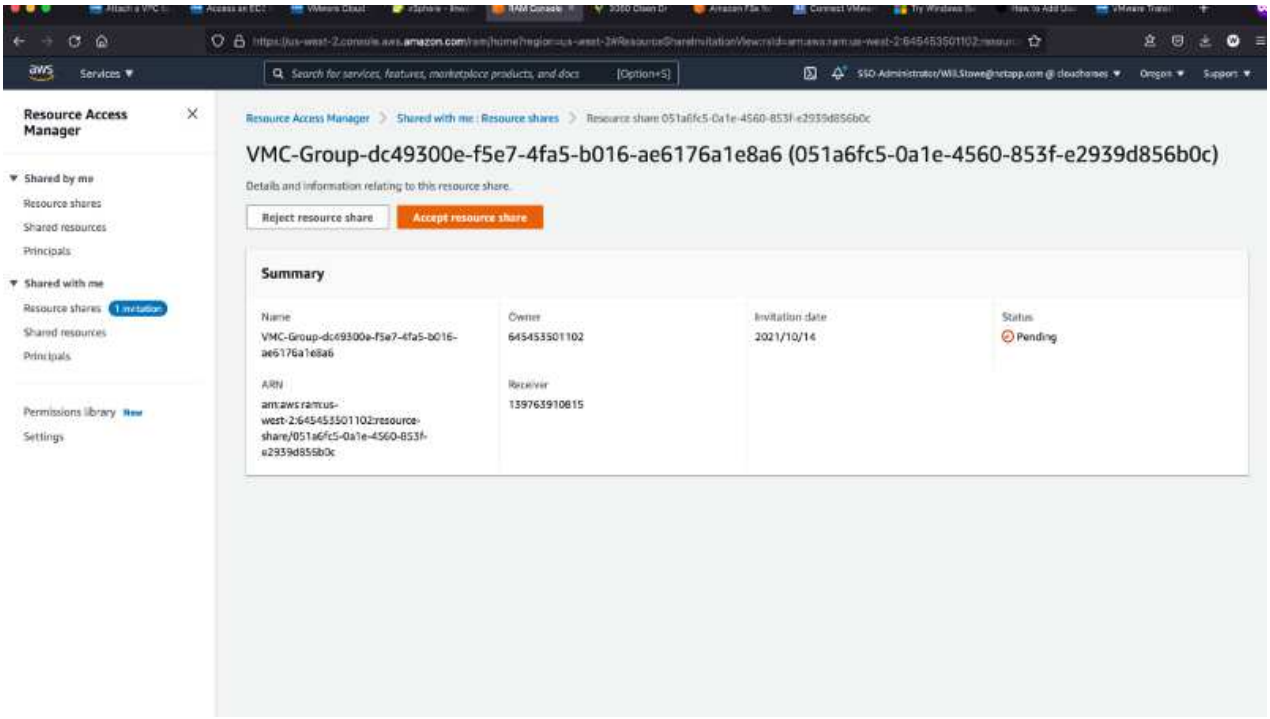
3. Attach the newly created VPC to the just created SDDC group. Select the External VPC tab and follow the instructions for attaching an External VPC to the group. This process can take 10 to 15 minutes to complete.



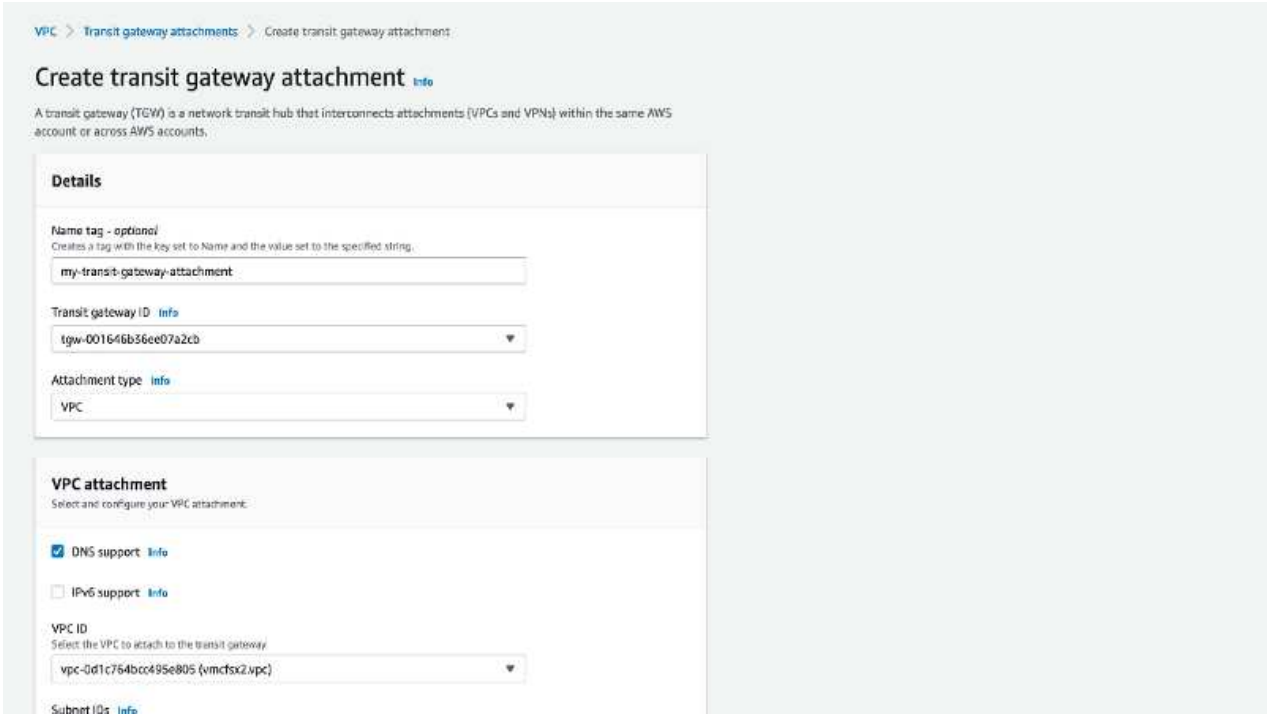


4. As part of the external VPC process, you are prompted through the AWS console to a new shared resource via the Resource Access Manager. The shared resource is the AWS Transit Gateway managed by VMware Transit Connect.

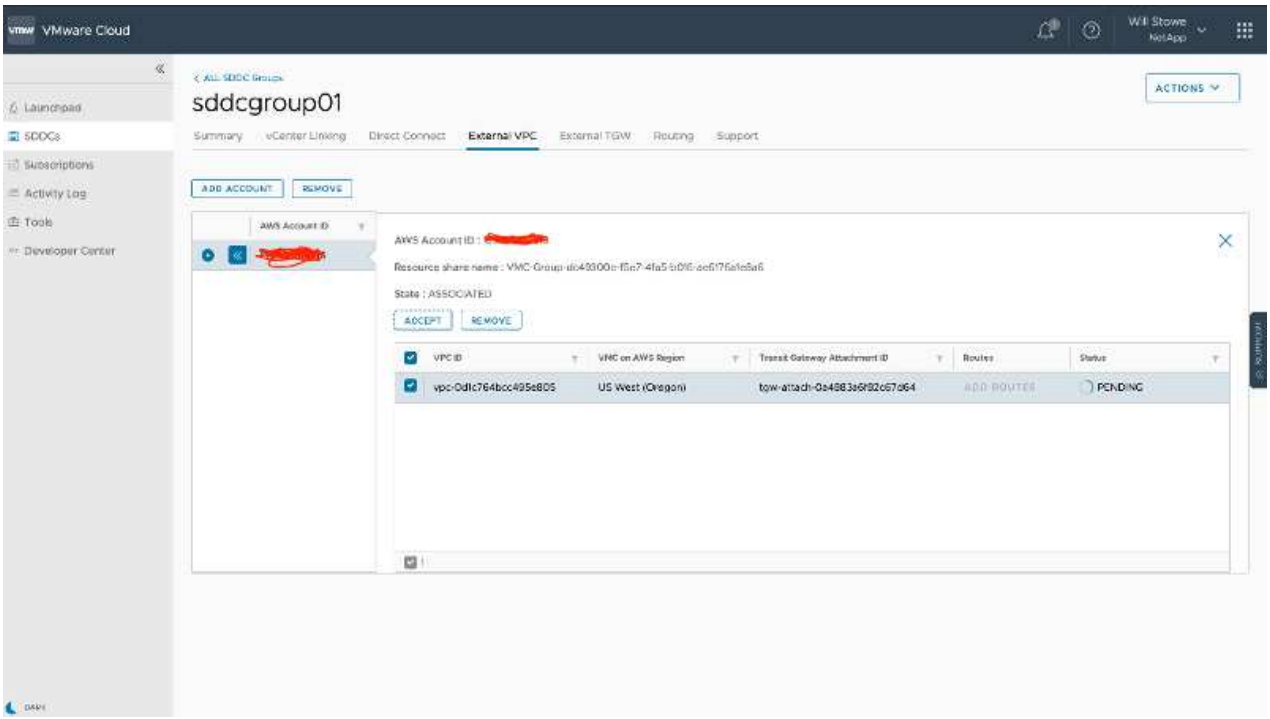




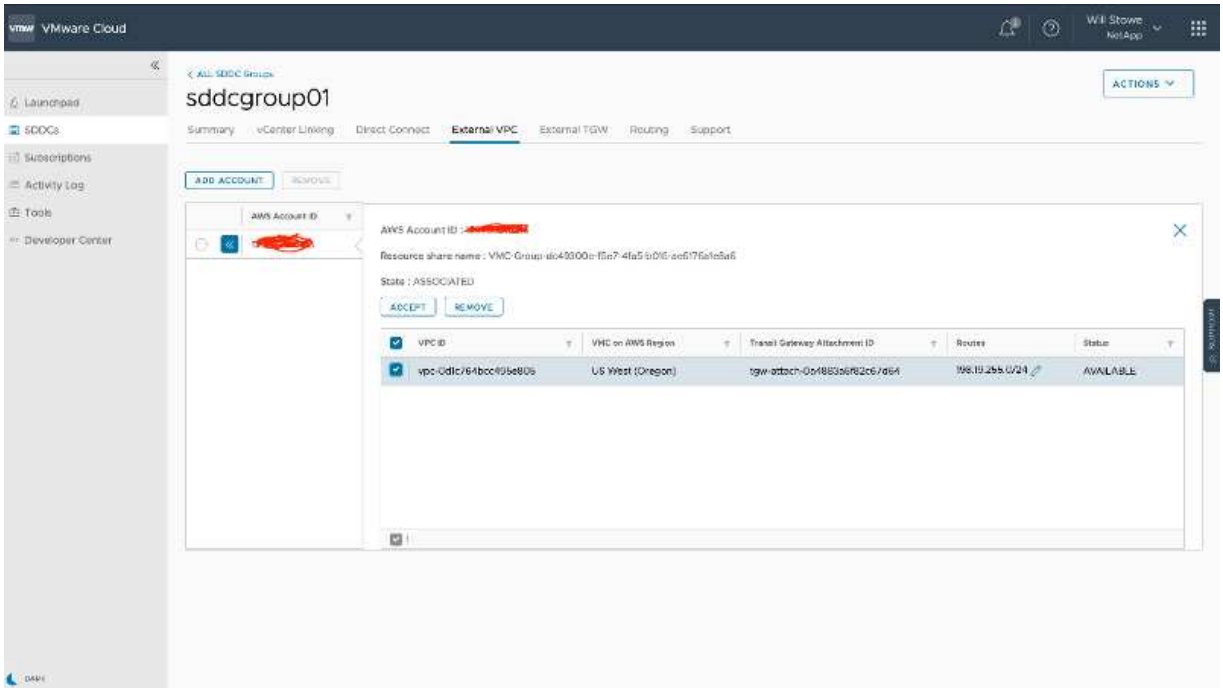
5. Create the Transit Gateway Attachment.



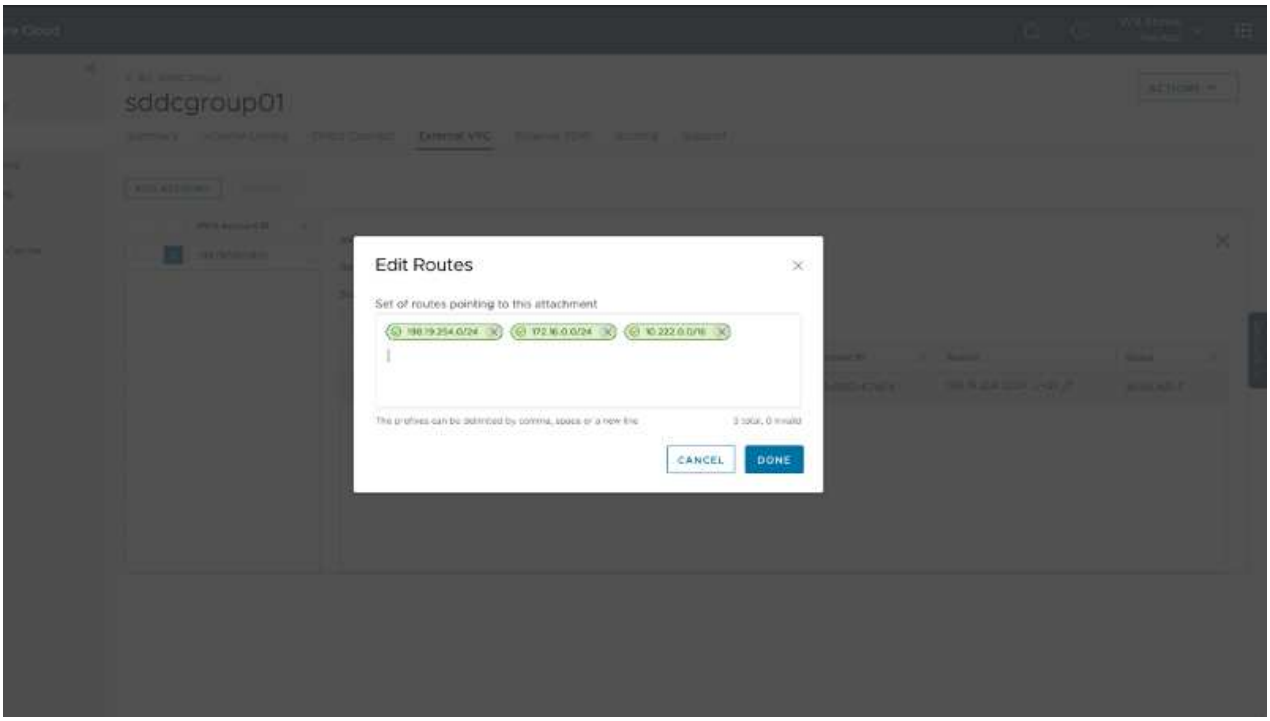
6. Back on the VMC Console, Accept the VPC attachment. This process can take approximately 10 minutes to complete.



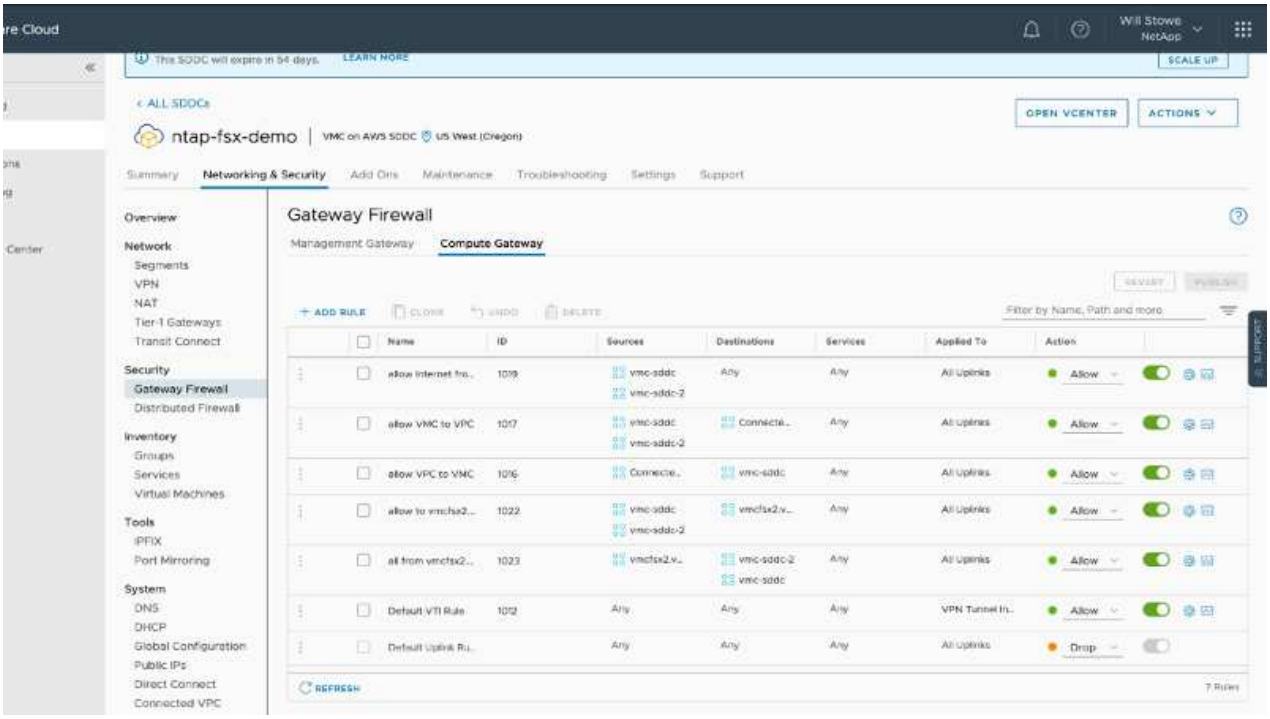
7. While in the External VPC tab, click the edit icon in the Routes column and add in the following required routes:
   - A route for the floating IP range for Amazon FSx for NetApp ONTAP floating IPs.
   - A route for the floating IP range for Cloud Volumes ONTAP (if applicable).
   - A route for the newly created external VPC address space.



8. Finally, allow bidirectional traffic firewall rules for access to FSx/CVO. Follow these detailed steps for compute gateway firewall rules for SDDC workload connectivity.



9. After the firewall groups are configured for both the Management and Compute gateway, the vCenter can be accessed as follows:



The next step is to verify that Amazon FSx ONTAP or Cloud Volumes ONTAP is configured depending on your requirements and that the volumes are provisioned to offload storage components from vSAN to optimize the deployment.

Deploy and configure the Virtualization Environment on Azure

As with on-premises, planning Azure VMware Solution is critical for a successful production-ready environment for creating VMs and migration.

This section describes how to set up and manage Azure VMware Solution and use it in combination with the available options for connecting NetApp storage.

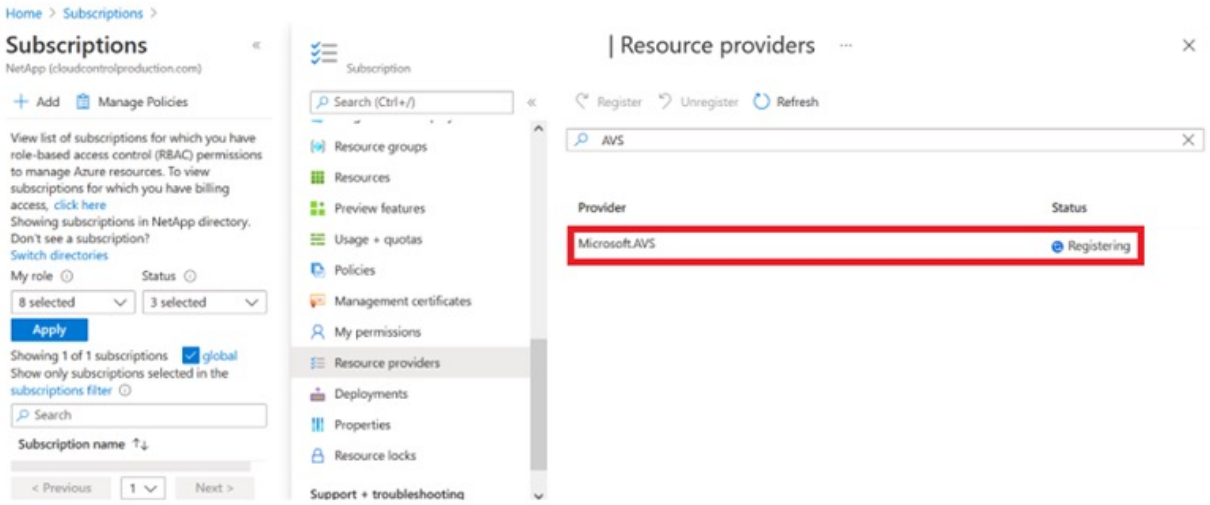
In-guest storage is the only supported method of connecting Azure NetApp Files and Cloud Volumes ONTAP to Azure VMware Solution.

The setup process can be broken down into the following steps:

Register the resource provider and create a private cloud

To use Azure VMware Solution, first register the resource provider within the identified subscription:

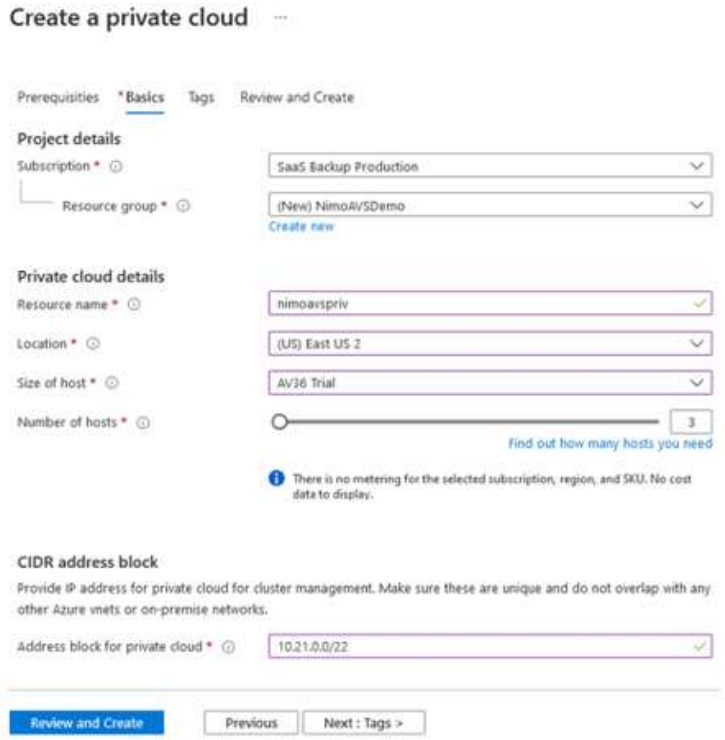
1. Sign in to the Azure portal.
2. On the Azure portal menu, select All Services.
3. In the All Services dialog box, enter the subscription and then select Subscriptions.
4. To view, select the subscription from the subscription list.
5. Select Resource Providers and enter Microsoft.AVS into the search.
6. If the resource provider is not registered, select Register.



7. After the resource provider is registered, create an Azure VMware Solution private cloud by using the Azure portal.
8. Sign in to the Azure portal.
9. Select Create a New Resource.
10. In the Search the Marketplace text box, enter Azure VMware Solution and select it from the results.
11. On the Azure VMware Solution page, select Create.
12. From the Basics tab, enter the values in the fields and select Review + Create.

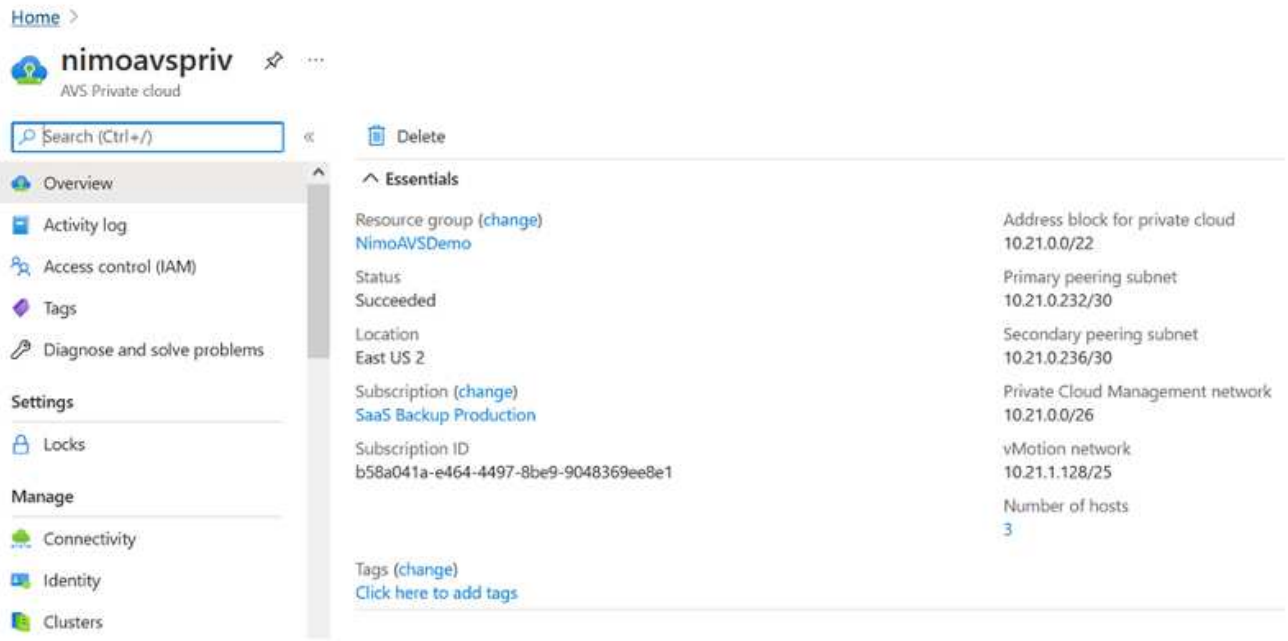
Notes:

- For a quick start, gather the required information during the planning phase.
- Select an existing resource group or create a new resource group for the private cloud. A resource group is a logical container in which the Azure resources are deployed and managed.
- Make sure the CIDR address is unique and does not overlap with other Azure Virtual Networks or on-premises networks. The CIDR represents the private cloud management network and is used for the cluster management services, such as vCenter Server and NSX-T Manager. NetApp recommends using a /22 address space. In this example, 10.21.0.0/22 is used.



The provisioning process takes approximately 4–5 hours. After the process is complete, verify that the deployment was successful by accessing the private cloud from the Azure portal. A status of Succeeded is displayed when the deployment is complete.

An Azure VMware Solution private cloud requires an Azure Virtual Network. Because Azure VMware Solution doesn't support on-premises vCenter, additional steps are required to integrate with an existing on-premises environment. Setting up an ExpressRoute circuit and a virtual network gateway is also required. While waiting for the cluster provisioning to complete, create a new virtual network or use an existing one to connect to Azure VMware Solution.



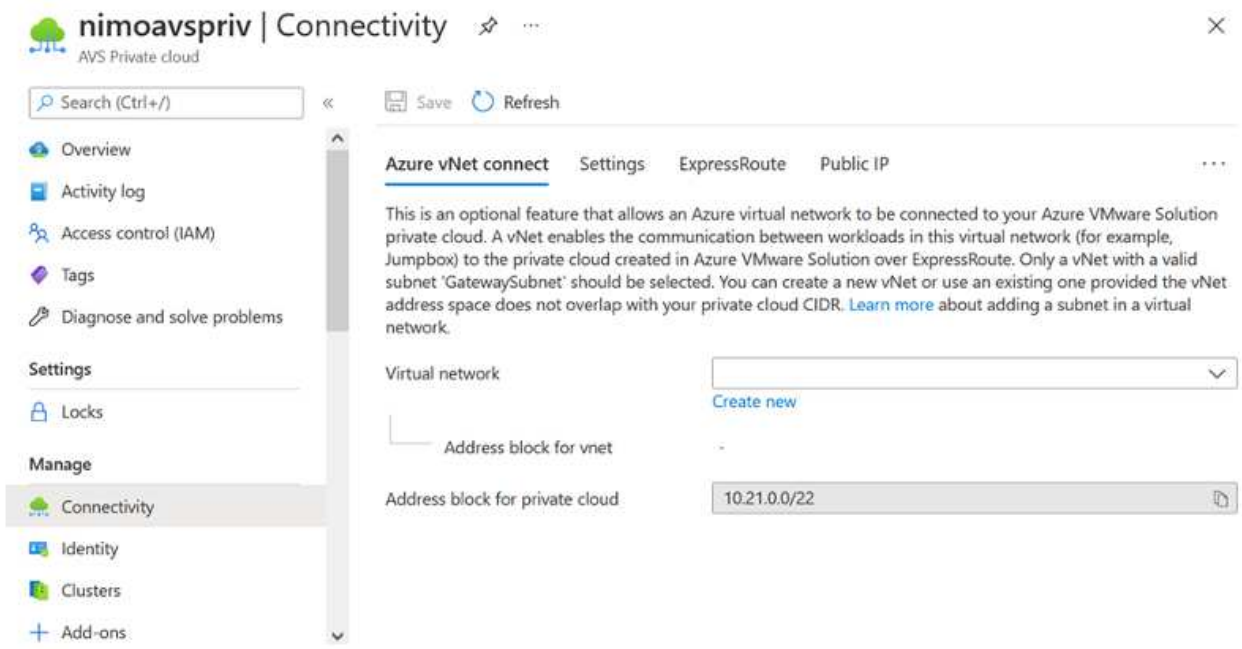
Connect to a new or existing ExpressRoute virtual network gateway

To create a new Azure Virtual Network (VNet), select the Azure VNet Connect tab. Alternatively, you can create one manually from the Azure portal by using the Create Virtual Network wizard:

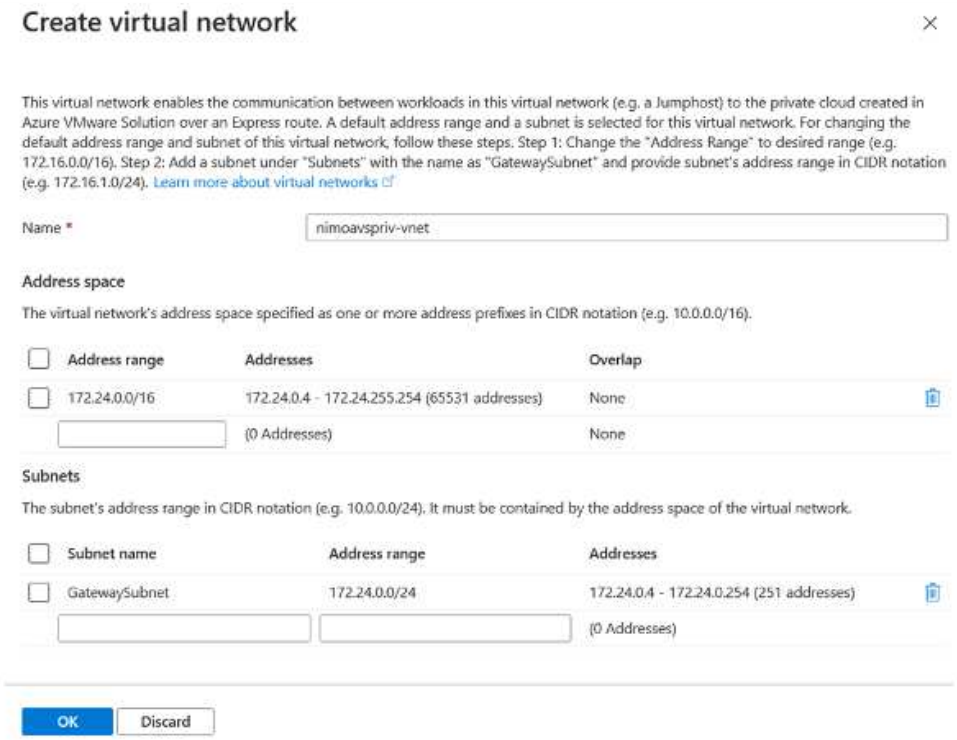
1. Go to Azure VMware Solution private cloud and access Connectivity under the Manage option.
2. Select Azure VNet Connect.
3. To create a new VNet, select the Create New option.

   This feature allows a VNet to be connected to the Azure VMware Solution private cloud. The VNet enables communication between workloads in this virtual network by automatically creating required components (for example, jump box, shared services such as Azure NetApp Files, and Cloud Volume ONTAP) to the private cloud created in Azure VMware Solution over ExpressRoute.

   Note: The VNet address space should not overlap with the private cloud CIDR.



4. Provide or update the information for the new VNet and select OK.

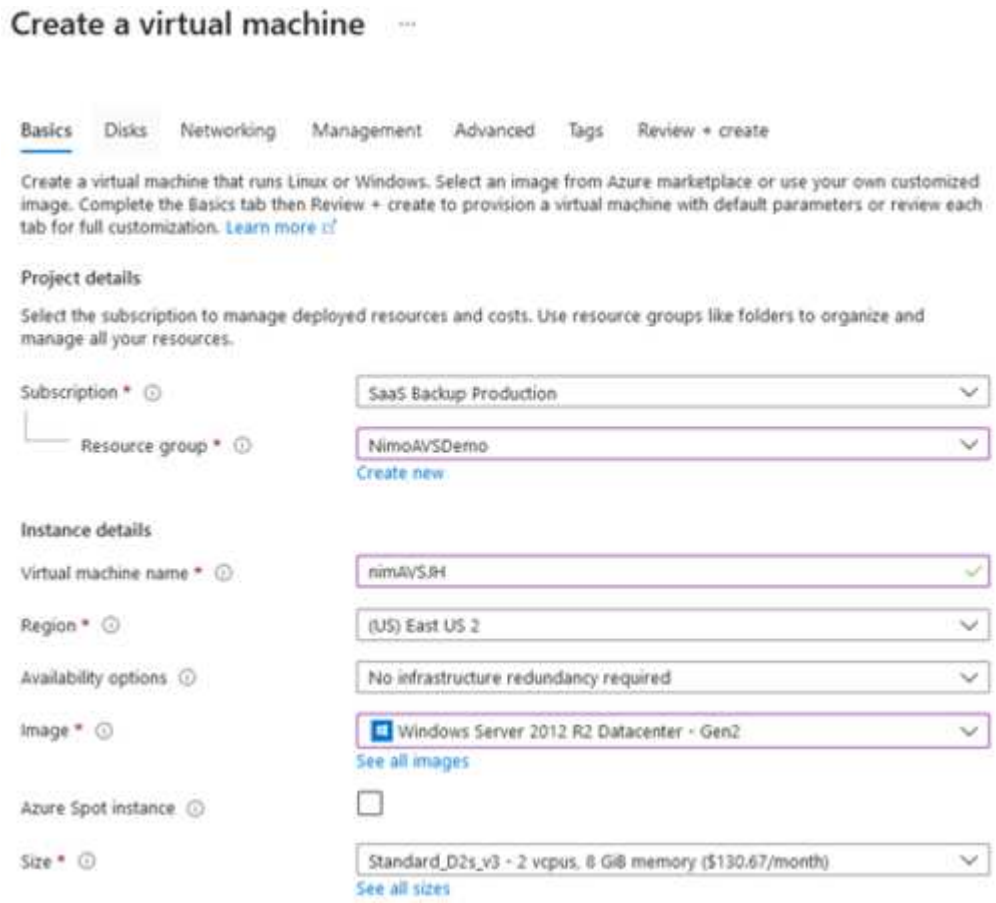


The VNet with the provided address range and gateway subnet is created in the designated subscription and resource group.

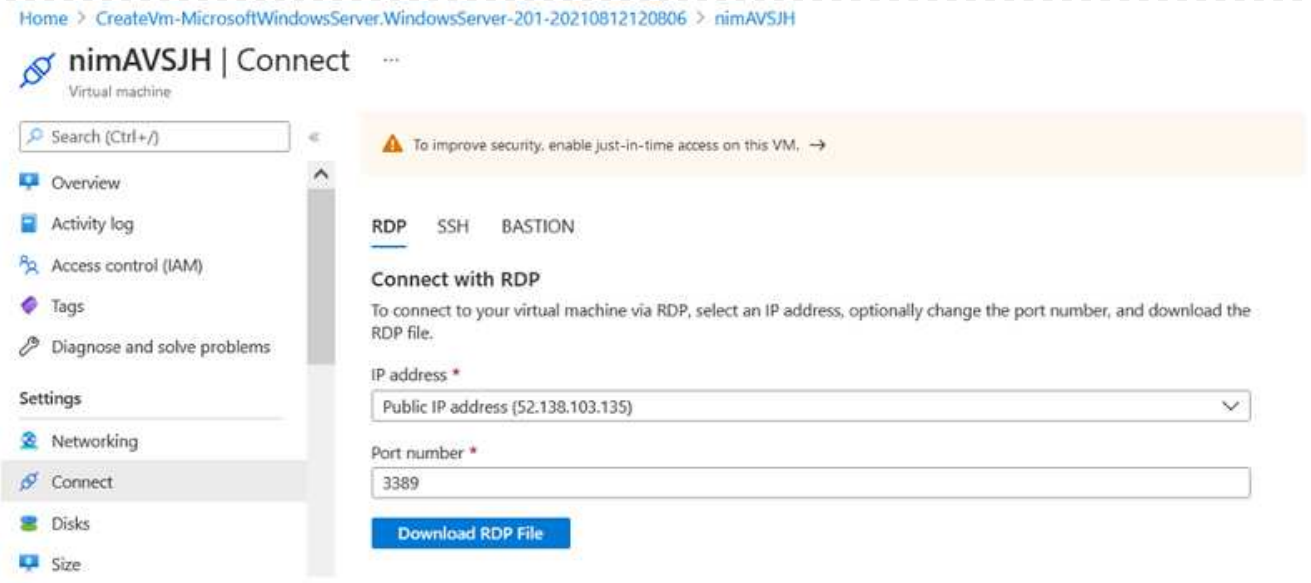
If you create a VNet manually, create a virtual network gateway with the appropriate SKU and ExpressRoute as the gateway type. After the deployment is complete, connect the ExpressRoute connection to the virtual network gateway containing Azure VMware Solution private cloud using the authorization key. For more information, see Configure networking for your VMware private cloud in Azure.

Validate the network connect and access to Azure VMware Solution private cloud

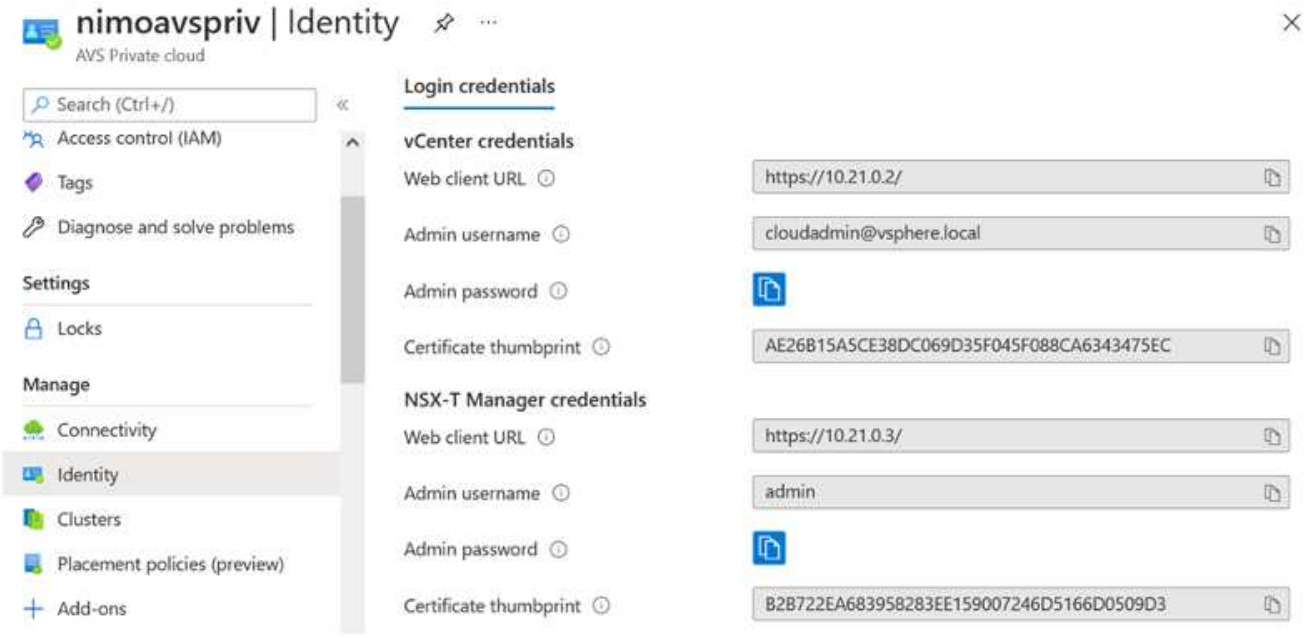
Azure VMware Solution does not allow you to manage a private cloud with on-premises VMware vCenter. Instead, jump host is required to connect to the Azure VMware Solution vCenter instance. Create a jump host in the designated resource group and sign in to the Azure VMware Solution vCenter. This jump host should be a Windows VM on the same virtual network that was created for connectivity and should provide access to both vCenter and the NSX Manager.



After the virtual machine is provisioned, use the Connect option to access RDP.

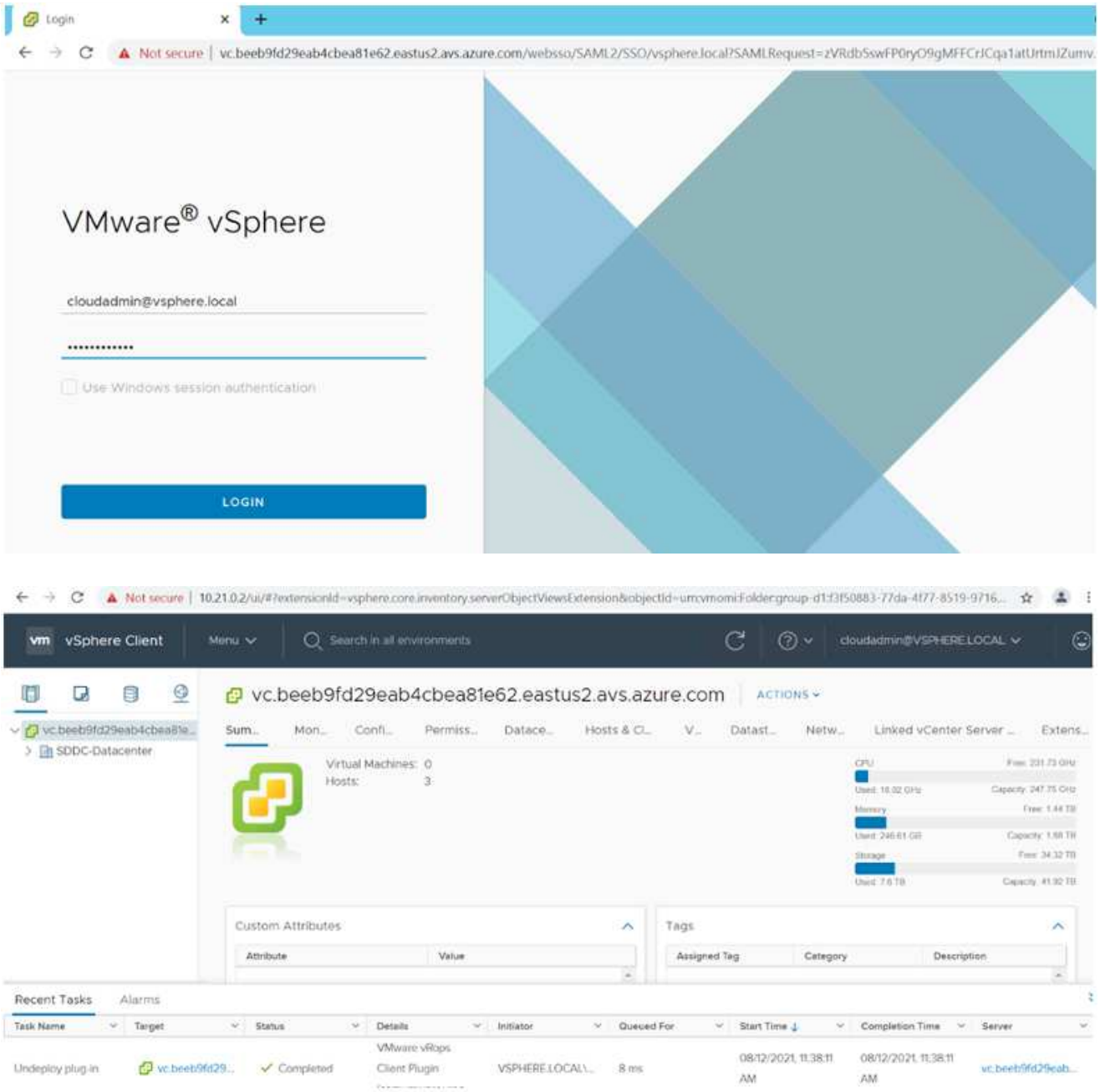


Sign in to vCenter from this newly created jump host virtual machine by using the cloud admin user . To access the credentials, go to the Azure portal and navigate to Identity (under the Manage option within the private cloud). The URLs and user credentials for the private cloud vCenter and NSX-T Manager can be copied from here.



In the Windows virtual machine, open a browser and navigate to the vCenter web client URL (https://10.21.0.2/) and use the admin user name as **cloudadmin@vsphere.local** and paste the copied password. Similarly, NSX-T manager can also be accessed using the web client URL (https://10.21.0.3/) and use the admin user name and paste the copied password to create new segments or modify the existing tier gateways.

The web client URLs are different for each SDDC provisioned.



The Azure VMware Solution SDDC is now deployed and configured. Leverage ExpressRoute Global Reach to connect the on-premises environment to Azure VMware Solution private cloud. For more information, see Peer on-premises environments to Azure VMware Solution.

Deploy and configure the Virtualization Environment on Google Cloud Platform (GCP)

As with on-premises, planning Google Cloud VMware Engine (GCVE) is critical for a successful production-ready environment for creating VMs and migration.

This section describes how to set up and manage GCVE and use it in combination with the available options for connecting NetApp storage.

In-guest storage is the only supported method of connecting Cloud Volumes ONTAP and Cloud Volumes Services to GCVE.

The setup process can be broken down into the following steps:

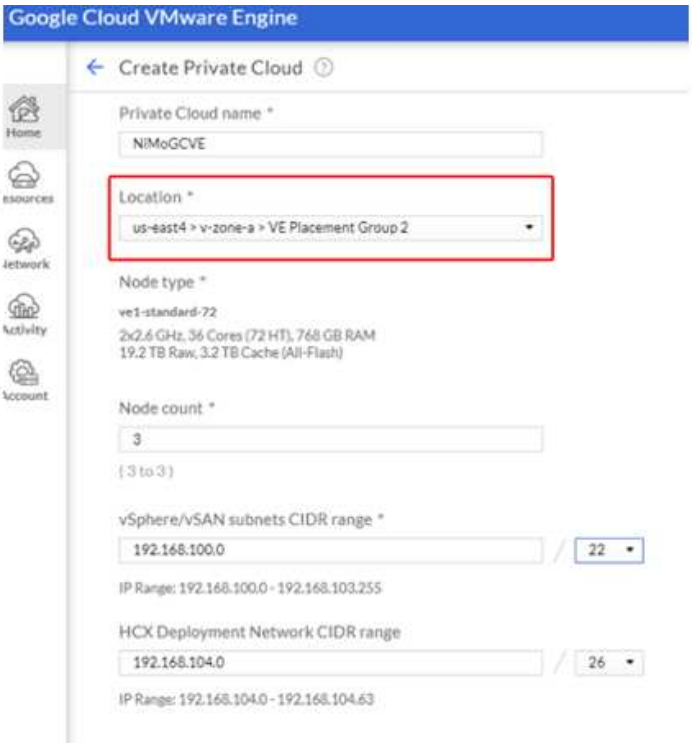
Deploy and configure GCVE

To configure a GCVE environment on GCP, login to the GCP console and access the VMware Engine portal.

Click on the “New Private Cloud” button and enter the desired configuration for the GCVE Private Cloud. On “Location”, make sure to deploy the private cloud in the same Region/Zone where CVS/CVO is deployed, to ensure the best performance and lowest latency.

Pre-requisites:

- Setup VMware Engine Service Admin IAM role
- Enable VMWare Engine API access and node quota
- Make sure that the CIDR range doesn’t overlap with any of your on-premises or cloud subnets. The CIDR range must be /27 or higher.



Note: Private cloud creation can take between 30 minutes to 2 hours.

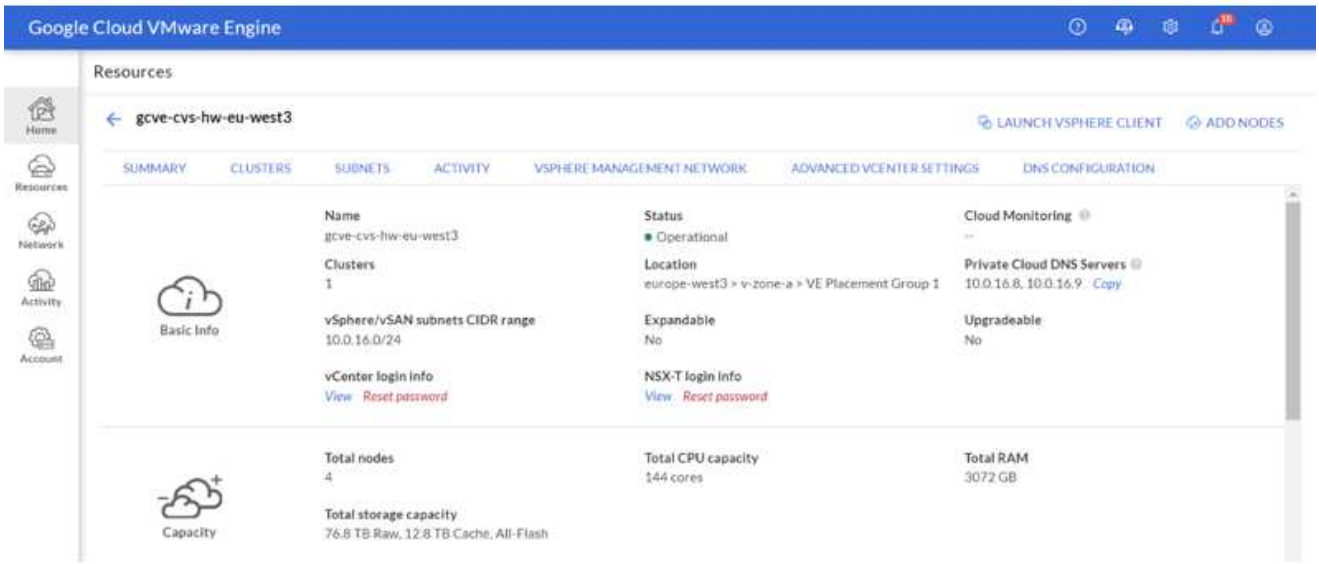
Enable Private Access to GCVE

Once the Private Cloud is provisioned, configure private access to the Private Cloud for high-throughput and low-latency data-path connection.

This will ensure that the VPC network where Cloud Volumes ONTAP instances are running is able to communicate with the GCVE Private Cloud. To do so, follow the GCP documentation. For the Cloud Volume Service, establish a connection between VMware Engine and Cloud Volumes Service by performing a one-time peering between the tenant host projects. For detailed steps, follow this link.

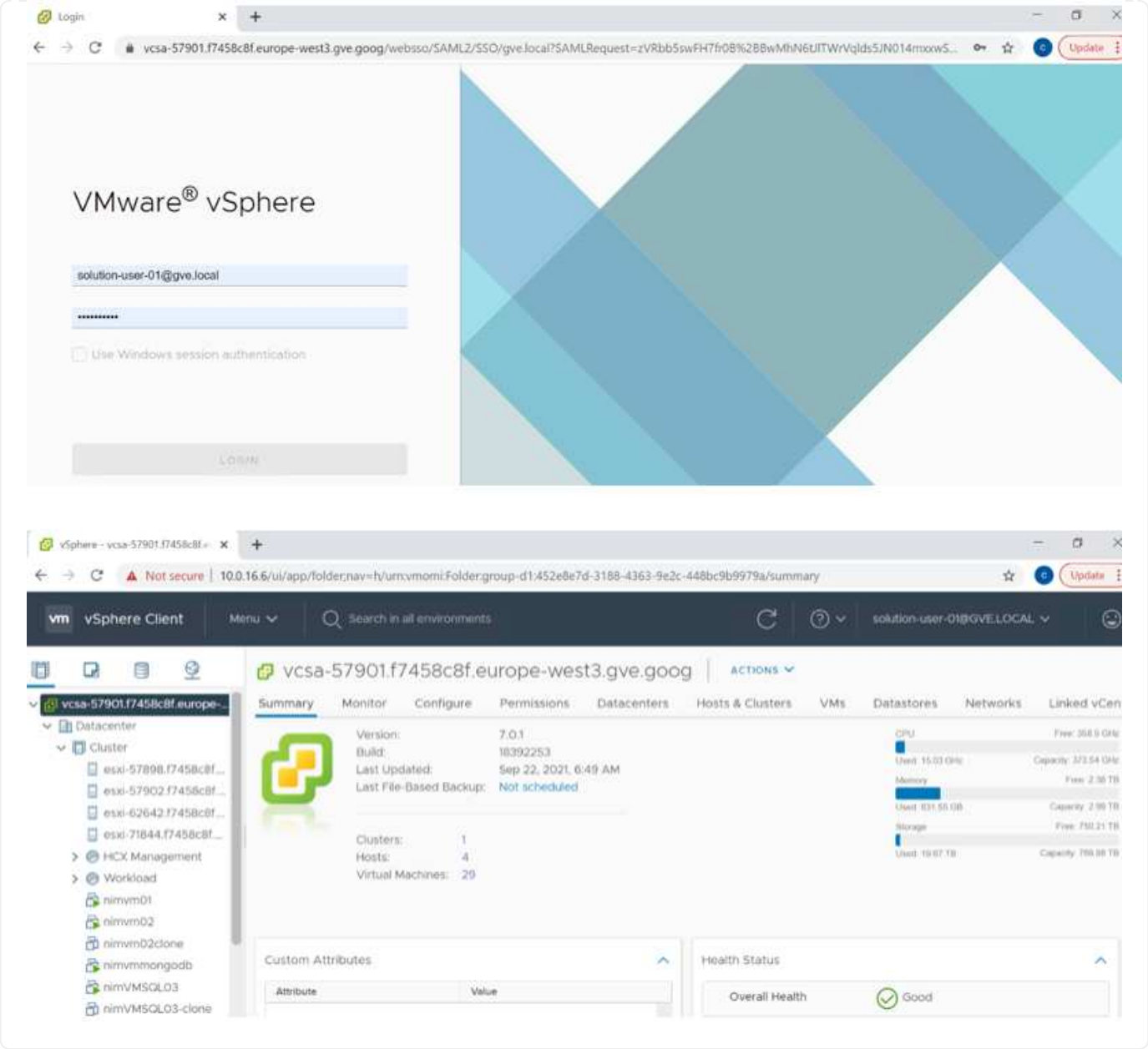
Tenant P	Service	Region	Routing Mode	Peered Project ID	Peered VPC	VPC Peering Sta...	Region Status
ke841388caa56b...	VPC Network	europe-west3	Global	cv-performance-te...	cloud-volumes-vpc	Active	Connected
jbd729510b3ebbf...	NetApp CVS	europe-west3	Global	y2b6c17202af6dc...	netapp-tenant-vpc	Active	Connected

Sign in to vcenter using the CloudOwner@gve.local user. To access the credentials, go to the VMware Engine portal, Go to Resources, and select the appropriate private cloud. In the Basic info section, click the View link for either vCenter login info (vCenter Server, HCX Manager) or NSX-T login info (NSX Manager).



In a Windows virtual machine, open a browser and navigate to the vCenter web client URL (https://10.0.16.6/) and use the admin user name as CloudOwner@gve.local and paste the copied password. Similarly, NSX-T manager can also be accessed using the web client URL (https://10.0.16.11/) and use the admin user name and paste the copied password to create new segments or modify the existing tier gateways.

For connecting from an on-premises network to VMware Engine private cloud, leverage cloud VPN or Cloud Interconnect for appropriate connectivity and make sure the required ports are open. For detailed steps, follow this link.



NetApp Storage options for Public Cloud Providers

Explore the options for NetApp as storage in the three major hyperscalers.

AWS / VMC

AWS supports NetApp storage in the following configurations:

- FSx ONTAP as guest connected storage
- Cloud Volumes ONTAP (CVO) as guest connected storage
- FSx ONTAP as a native datastore[1]

View the detailed guest connect storage options for VMC.

Read more about FSx ONTAP as a native datastore[1].

1 - Currently in Private Preview

Azure / AVS

Azure supports NetApp storage in the following configurations:

- Azure NetApp Files (ANF) as guest connected storage
- Cloud Volumes ONTAP (CVO) as guest connected storage
- Azure NetApp Files (ANF) as a native datastore[1]

View the detailed guest connect storage options for AVS.

Read more about Azure NetApp Files (ANF) as a native datastore[1].

1 - Currently in Private Preview

GCP / GCVE

Google Cloud supports NetApp storage in the following configurations:

- Cloud Volumes ONTAP (CVO) as guest connected storage
- Cloud Volumes Service (CVS) as guest connected storage
- Cloud Volumes Service (CVS) as a native datastore[1]

View the detailed guest connect storage options for GCVE.

Read more about Cloud Volumes Service (CVS) as a native datastore[1].

1 - Currently in Private Preview

NetApp Guest Connected Storage Options for AWS

AWS supports guest connected NetApp storage with the native FSx service (FSx ONTAP) or with Cloud Volumes ONTAP (CVO).

FSx ONTAP

Amazon FSx for NetApp ONTAP is a fully managed service that provides highly reliable, scalable, high-performing, and feature-rich file storage built on NetApp's popular ONTAP file system. FSx for ONTAP

combines the familiar features, performance, capabilities, and API operations of NetApp file systems with the agility, scalability, and simplicity of a fully managed AWS service.

FSx for ONTAP provides feature-rich, fast, and flexible shared file storage that's broadly accessible from Linux, Windows, and macOS compute instances running in AWS or on premises. FSx for ONTAP offers high-performance solid state drive (SSD) storage with submillisecond latencies. With FSx for ONTAP, you can achieve SSD levels of performance for your workload while paying for SSD storage for only a small fraction of your data.

Managing your data with FSx for ONTAP is easier because you can snapshot, clone, and replicate your files with the click of a button. In addition, FSx for ONTAP automatically tiers your data to lower-cost, elastic storage, lessening the need for you to provision or manage capacity.

FSx for ONTAP also provides highly available and durable storage with fully managed backups and support for cross-Region disaster recovery. To make it easier to protect and secure your data, FSx for ONTAP supports popular data security and antivirus applications.

FSx ONTAP as guest connected storage

Configure Amazon FSx for NetApp ONTAP with VMware Cloud on AWS

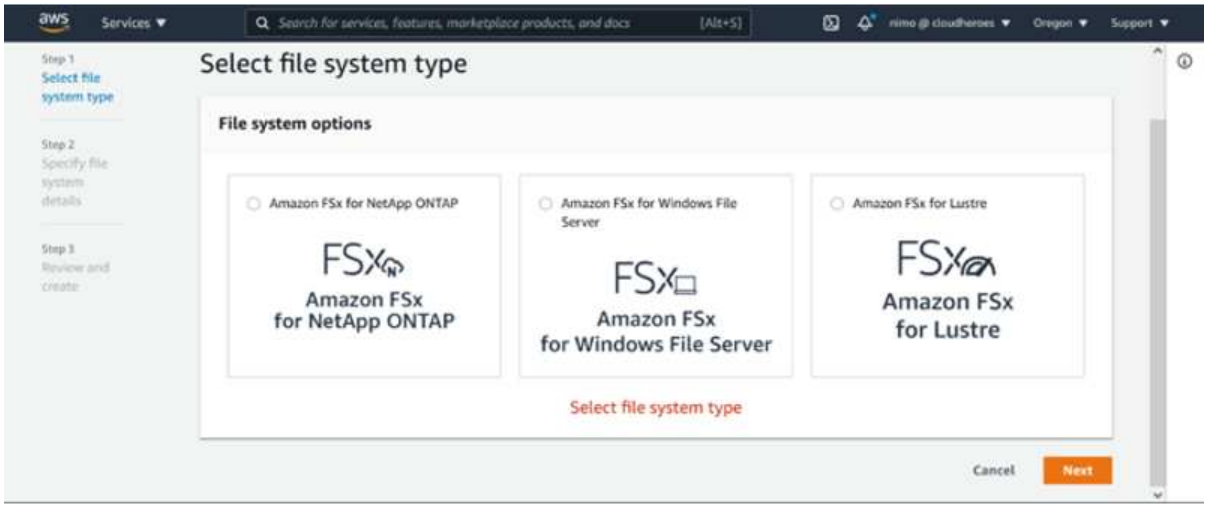
Amazon FSx for NetApp ONTAP files shares and LUNs can be mounted from VMs that are created within the VMware SDDC environment at VMware Cloud at AWS. The volumes can also be mounted on the Linux client and mapped on the Windows client using the NFS or SMB protocol, and LUNS can be accessed on Linux or Windows clients as block devices when mounted over iSCSI. Amazon FSx for the NetApp ONTAP file system can be set up quickly with the following steps.

Amazon FSx for NetApp ONTAP and VMware Cloud on AWS must be in the same availability zone to achieve better performance and avoid data transfer charges between availability zones.

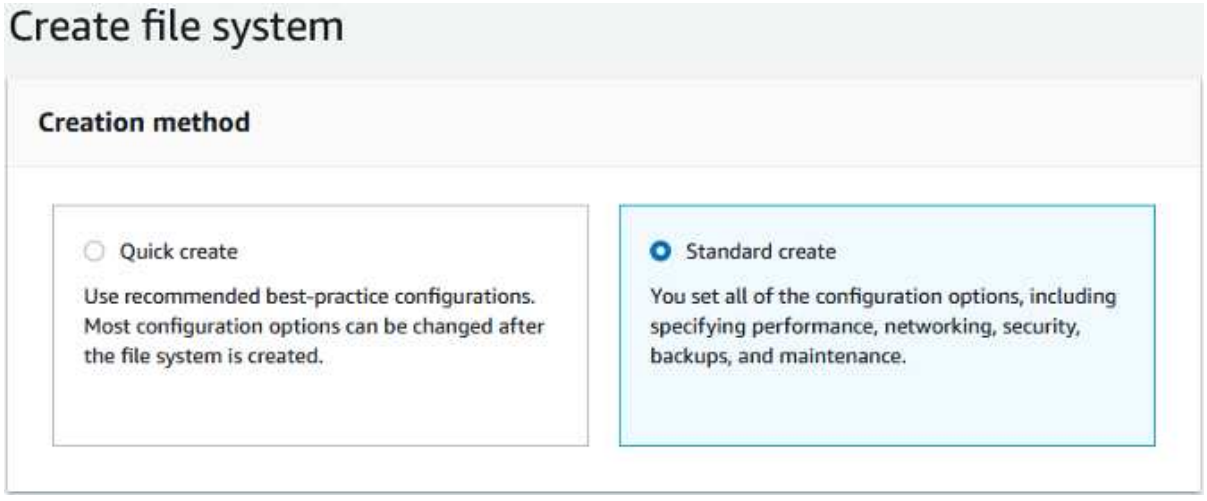
Create and mount Amazon FSx for ONTAP volumes

To create and mount Amazon FSx for NetApp ONTAP file system, complete the following steps:

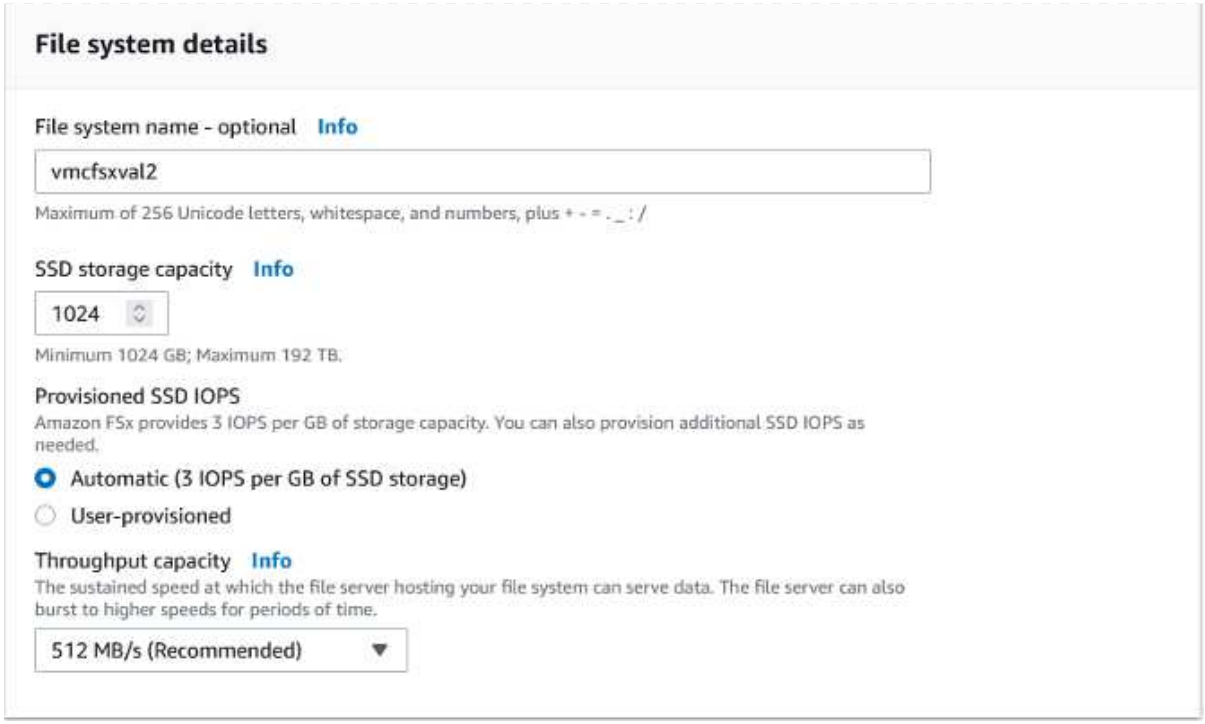
1. Open the Amazon FSx console and choose Create file system to start the file system creation wizard.
2. On the Select File System Type page, choose Amazon FSx for NetApp ONTAP, and then choose Next. The Create File System page appears.



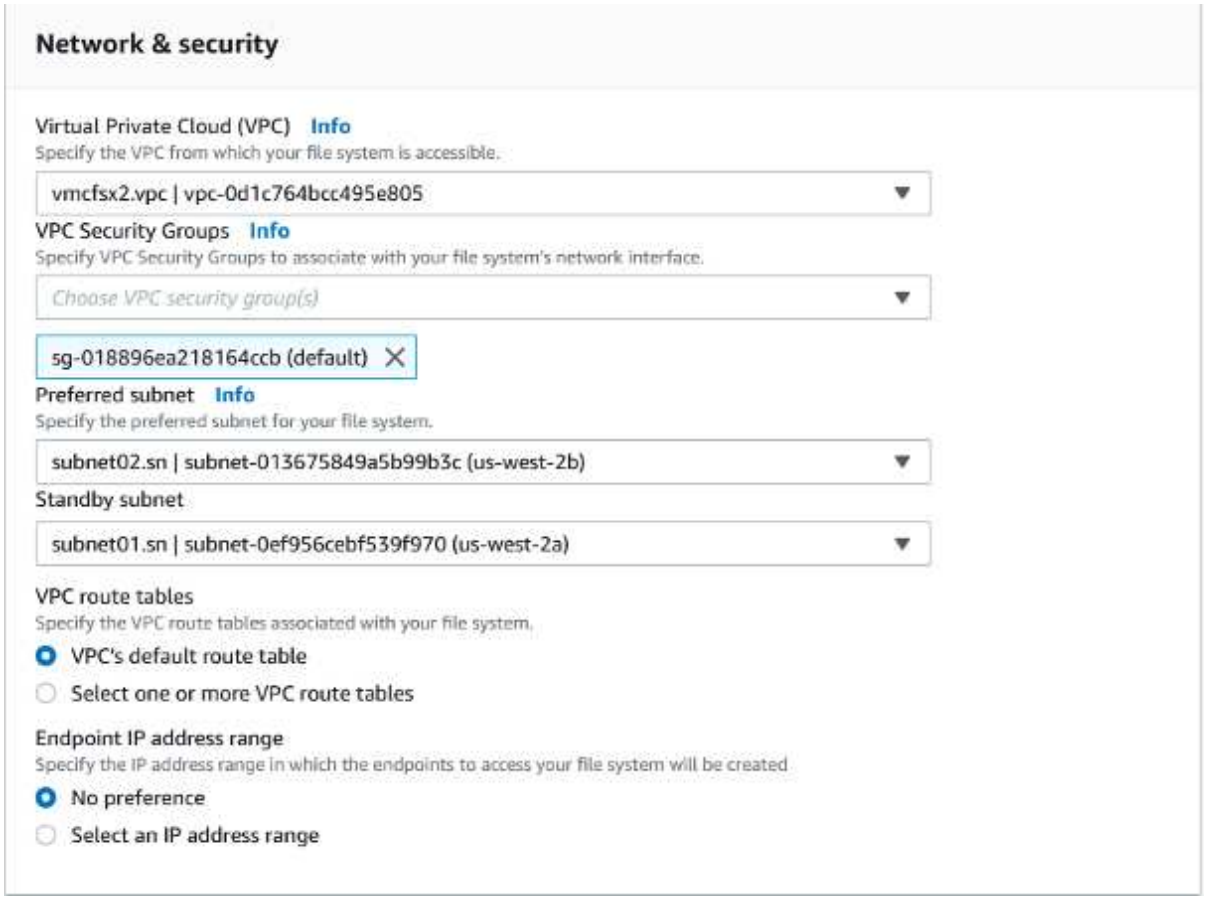
3. In the Networking section, for Virtual Private Cloud (VPC), choose the appropriate VPC and preferred subnets along with the route table. In this case, vmcfsx2.vpc is selected from the dropdown.



4. For the creation method, choose Standard Create. You can also choose Quick Create, but this document uses the Standard create option.

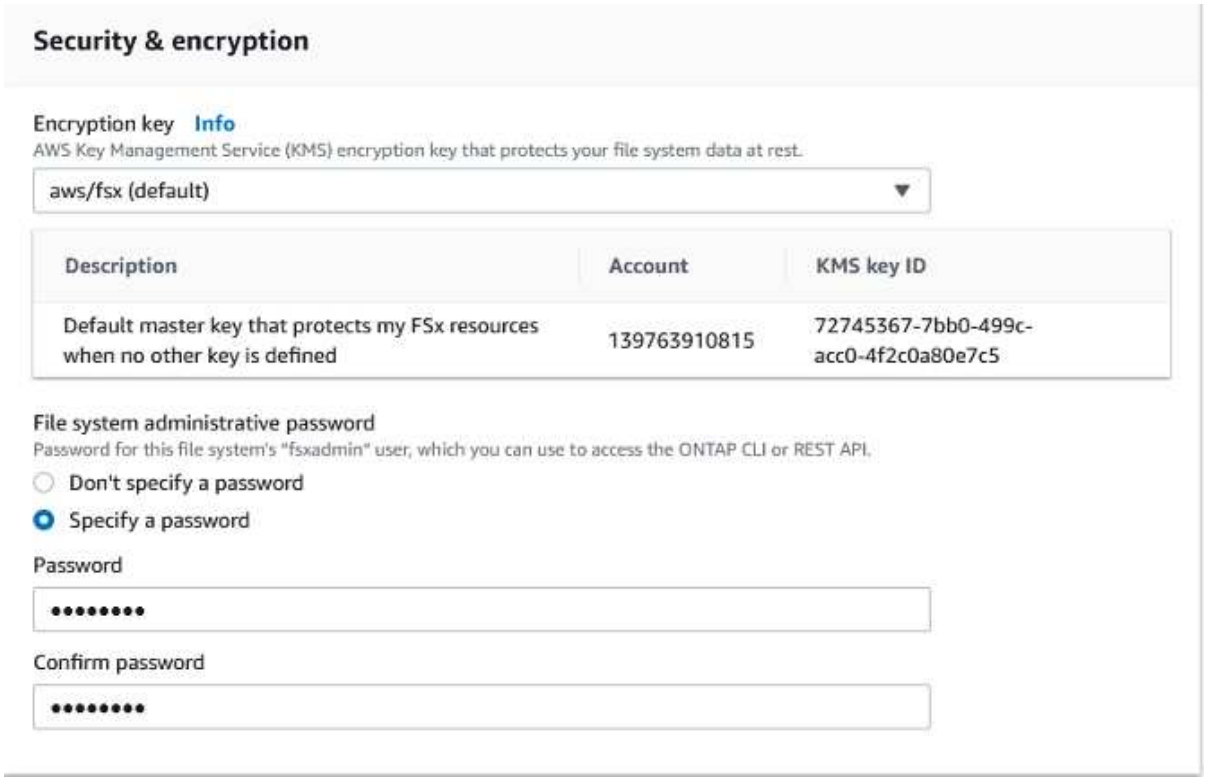


5. In the Networking section, for Virtual Private Cloud (VPC), choose the appropriate VPC and preferred subnets along with the route table. In this case, vmcfsx2.vpc is selected from the dropdown.

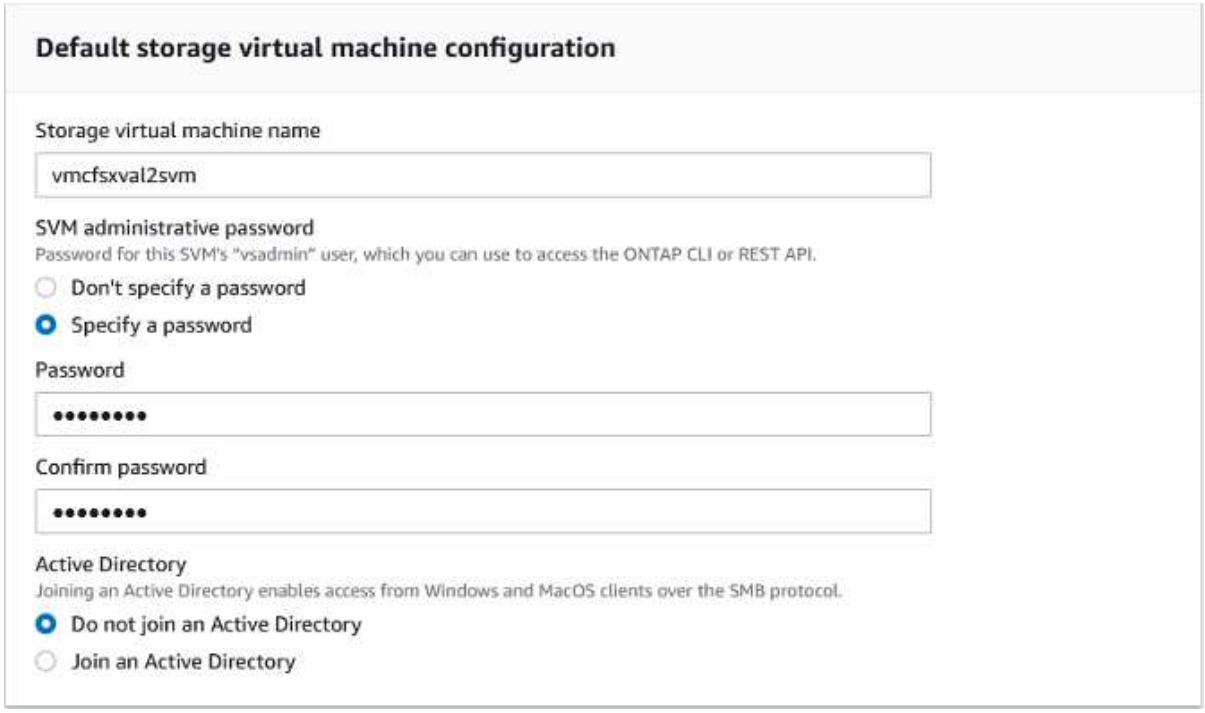


In the Networking section, for Virtual Private Cloud (VPC), choose the appropriate VPC and preferred subnets along with the route table. In this case, vmcfsx2.vpc is selected from the dropdown.

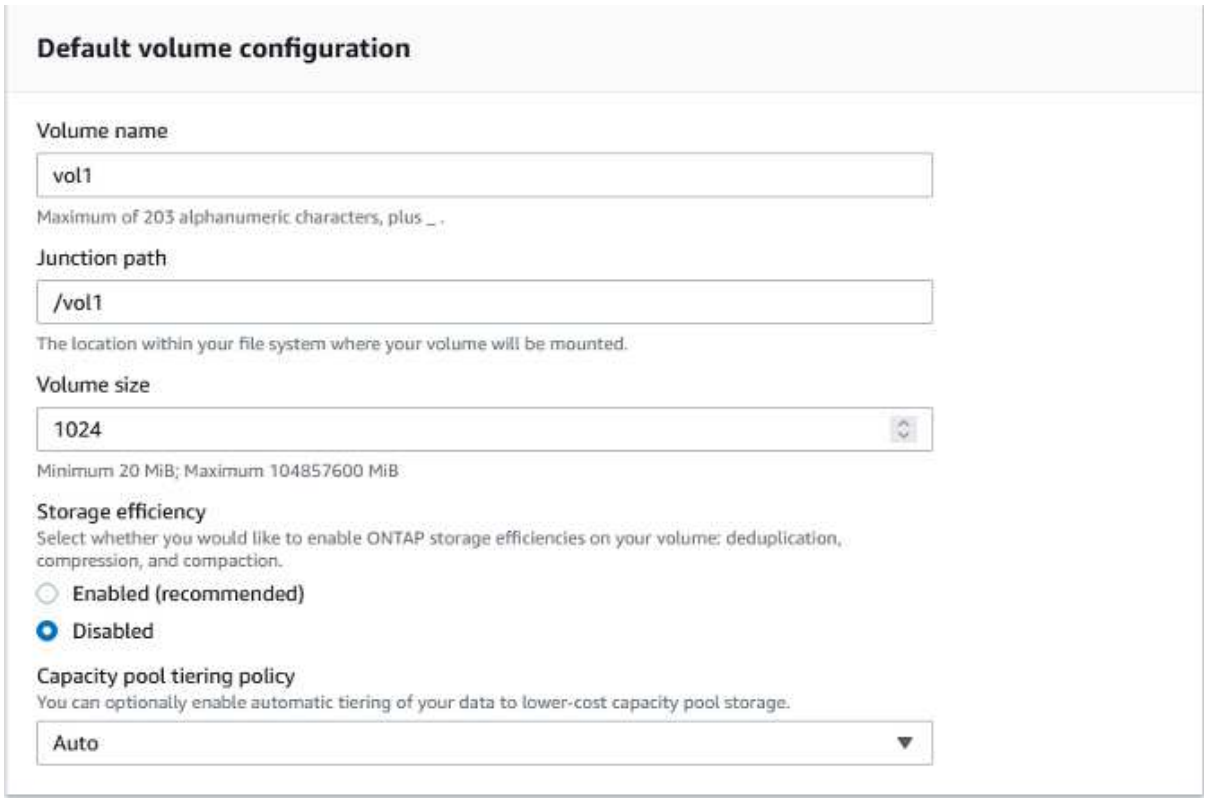
6. In the Security & Encryption section, for the Encryption Key, choose the AWS Key Management Service (AWS KMS) encryption key that protects the file system's data at rest. For the File System Administrative Password, enter a secure password for the fsxadmin user.



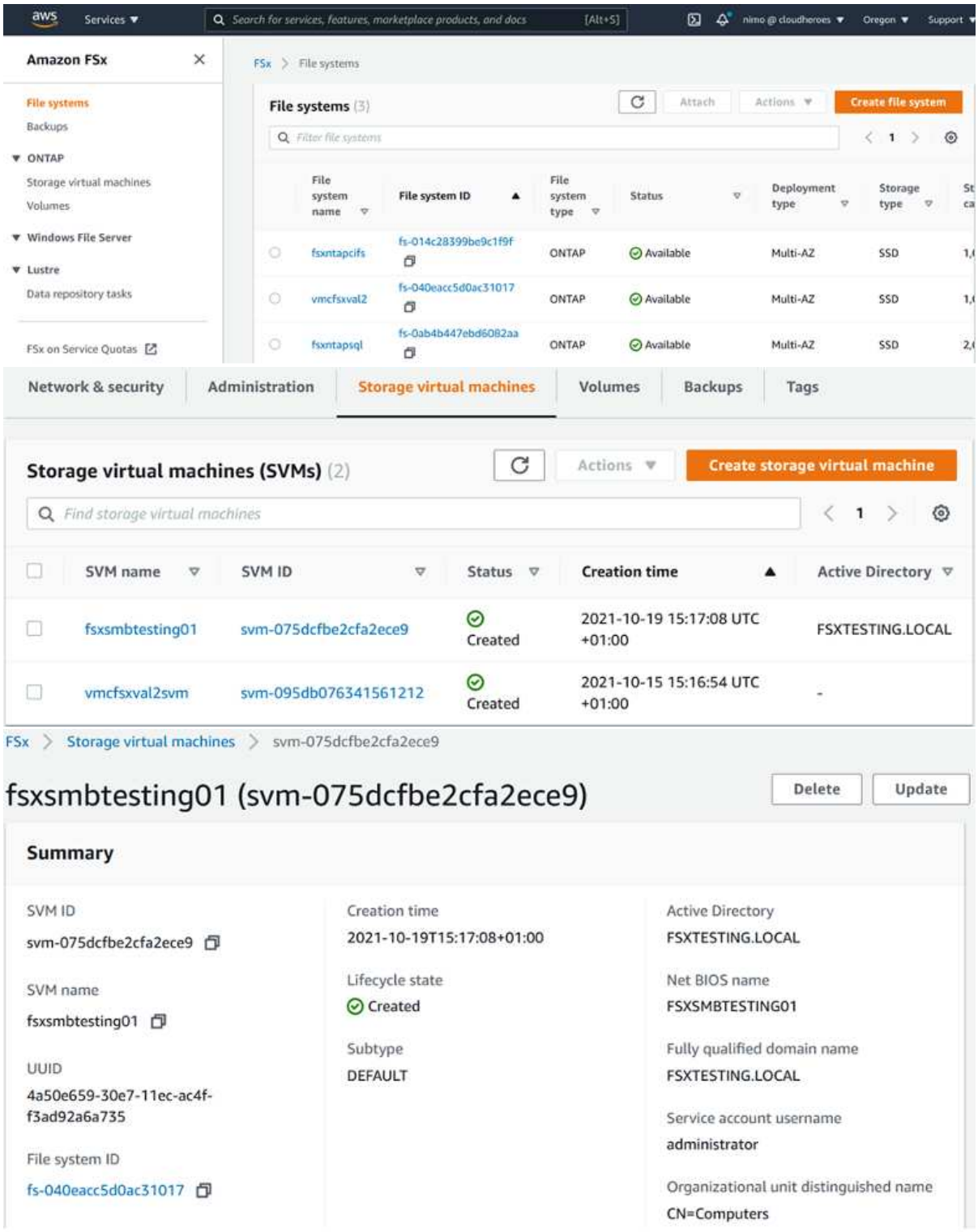
7. In virtual machine and specify the password to use with vsadmin for administering ONTAP using REST APIs or the CLI. If no password is specified, a fsxadmin user can be used for administering the SVM. In the Active Directory section, make sure to join Active Directory to the SVM for provisioning SMB shares. In the Default Storage Virtual Machine Configuration section, provide a name for the storage in this validation, SMB shares are provisioned using a self-managed Active Directory domain.



8. In the Default Volume Configuration section, specify the volume name and size. This is an NFS volume. For Storage Efficiency, choose Enabled to turn on the ONTAP storage efficiency features (compression, deduplication, and compaction) or Disabled to turn them off.



9. Review the file system configuration shown on the Create File System page.
10. Click Create File System.



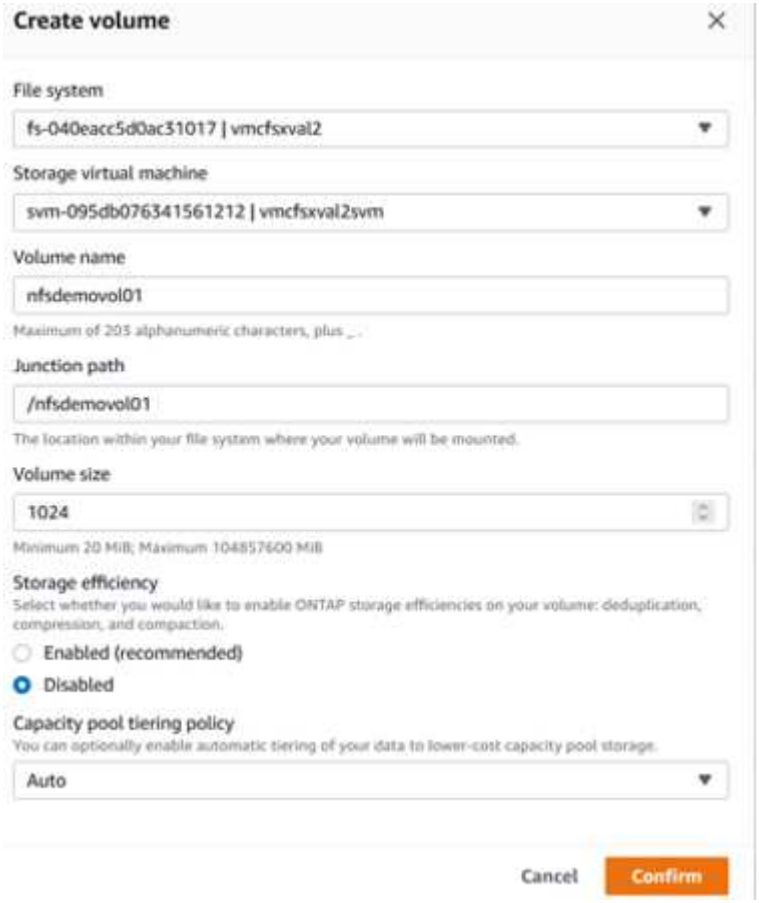
For more detailed information, see Getting started with Amazon FSx for NetApp ONTAP.

After the file system is created as above, create the volume with the required size and protocol.

1. Open the Amazon FSx console.
2. In the left navigation pane, choose File systems, and then choose the ONTAP file system that you want to create a volume for.
3. Select the Volumes tab.

4. Select the Create Volume tab.
5. The Create Volume dialog box appears.

For demo purposes, an NFS volume is created in this section that can be easily mounted on VMs running on VMware cloud on AWS. nfsdemovol01 is created as depicted below:



Mount FSx ONTAP volume on Linux client

To mount the FSx ONTAP volume created in the previous step. from the Linux VMs within VMC on AWS SDDC, complete the following steps:

1. Connect to the designated Linux instance.
2. Open a terminal on the instance using Secure Shell (SSH) and log in with the appropriate credentials.
3. Make a directory for the volume's mount point with the following command:

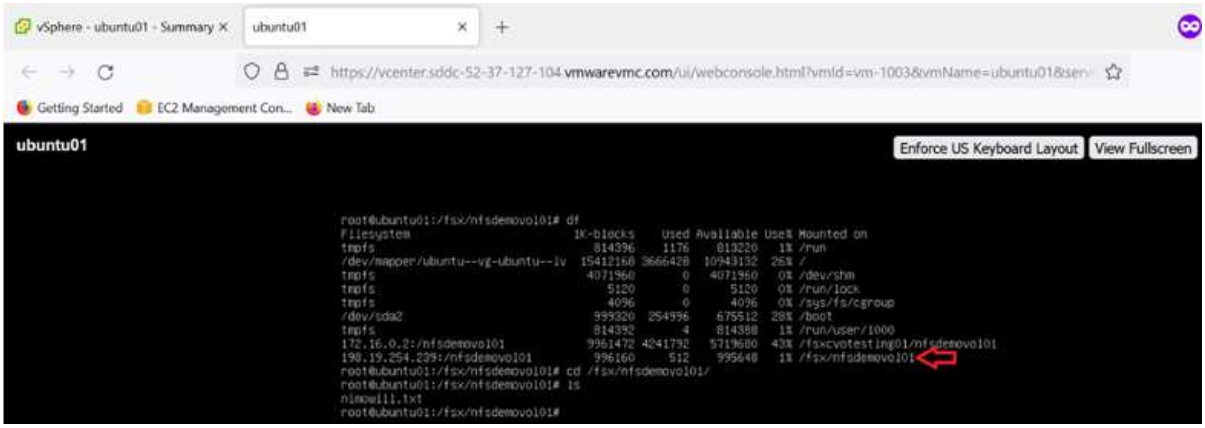
```
$ sudo mkdir /fsx/nfsdemovol01
```

4. Mount the Amazon FSx for NetApp ONTAP NFS volume to the directory that is created in the previous step.

```
sudo mount -t nfs nfsvers=4.1,198.19.254.239:/nfsdemovol01
/fsx/nfsdemovol01
```

```
root@ubuntu01:/fsx/nfsdemovol01# mount -t nfs 198.19.254.239:/nfsdemovol01 /fsx/nfsdemovol01
```

5. Once executed, run the df command to validate the mount.



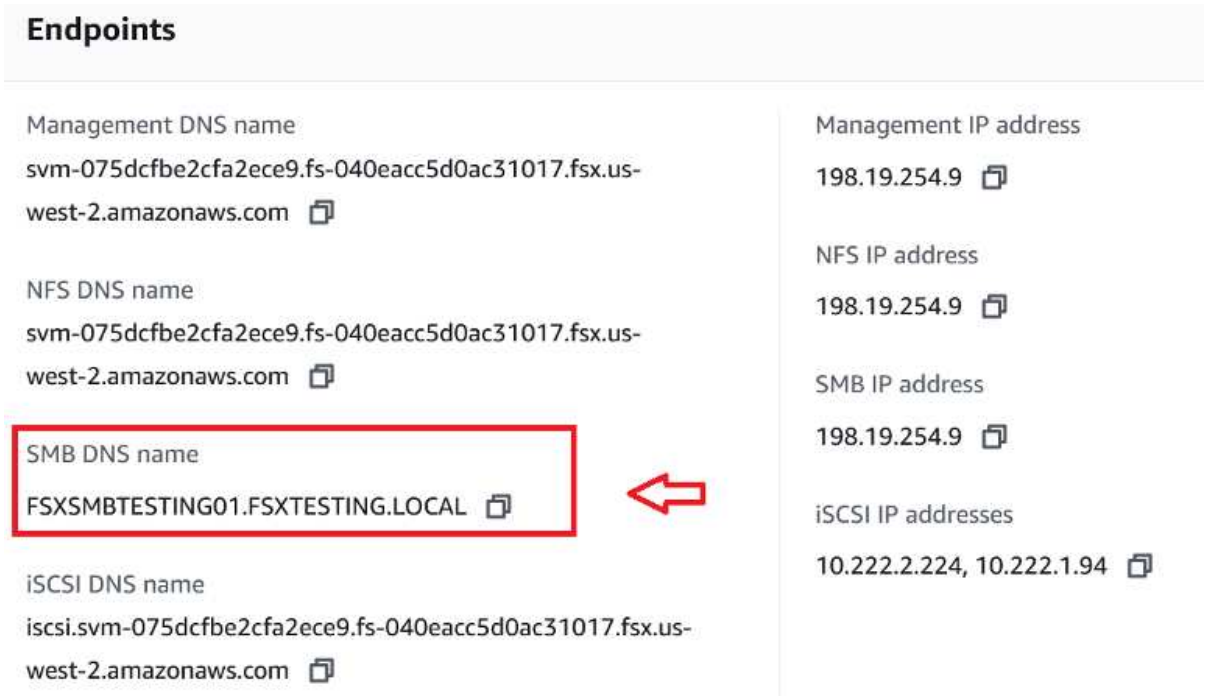
► https://docs.netapp.com/us-en/netapp-solutions/media/vmc_linux_vm_nfs.mp4 *(video)*

Attach FSx ONTAP volumes to Microsoft Windows clients

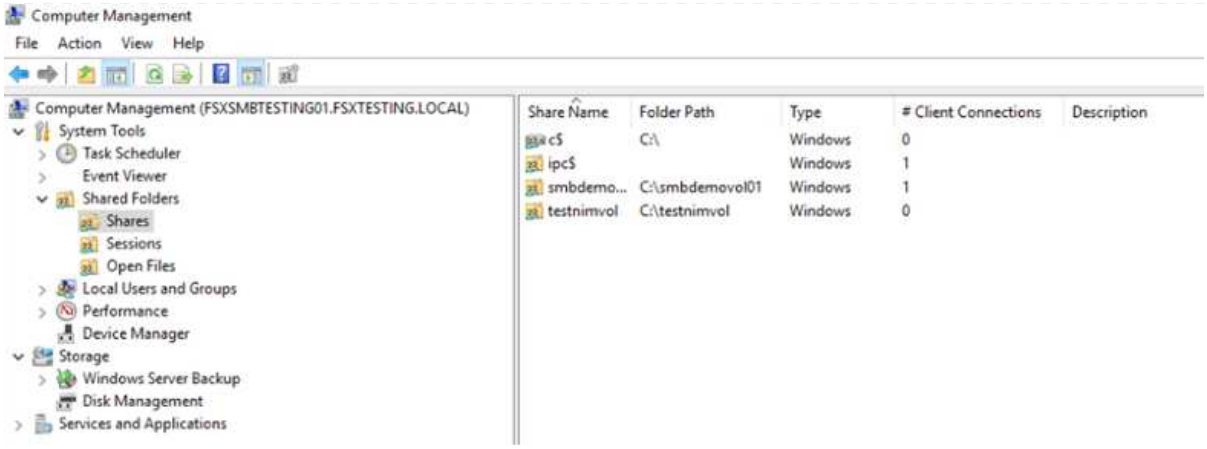
To manage and map file shares on an Amazon FSx file system, the Shared Folders GUI must be used.

1. Open the Start menu and run fsmgmt.msc using Run As Administrator. Doing this opens the Shared Folders GUI tool.
2. Click Action > All tasks and choose Connect to Another Computer.
3. For Another Computer, enter the DNS name for the storage virtual machine (SVM). For example, FSXSMBTESTING01.FSXTESTING.LOCAL is used in this example.

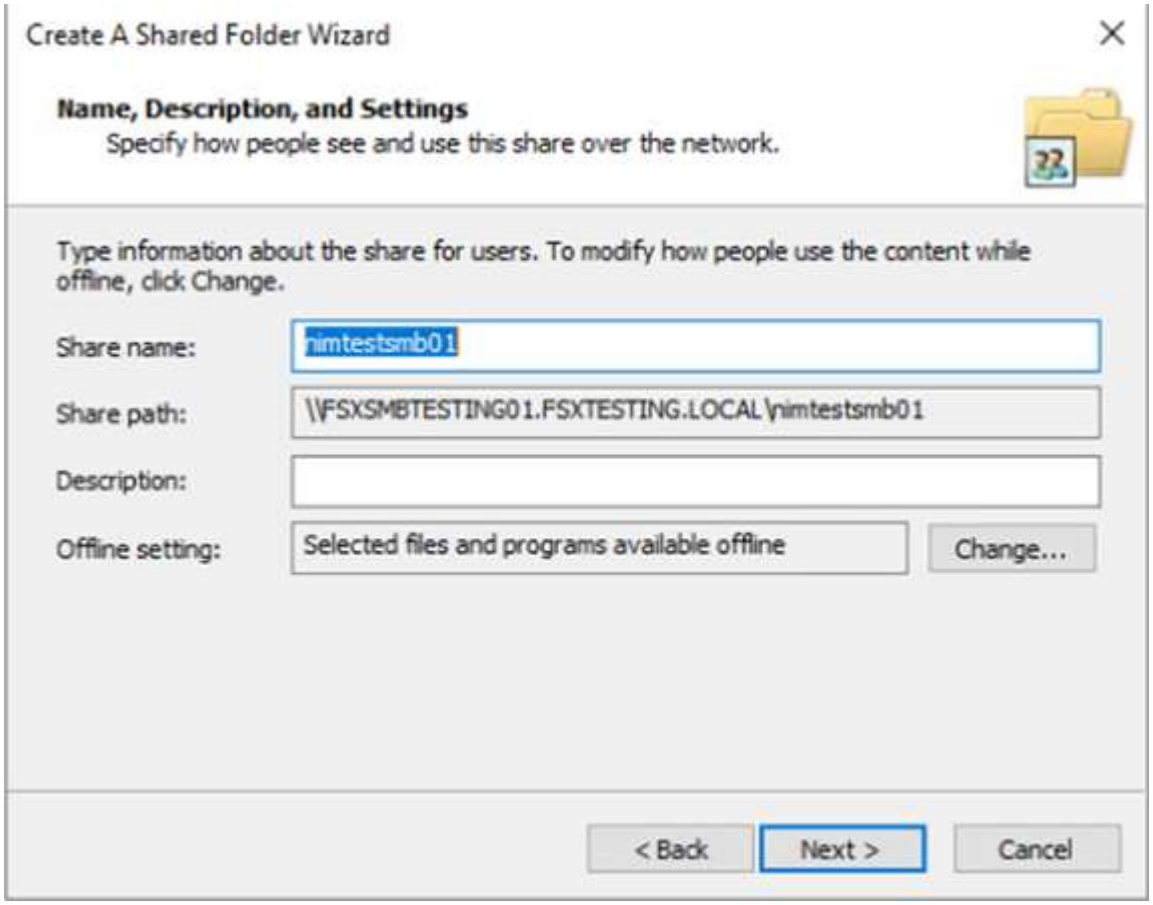
   Tp find the SVM's DNS name on the Amazon FSx console, choose Storage Virtual Machines, choose SVM, and then scroll down to Endpoints to find the SMB DNS name. Click OK. The Amazon FSx file system appears in the list for the Shared Folders.



4. In the Shared Folders tool, choose Shares in the left pane to see the active shares for the Amazon FSx file system.

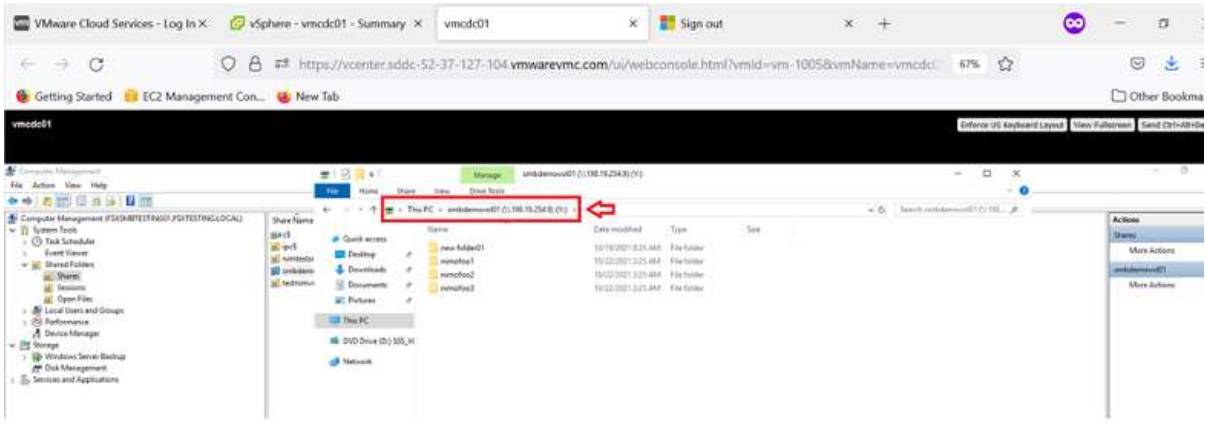


5. Now choose a new share and complete the Create a Shared Folder wizard.



To learn more about creating and managing SMB shares on an Amazon FSx file system, see Creating SMB Shares.

6. After connectivity is in place, the SMB share can be attached and used for application data. To accomplish this, Copy the share path and use the Map Network Drive option to mount the volume on the VM running on VMware Cloud on the AWS SDDC.



Connect a FSx for NetApp ONTAP LUN to a host using iSCSI

► https://docs.netapp.com/us-en/netapp-solutions/media/vmc_windows_vm_iscsi.mp4 *(video)*

iSCSI traffic for FSx traverses the VMware Transit Connect/AWS Transit Gateway via the routes provided in the previous section. To configure a LUN in Amazon FSx for NetApp ONTAP, follow the documentation found here.

On Linux clients, make sure that the iSCSI daemon is running. After the LUNs are provisioned, refer to the detailed guidance on iSCSI configuration with Ubuntu (as an example) here.

In this paper, connecting the iSCSI LUN to a Windows host is depicted:

Provision a LUN in FSx for NetApp ONTAP:

1. Access the NetApp ONTAP CLI using the management port of the FSx for the ONTAP file system.
2. Create the LUNs with the required size as indicated by the sizing output.

```
FsxId040eacc5d0ac31017::> lun create -vserver vmcfsxval2svm
-volume nimfsxscsivol -lun nimofsxlun01 -size 5gb -ostype
windows -space-reserve enabled
```

   In this example, we created a LUN of size 5g (5368709120).

3. Create the necessary igroups to control which hosts have access to specific LUNs.

```
FsxId040eacc5d0ac31017::> igroup create -vserver vmcfsxval2svm
-igroup winIG -protocol iscsi -ostype windows -initiator
iqn.1991-05.com.microsoft:vmcdc01.fsxtesting.local

FsxId040eacc5d0ac31017::> igroup show

Vserver   Igroup       Protocol OS Type  Initiators

--------- ------------ -------- --------
------------------------------------

vmcfsxval2svm

          ubuntu01     iscsi    linux    iqn.2021-
10.com.ubuntu:01:initiator01

vmcfsxval2svm

          winIG        iscsi    windows  iqn.1991-
05.com.microsoft:vmcdc01.fsxtesting.local
```

   Two entries were displayed.

4. Map the LUNs to igroups using the following command:

```
FsxId040eacc5d0ac31017::> lun map -vserver vmcfsxval2svm -path
/vol/nimfsxscsivol/nimofsxlun01 -igroup winIG

FsxId040eacc5d0ac31017::> lun show

Vserver   Path                            State   Mapped   Type
Size

--------- ------------------------------ ------- --------
-------- --------

vmcfsxval2svm

          /vol/blocktest01/lun01          online  mapped   linux
5GB

vmcfsxval2svm

          /vol/nimfsxscsivol/nimofsxlun01 online  mapped
windows       5GB
```

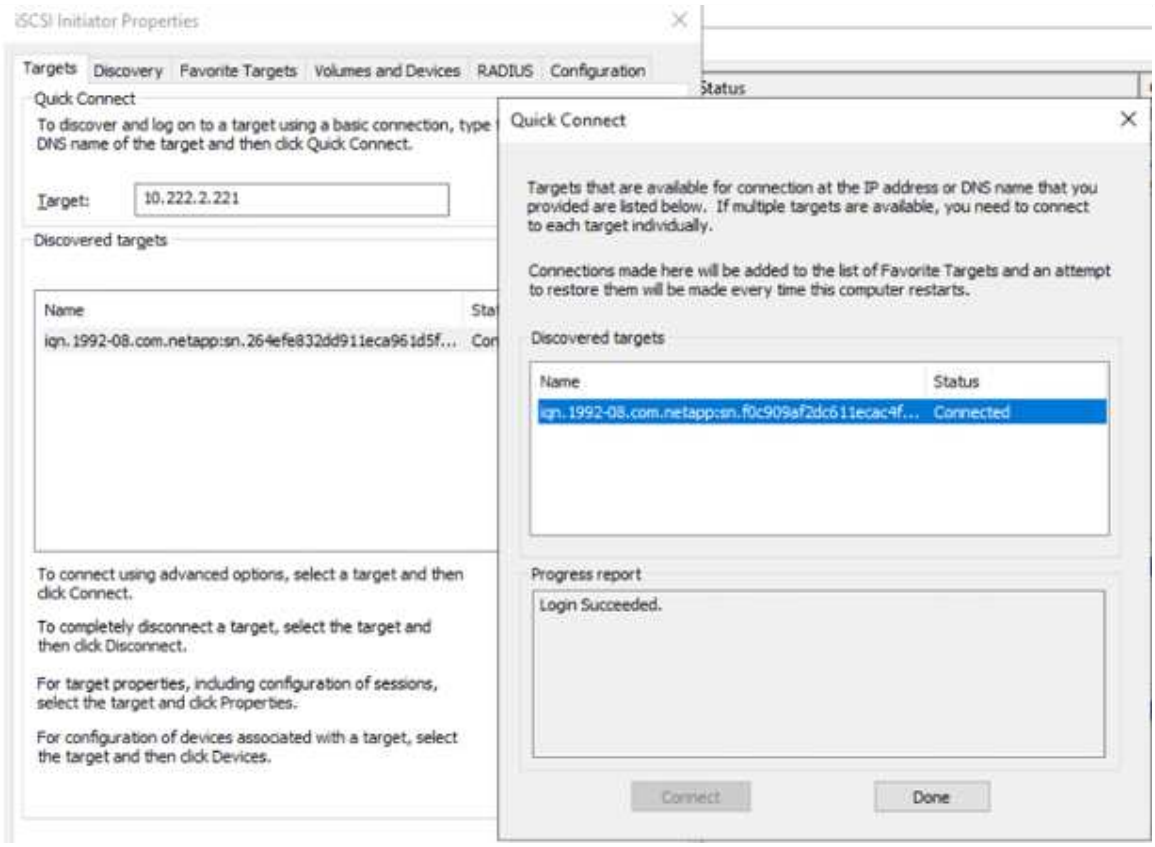
Two entries were displayed.

5. Connect the newly provisioned LUN to a Windows VM:

   To connect the new LUN tor a Windows host residing on VMware cloud on AWS SDDC, complete the following steps:

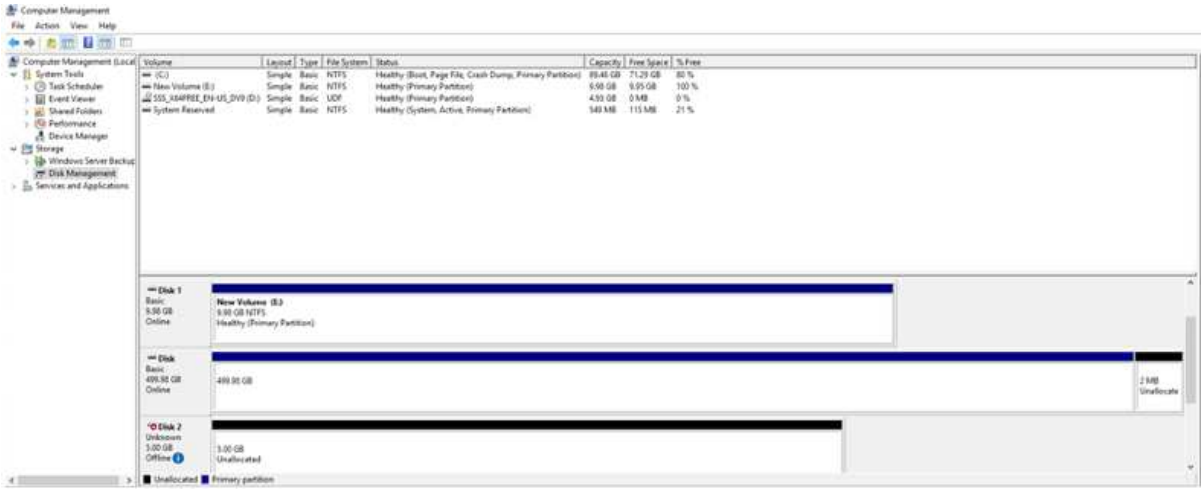
   a. RDP to the Windows VM hosted on the VMware Cloud on AWS SDDC.
   b. Navigate to Server Manager > Dashboard > Tools > iSCSI Initiator to open the iSCSI Initiator Properties dialog box.
   c. From the Discovery tab, click Discover Portal or Add Portal and then enter the IP address of the iSCSI target port.
   d. From the Targets tab, select the target discovered and then click Log On or Connect.
   e. Select Enable Multipath, and then select “Automatically Restore This Connection When the Computer Starts” or “Add This Connection to the List of Favorite Targets”. Click Advanced.

   > The Windows host must have an iSCSI connection to each node in the cluster. The native DSM selects the best paths to use.



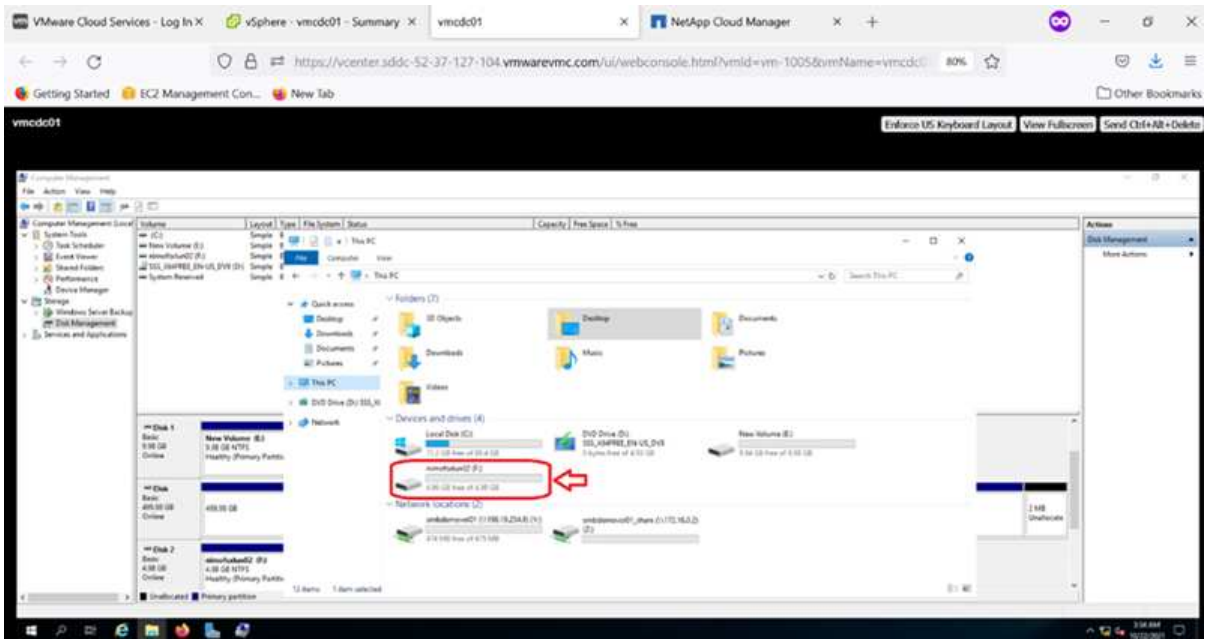
LUNs on the storage virtual machine (SVM) appear as disks to the Windows host. Any new disks that are added are not automatically discovered by the host. Trigger a manual rescan to discover the disks by completing the following steps:

1. Open the Windows Computer Management utility: Start > Administrative Tools > Computer Management.
2. Expand the Storage node in the navigation tree.
3. Click Disk Management.
4. Click Action > Rescan Disks.



When a new LUN is first accessed by the Windows host, it has no partition or file system. Initialize the LUN and, optionally, format the LUN with a file system by completing the following steps:

1. Start Windows Disk Management.
2. Right-click the LUN, and then select the required disk or partition type.
3. Follow the instructions in the wizard. In this example, drive F: is mounted.



Cloud Volumes ONTAP (CVO)

Cloud volumes ONTAP, or CVO, is the industry-leading cloud data management solution built on NetApp's ONTAP storage software, available natively on Amazon Web Services (AWS), Microsoft Azure and Google Cloud Platform (GCP).

It is a software-defined version of ONTAP that consumes cloud-native storage, allowing you to have the same storage software in the cloud and on-premises, reducing the need to retrain you IT staff in all-new methods to manage your data.

CVO gives customers the ability to seamlessly move data from the edge, to the data center, to the cloud and back, bringing your hybrid cloud together — all managed with a single-pane management console, NetApp Cloud Manager.

By design, CVO delivers extreme performance and advanced data management capabilities to satisfy even your most demanding applications in the cloud

Cloud Volumes ONTAP (CVO) as guest connected storage

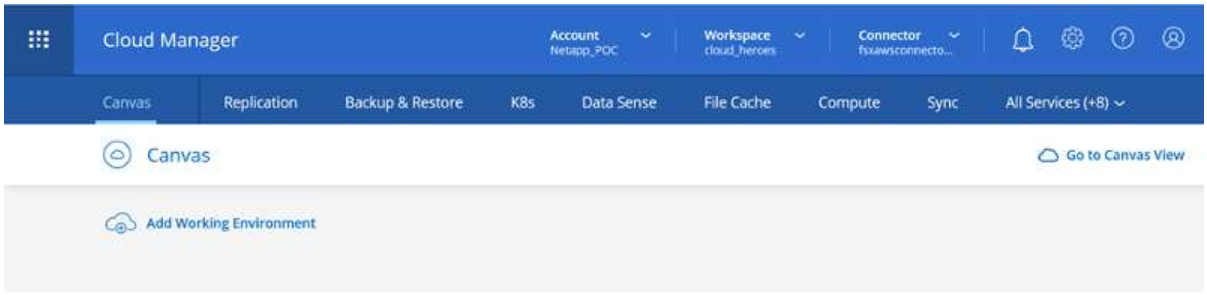
Deploy new Cloud Volumes ONTAP instance in AWS (do it yourself)

Cloud Volumes ONTAP shares and LUNs can be mounted from VMs that are created in the VMware Cloud on AWS SDDC environment. The volumes can also be mounted on native AWS VM Linux Windows clients, and LUNS can be accessed on Linux or Windows clients as block devices when mounted over iSCSI because Cloud Volumes ONTAP supports iSCSI, SMB, and NFS protocols. Cloud Volumes ONTAP volumes can be set up in a few simple steps.

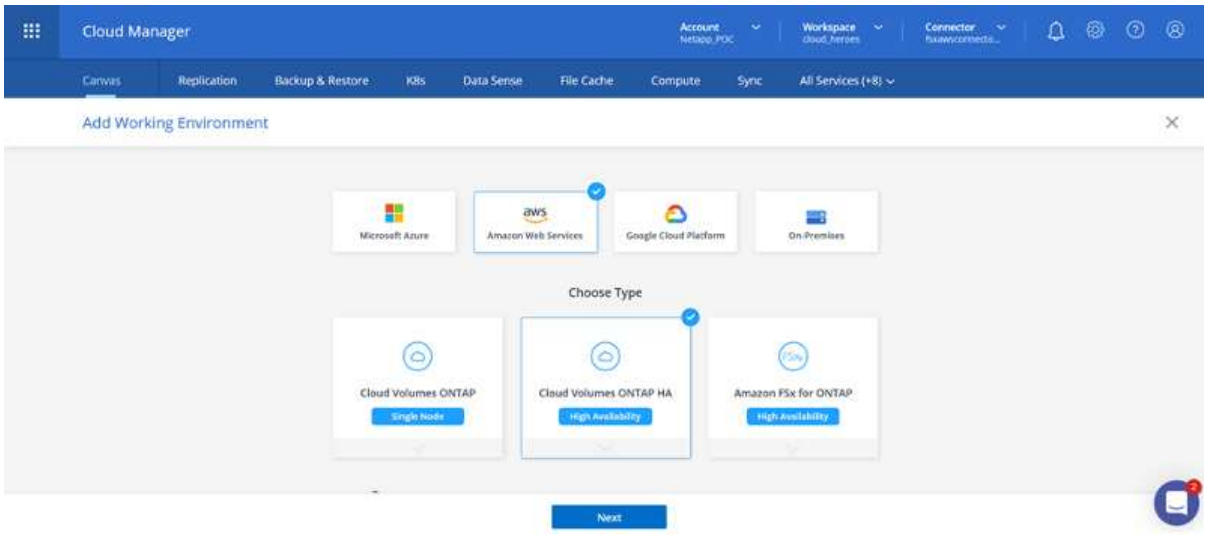
To replicate volumes from an on-premises environment to the cloud for disaster recovery or migration purposes, establish network connectivity to AWS, either using a site-to-site VPN or DirectConnect. Replicating data from on-premises to Cloud Volumes ONTAP is outside the scope of this document. To replicate data between on-premises and Cloud Volumes ONTAP systems, see Setting up data replication between systems.

Use the Cloud Volumes ONTAP sizer to accurately size the Cloud Volumes ONTAP instances. Also, monitor on-premises performance to use as inputs in the Cloud Volumes ONTAP sizer.

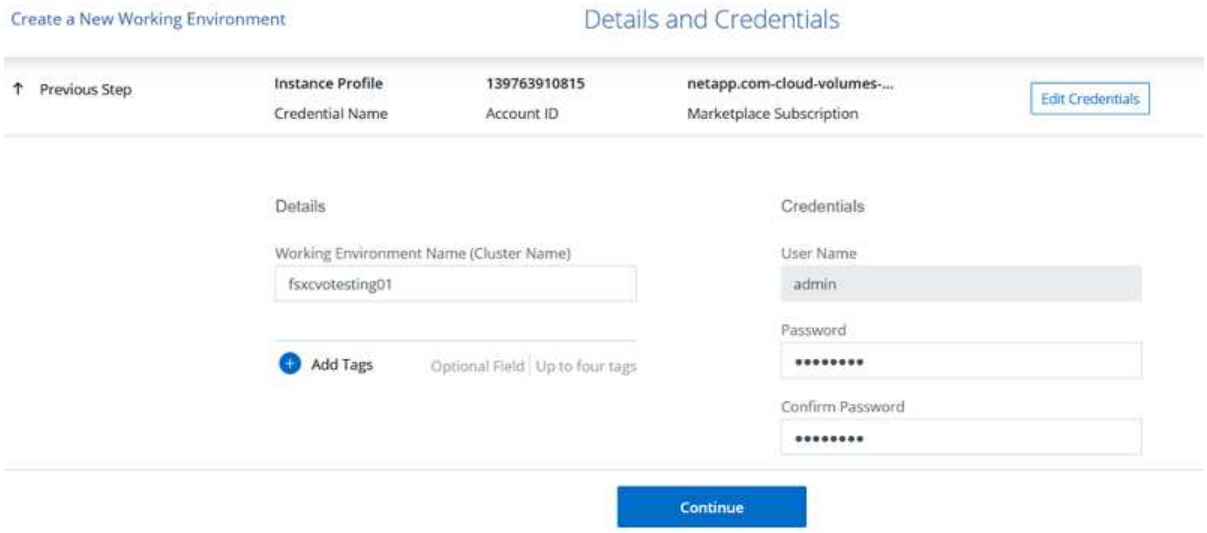
1. Log into NetApp Cloud Central; the Fabric View screen is displayed. Locate the Cloud Volumes ONTAP tab and select Go to Cloud Manager. After you are logged in, the Canvas screen is displayed.



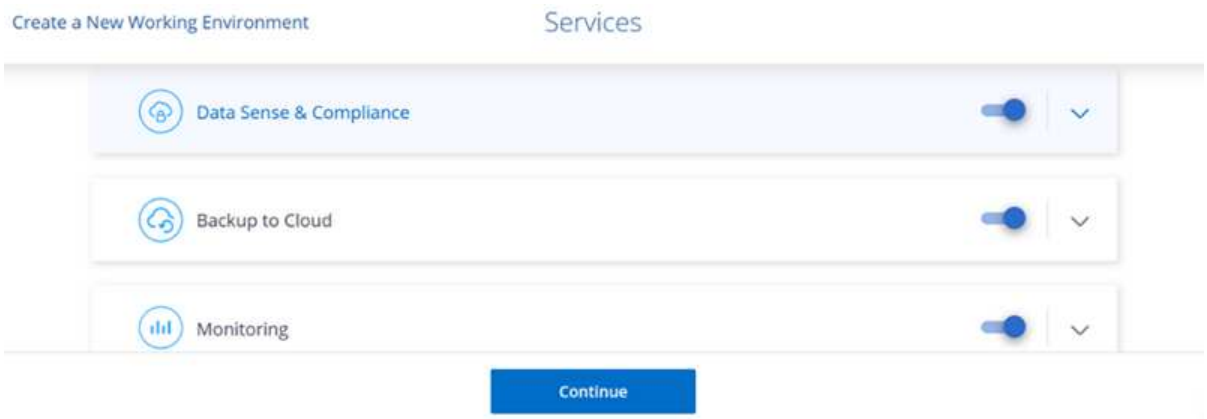
2. On the Cloud Manager home page, click Add a Working Environment and then select AWS as the cloud and the type of the system configuration.



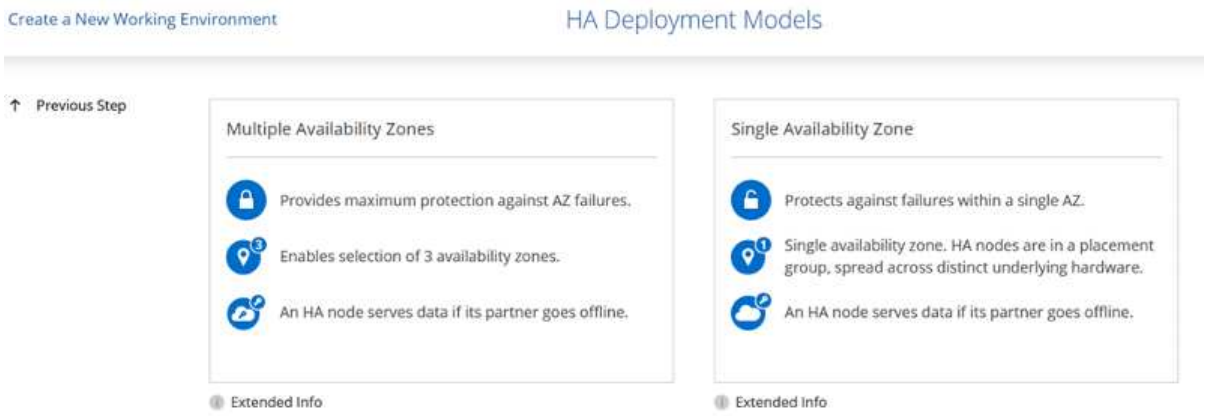
3. Provide the details of the environment to be created including the environment name and admin credentials. Click Continue.



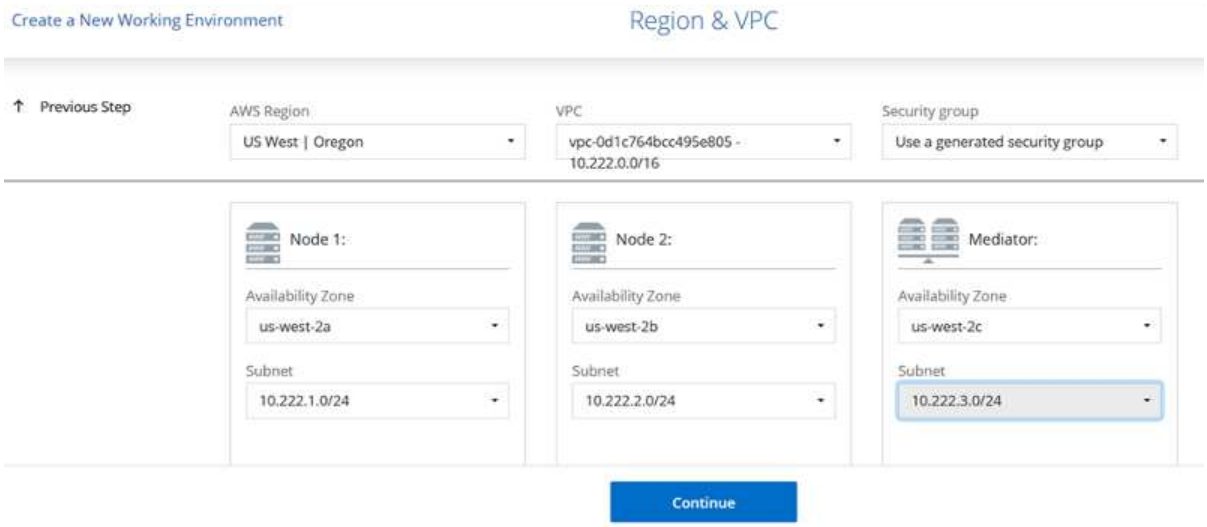
4. Select the add-on services for Cloud Volumes ONTAP deployment, including Cloud Data Sense, Cloud Backup, and Cloud Insights. Click Continue.



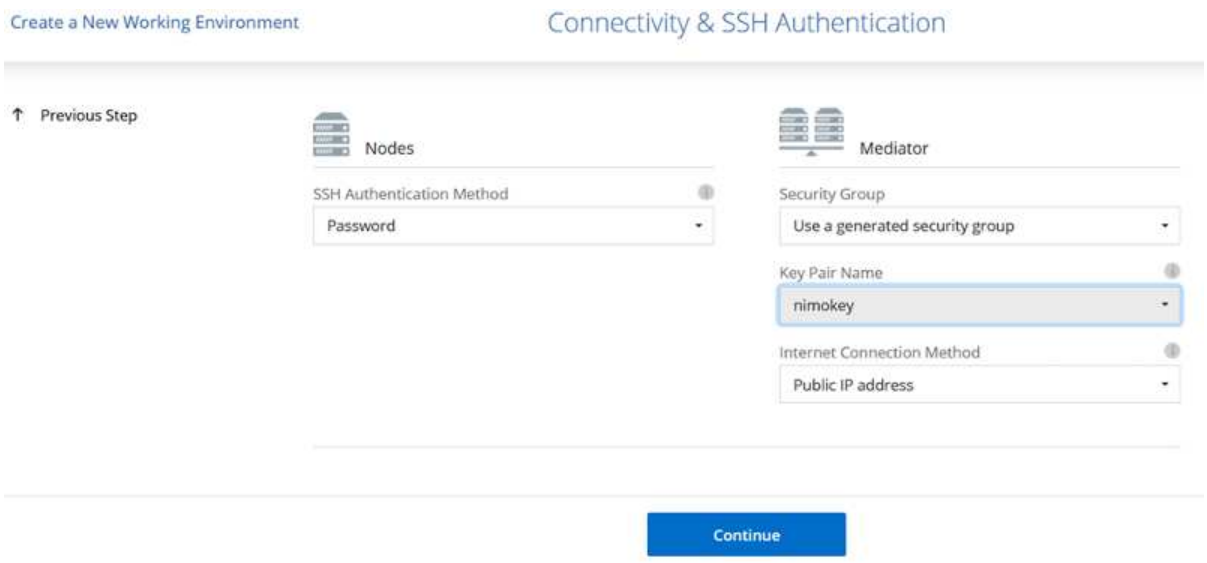
5. On the HA Deployment Models page, choose the Multiple Availability Zones configuration.



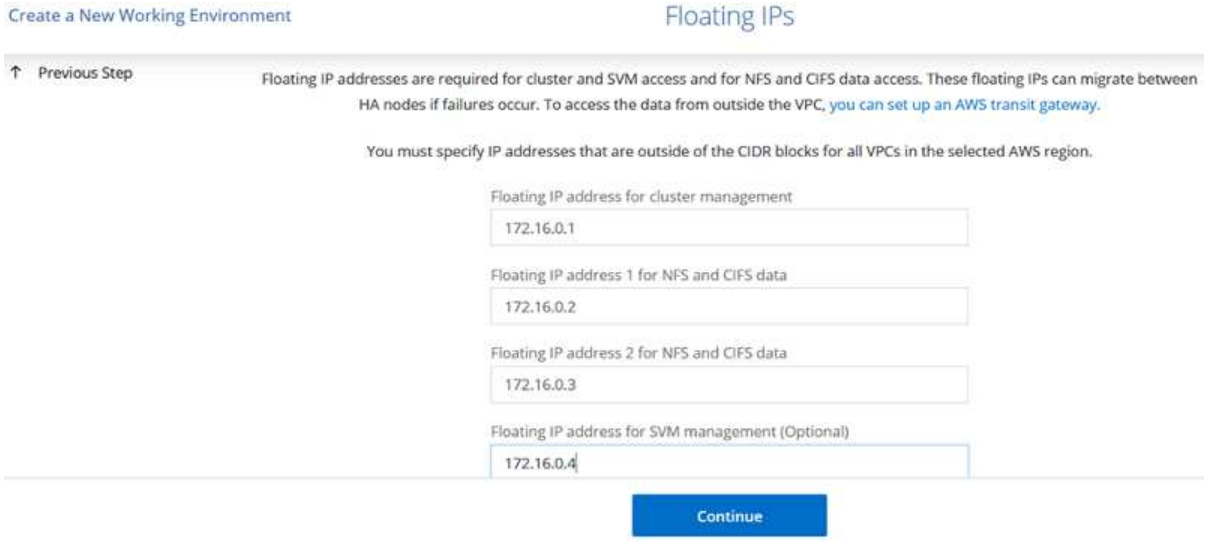
6. On the Region & VPC page, enter the network information and then click Continue.



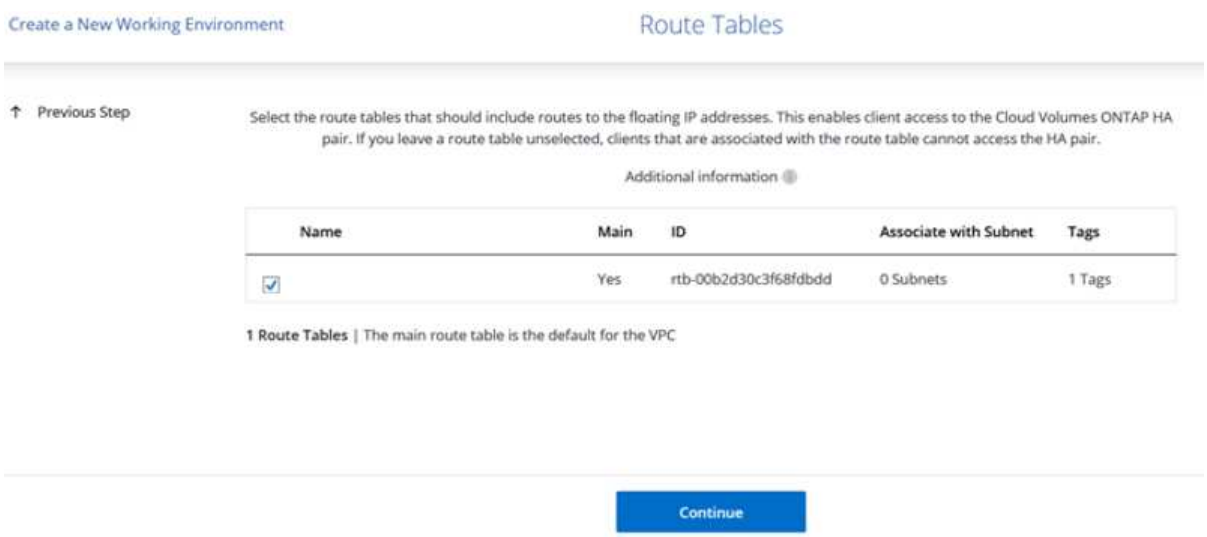
7. On the Connectivity and SSH Authentication page, choose connection methods for the HA pair and the mediator.



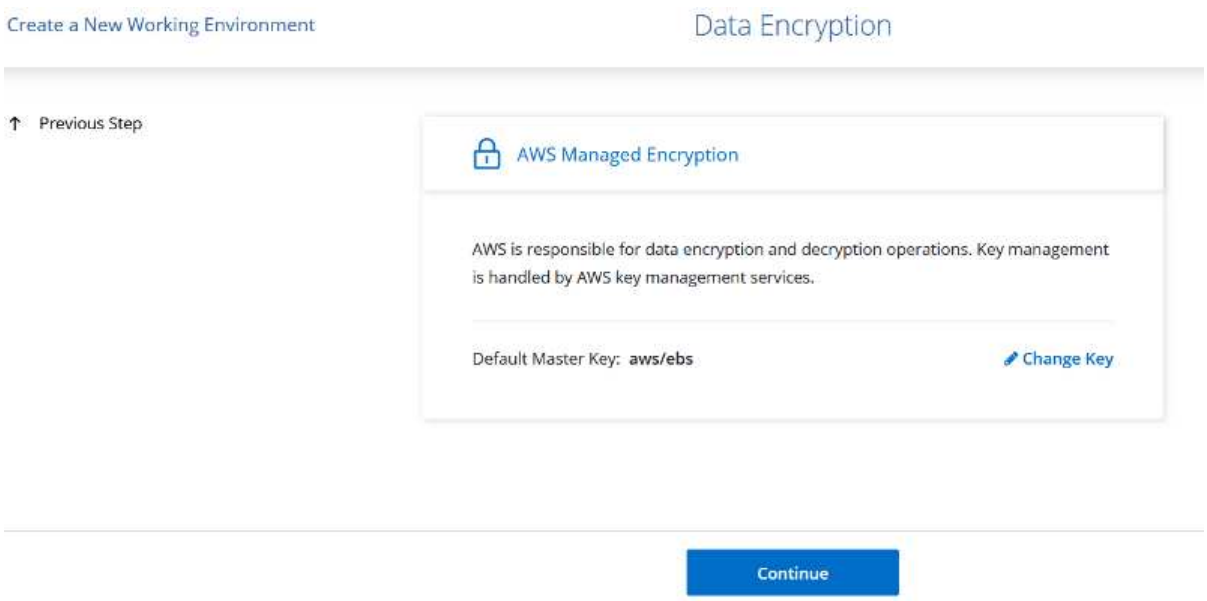
8. Specify the floating IP addresses and then click Continue.



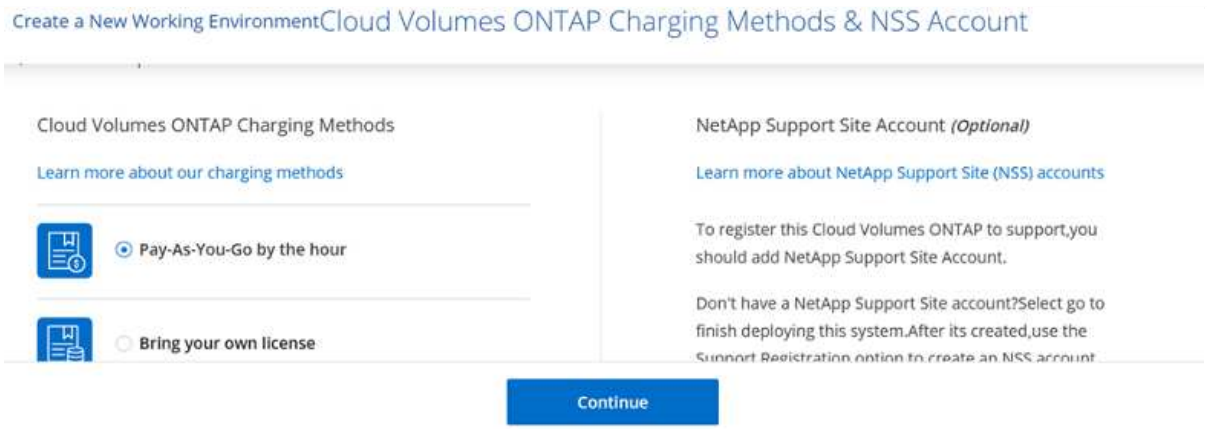
9. Select the appropriate route tables to include routes to the floating IP addresses and then click Continue.



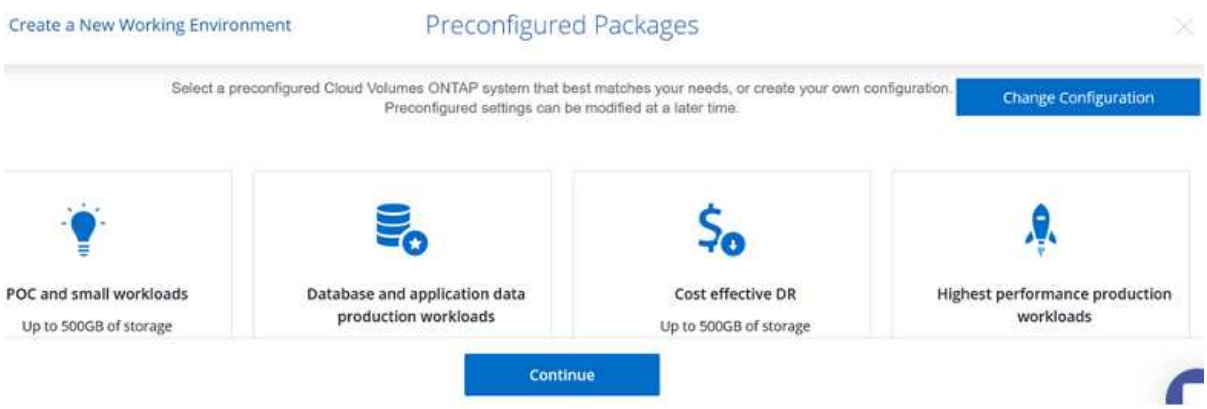
10. On the Data Encryption page, choose AWS-managed encryption.



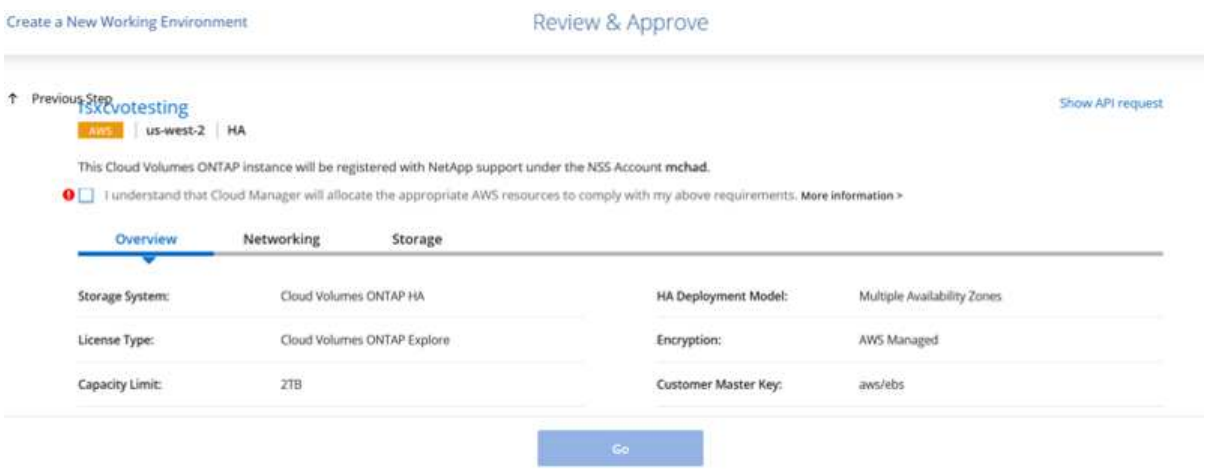
11. Select the license option: Pay-As-You-Go or BYOL for using an existing license. In this example, the Pay-As-You-Go option is used.



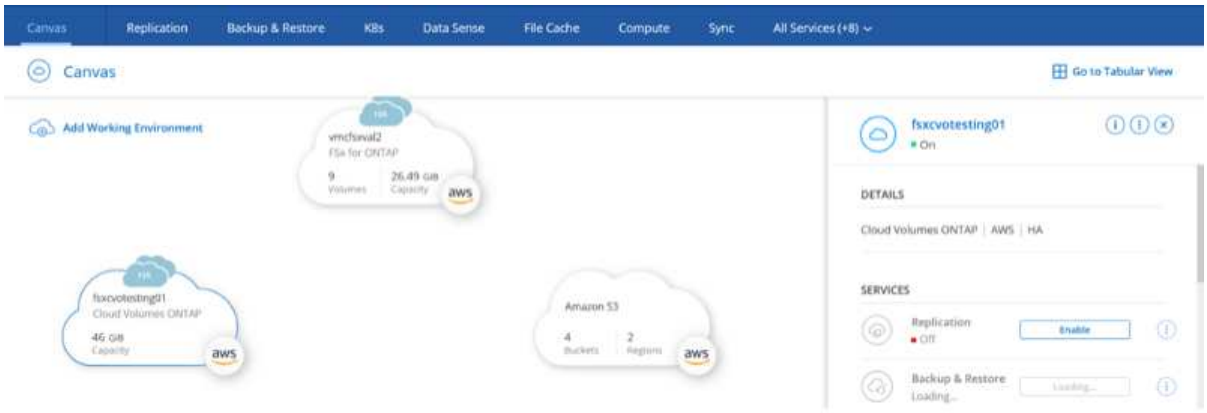
12. Select between several preconfigured packages available based on the type of workload to be deployed on the VMs running on the VMware cloud on AWS SDDC.



13. On the Review & Approve page, review and confirm the selections.To create the Cloud Volumes ONTAP instance, click Go.

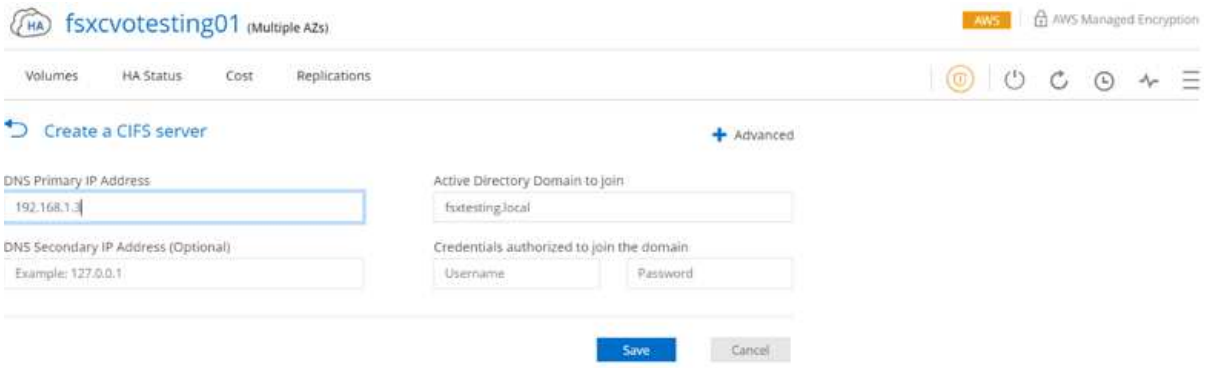


14. After Cloud Volumes ONTAP is provisioned, it is listed in the working environments on the Canvas page.

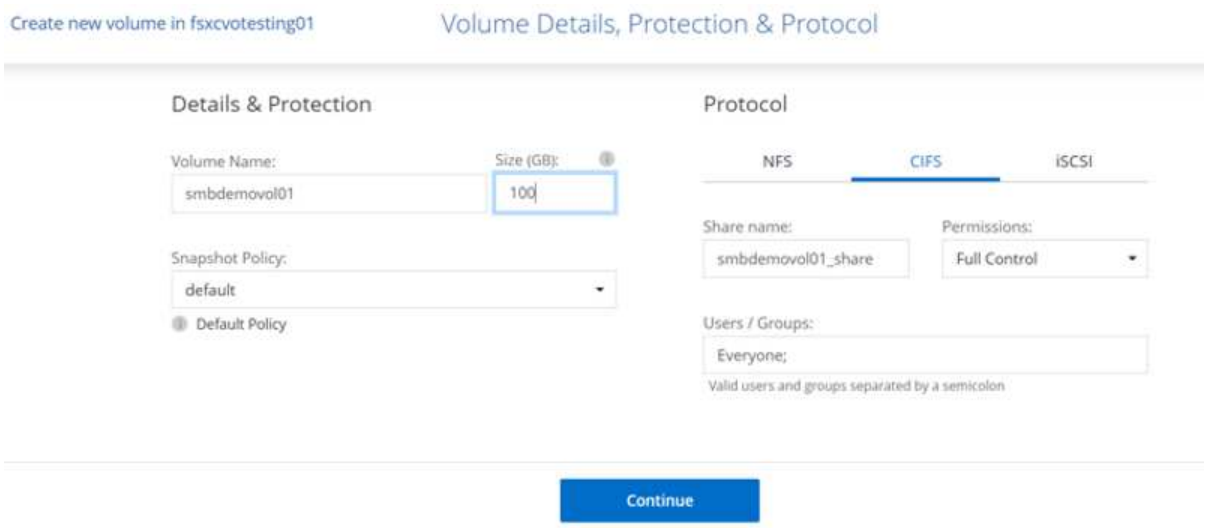

Canvas
Replication
Backup & Restore
K8s
Data Sense
File Cache
Compute
Sync
All Services (+8)
Canvas
Go to Tabular View
Add Working Environment
vmchsnvl2
FSx for ONTAP
9
Volumes
26.49 GiB
Capacity
aws
fsxcvotesting01
Cloud Volumes ONTAP
46 GiB
Capacity
aws
Amazon S3
4
Buckets
2
Regions
aws
fsxcvotesting01
On
DETAILS
Cloud Volumes ONTAP | AWS | HA
SERVICES
Replication
Off
Enable
Backup & Restore
Loading...

Additional configurations for SMB volumes

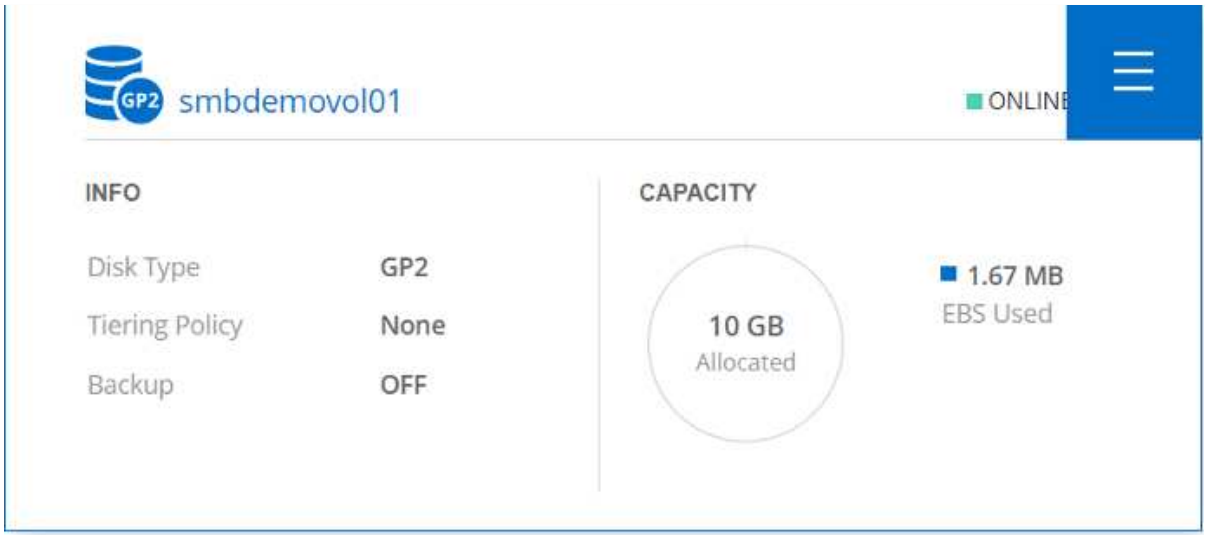
1. After the working environment is ready, make sure the CIFS server is configured with the appropriate DNS and Active Directory configuration parameters. This step is required before you can create the SMB volume.



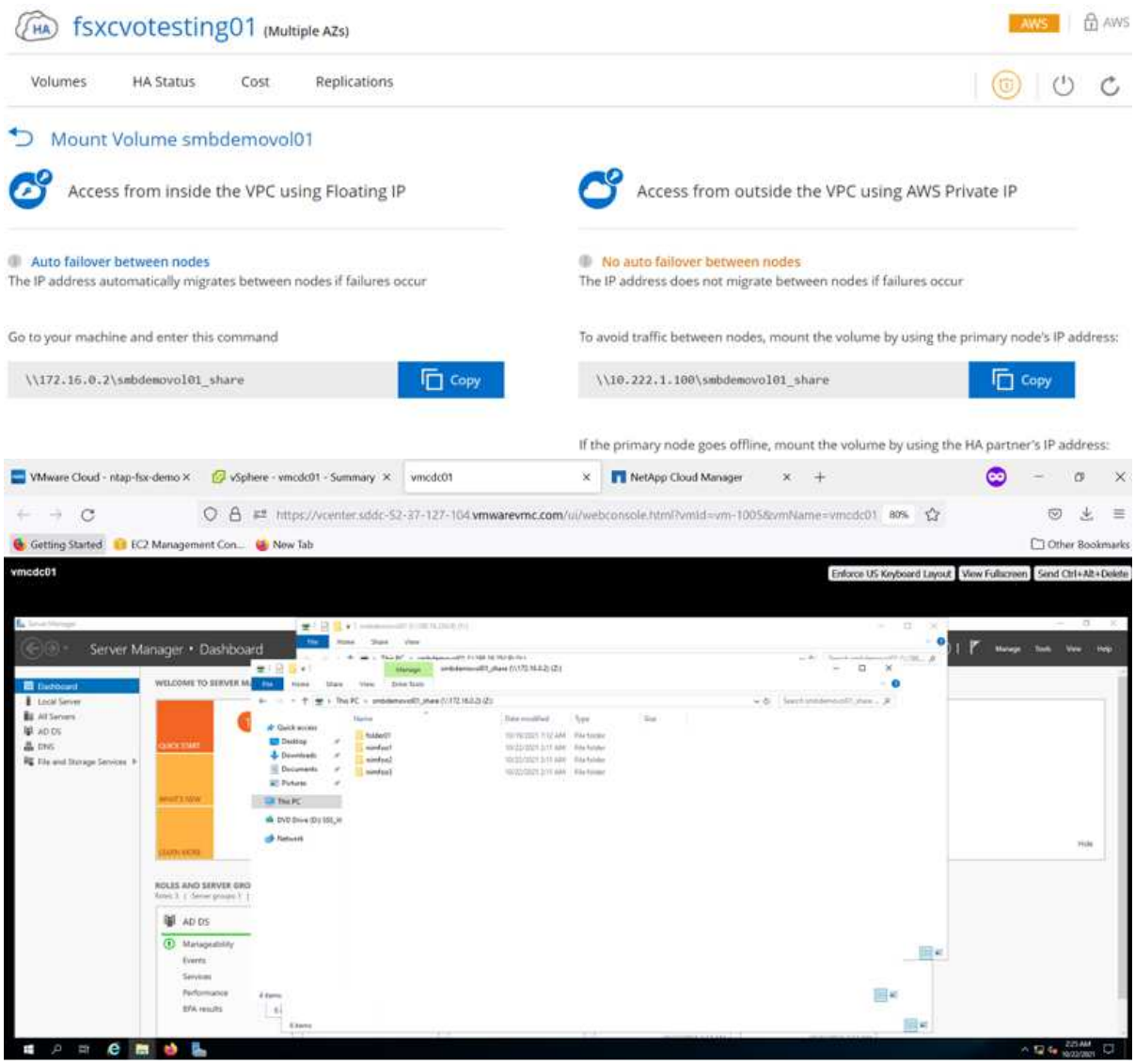
2. Select the CVO instance to create the volume and click the Create Volume option. Choose the appropriate size and cloud manager chooses the containing aggregate or use advanced allocation mechanism to place on a specific aggregate. For this demo, SMB is selected as the protocol.



3. After the volume is provisioned, it is availabe under the Volumes pane. Because a CIFS share is provisioned, you should give your users or groups permission to the files and folders and verify that those users can access the share and create a file.



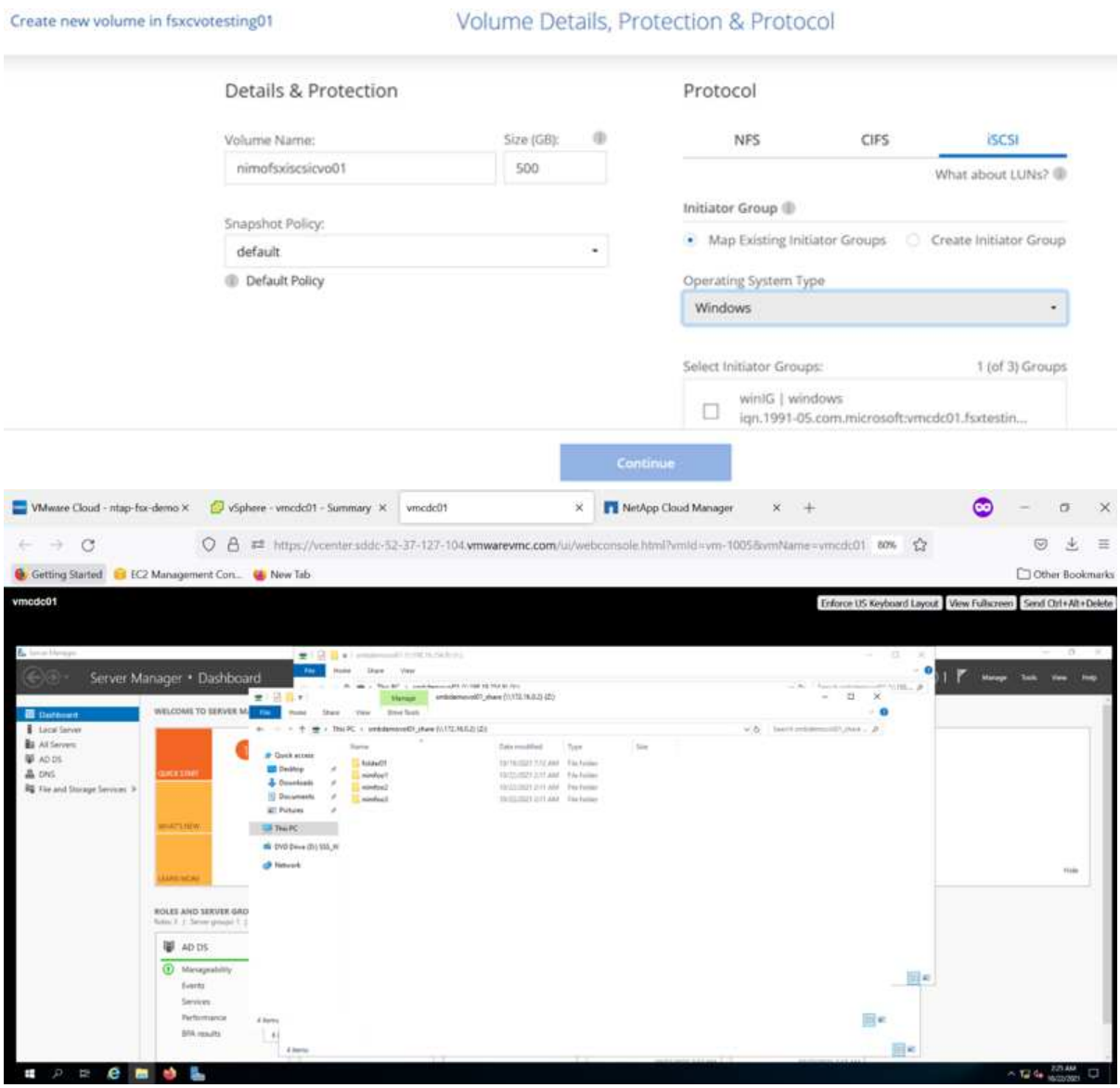
4. After the volume is created, use the mount command to connect to the share from the VM running on the VMware Cloud in AWS SDDC hosts.
5. Copy the following path and use the Map Network Drive option to mount the volume on the VM running on the VMware Cloud in AWS SDDC.



Connect the LUN to a host

To connect the Cloud Volumes ONTAP LUN to a host, complete the following steps:

1. On the Cloud Manager Canvas page, double-click the Cloud Volumes ONTAP working environment to create and manage volumes.
2. Click Add Volume > New Volume, select iSCSI, and click Create Initiator Group. Click Continue.



3. After the volume is provisioned, select the volume, and then click Target IQN. To copy the iSCSI Qualified Name (IQN), click Copy. Set up an iSCSI connection from the host to the LUN.

To accomplish the same for the host residing on the VMware Cloud on AWS SDDC, complete the following steps:

a. RDP to the VM hosted on VMware cloud on AWS.
b. Open the iSCSI Initiator Properties dialog box: Server Manager > Dashboard > Tools > iSCSI Initiator.
c. From the Discovery tab, click Discover Portal or Add Portal and then enter the IP address of the

iSCSI target port.

d. From the Targets tab, select the target discovered and then click Log On or Connect.

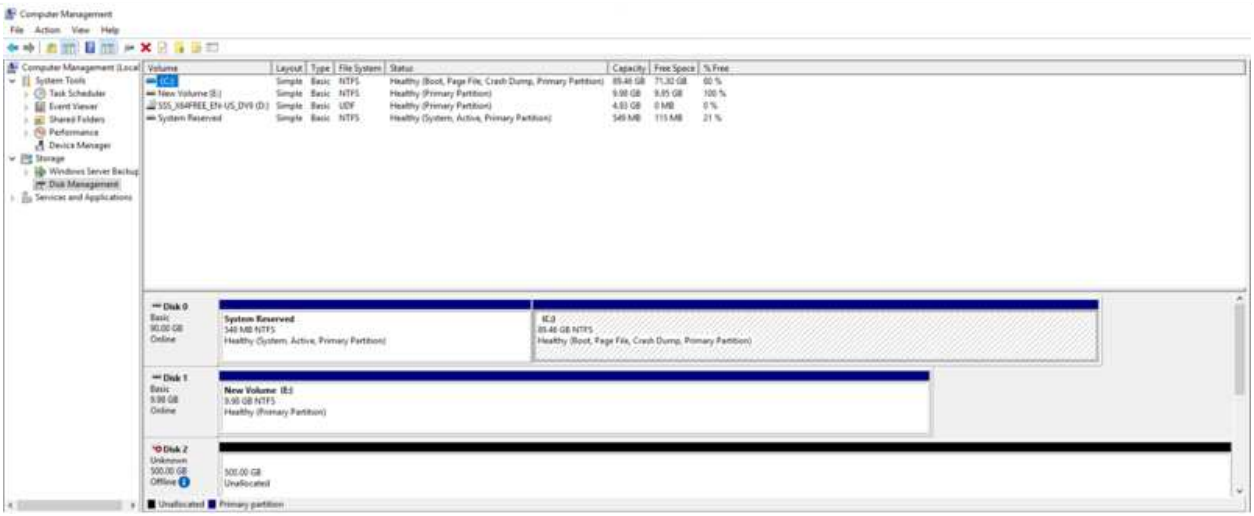
e. Select Enable Multipath, and then select Automatically Restore This Connection When the Computer Starts or Add This Connection to the List of Favorite Targets. Click Advanced.

The Windows host must have an iSCSI connection to each node in the cluster. The native DSM selects the best paths to use.

+

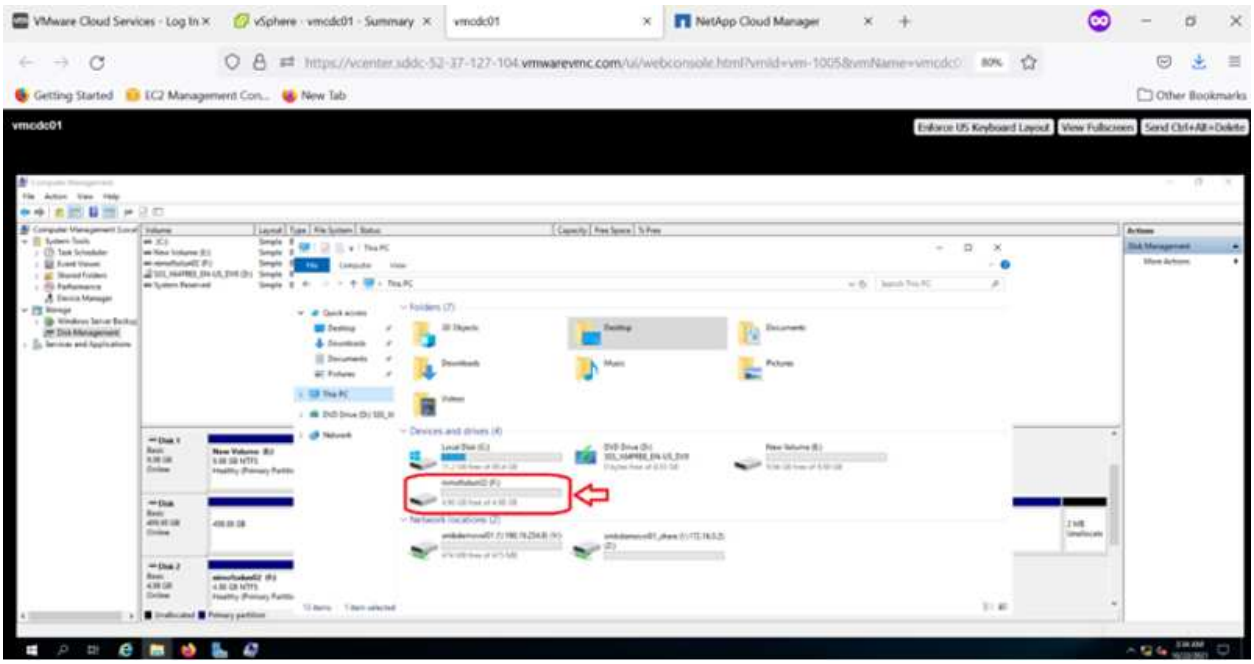
LUNs from the SVM appear as disks to the Windows host. Any new disks that are added are not automatically discovered by the host. Trigger a manual rescan to discover the disks by completing the following steps:

1. Open the Windows Computer Management utility: Start > Administrative Tools > Computer Management.
2. Expand the Storage node in the navigation tree.
3. Click Disk Management.
4. Click Action > Rescan Disks.



When a new LUN is first accessed by the Windows host, it has no partition or file system. Initialize the LUN; and optionally, format the LUN with a file system by completing the following steps:

1. Start Windows Disk Management.
2. Right-click the LUN, and then select the required disk or partition type.
3. Follow the instructions in the wizard. In this example, drive F: is mounted.



On the Linux clients, ensure the iSCSI daemon is running. After the LUNs are provisioned, refer to the detailed guidance on iSCSI configuration for your Linux distribution. For example, Ubuntu iSCSI configuration can be found here. To verify, run lsblk cmd from the shell.

Mount Cloud Volumes ONTAP NFS volume on Linux client

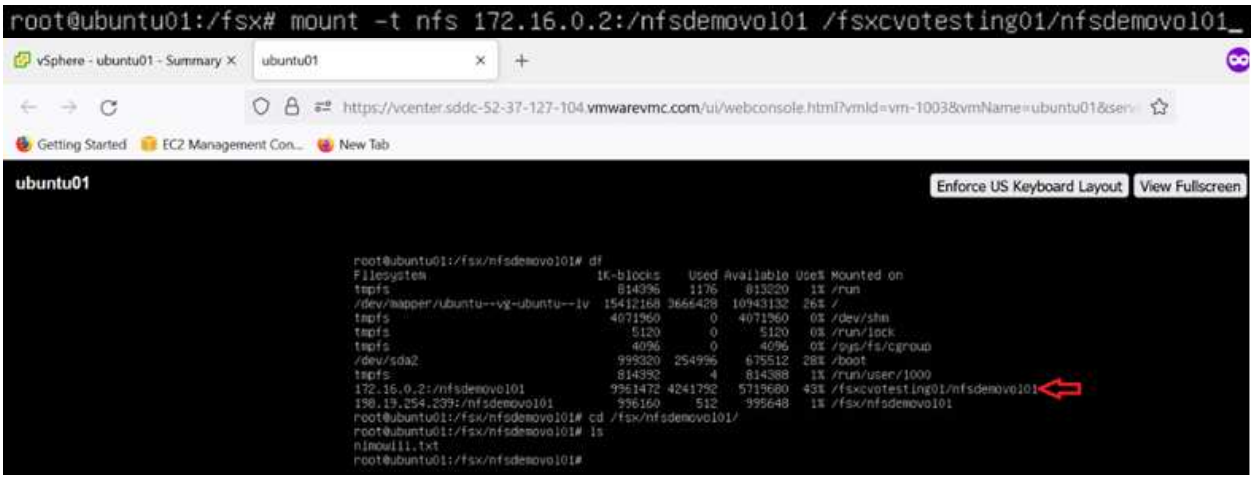
To mount the Cloud Volumes ONTAP (DIY) file system from VMs within VMC on AWS SDDC, complete the following steps:

1. Connect to the designated Linux instance.
2. Open a terminal on the instance using secure shell (SSH) and log in with the appropriate credentials.
3. Make a directory for the volume's mount point with the following command.

```
$ sudo mkdir /fsxcvotesting01/nfsdemovol01
```

4. Mount the Amazon FSx for NetApp ONTAP NFS volume to the directory that is created in the previous step.

```
sudo mount -t nfs nfsvers=4.1,172.16.0.2:/nfsdemovol01
/fsxcvotesting01/nfsdemovol01
```



NetApp Guest Connected Storage Options for Azure

Azure supports guest connected NetApp storage with the native Azure NetApp Files (ANF) service or with Cloud Volumes ONTAP (CVO).

Azure NetApp Files (ANF)

Azure netApp Files brings enterprise-grade data management and storage to Azure so you can manage your workloads and applications with ease. Migrate your workloads to the cloud and run them without sacrificing performance.

Azure netApp Files removes obstacles, so you can move all of your file-based applications to the cloud. For the first time, you do not

have to re-architect your applications, and you get persistent storage for your applications without complexity.

Because the service is delivered through the Microsoft Azure Portal, users experience a fully managed service as part of their Microsoft enterprise Agreement. World-class support, managed by Microsoft, gives you complete peace of mind. This single solution enables you to quickly and easily add multiprotocol workloads. you can build and deploy both Windows and Linux file-based applications, even for legacy environments.

Azure NetApp Files (ANF) as guest connected storage

Configure Azure NetApp Files with Azure VMware Solution (AVS)

Azure NetApp Files shares can be mounted from VMs that are created in the Azure VMware Solution SDDC environment. The volumes can also be mounted on the Linux client and mapped on the Windows client because Azure NetApp Files supports SMB and NFS protocols. Azure NetApp Files volumes can be set up in five simple steps.

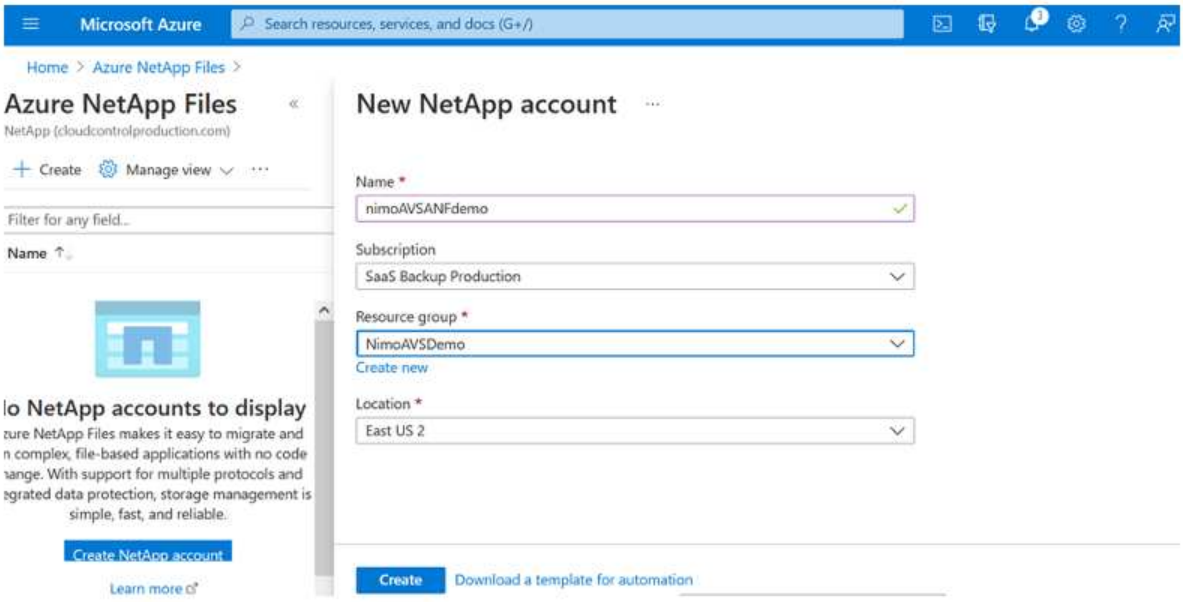
Azure NetApp Files and Azure VMware Solution must be in the same Azure region.

Create and mount Azure NetApp Files volumes

To create and mount Azure NetApp Files volumes, complete the following steps:

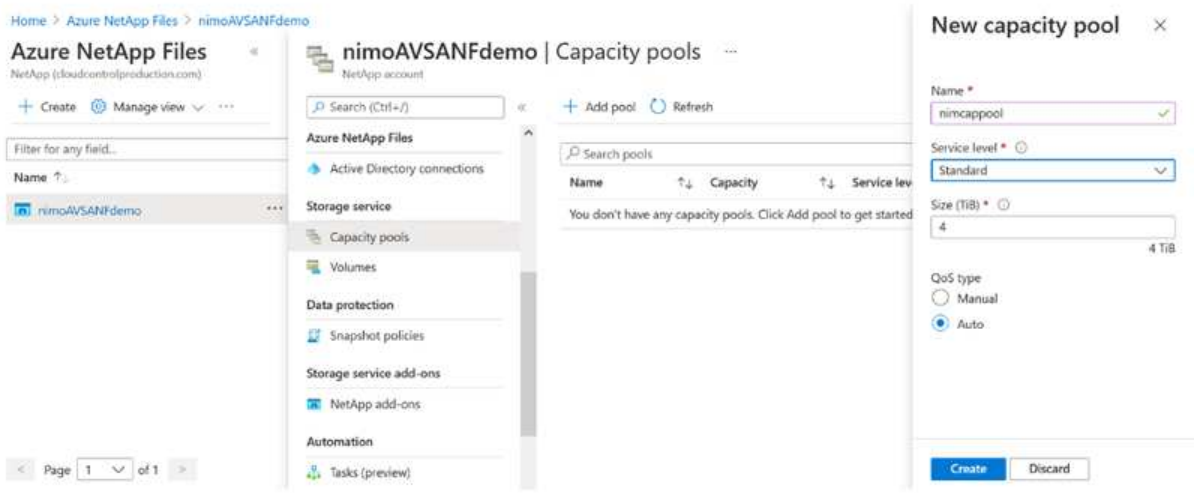
1. Log in to the Azure Portal and access Azure NetApp Files. Verify access to the Azure NetApp Files service and register the Azure NetApp Files Resource Provider by using the *az provider register --namespace Microsoft.NetApp –wait* command. After registration is complete, create a NetApp account.

   For detailed steps, see Azure NetApp Files shares. This page will guide you through the step-by-step process.

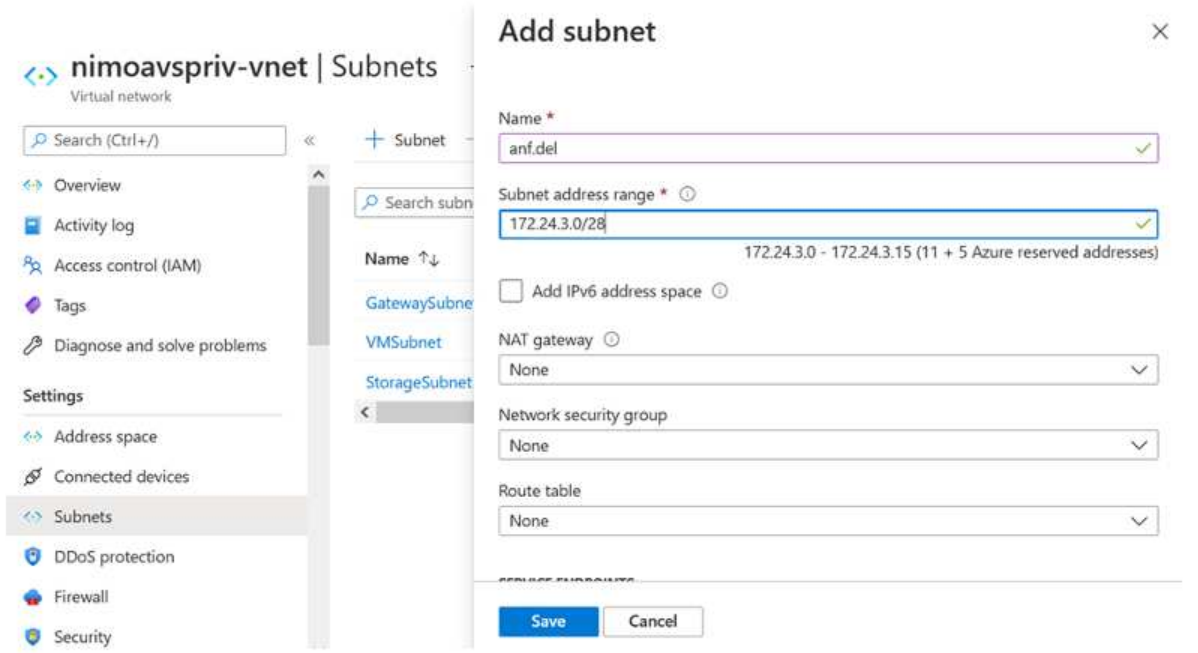


2. After the NetApp account is created, set up the capacity pools with the required service level and size.

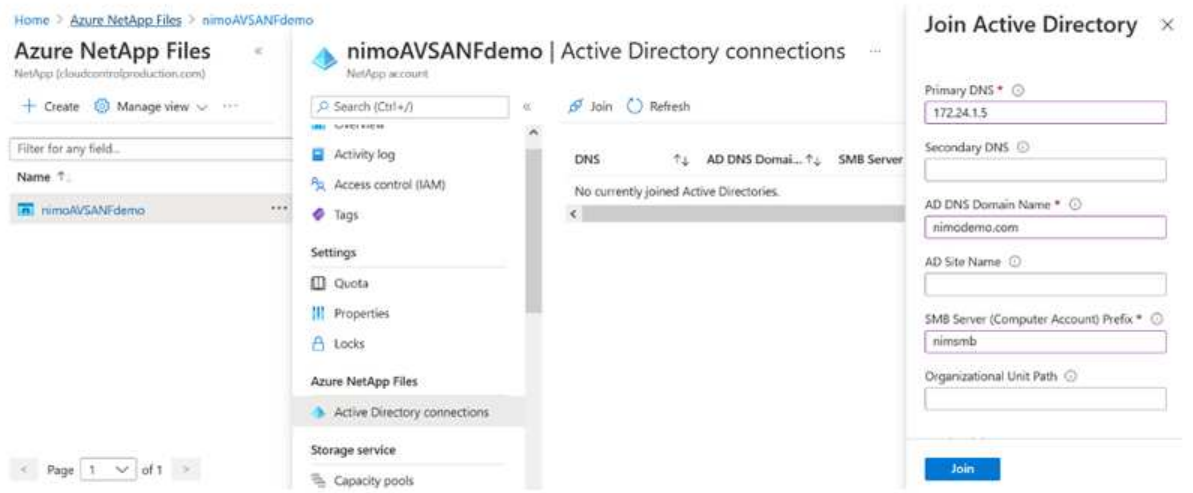
   For more information, see Set up a capacity pool.



3. Configure the delegated subnet for Azure NetApp Files and specify this subnet while creating the volumes. For detailed steps to create delegated subnet, see Delegate a subnet to Azure NetApp Files.

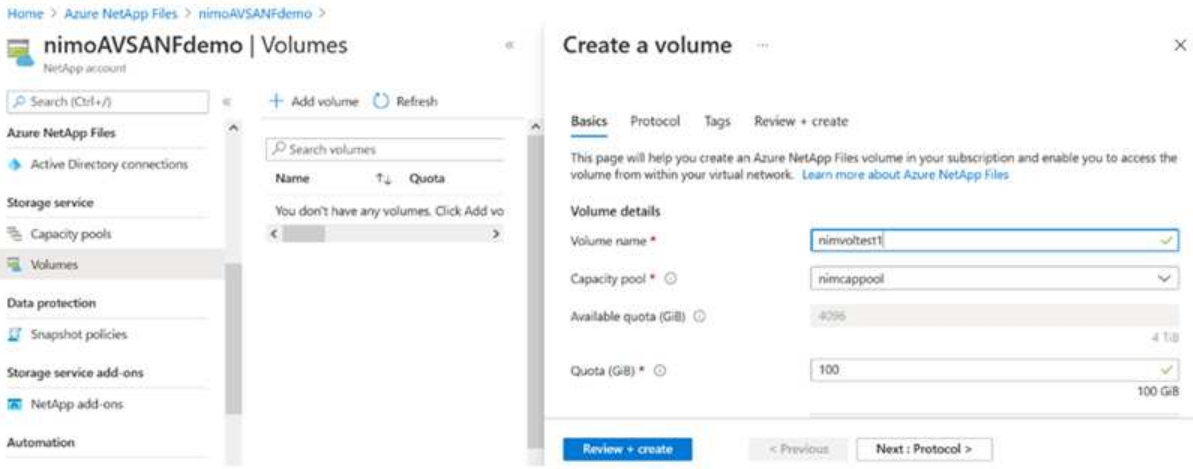


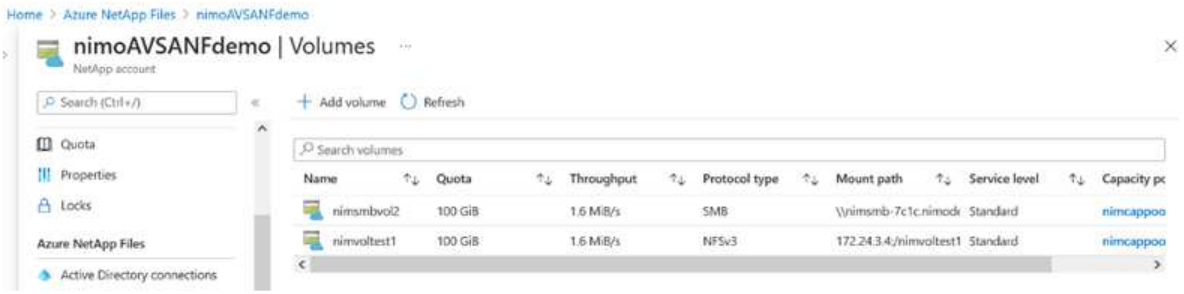
4. Add an SMB volume by using the Volumes blade under the Capacity Pools blade. Make sure the Active Directory connector is configured prior to creating the SMB volume.



5. Click Review + Create to create the SMB volume.

   If the application is SQL Server, then enable the SMB continuous availability.

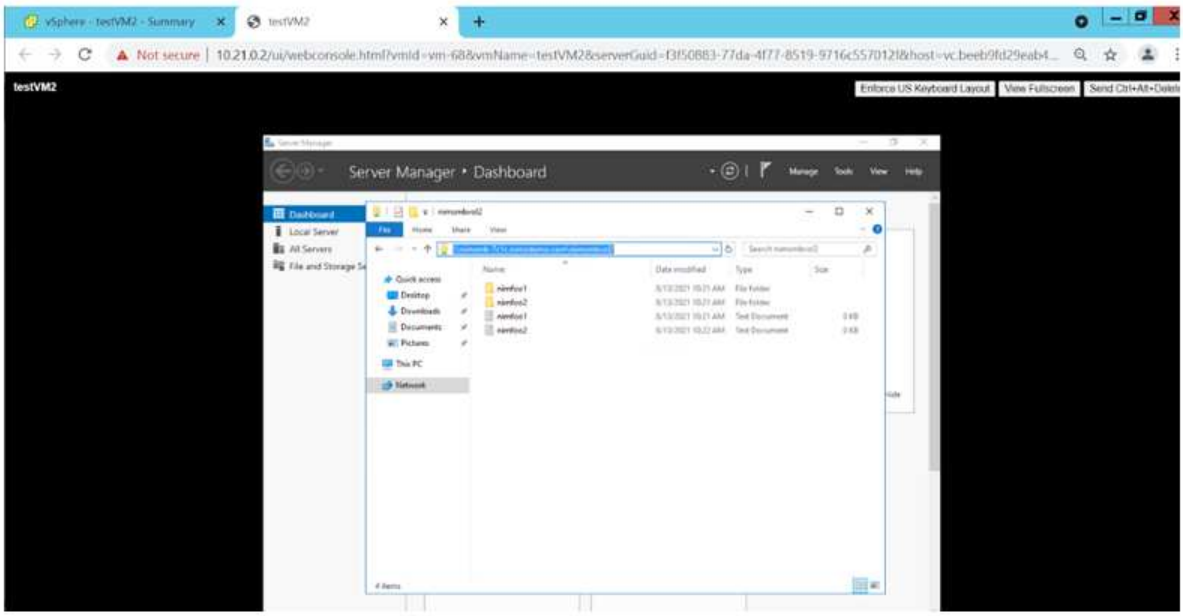


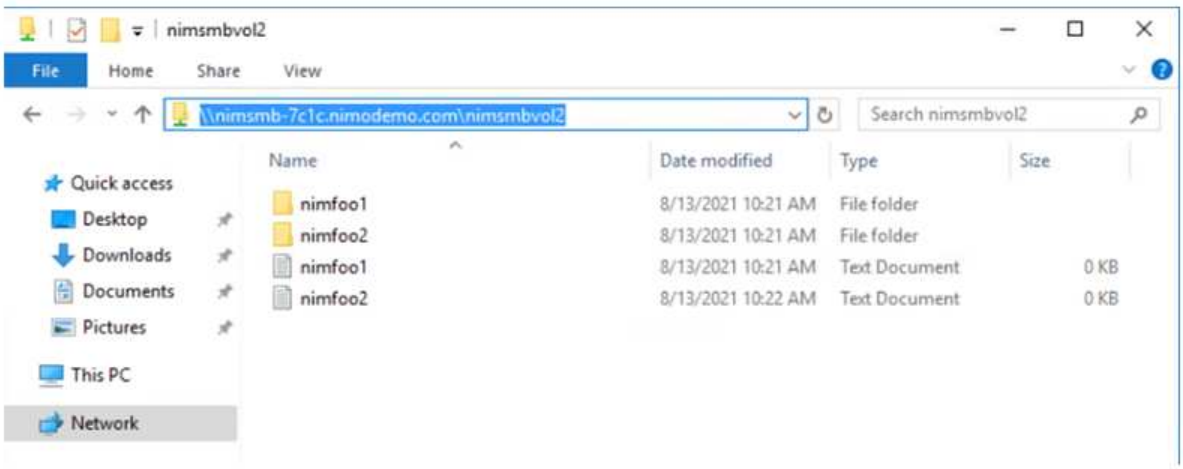


To learn more about Azure NetApp Files volume performance by size or quota, see Performance considerations for Azure NetApp Files.

6. After the connectivity is in place, the volume can be mounted and used for application data.

   To accomplish this, from the Azure portal, click the Volumes blade, and then select the volume to mount and access the mount instructions. Copy the path and use the Map Network Drive option to mount the volume on the VM running on Azure VMware Solution SDDC.





7. To mount NFS volumes on Linux VMs running on Azure VMware Solution SDDC, use this same process. Use volume reshaping or dynamic service level capability to meet the workload demands.

```
nimoadmin@nimoadmin-virtual-machine:~$ sudo mount -t nfs -o rw,hard,tcp 172.24.
3.4:/nimodemonfsv1 /home/nimoadmin/nimodemo11
nimoadmin@nimoadmin-virtual-machine:~$ df
Filesystem                  1K-blocks    Used Available Use% Mounted on
udev                          8168112       0   8168112   0% /dev
tmpfs                         1639548    1488   1638060   1% /run
/dev/sda5                    50824704 7902752  40310496  17% /
tmpfs                         8197728       0   8197728   0% /dev/shm
tmpfs                            5120       0      5120   0% /run/lock
tmpfs                         8197728       0   8197728   0% /sys/fs/cgroup
/dev/loop0                      56832   56832         0 100% /snap/core18/2128
/dev/loop2                      66688   66688         0 100% /snap/gtk-common-the
mes/1515
/dev/loop1                     224256  224256         0 100% /snap/gnome-3-34-180
4/72
/dev/loop3                      52224   52224         0 100% /snap/snap-store/547
/dev/loop4                      33152   33152         0 100% /snap/snapd/12704
/dev/sda1                      523248       4    523244   1% /boot/efi
tmpfs                         1639544      52   1639492   1% /run/user/1000
/dev/sr0                        54738   54738         0 100% /media/nimoadmin/VMw
are Tools
172.24.3.4:/nimodemonfsv1 104857600       0 104857600   0% /home/nimoadmin/nimo
demo11
nimoadmin@nimoadmin-virtual-machine:~$
```

For more information, see Dynamically change the service level of a volume.

Cloud Volumes ONTAP (CVO)

Cloud volumes ONTAP, or CVO, is the industry-leading cloud data management solution built on NetApp's ONTAP storage software, available natively on Amazon Web Services (AWS), Microsoft Azure and Google Cloud Platform (GCP).

It is a software-defined version of ONTAP that consumes cloud-native storage, allowing you to have the same storage software in the cloud and on-premises, reducing the need to retrain you IT staff in all-new methods to manage your data.

CVO gives customers the ability to seamlessly move data from the edge, to the data center, to the cloud and back, bringing your hybrid cloud together — all managed with a single-pane management console, NetApp Cloud Manager.

By design, CVO delivers extreme performance and advanced data management capabilities to satisfy even your most demanding applications in the cloud

Cloud Volumes ONTAP (CVO) as guest connected storage

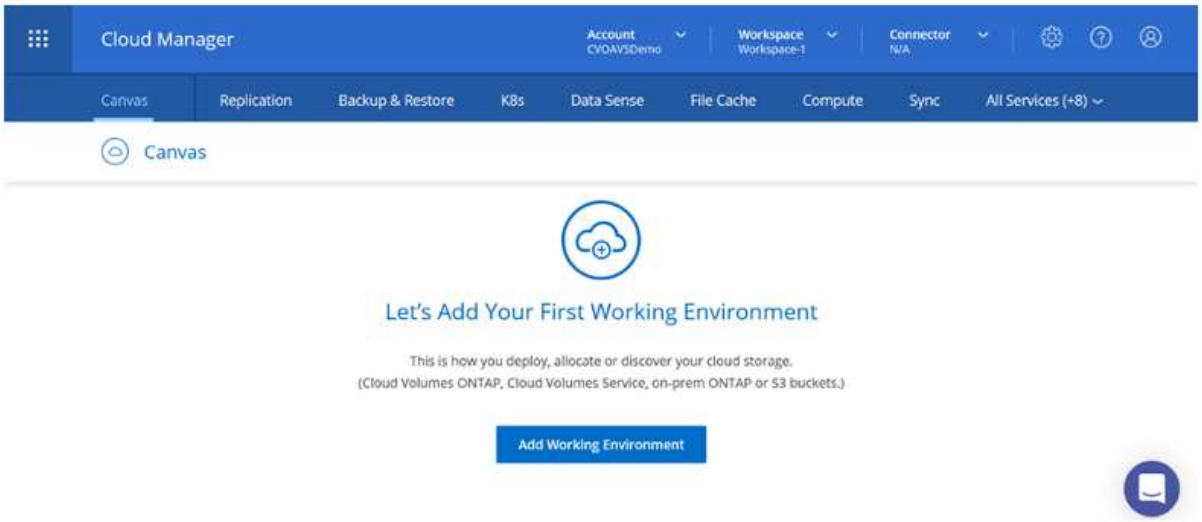
Deploy new Cloud Volumes ONTAP in Azure

Cloud Volumes ONTAP shares and LUNs can be mounted from VMs that are created in the Azure VMware Solution SDDC environment. The volumes can also be mounted on the Linux client and on Windows client because Cloud Volumes ONTAP supports iSCSI, SMB, and NFS protocols. Cloud Volumes ONTAP volumes can be set up in a few simple steps.

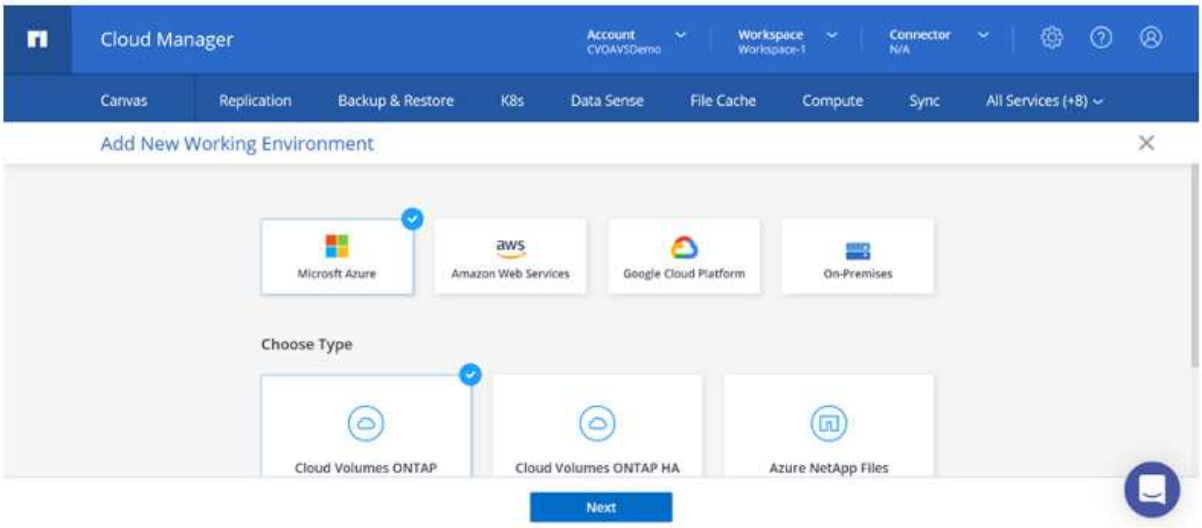
To replicate volumes from an on-premises environment to the cloud for disaster recovery or migration purposes, establish network connectivity to Azure, either using a site-to-site VPN or ExpressRoute. Replicating data from on-premises to Cloud Volumes ONTAP is outside the scope of this document. To replicate data between on-premises and Cloud Volumes ONTAP systems, see Setting up data replication between systems.

Use Cloud Volumes ONTAP sizer to accurately size the Cloud Volumes ONTAP instances. Also monitor on-premises performance to use as inputs in the Cloud Volumes ONTAP sizer.

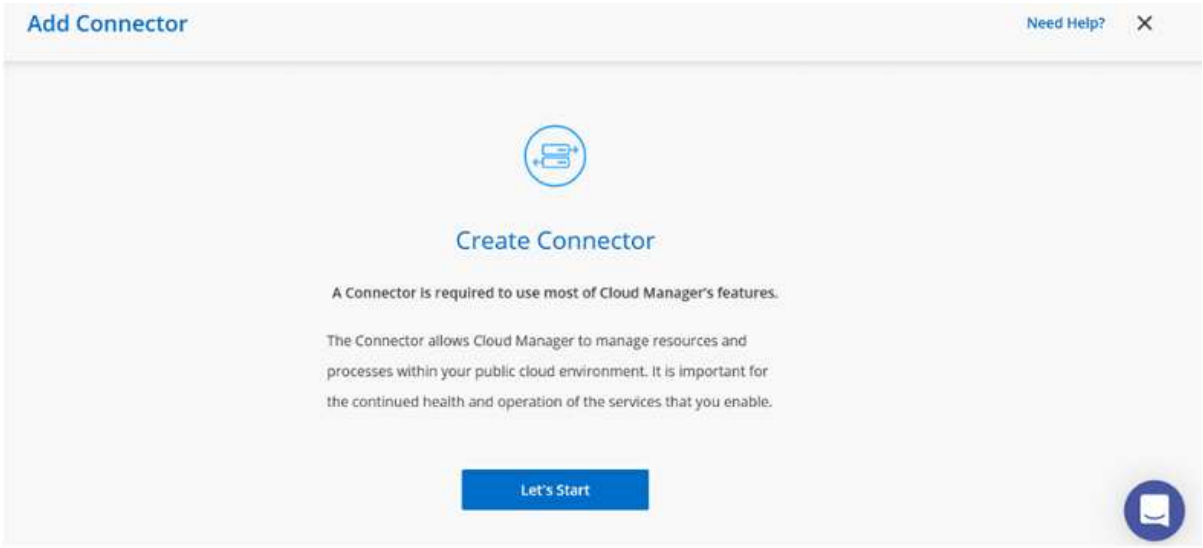
1. Log in to NetApp Cloud Central—the Fabric View screen is displayed. Locate the Cloud Volumes ONTAP tab and select Go to Cloud Manager. After you are logged in, the Canvas screen is displayed.



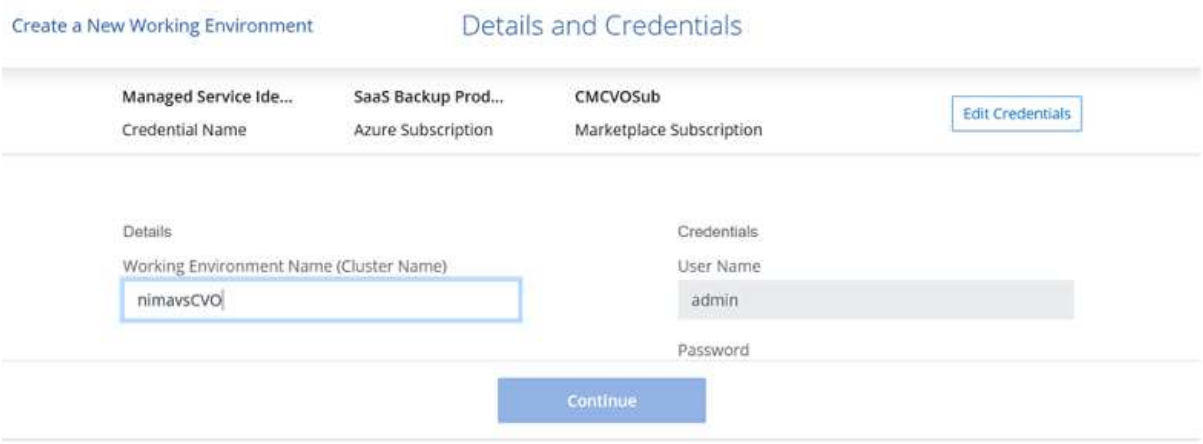
2. On the Cloud Manager home page, click Add a Working Environment and then select Microsoft Azure as the cloud and the type of the system configuration.



3. When creating the first Cloud Volumes ONTAP working environment, Cloud Manager prompts you to deploy a Connector.

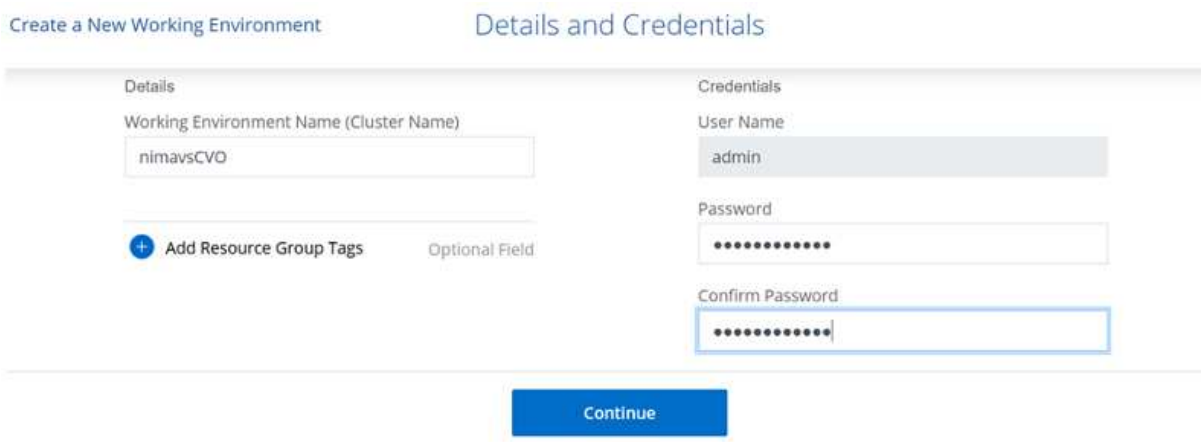


4. After the connector is created, update the Details and Credentials fields.

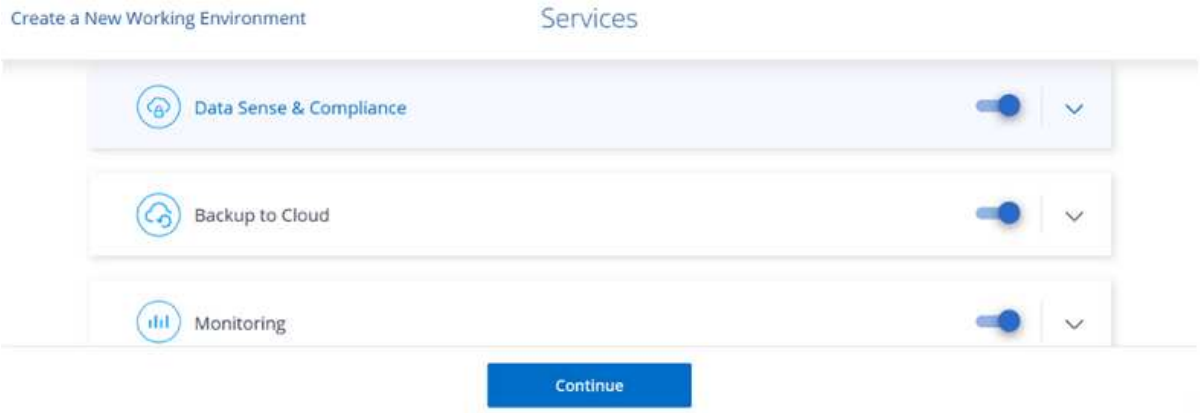


5. Provide the details of the environment to be created including the environment name and admin

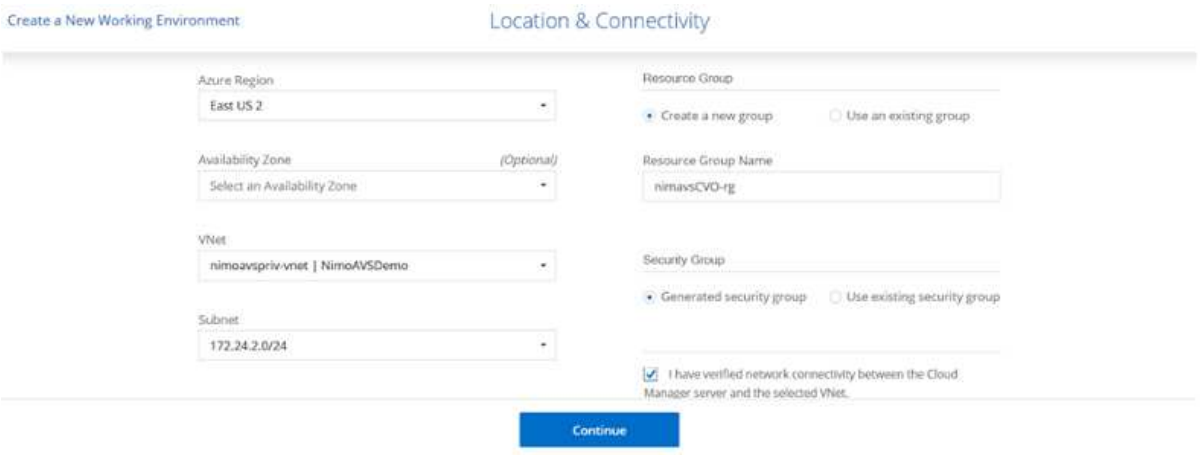
credentials. Add resource group tags for the Azure environment as an optional parameter. After you are done, click Continue.



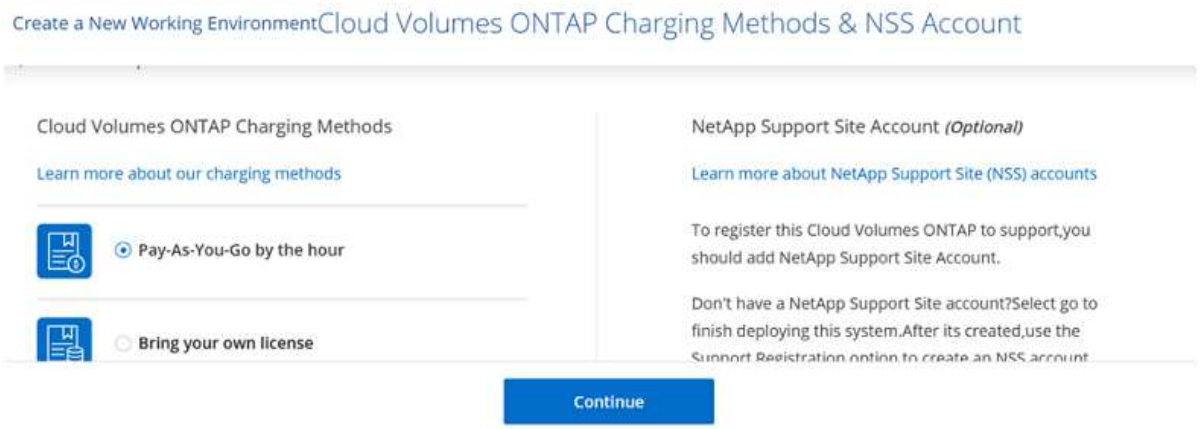
6. Select the add-on services for Cloud Volumes ONTAP deployment, including Cloud Data Sense, Cloud Backup, and Cloud Insights. Select the services and then click Continue.



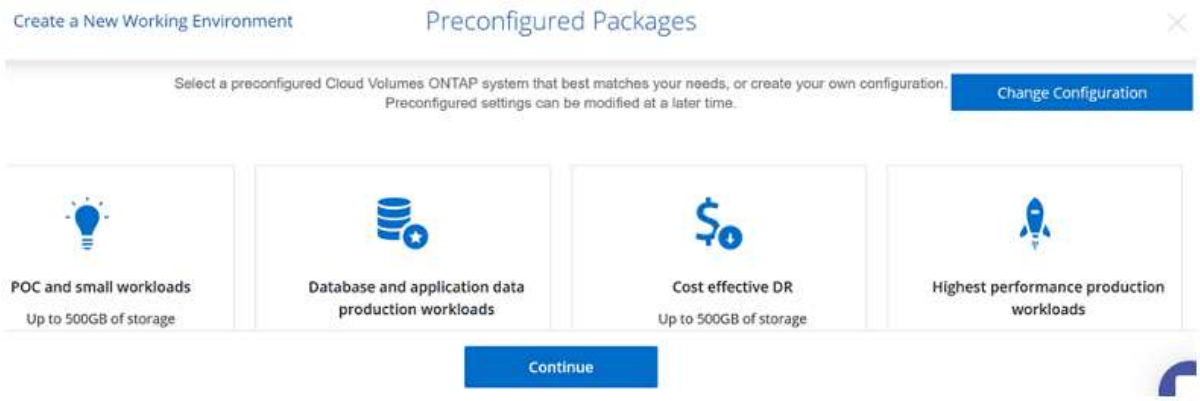
7. Configure the Azure location and connectivity. Select the Azure Region, resource group, VNet, and subnet to be used.



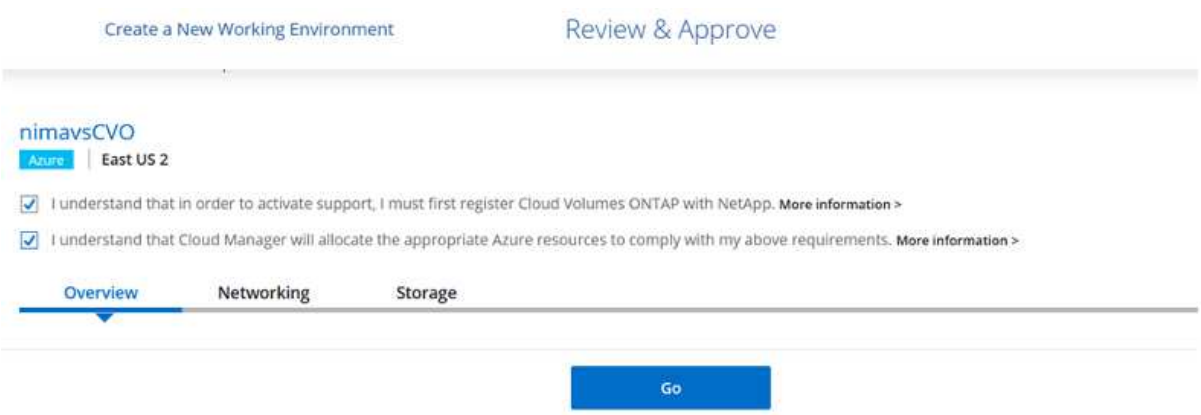
8. Select the license option: Pay-As-You-Go or BYOL for using existing license. In this example, Pay-As-You-Go option is used.



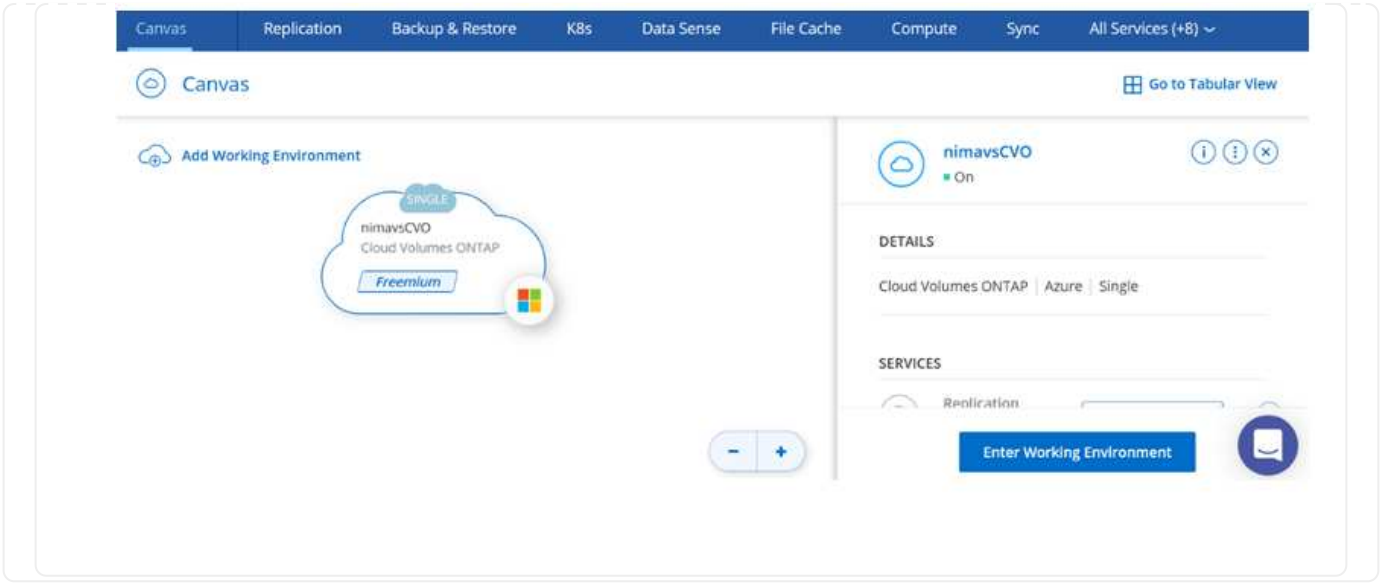
9. Select between several preconfigured packages available for the various types of workloads.



10. Accept the two agreements regarding activating support and allocation of Azure resources.To create the Cloud Volumes ONTAP instance, click Go.

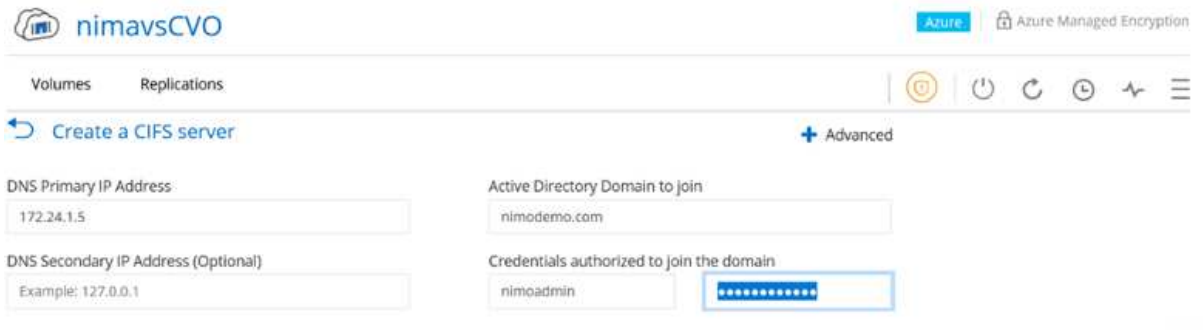


11. After Cloud Volumes ONTAP is provisioned, it is listed in the working environments on the Canvas page.

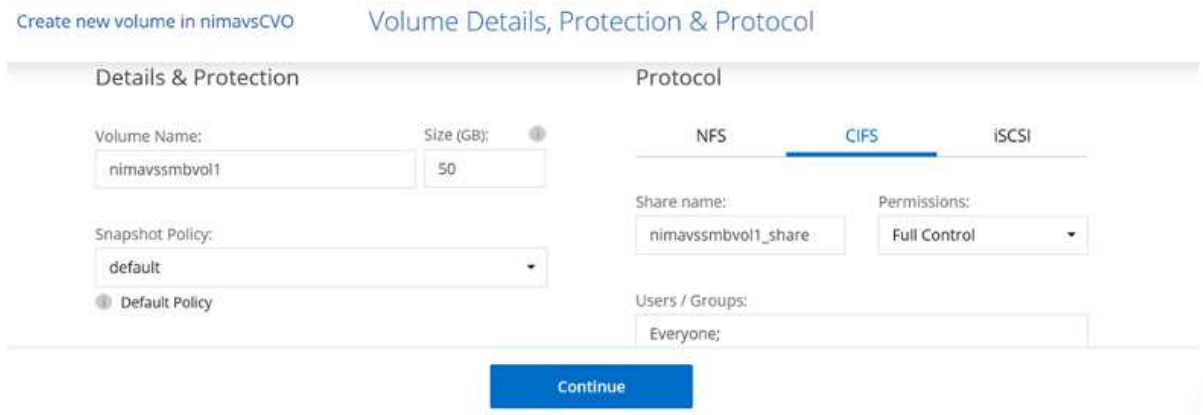

Canvas
Replication
Backup & Restore
K8s
Data Sense
File Cache
Compute
Sync
All Services (+8)
Canvas
Go to Tabular View
Add Working Environment
SINGLE
nimavsCVO
Cloud Volumes ONTAP
Freemium
nimavsCVO
On
DETAILS
Cloud Volumes ONTAP | Azure | Single
SERVICES
Replication
Enter Working Environment

Additional configurations for SMB volumes

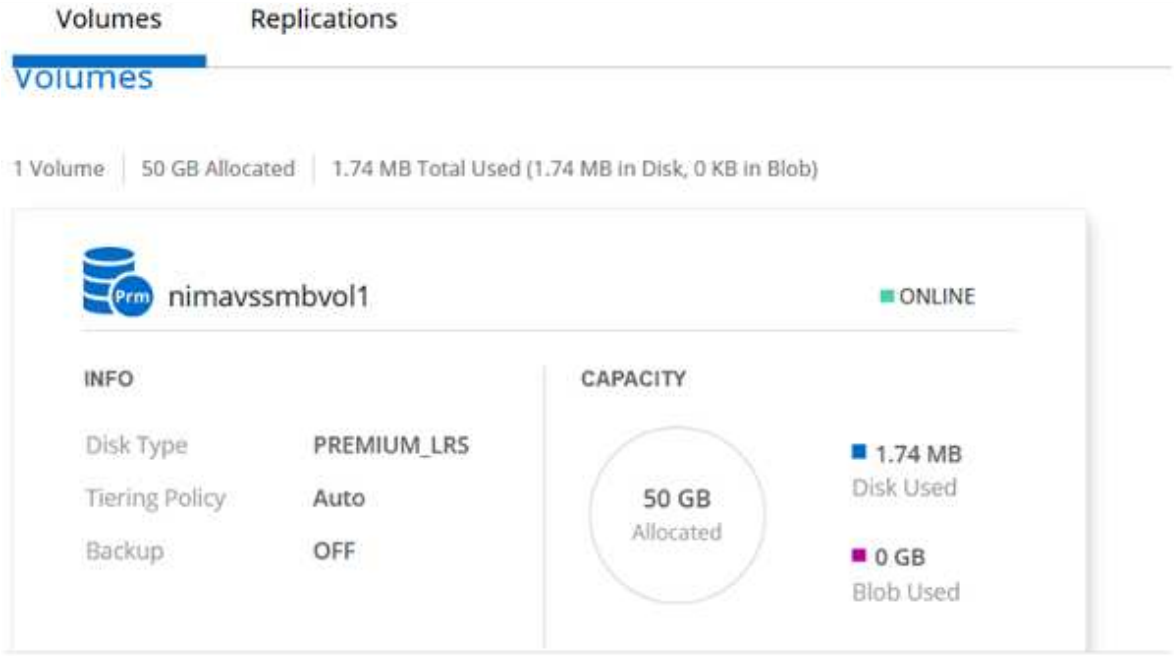
1. After the working environment is ready, make sure the CIFS server is configured with the appropriate DNS and Active Directory configuration parameters. This step is required before you can create the SMB volume.



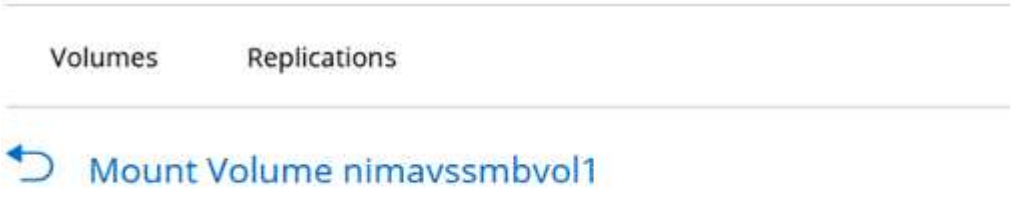
2. Creating the SMB volume is an easy process. Select the CVO instance to create the volume and click the Create Volume option. Choose the appropriate size and cloud manager chooses the containing aggregate or use advanced allocation mechanism to place on a specific aggregate. For this demo, SMB is selected as the protocol.

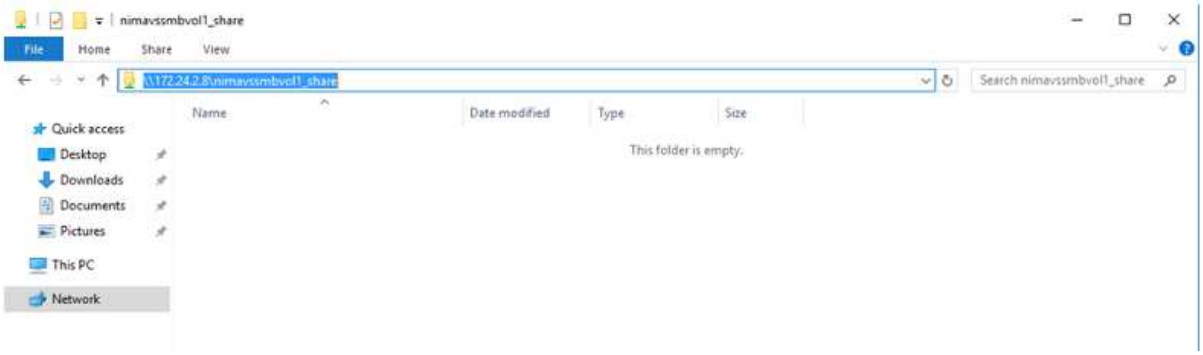


3. After the volume is provisioned, it will be availabe under the Volumes pane. Because a CIFS share is provisioned, give your users or groups permission to the files and folders and verify that those users can access the share and create a file. This step is not required if the volume is replicated from an on-premises environment because the file and folder permissions are all retained as part of SnapMirror replication.



4. After the volume is created, use the mount command to connect to the share from the VM running on the Azure VMware Solution SDDC hosts.
5. Copy the following path and use the Map Network Drive option to mount the volume on the VM running on Azure VMware Solution SDDC.

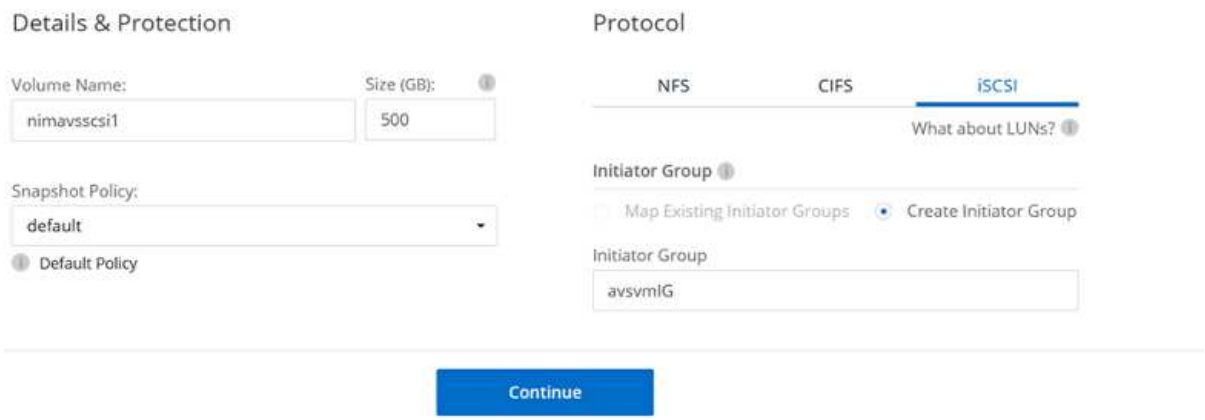




Connect the LUN to a host

To connect the LUN to a host, complete the following steps:

1. On the Canvas page, double-click the Cloud Volumes ONTAP working environment to create and manage volumes.
2. Click Add Volume > New Volume and select iSCSI and click Create Initiator Group. Click Continue.



3. After the volume is provisioned, select the volume, and then click Target IQN. To copy the iSCSI Qualified Name (IQN), click Copy. Set up an iSCSI connection from the host to the LUN.

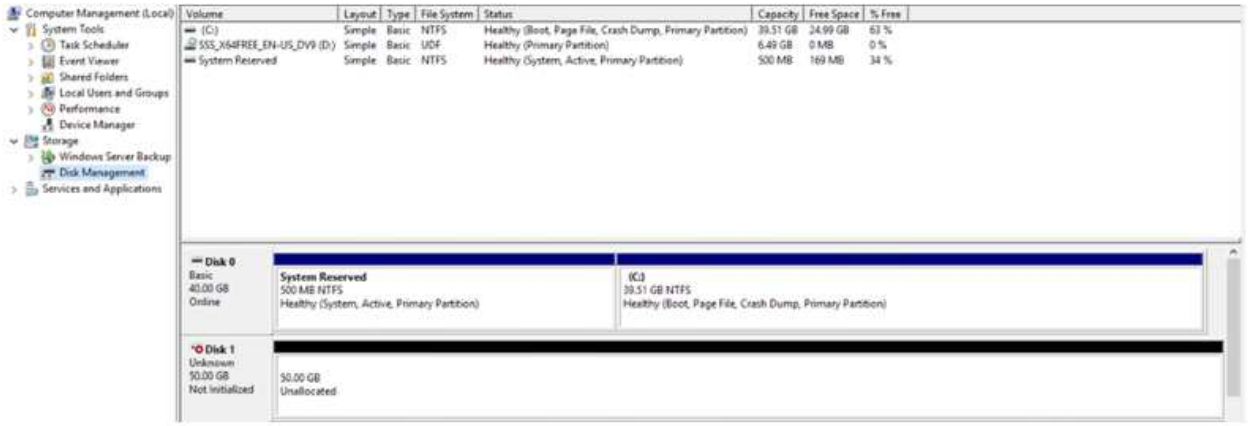
   To accomplish the same for the host residing on Azure VMware Solution SDDC:

   a. RDP to the VM hosted on Azure VMware Solution SDDC.
   b. Open the iSCSI Initiator Properties dialog box: Server Manager > Dashboard > Tools > iSCSI Initiator.
   c. From the Discovery tab, click Discover Portal or Add Portal and then enter the IP address of the iSCSI target port.
   d. From the Targets tab, select the target discovered and then click Log on or Connect.
   e. Select Enable multipath, and then select Automatically Restore This Connection When the Computer Starts or Add This Connection to the List of Favorite Targets. Click Advanced.

      Note: The Windows host must have an iSCSI connection to each node in the cluster. The native DSM selects the best paths to use.

LUNs on storage virtual machine (SVM) appear as disks to the Windows host. Any new disks that are added are not automatically discovered by the host. Trigger a manual rescan to discover the disks by completing the following steps:

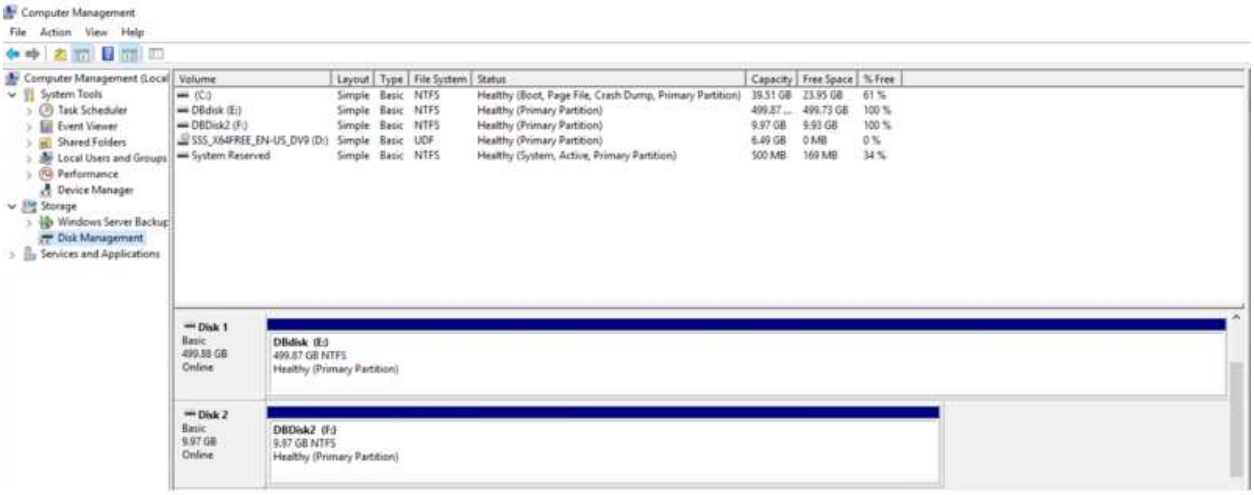
1. Open the Windows Computer Management utility: Start > Administrative Tools > Computer Management.
2. Expand the Storage node in the navigation tree.
3. Click Disk Management.
4. Click Action > Rescan Disks.

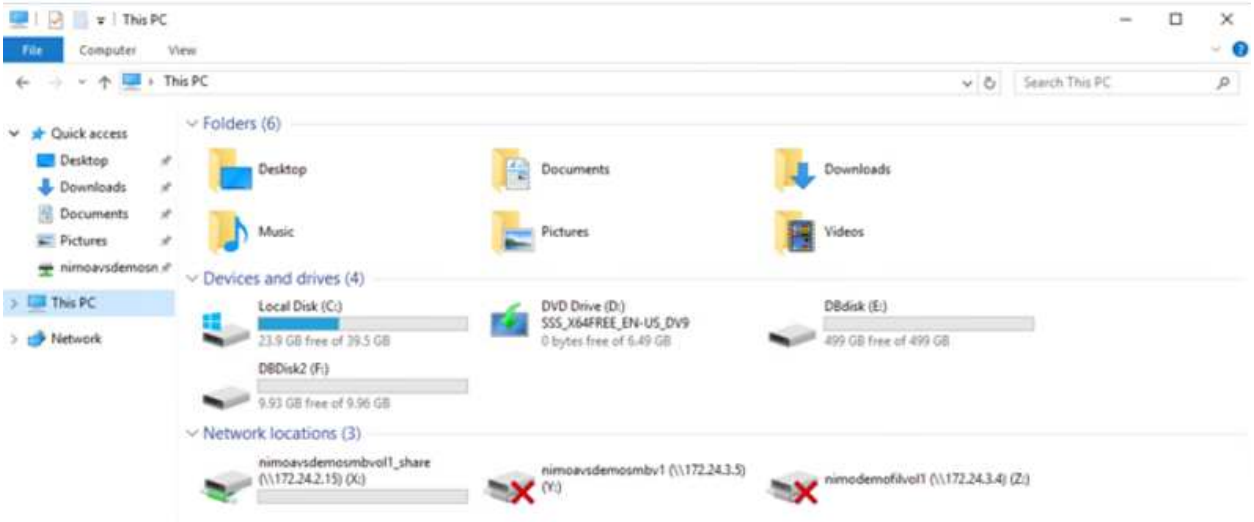


When a new LUN is first accessed by the Windows host, it has no partition or file system. Initialize the LUN; and optionally, format the LUN with a file system by completing the following steps:

1. Start Windows Disk Management.

2. Right-click the LUN, and then select the required disk or partition type.
3. Follow the instructions in the wizard. In this example, drive E: is mounted





NetApp Storage Options for GCP

GCP supports guest connected NetApp storage with Cloud Volumes ONTAP (CVO) or Cloud Volumes Service (CVS).

Cloud Volumes ONTAP (CVO)

Cloud volumes ONTAP, or CVO, is the industry-leading cloud data management solution built on NetApp's ONTAP storage software, available natively on Amazon Web Services (AWS), Microsoft Azure and Google Cloud Platform (GCP).

It is a software-defined version of ONTAP that consumes cloud-native storage, allowing you to have the same storage software in the cloud and on-premises, reducing the need to retrain you IT staff in all-new methods to manage your data.

CVO gives customers the ability to seamlessly move data from the edge, to the data center, to the cloud and back, bringing your hybrid cloud together — all managed with a single-pane management console, NetApp

Cloud Manager.

By design, CVO delivers extreme performance and advanced data management capabilities to satisfy even your most demanding applications in the cloud

Cloud Volumes ONTAP (CVO) as guest connected storage

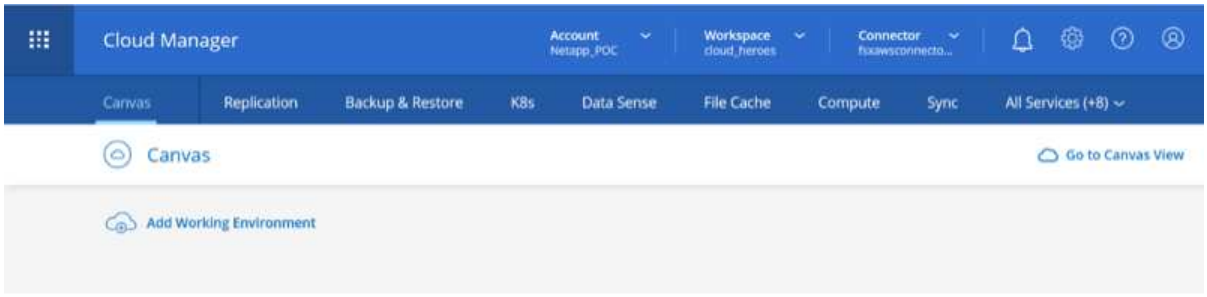
Deploy Cloud Volumes ONTAP in Google Cloud (Do It Yourself)

Cloud Volumes ONTAP shares and LUNs can be mounted from VMs that are created in the GCVE private cloud environment. The volumes can also be mounted on the Linux client and on Windows client and LUNS can be accessed on Linux or Windows clients as block devices when mounted over iSCSI because Cloud Volumes ONTAP supports iSCSI, SMB, and NFS protocols. Cloud Volumes ONTAP volumes can be set up in a few simple steps.

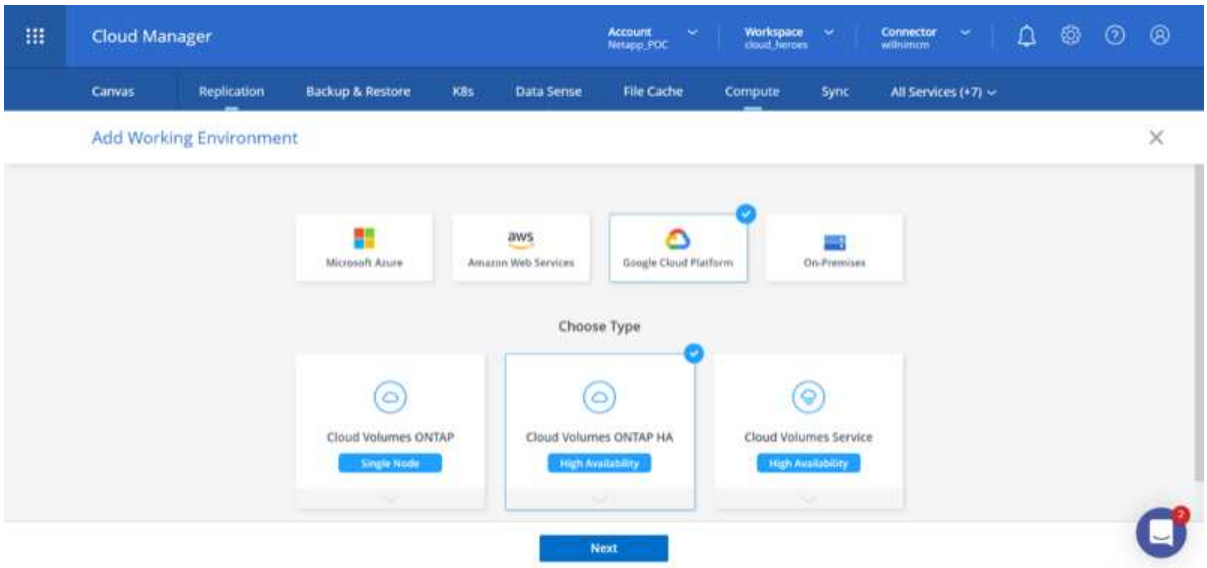
To replicate volumes from an on-premises environment to the cloud for disaster recovery or migration purposes, establish network connectivity to Google Cloud, either using a site-to-site VPN or Cloud Interconnect. Replicating data from on-premises to Cloud Volumes ONTAP is outside the scope of this document. To replicate data between on-premises and Cloud Volumes ONTAP systems, see xref:./ehc/gcp/Setting up data replication between systems.

Use Cloud Volumes ONTAP sizer to accurately size the Cloud Volumes ONTAP instances. Also monitor on-premises performance to use as inputs in the Cloud Volumes ONTAP sizer.

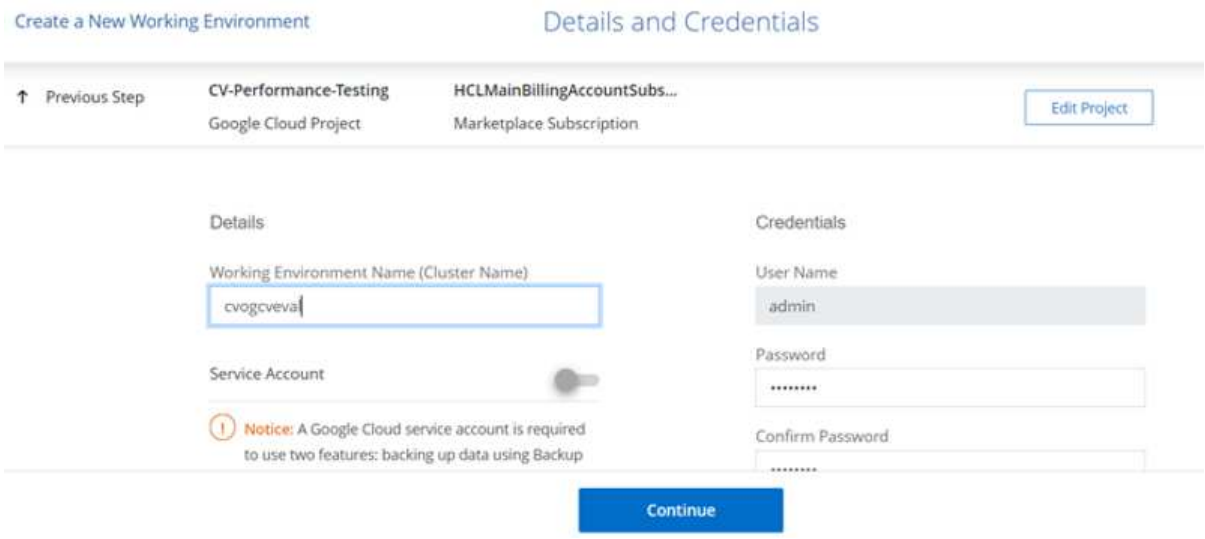
1. Log in to NetApp Cloud Central—the Fabric View screen is displayed. Locate the Cloud Volumes ONTAP tab and select Go to Cloud Manager. After you are logged in, the Canvas screen is displayed.



2. On the Cloud Manager Canvas tab, click Add a Working Environment and then select Google Cloud Platform as the cloud and the type of the system configuration. Then, click Next.

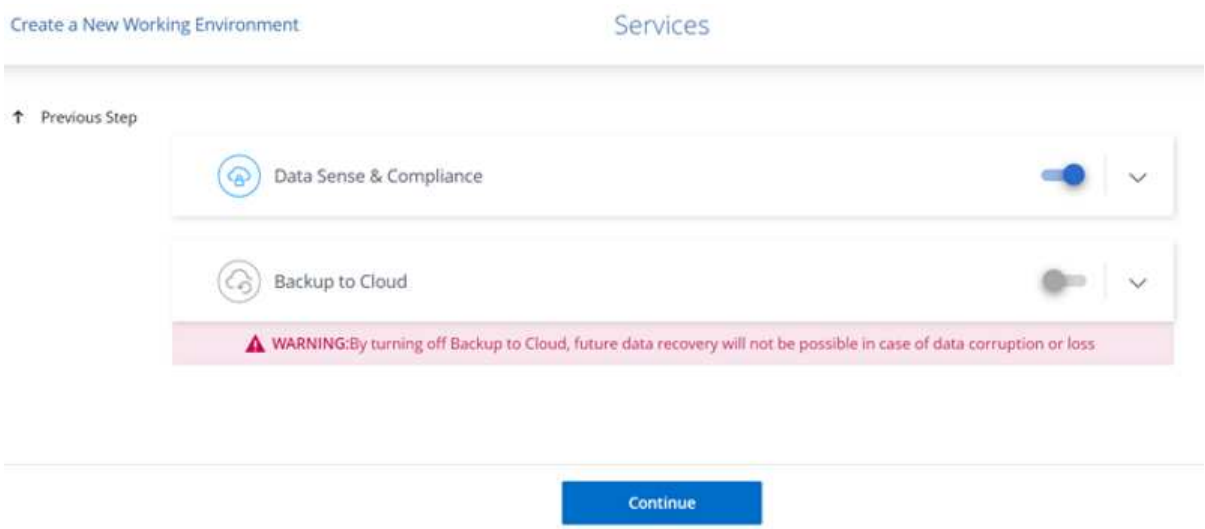


3. Provide the details of the environment to be created including the environment name and admin credentials. After you are done, click Continue.

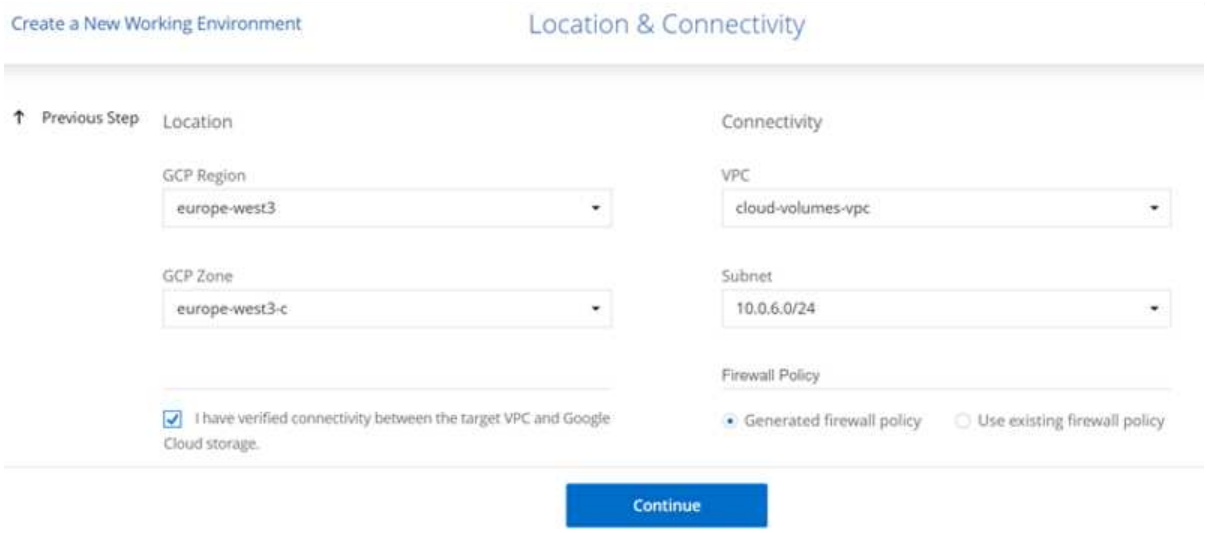


4. Select or deselect the add-on services for Cloud Volumes ONTAP deployment, including Data Sense & Compliance or Backup to Cloud. Then, click Continue.

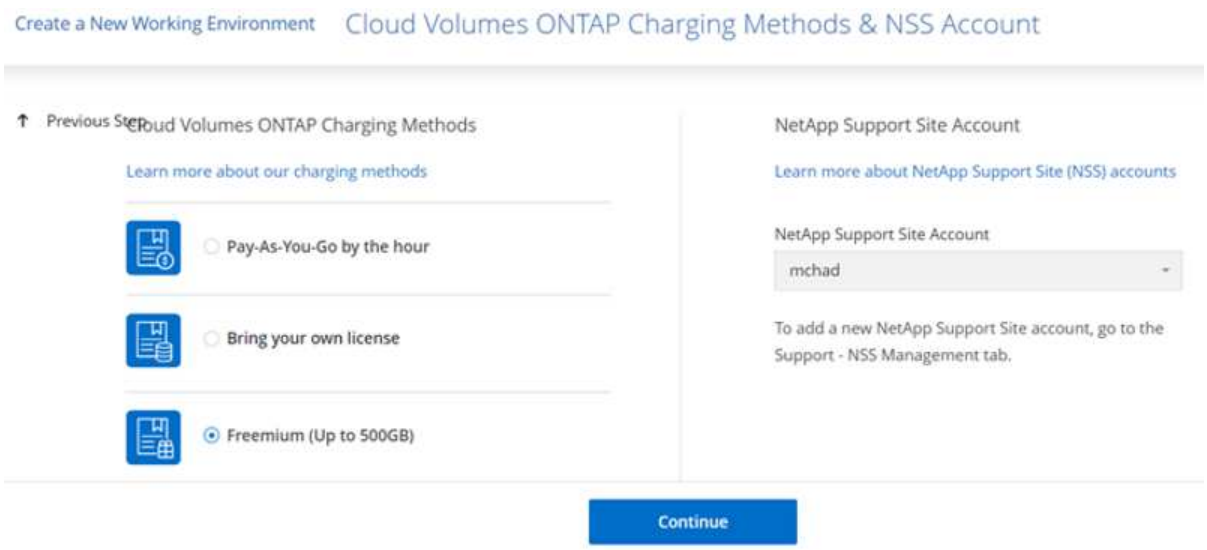
   HINT: A verification pop-up message will be displayed when deactivating add-on services. Add-on services can be added/removed after CVO deployment, consider to deselect them if not needed from the beginning to avoid costs.



5. Select a location, choose a firewall policy, and select the checkbox to confirm network connectivity to Google Cloud storage.

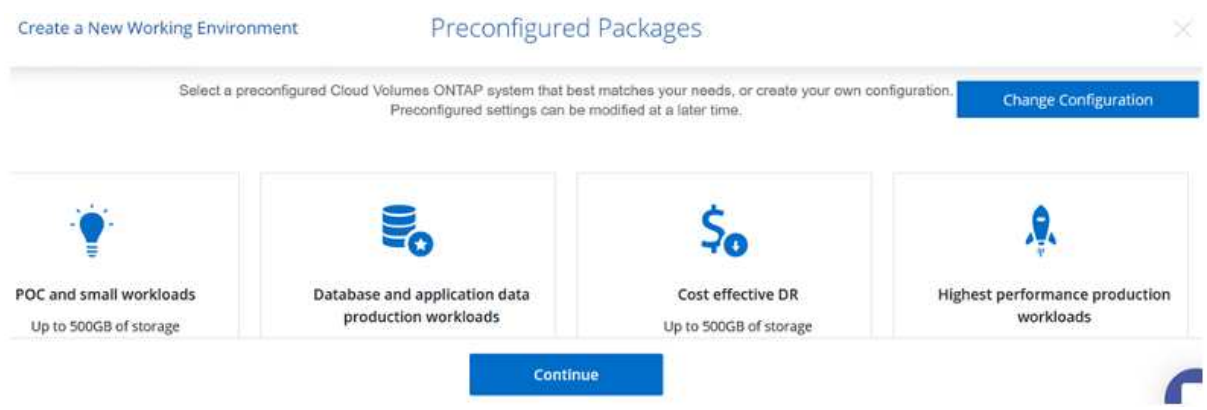


6. Select the license option: Pay-As-You-Go or BYOL for using existing license. In this example, Freemium option is used. Then, click on Continue.

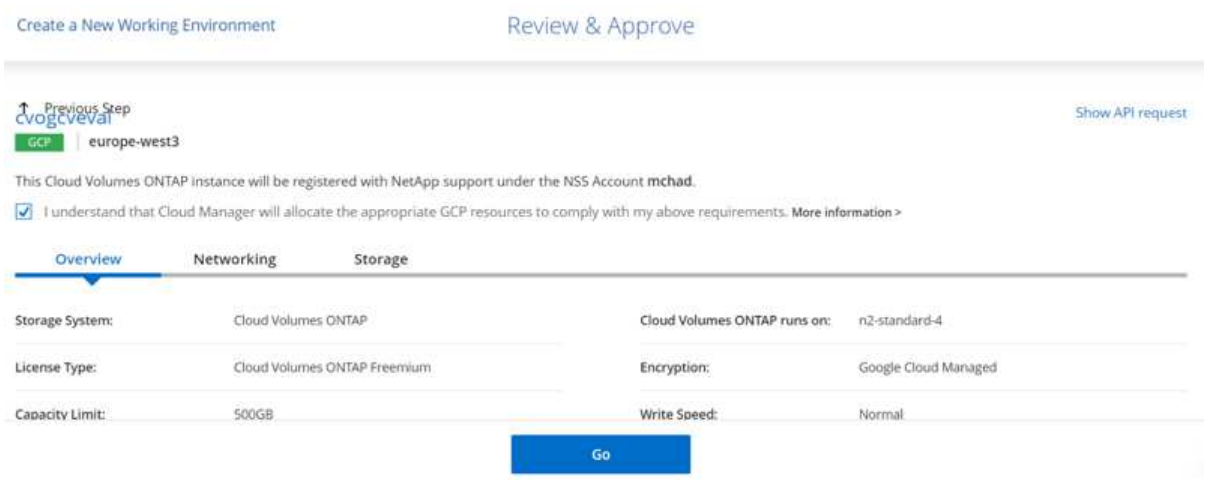


7. Select between several preconfigured packages available based on the type of workload that will be deployed on the VMs running on VMware cloud on AWS SDDC.

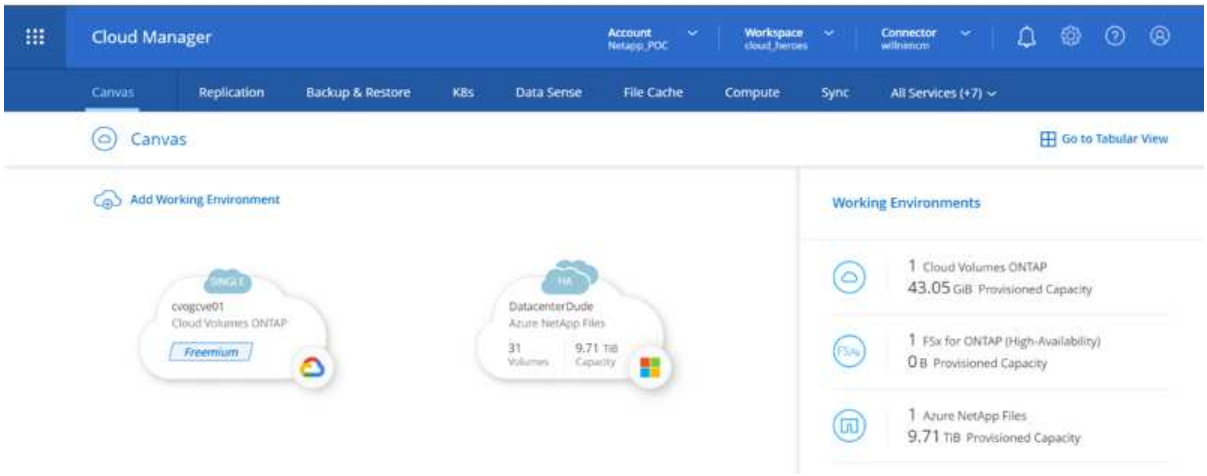
   HINT: Hoover your mouse over the tiles for details or customize CVO components and ONTAP version by clicking on Change Configuration.



8. On the Review & Approve page, review and confirm the selections.To create the Cloud Volumes ONTAP instance, click Go.



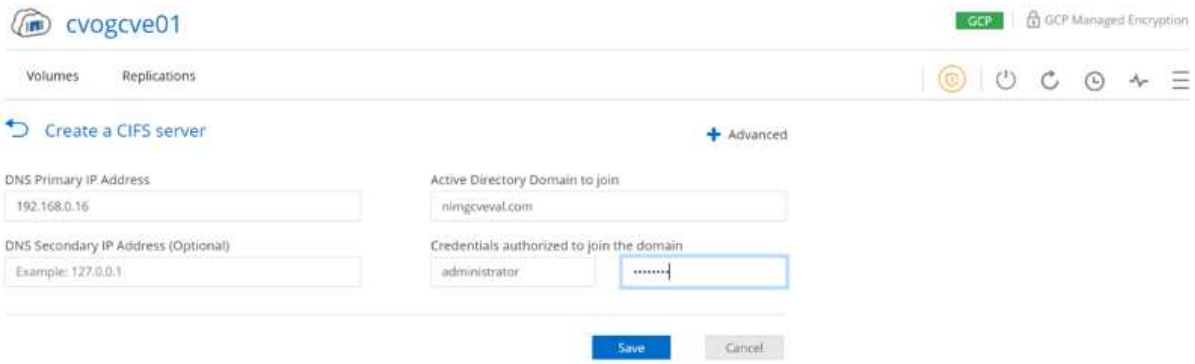
9. After Cloud Volumes ONTAP is provisioned, it is listed in the working environments on the Canvas page.



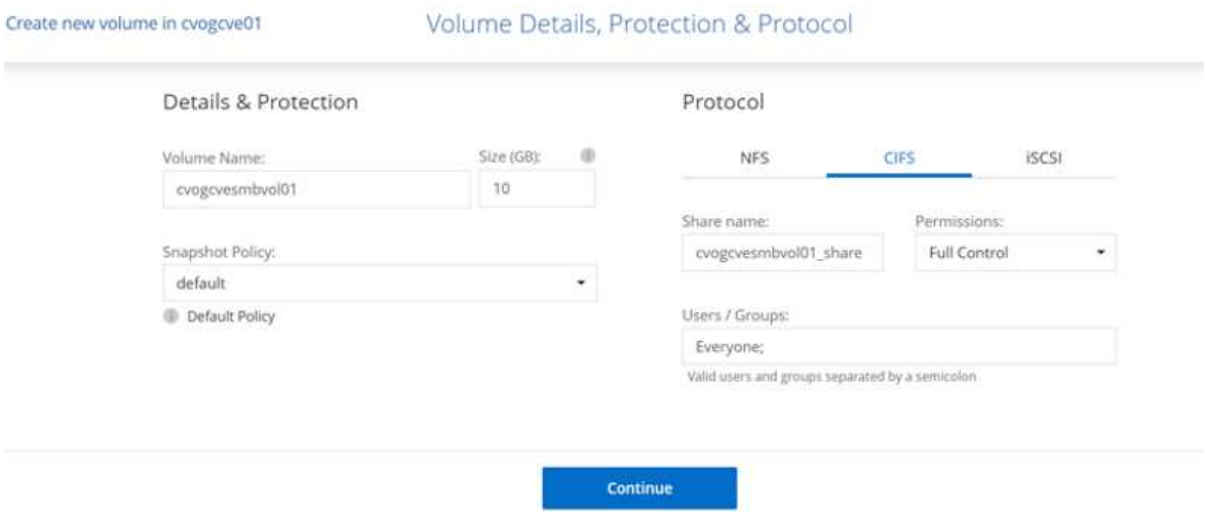
Additional configurations for SMB volumes

1. After the working environment is ready, make sure the CIFS server is configured with the appropriate DNS and Active Directory configuration parameters. This step is required before you can create the SMB volume.

   HINT: Click on the Menu Icon (º), select Advanced to display more options and select CIFS setup.



2. Creating the SMB volume is an easy process. At Canvas, double-click the Cloud Volumes ONTAP working environment to create and manage volumes and click on the Create Volume option. Choose the appropriate size and cloud manager chooses the containing aggregate or use advanced allocation mechanism to place on a specific aggregate. For this demo, CIFS/SMB is selected as the protocol.

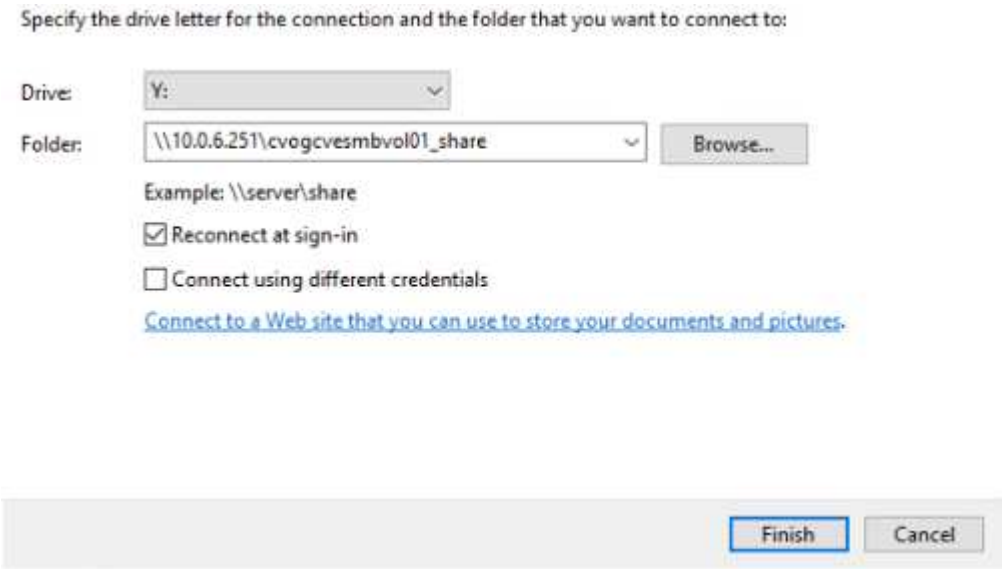


3. After the volume is provisioned, it will be availabe under the Volumes pane. Because a CIFS share is provisioned, give your users or groups permission to the files and folders and verify that those users can access the share and create a file. This step is not required if the volume is replicated from an on-premises environment because the file and folder permissions are all retained as part of SnapMirror replication.

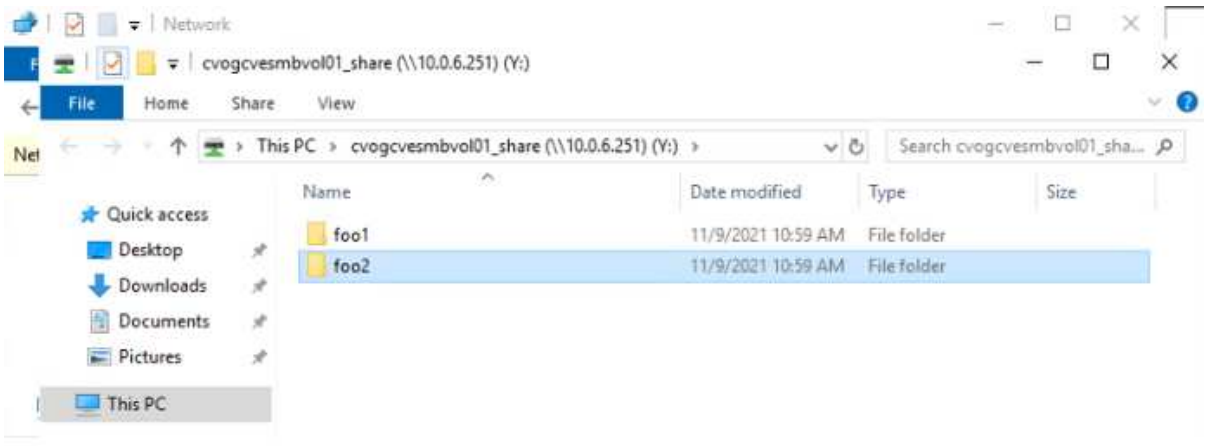
   HINT: Click on the volume menu (º) to display its options.

4. After the volume is created, use the mount command to display the volume connection instructions, then connect to the share from the VMs on Google Cloud VMware Engine.

5. Copy the following path and use the Map Network Drive option to mount the volume on the VM running on the Google Cloud VMware Engine.



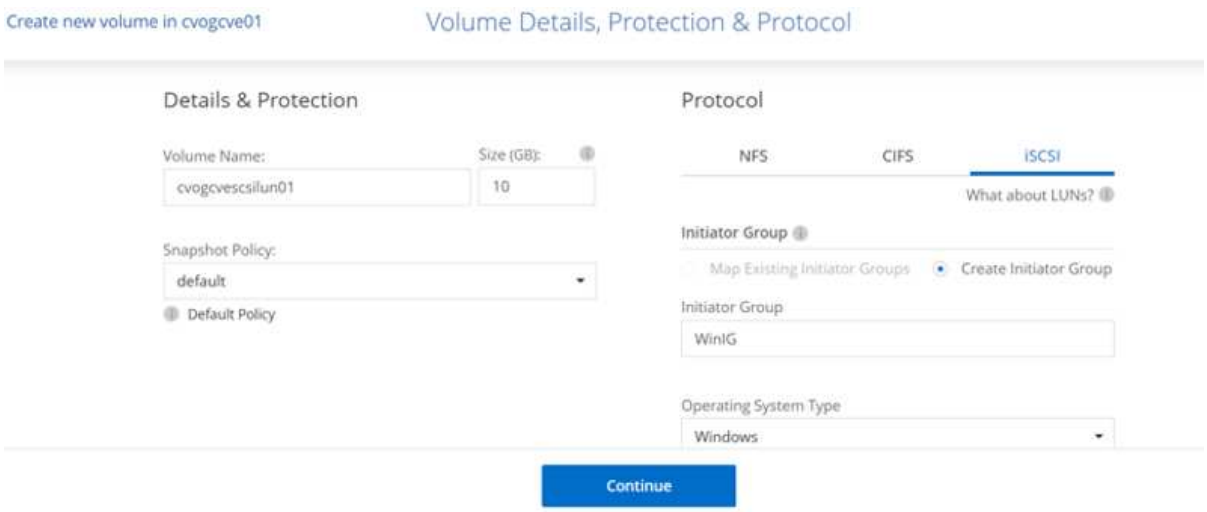
Once mapped, it can be easily accessed, and the NTFS permissions can be set accordingly.

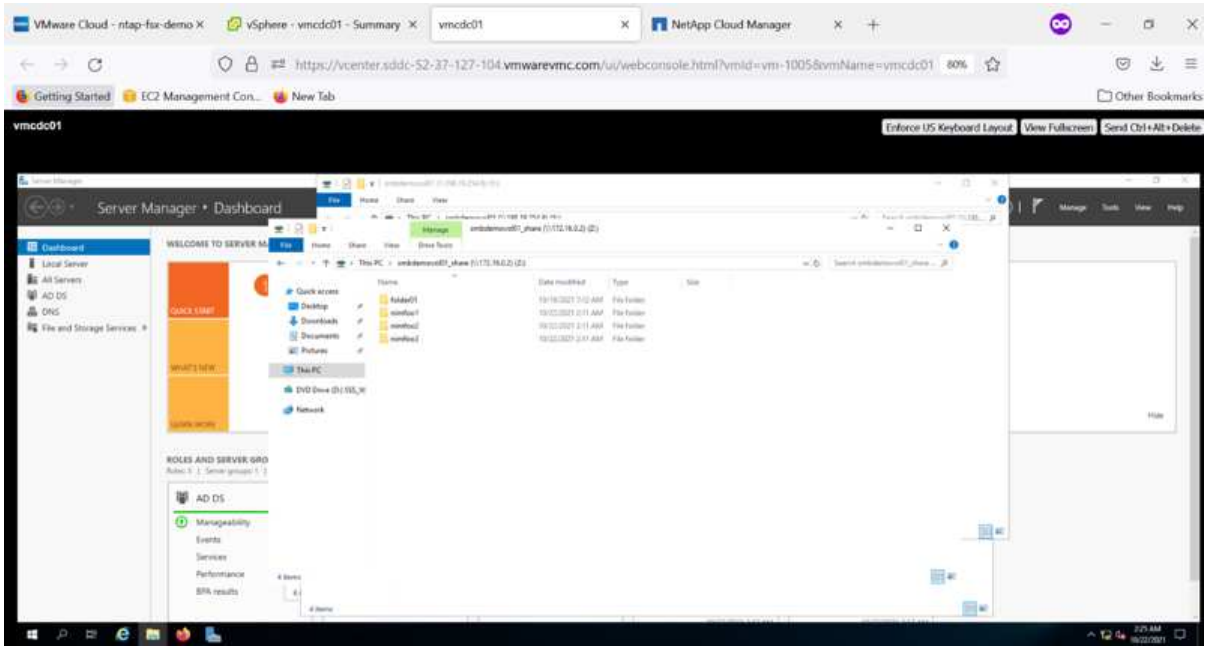


Connect the LUN on Cloud Volumes ONTAP to a host

To connect the cloud volumes ONTAP LUN to a host, complete the following steps:

1. On the Canvas page, double-click the Cloud Volumes ONTAP working environment to create and manage volumes.
2. Click Add Volume > New Volume and select iSCSI and click Create Initiator Group. Click Continue.





3. After the volume is provisioned, select the volume menu (º), and then click Target iQN. To copy the iSCSI Qualified Name (iQN), click Copy. Set up an iSCSI connection from the host to the LUN.

To accomplish the same for the host residing on Google Cloud VMware Engine:

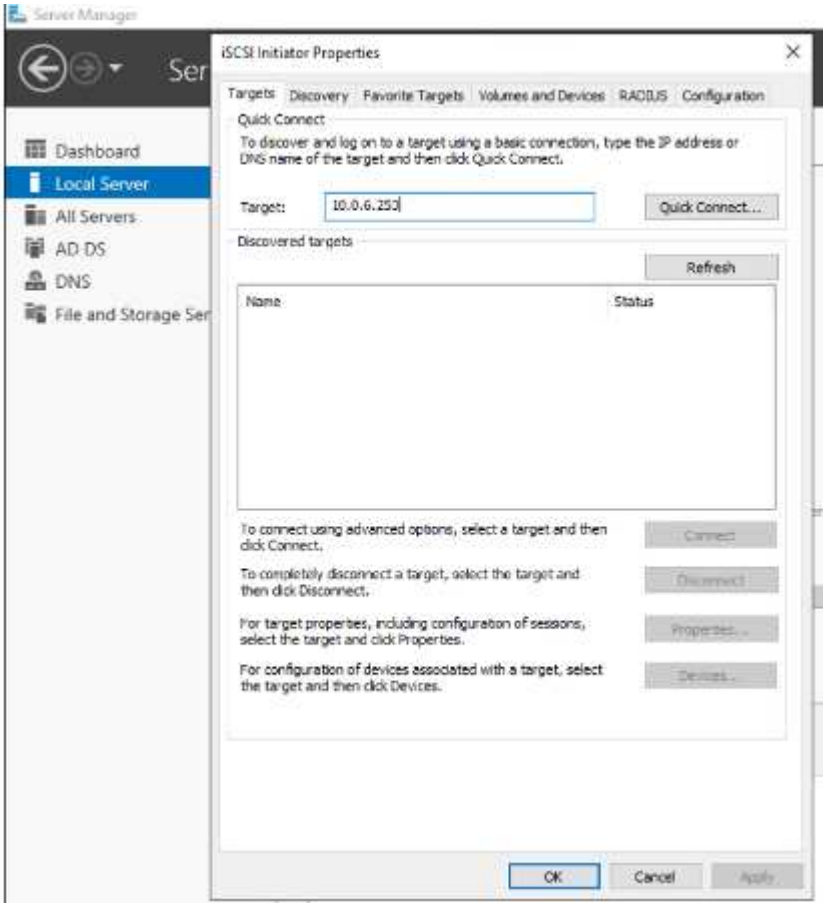
a. RDP to the VM hosted on Google Cloud VMware Engine.
b. Open the iSCSI Initiator Properties dialog box: Server Manager > Dashboard > Tools > iSCSI Initiator.

c. From the Discovery tab, click Discover Portal or Add Portal and then enter the IP address of the iSCSI target port.

d. From the Targets tab, select the target discovered and then click Log on or Connect.

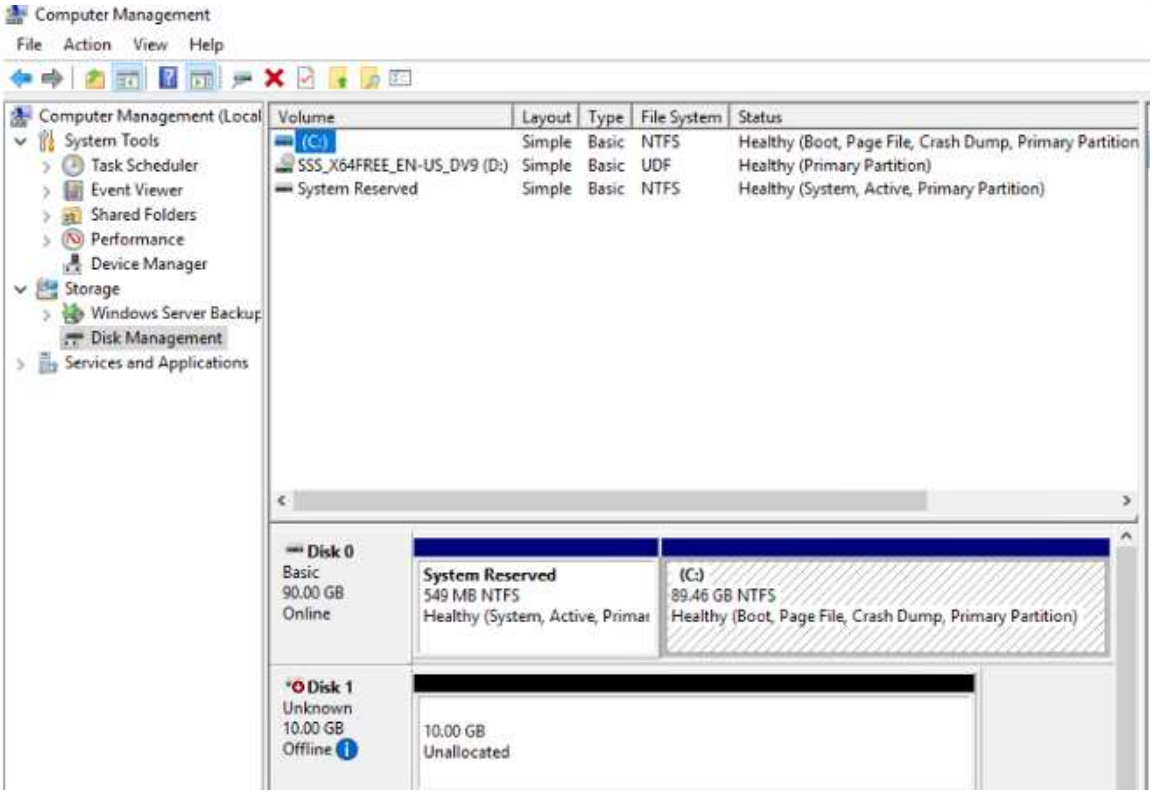
e. Select Enable multipath, and then select Automatically Restore This Connection When the Computer Starts or Add This Connection to the List of Favorite Targets. Click Advanced.

> The Windows host must have an iSCSI connection to each node in the cluster. The native DSM selects the best paths to use.



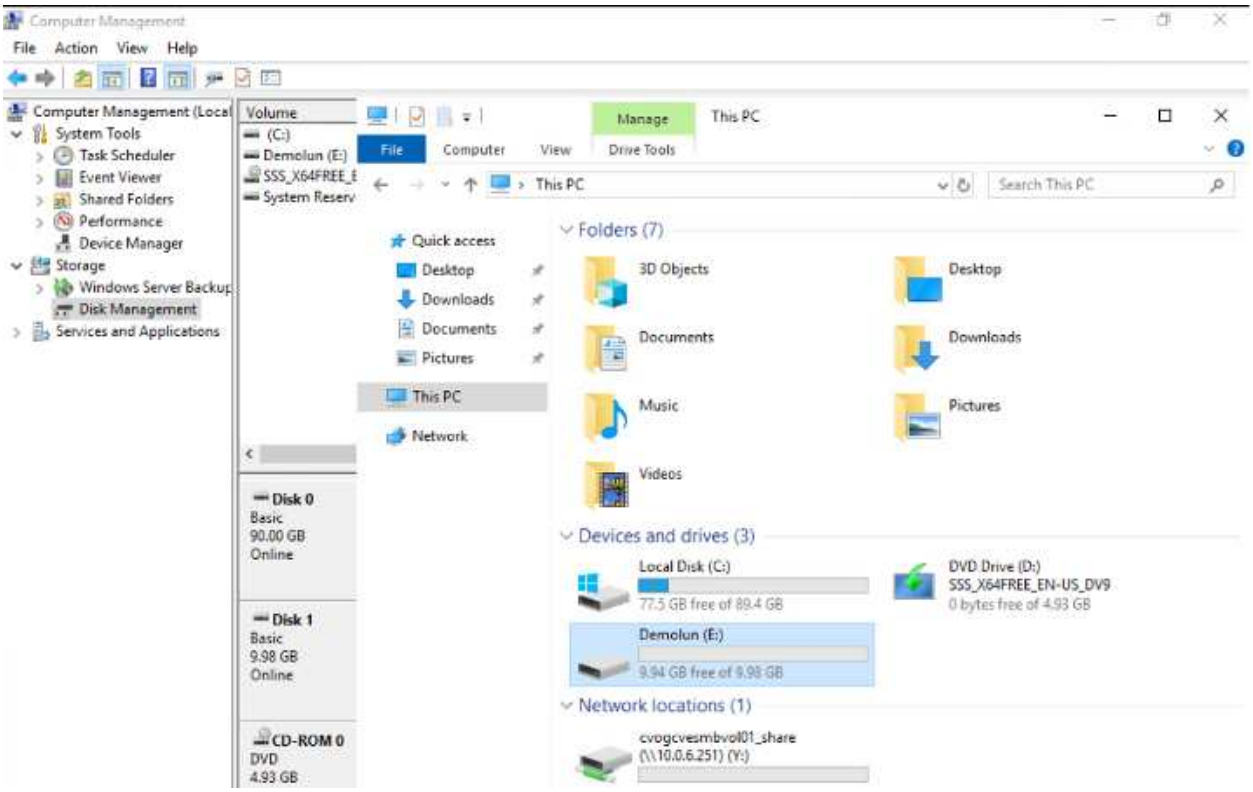
LUNs on storage virtual machine (SVM) appear as disks to the Windows host. Any new disks that are added are not automatically discovered by the host. Trigger a manual rescan to discover the disks by completing the following steps:

1. Open the Windows Computer Management utility: Start > Administrative Tools > Computer Management.
2. Expand the Storage node in the navigation tree.
3. Click Disk Management.
4. Click Action > Rescan Disks.



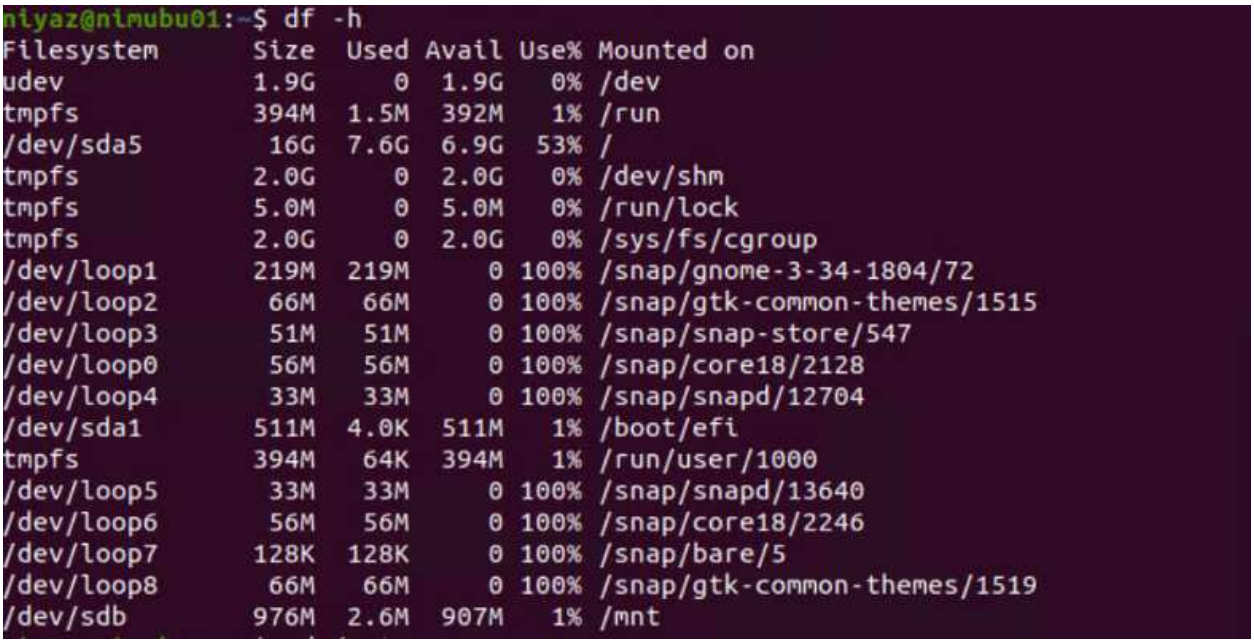
When a new LUN is first accessed by the Windows host, it has no partition or file system. Initialize the LUN; and optionally, format the LUN with a file system by completing the following steps:

5. Start Windows Disk Management.
6. Right-click the LUN, and then select the required disk or partition type.
7. Follow the instructions in the wizard. In this example, drive F: is mounted.



On the Linux clients, ensure the iSCSI daemon is running. Once the LUNs are provisioned, refer to the detailed guidance on iSCSI configuration with Ubuntu as an example here. To verify, run lsblk cmd from the shell.

```
niyaz@nimubu01:~$ lsblk
NAME   MAJ:MIN RM  SIZE RO TYPE MOUNTPOINT
loop0    7:0    0 55.4M  1 loop /snap/core18/2128
loop1    7:1    0  219M  1 loop /snap/gnome-3-34-1804/72
loop2    7:2    0 65.1M  1 loop /snap/gtk-common-themes/1515
loop3    7:3    0   51M  1 loop /snap/snap-store/547
loop4    7:4    0 32.3M  1 loop /snap/snapd/12704
loop5    7:5    0 32.5M  1 loop /snap/snapd/13640
loop6    7:6    0 55.5M  1 loop /snap/core18/2246
loop7    7:7    0    4K  1 loop /snap/bare/5
loop8    7:8    0 65.2M  1 loop /snap/gtk-common-themes/1519
sda      8:0    0   16G  0 disk
├─sda1   8:1    0  512M  0 part /boot/efi
├─sda2   8:2    0    1K  0 part
└─sda5   8:5    0 15.5G  0 part /
sdb      8:16   0    1G  0 disk
```

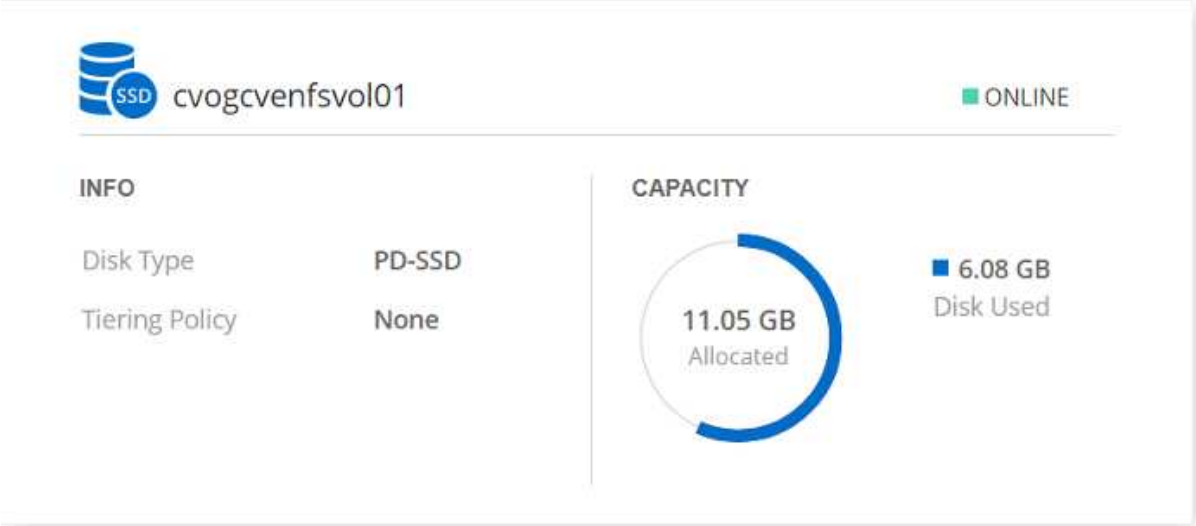

niyaz@nimubu01:~$ df -h
Filesystem Size Used Avail Use% Mounted on
udev 1.9G 0 1.9G 0% /dev
tmpfs 394M 1.5M 392M 1% /run
/dev/sda5 16G 7.6G 6.9G 53% /
tmpfs 2.0G 0 2.0G 0% /dev/shm
tmpfs 5.0M 0 5.0M 0% /run/lock
tmpfs 2.0G 0 2.0G 0% /sys/fs/cgroup
/dev/loop1 219M 219M 0 100% /snap/gnome-3-34-1804/72
/dev/loop2 66M 66M 0 100% /snap/gtk-common-themes/1515
/dev/loop3 51M 51M 0 100% /snap/snap-store/547
/dev/loop0 56M 56M 0 100% /snap/core18/2128
/dev/loop4 33M 33M 0 100% /snap/snapd/12704
/dev/sda1 511M 4.0K 511M 1% /boot/efi
tmpfs 394M 64K 394M 1% /run/user/1000
/dev/loop5 33M 33M 0 100% /snap/snapd/13640
/dev/loop6 56M 56M 0 100% /snap/core18/2246
/dev/loop7 128K 128K 0 100% /snap/bare/5
/dev/loop8 66M 66M 0 100% /snap/gtk-common-themes/1519
/dev/sdb 976M 2.6M 907M 1% /mnt

Mount Cloud Volumes ONTAP NFS volume on Linux client

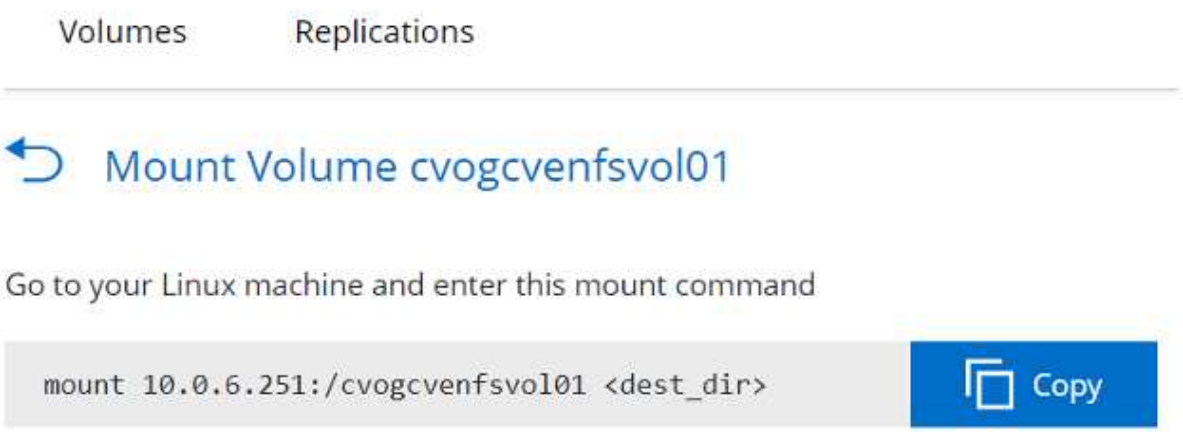
To mount the Cloud Volumes ONTAP (DIY) file system from VMs within Google Cloud VMware Engine, follow the below steps:

Provision the volume following the below steps

1. In the Volumes tab, click Create New Volume.
2. On the Create New Volume page, select a volume type:



3. In the Volumes tab, place your mouse cursor over the volume, select the menu icon (º), and then click Mount Command.



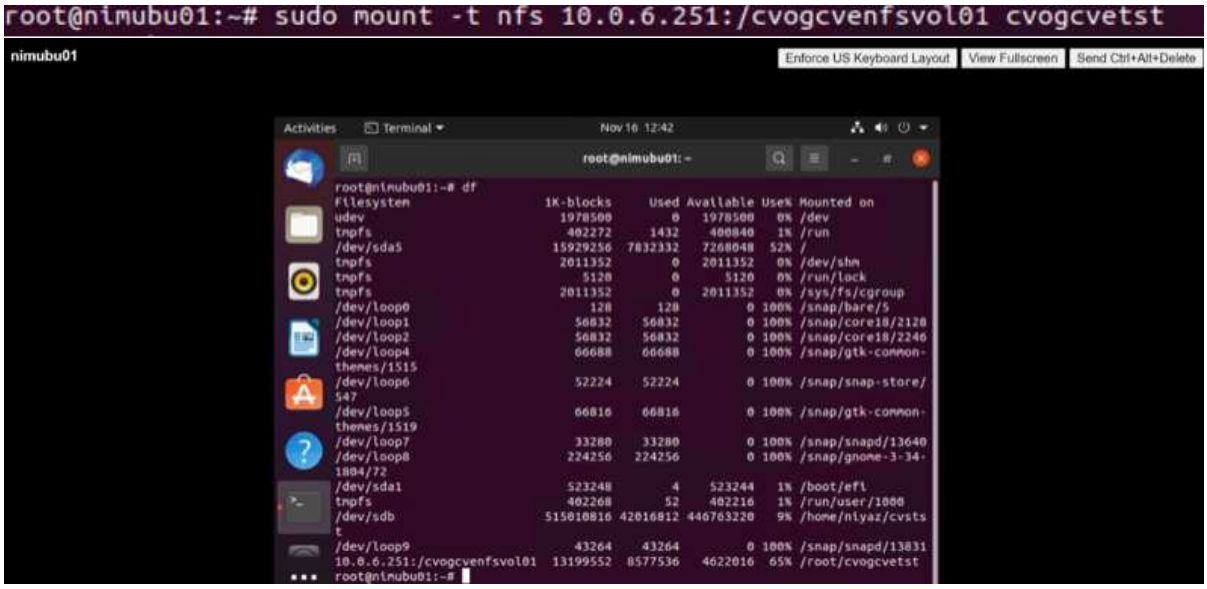
4. Click Copy.
5. Connect to the designated Linux instance.
6. Open a terminal on the instance using secure shell (SSH) and log in with the appropriate credentials.
7. Make a directory for the volume's mount point with the following command.

```
$ sudo mkdir /cvogcvetst
```

```
root@nimubu01:~# sudo mkdir cvogcvetst
```

8. Mount the Cloud Volumes ONTAP NFS volume to the directory that is created in the previous step.

```
sudo mount 10.0.6.251:/cvogcvenfsvol01 /cvogcvetst
```



Cloud Volumes Service (CVS)

Cloud Volumes Services (CVS) is a complete portfolio of data services to deliver advanced cloud solutions. Cloud Volumes Services supports multiple file access protocols for major cloud providers (NFS and SMB support).

Other benefits and features include: data protection and restore with Snapshot; special features to replicate, sync and migrate data destinations on-prem or in the cloud; and consistent high performance at the level of a dedicated flash storage system.

Cloud Volumes Service (CVS) as guest connected storage

Configure Cloud Volumes Service with VMware Engine

Cloud Volumes Service shares can be mounted from VMs that are created in the VMware Engine environment. The volumes can also be mounted on the Linux client and mapped on the Windows client because Cloud Volumes Service supports SMB and NFS protocols. Cloud Volumes Service volumes can be set up in simple steps.

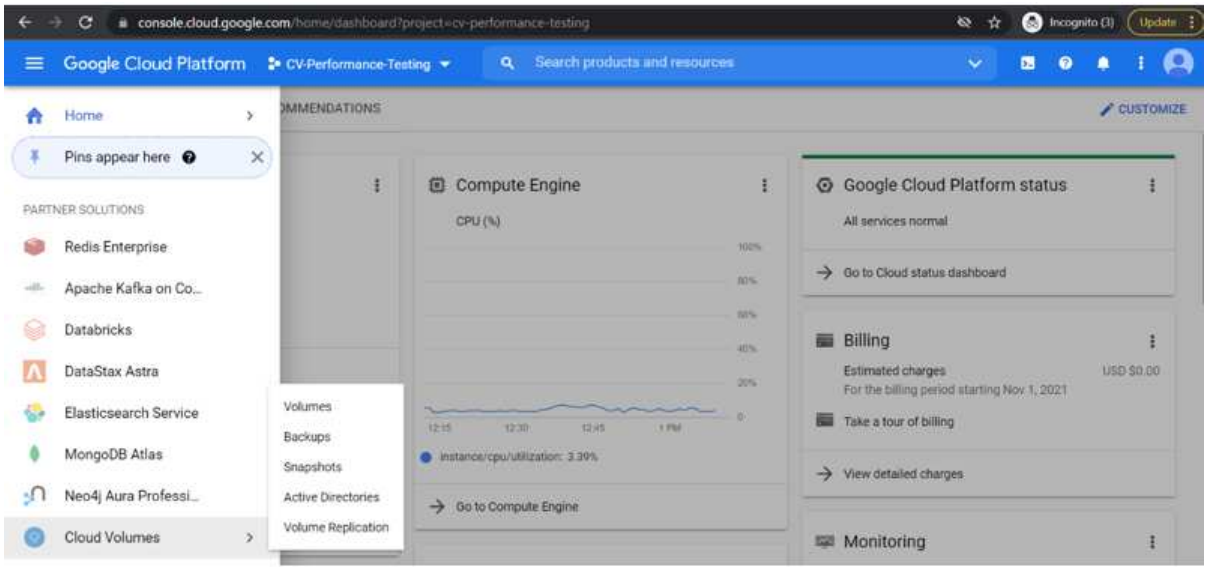
Cloud Volume Service and Google Cloud VMware Engine private cloud must be in the same region.

To purchase, enable and configure NetApp Cloud Volumes Service for Google Cloud from the Google Cloud Marketplace, follow this detailed guide.

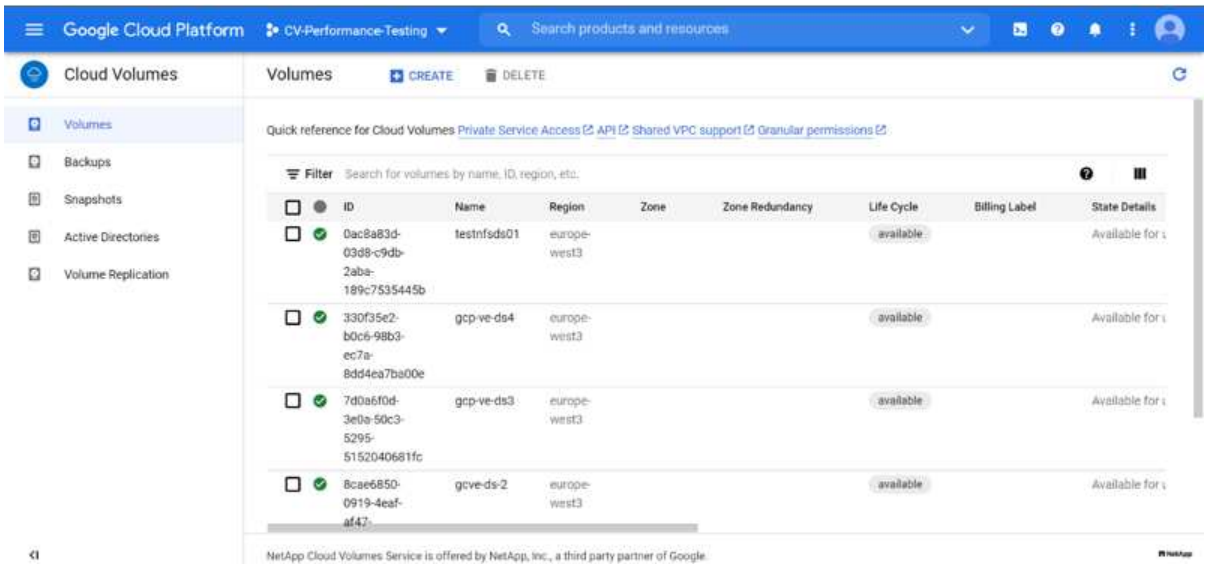
Create a CVS NFS volume to GCVE private cloud

To create and mount NFS volumes, complete the following steps:

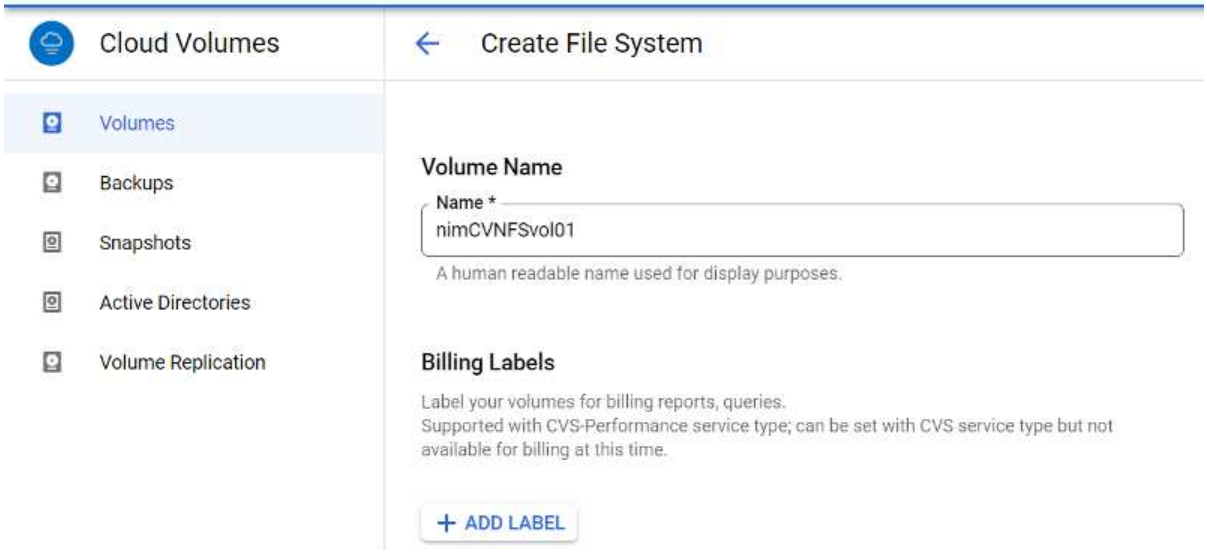
1. Access Cloud Volumes from Partner Solutions within the Google cloud console.



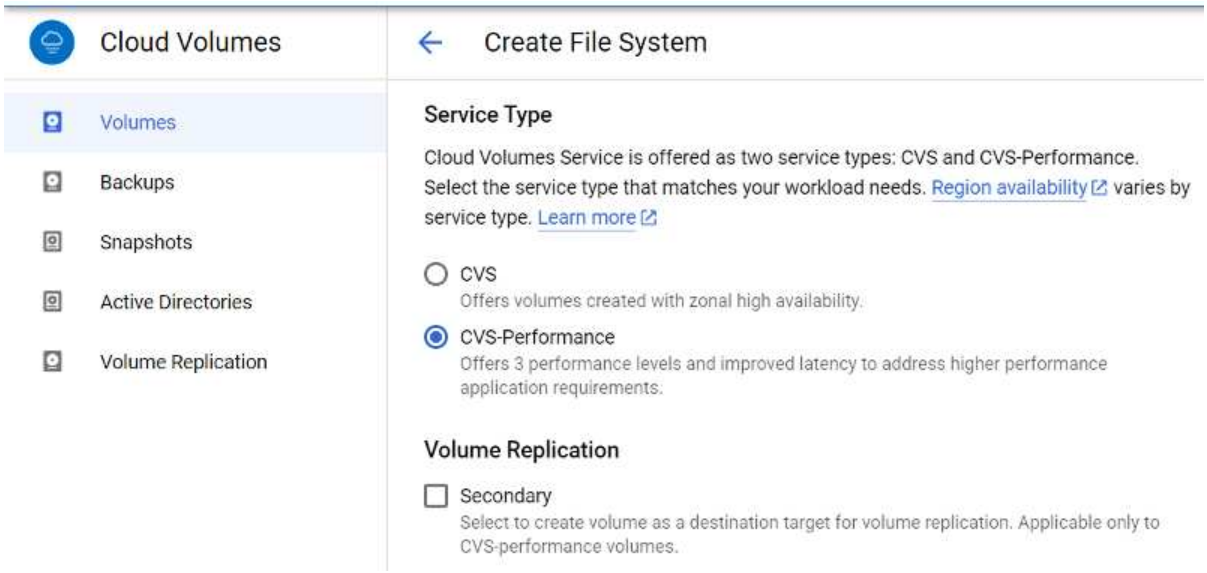
2. In the Cloud Volumes Console, go to the Volumes page and click Create.



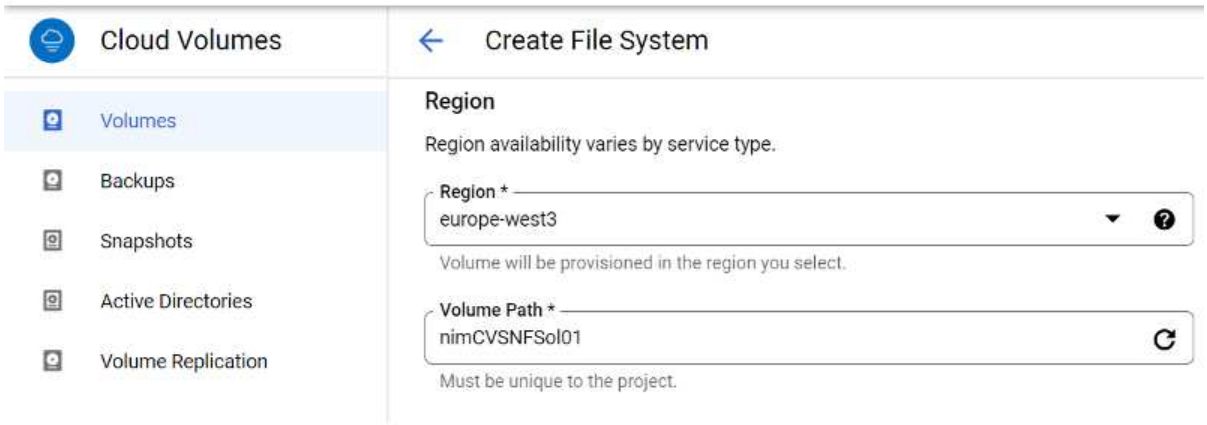
3. On the Create File System page, specify the volume name and billing labels as required for chargeback mechanisms.



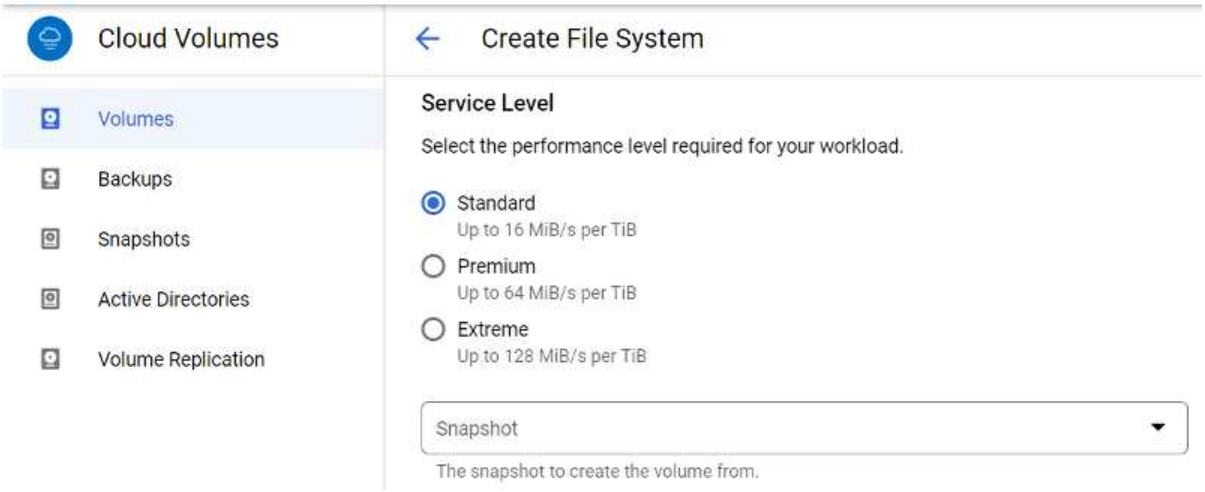
4. Select the appropriate service. For GCVE, choose CVS-Performance and desired service level for improved latency and higher performance based on the application workload requirements.



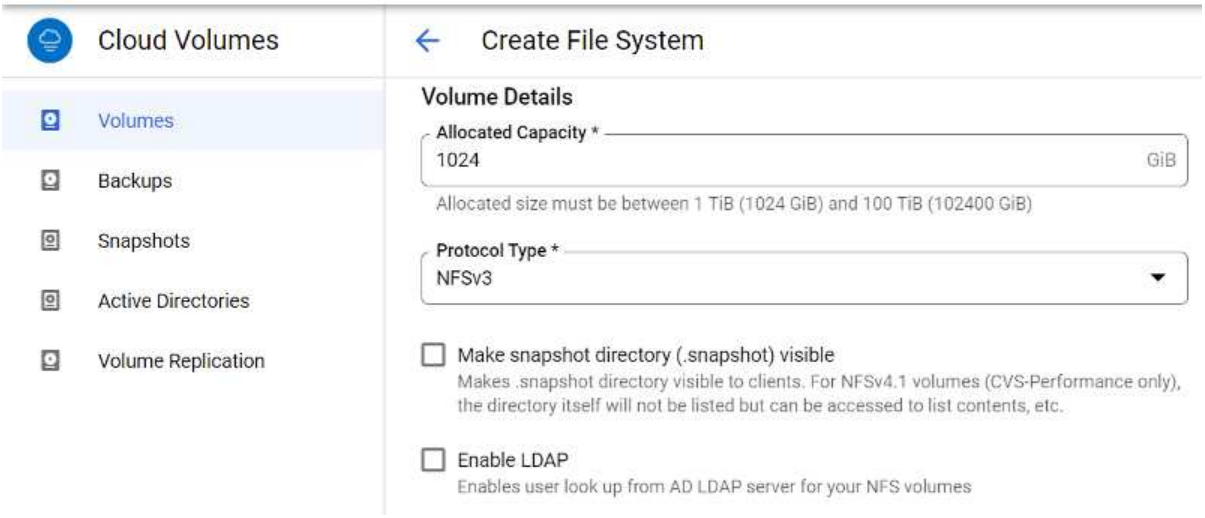
5. Specify the Google Cloud region for the volume and volume path (The volume path must be unique across all of cloud volumes in the project)



6. Select the level of performance for the volume.

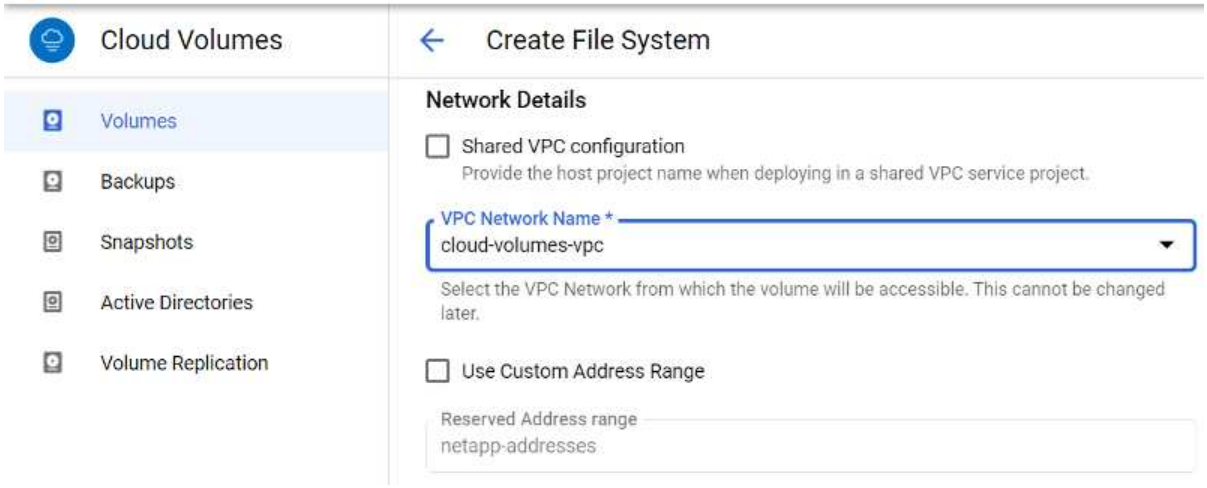


7. Specify the size of the volume and the protocol type. In this testing, NFSv3 is used.



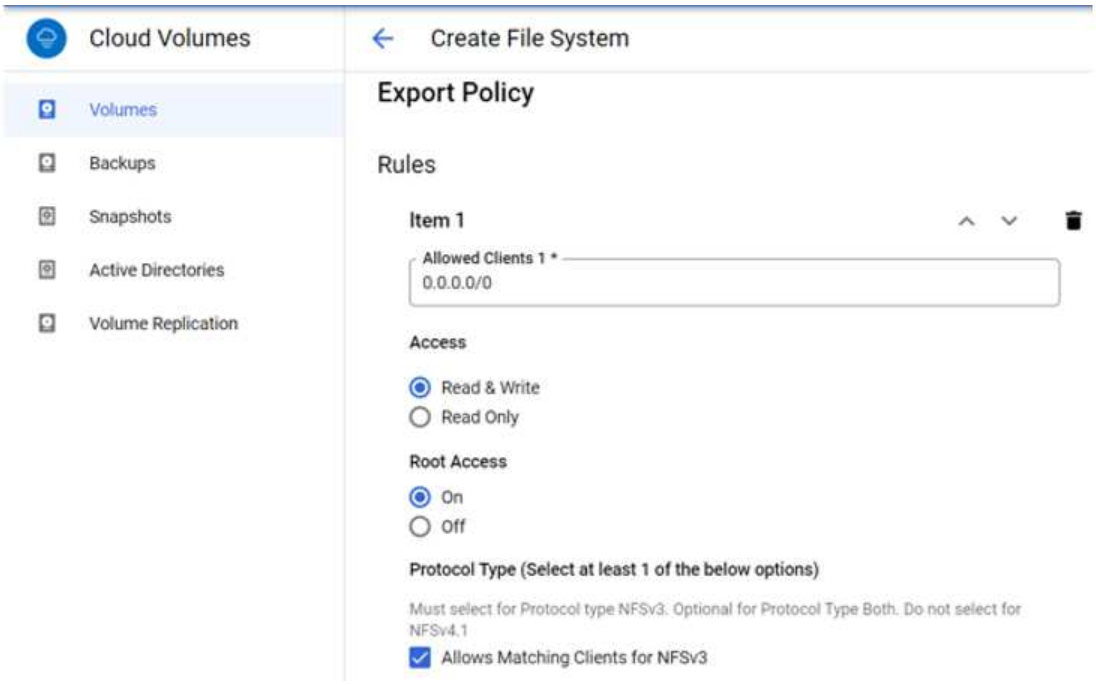
8. In this step, select the VPC Network from which the volume will be accessible. Ensure VPC peering is in place.

   HINT: If VPC peering has not been done, a pop-up button will be displayed to guide you through the peering commands. Open a Cloud Shell session and execute the appropriate commands to peer your VPC with Cloud Volumes Service producer. In case you decide to prepare VPC peering in beforehand, refer to these instructions.



9. Manage the Export policy rules by adding the appropriate rules and Select the checkbox for the corresponding NFS version.

   Note: Access to NFS volumes won't be possible unless an export policy is added.



10. Click Save to create the volume.

Mounting NFS exports to VMs running on VMware Engine

Before preparing to mount the NFS volume, ensure the peering status of private connection is listed as Active. Once status is Active, use the mount command.

To mount an NFS volume, do the following:

1. In the Cloud Console, go to Cloud Volumes > Volumes.
2. Go to the Volumes page
3. Click the NFS volume for which you want to mount NFS exports.
4. Scroll to the right, under Show More, click Mount Instructions.

To perform the mounting process from within the guest OS of the VMware VM, follow the below steps:

1. Use SSH client and SSH to the virtual machine.
2. Install the nfs client on the instance.
   a. On Red Hat Enterprise Linux or SuSE Linux instance:

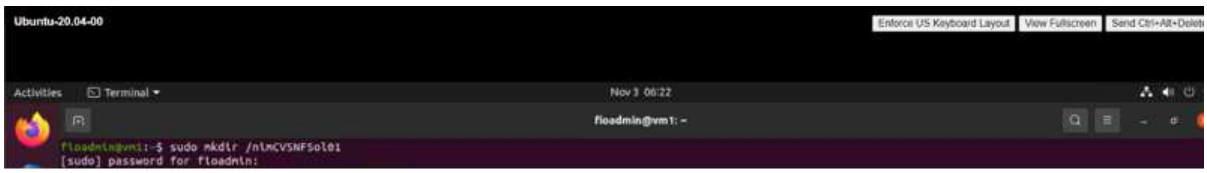
```
sudo yum install -y nfs-utils
```

   b. On an Ubuntu or Debian instance:

```
sudo apt-get install nfs-common
```

3. Create a new directory on the instance, such as "/nimCVSNFSol01":

```
sudo mkdir /nimCVSNFSol01
```



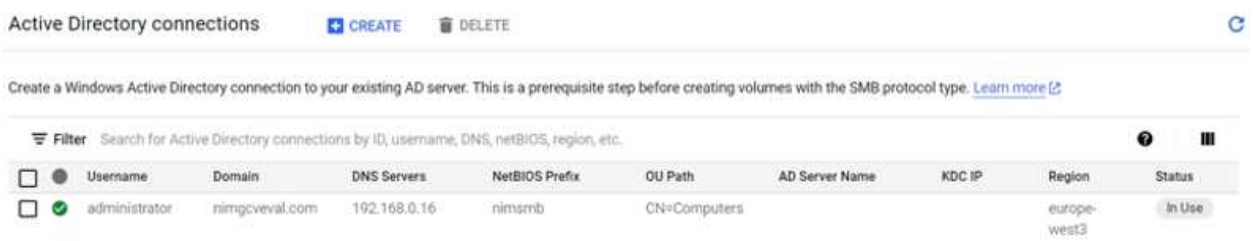
4. Mount the volume using the appropriate command. Example command from the lab is below:

```
sudo mount -t nfs -o rw,hard,rsize=65536,wsize=65536,vers=3,tcp
10.53.0.4:/nimCVSNFSol01 /nimCVSNFSol01
```

```
root@vm1:~# df
Filesystem                      1K-blocks       Used    Available Use% Mounted on
udev                             16409952          0     16409952   0% /dev
tmpfs                             3288328       1580      3286748   1% /run
/dev/sdb5                        61145932   19231356     38778832  34% /
tmpfs                            16441628          0     16441628   0% /dev/shm
tmpfs                                5120          0         5120   0% /run/lock
tmpfs                            16441628          0     16441628   0% /sys/fs/cgroup
/dev/loop0                             128        128            0 100% /snap/bare/5
/dev/loop1                           56832      56832            0 100% /snap/core18/2128
/dev/loop2                           66688      66688            0 100% /snap/gtk-common-themes/1515
/dev/loop4                           66816      66816            0 100% /snap/gtk-common-themes/1519
/dev/loop3                           52224      52224            0 100% /snap/snap-store/547
/dev/loop5                          224256     224256            0 100% /snap/gnome-3-34-1804/72
/dev/sdb1                           523248          4       523244   1% /boot/efi
tmpfs                              3288324         28      3288296   1% /run/user/1000
10.53.0.4:/gcve-ds-1          107374182400 1136086016 106238096384   2% /base
/dev/mapper/nfsprdvg1-prod01     419155968   55384972    363770996  14% /datastore1
/dev/loop8                           33280      33280            0 100% /snap/snapd/13270
/dev/loop6                           33280      33280            0 100% /snap/snapd/13640
/dev/loop7                           56832      56832            0 100% /snap/core18/2246
10.53.0.4:/nimCVSNFSol01      107374182400        256 107374182144   1% /nimCVSNFSol01
root@vm1:~#
```

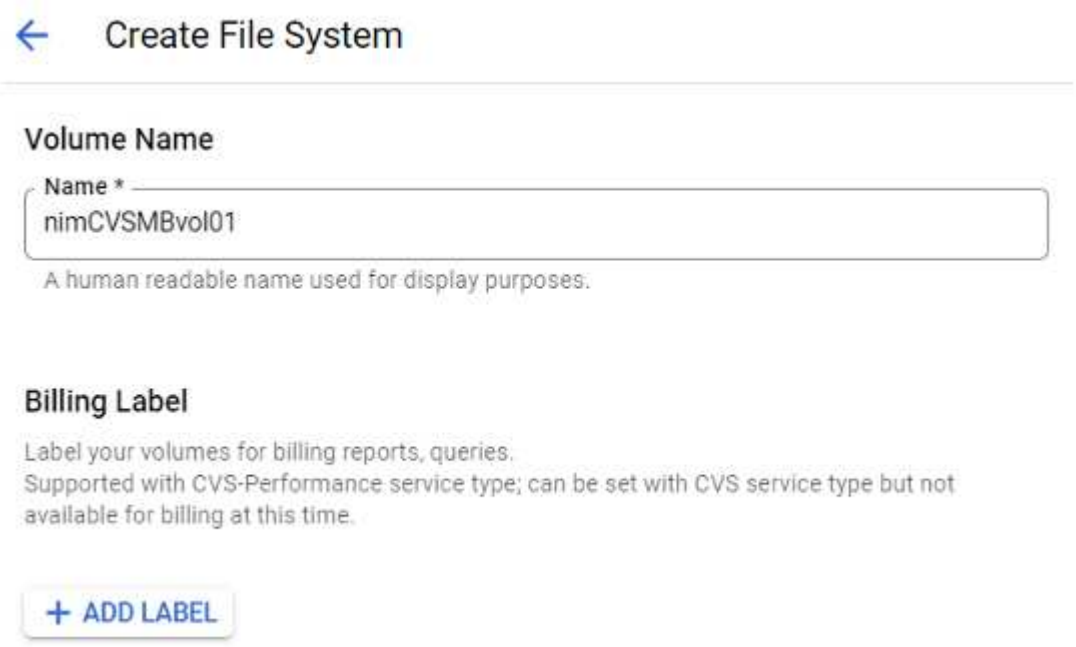
Creating and Mounting SMB Share to VMs running on VMware Engine

For SMB volumes, make sure the Active Directory connections is configured prior to creating the SMB volume.

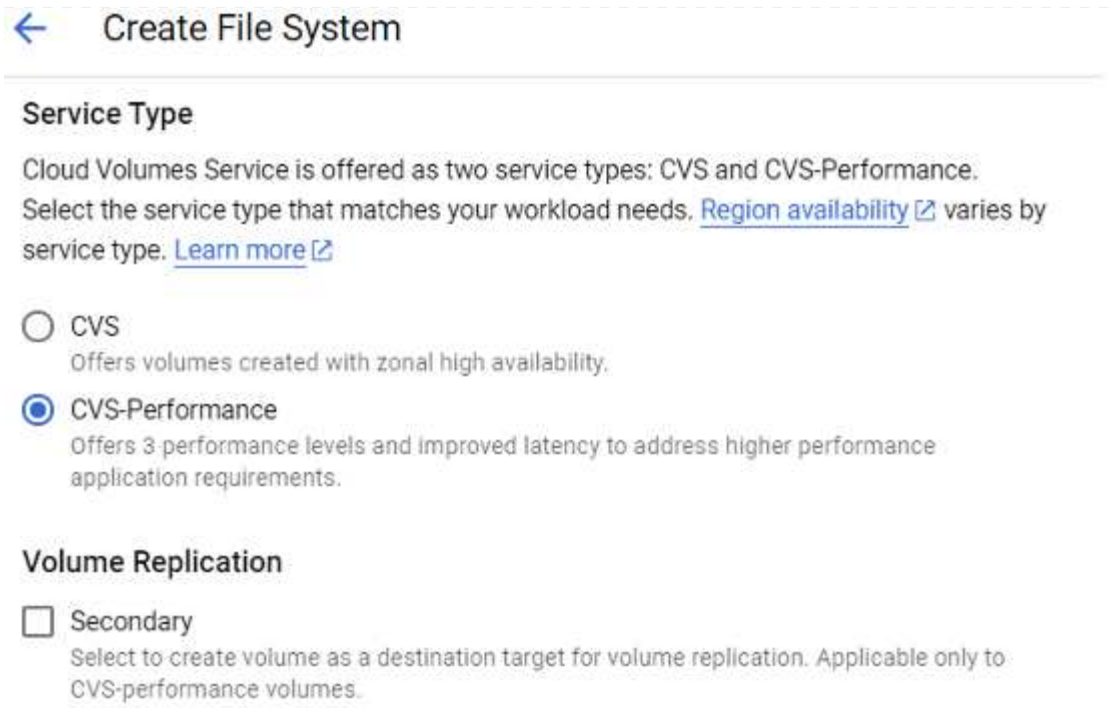


Once the AD connection is in place, create the volume with the desired service level. The steps are like creating NFS volume except selecting the appropriate protocol.

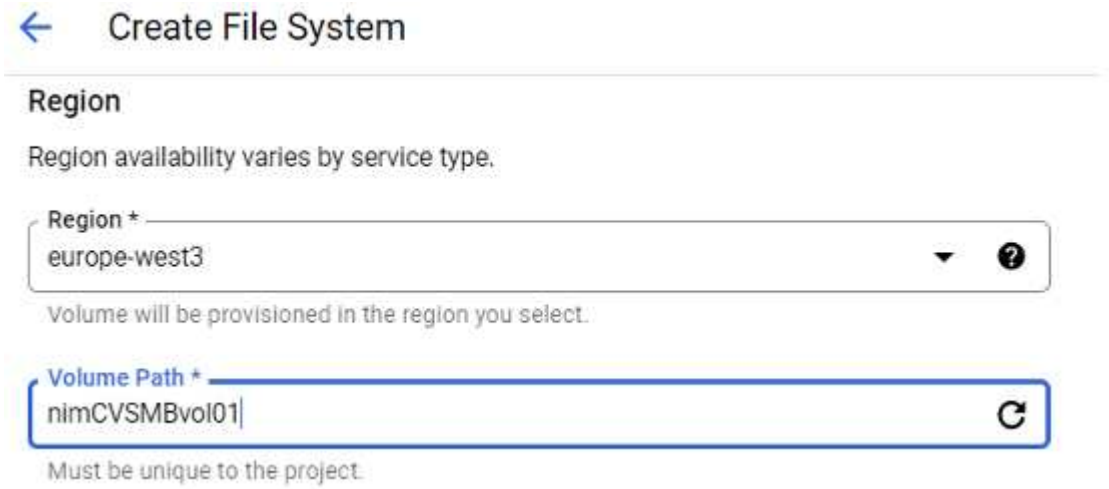
1. In the Cloud Volumes Console, go to the Volumes page and click Create.
2. On the Create File System page, specify the volume name and billing labels as required for chargeback mechanisms.



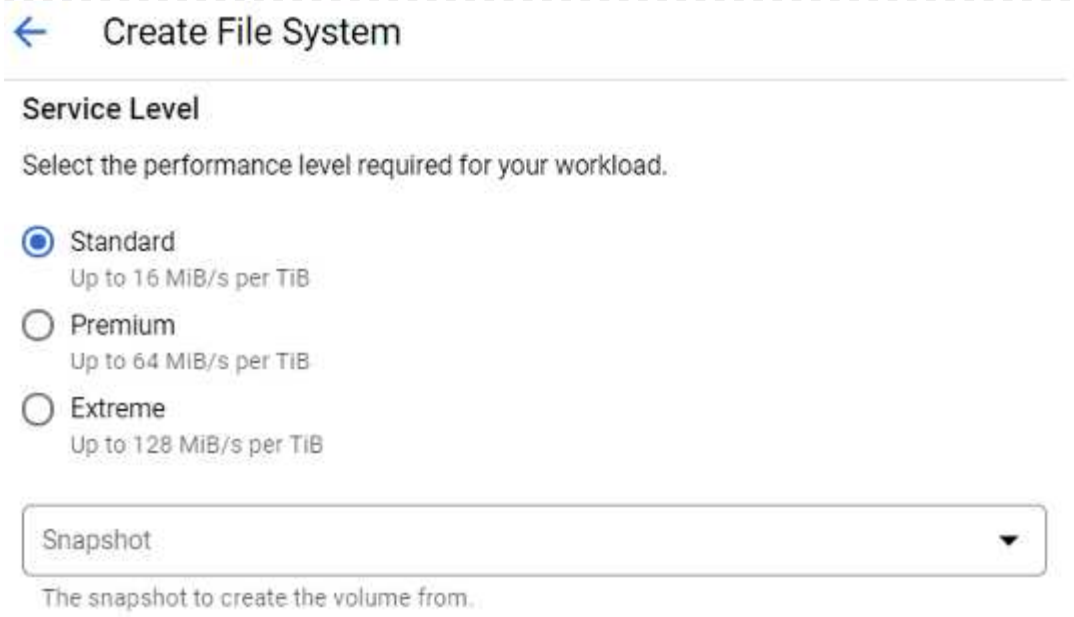
3. Select the appropriate service. For GCVE, choose CVS-Performance and desired service level for improved latency and higher performance based on the workload requirements.



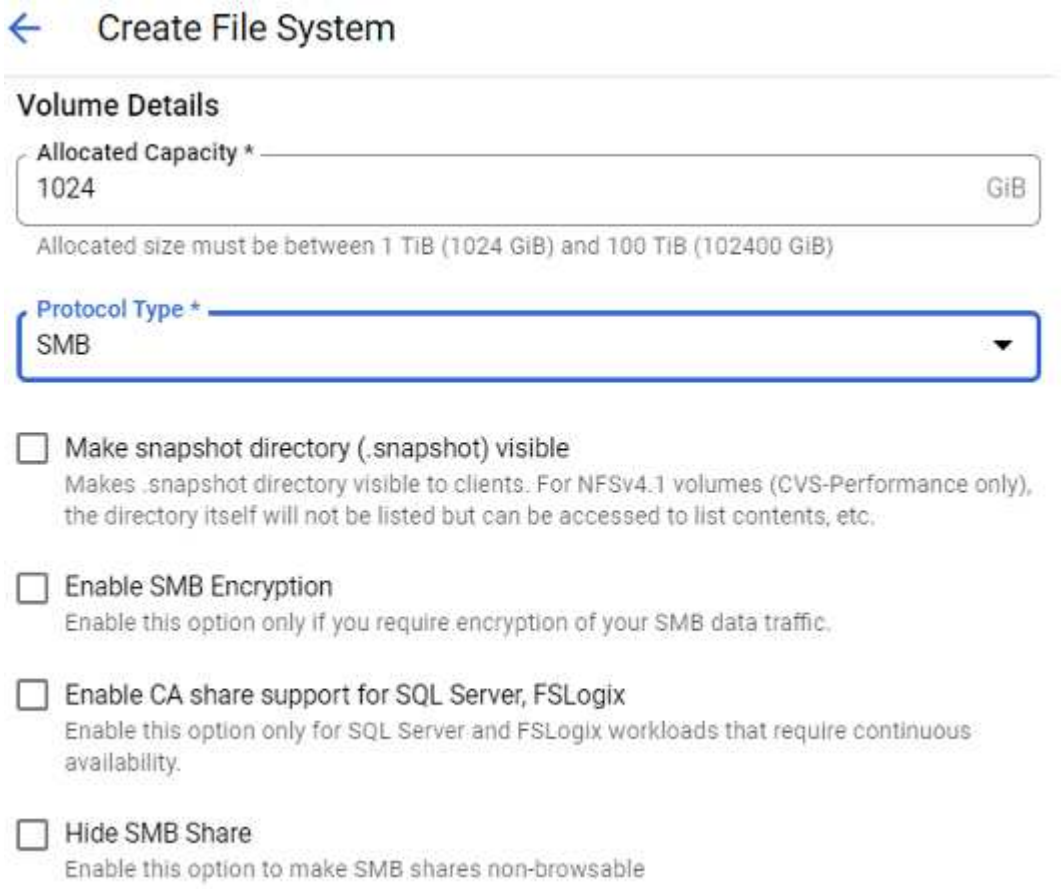
4. Specify the Google Cloud region for the volume and volume path (The volume path must be unique across all of cloud volumes in the project)



5. Select the level of performance for the volume.



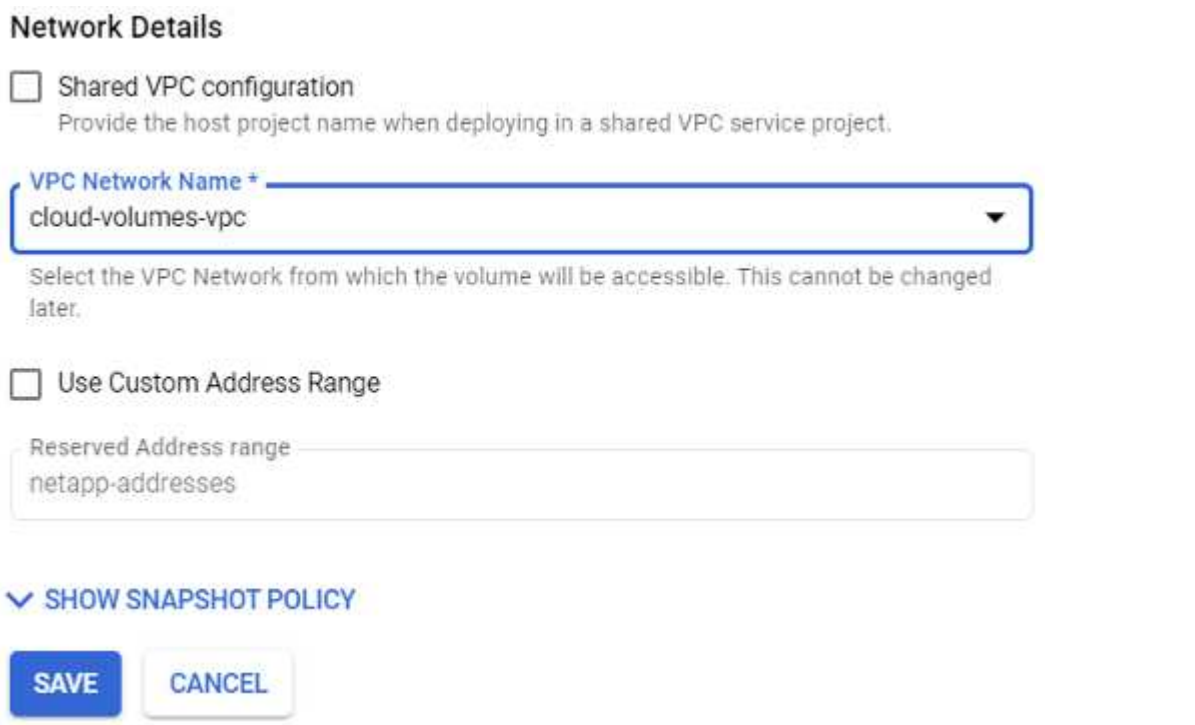
6. Specify the size of the volume and the protocol type. In this testing, SMB is used.



7. In this step, select the VPC Network from which the volume will be accessible. Ensure VPC peering is in place.

   HINT: If VPC peering has not been done, a pop-up button will be displayed to guide you through the peering commands. Open a Cloud Shell session and execute the appropriate commands to peer your VPC with Cloud Volumes Service producer. In case you decide to prepare VPC

peering in beforehand, refer to these instructions.



8. Click Save to create the volume.

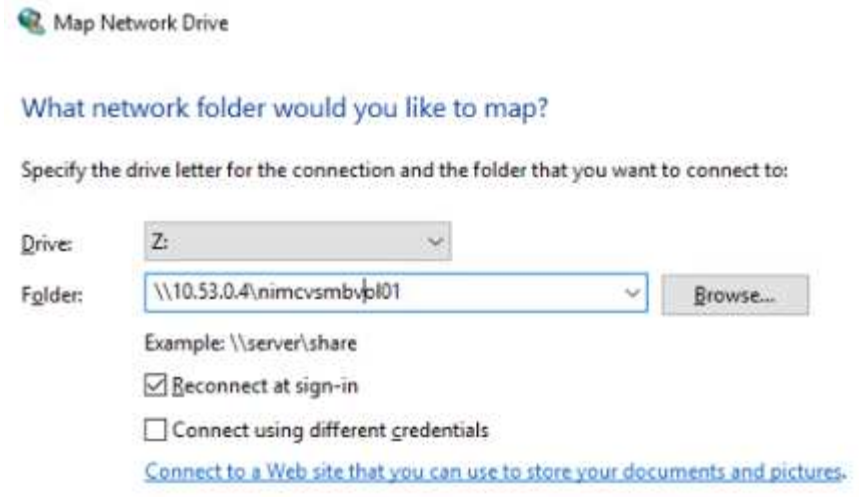
To mount the SMB volume, do the following:

1. In the Cloud Console, go to Cloud Volumes > Volumes.
2. Go to the Volumes page
3. Click the SMB volume for which you want to map an SMB share.
4. Scroll to the right, under Show More, click Mount Instructions.

To perform the mounting process from within the Windows guest OS of the VMware VM, follow the below steps:

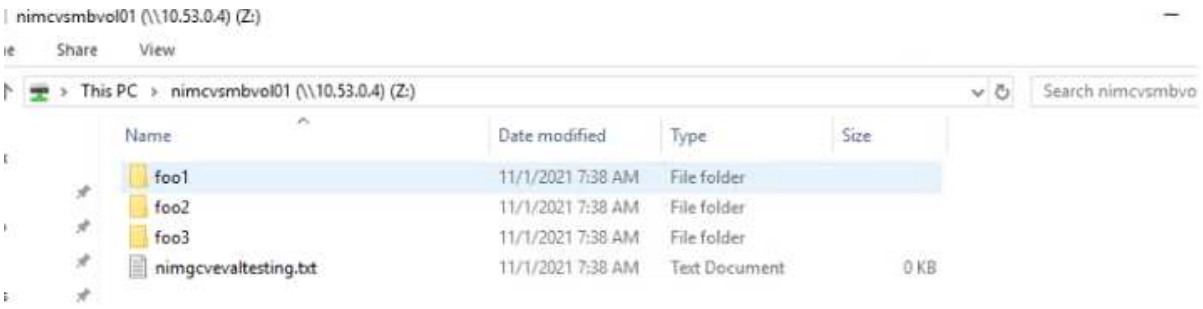
1. Click the Start button and then click on Computer.
2. Click Map Network Drive.
3. In the Drive list, click any available drive letter.
4. In the folder box, type:

```
\\nimsmb-3830.nimgcveval.com\nimCVSMBvol01
```



To connect every time you log on to your computer, select the Reconnect at sign-in check box.

5. Click Finish.



Summary and Conclusion: Why NetApp Hybrid Multi-Cloud with VMware

NetApp Cloud Volumes along with VMware solutions for the major hyperscalers provides great potential for organizations looking to leverage hybrid cloud. The rest of this section provides the use cases that show integrating NetApp Cloud Volumes enables true hybrid multi-cloud capabilities.

Use case #1: Optimizing storage

When performing a sizing exercise using RVtools output, it is always evident that the horsepower (vCPU/vMem) scale is parallel with storage. Many times, organizations find themselves in a situation where the storage space requires drives the size of the cluster well beyond what is needed for horsepower.

By integrating NetApp Cloud Volumes, organizations can realize a vSphere-based cloud solution with a simple migration approach, with no re-platforming, no IP changes, and no architectural changes. Additionally, this optimization enables you to scale the storage footprint while keeping the host count to least amount required in vSphere, but no change to the storage hierarchy, security, or files made available. This allows you to optimize the deployment and reduce the overall TCO by 35–45%. This integration also enables you to scale storage from warm storage to production-level performance in seconds.

Use case #2: Cloud migration

Organizations are under pressure to migrate applications from on-premises data centers to the Public Cloud for multiple reasons: an upcoming lease expiration; a finance directive to move from capital expenditure (capex) spending to operational expenditures (opex) spending; or simply a top-down mandate to move everything to the cloud.

When speed is critical, only a streamlined migration approach is feasible because re-platforming and refactoring applications to adapt to the cloud's particular IaaS platform is slow and expensive, often taking months. By combining NetApp Cloud Volumes with the bandwidth-efficient SnapMirror replication for guest-connected storage (including RDMs in conjunction with application-consistent Snapshot copies and HCX, cloud specific migration (e.g. Azure Migrate), or third-party products for replicating VMs), this transition is even easier than relying on time-consuming I/O filters mechanisms.

Use case #3: Data center expansion

When a data center reaches capacity limits due to seasonal demand spikes or just steady organic growth, moving to the cloud-hosted VMware along with NetApp Cloud Volumes is an easy solution. Leveraging NetApp Cloud Volumes allows storage creation, replication, and expansion very easily by providing high availability across availability zones and dynamic scaling capabilities. Leveraging NetApp Cloud Volumes helps in minimizing host cluster capacity by overcoming the need for stretch clusters.

Use case #4: Disaster recovery to the cloud

In a traditional approach, if a disaster occurs, the VMs replicated to the cloud would require conversion to the cloud's own hypervisor platform before they could be restored – not a task to be handled during a crisis.

By using NetApp Cloud Volumes for guest-connected storage using SnapCenter and SnapMirror replication from on-premises along with public cloud virtualization solutions, a better approach for disaster recovery can be devised allowing VM replicas to be recovered on fully consistent VMware SDDC infrastructure along with cloud specific recovery tools (e.g. Azure Site Recovery) or equivalent third-party tools such as Veeam. This approach also enables you to perform disaster recovery drills and recovery from ransomware quickly. This also enables you to scale to full production for testing or during a disaster by adding hosts on-demand.

Use case #5: Application modernization

After applications are in the public cloud, organizations will want to take advantage of the hundreds of powerful cloud services to modernize and extend them. With the use of NetApp Cloud Volumes, modernization is an easy process because the application data is not locked into vSAN and allows data mobility for a wide range of use cases, including Kubernetes.

Conclusion

Whether you are targeting an all-cloud or hybrid cloud, NetApp Cloud Volumes provides excellent options to deploy and manage the application workloads along with file services and block protocols while reducing the TCO by making the data requirements seamless to the application layer.

Whatever the use case, choose your favorite cloud/hyperscaler together with NetApp Cloud Volumes for rapid realization of cloud benefits, consistent infrastructure, and operations across on-premises and multiple clouds, bidirectional portability of workloads, and enterprise-grade capacity and performance.

It is the same familiar process and procedures that are used to connect the storage. Remember, it is just the position of the data that changed with new names; the tools and processes all remain the same and NetApp Cloud Volumes helps in optimizing the overall deployment.

VMware Hybrid Cloud Use Cases

Use Cases for NetApp Hybrid Multi-Cloud 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 native 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 multi-cloud architecture.

Understanding the Importance of Native Storage Options

While VMware in any cloud delivers unique hybrid capabilities to every customer, limited native 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 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.

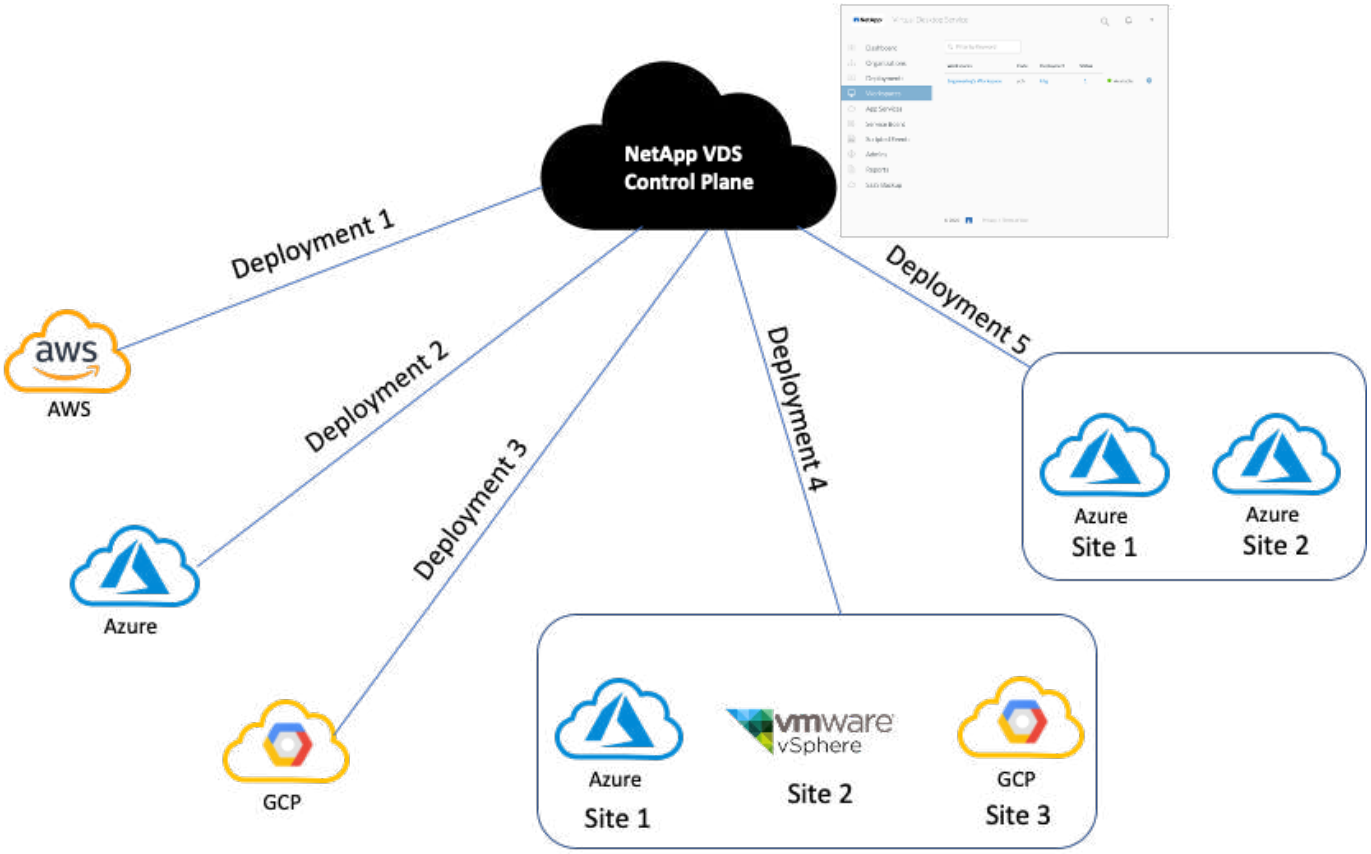
With Microsoft Azure Windows Virtual Desktop service, Microsoft takes care of maintenance for Remote Desktop Services components, allowing customers to focus on provisioning workspaces in the cloud. Customers must provision and manage the complete stack which requires special skills to manage VDI environments.

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.

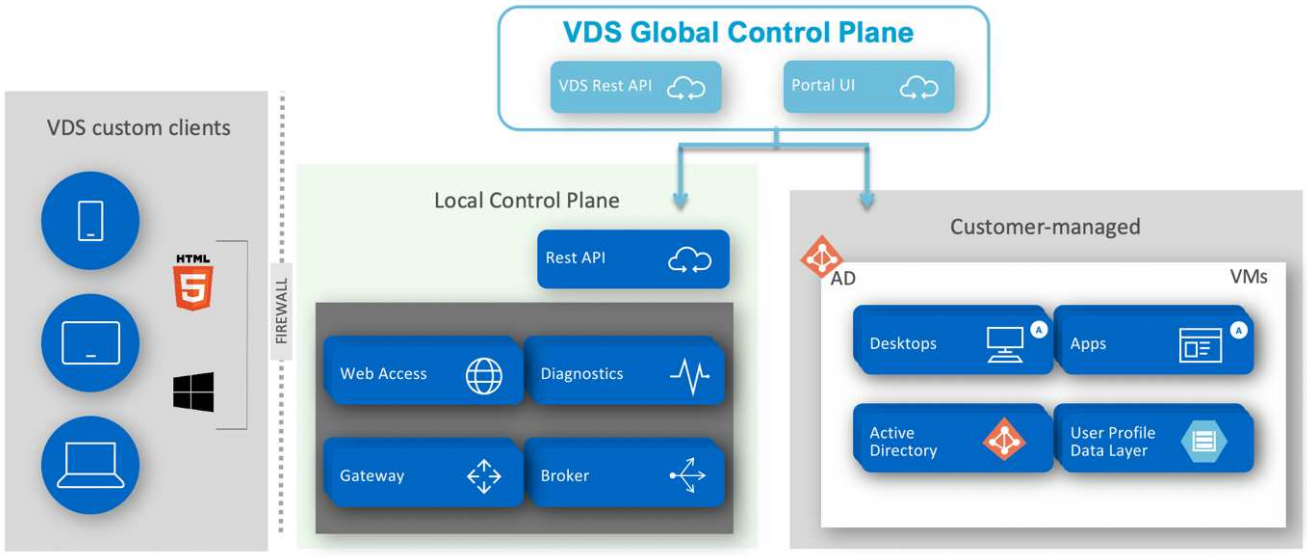
A sample deployment topology is shown in the following figure.



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.

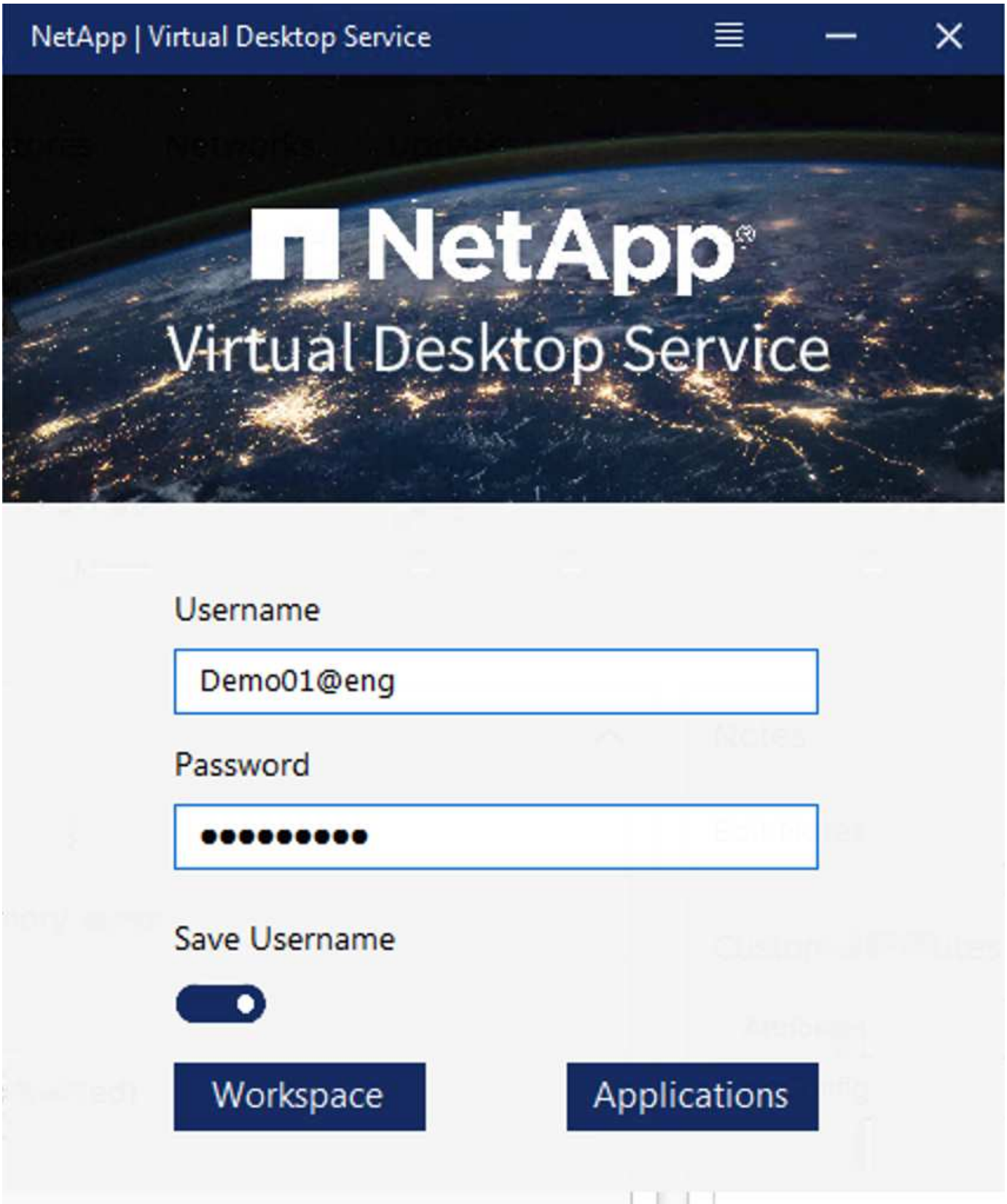
For WVD in Azure, Microsoft provides a platform-as-a-service that is consumed by NetApp VDS. For other environments, NetApp VDS orchestrates the deployment and configuration of Microsoft Remote Desktop Services. NetApp VDS supports both WVD Classic and WVD ARM and can also be used to upgrade existing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



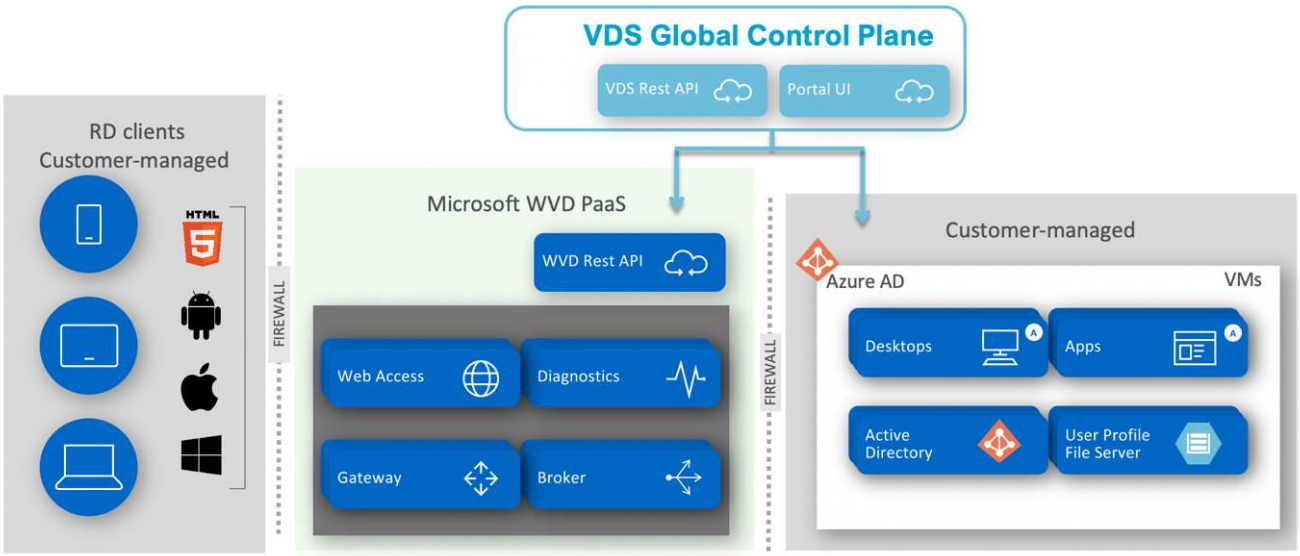
For RDS implementations, NetApp VDS can be readily accessed from Windows and browsers using client software that can be customized to include customer logo and images. Based on user credentials, it provides user access to approved workspaces and applications. There is no need to configure the gateway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

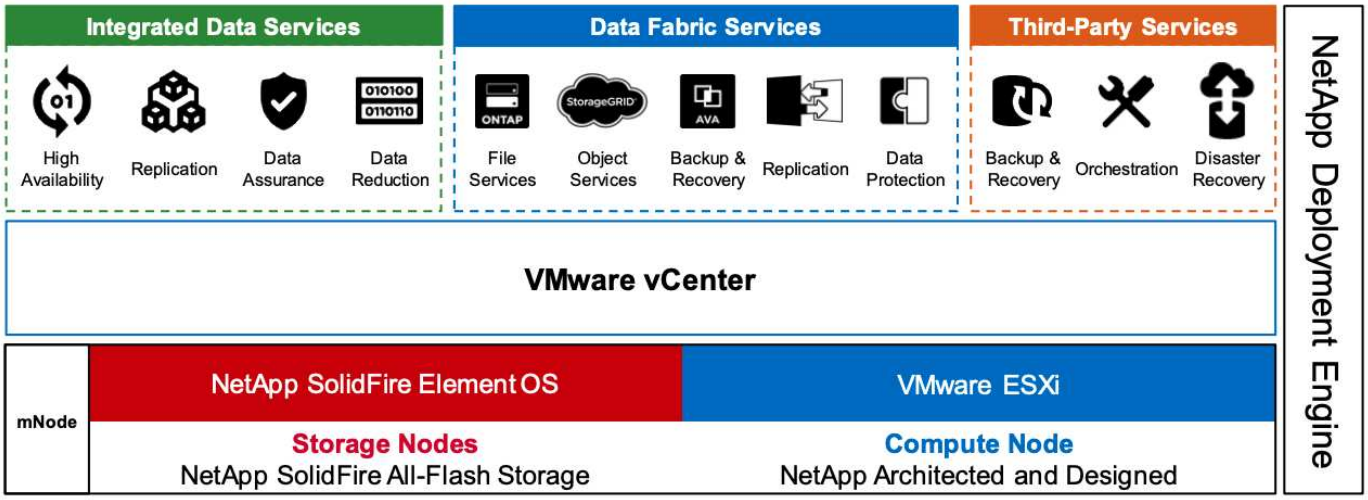
Next: NetApp HCI Overview

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

	V100S	RTX 8000	RTX 6000	T4 (Available on NetApp HCI H615C)	M10 (Available on NetApp HCI H610C)	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.

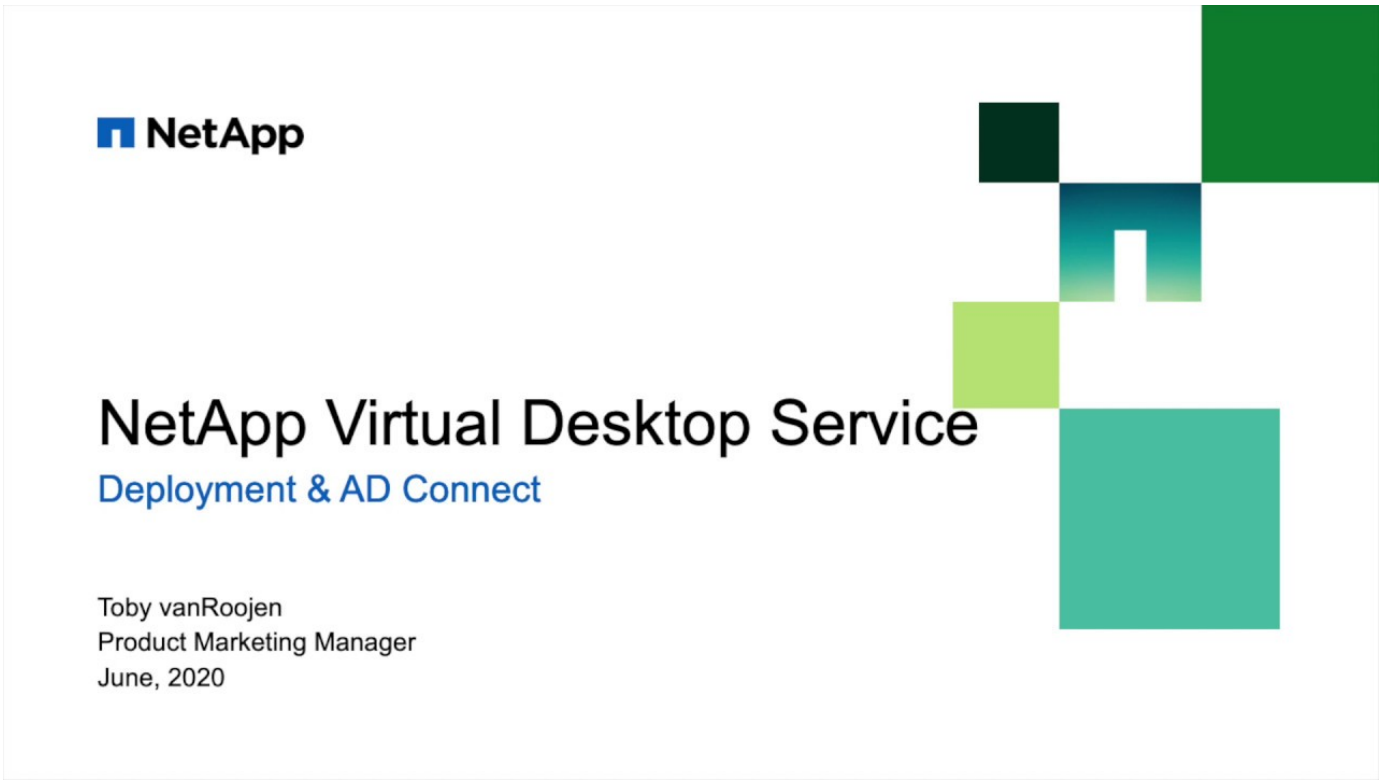
A Quadro vDWS license enables you to use GRID vPC and NVIDIA vComputeServer.

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.

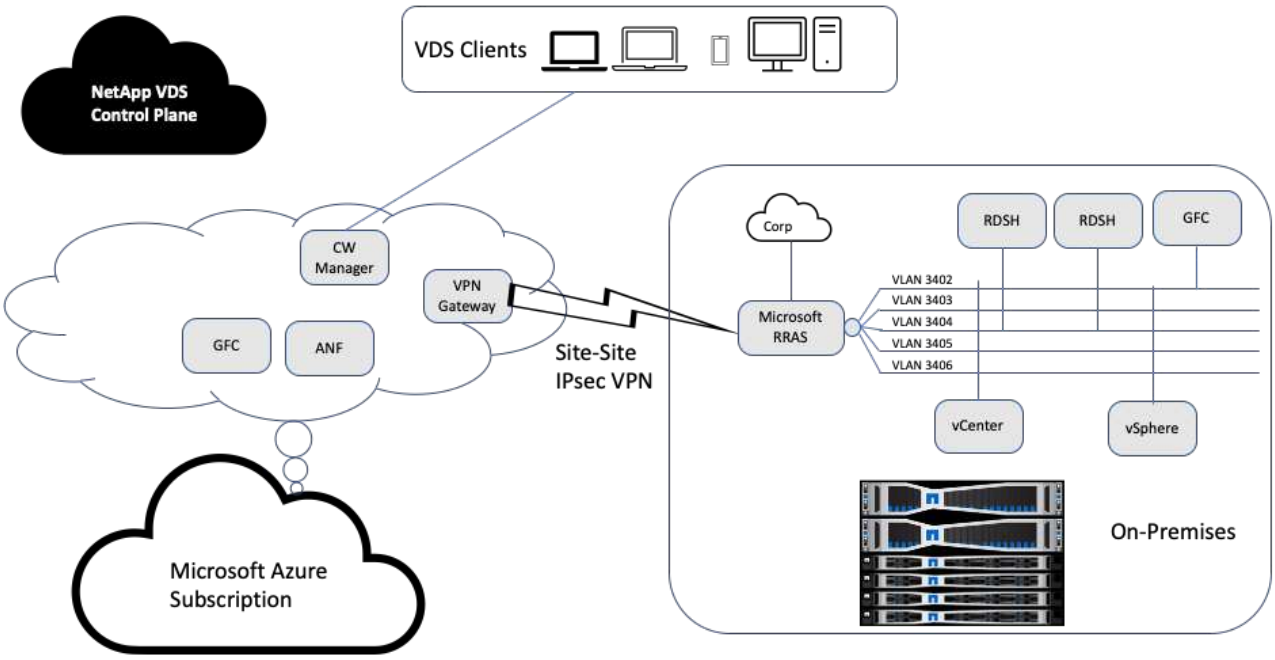


Next: Hybrid Cloud Environment

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.

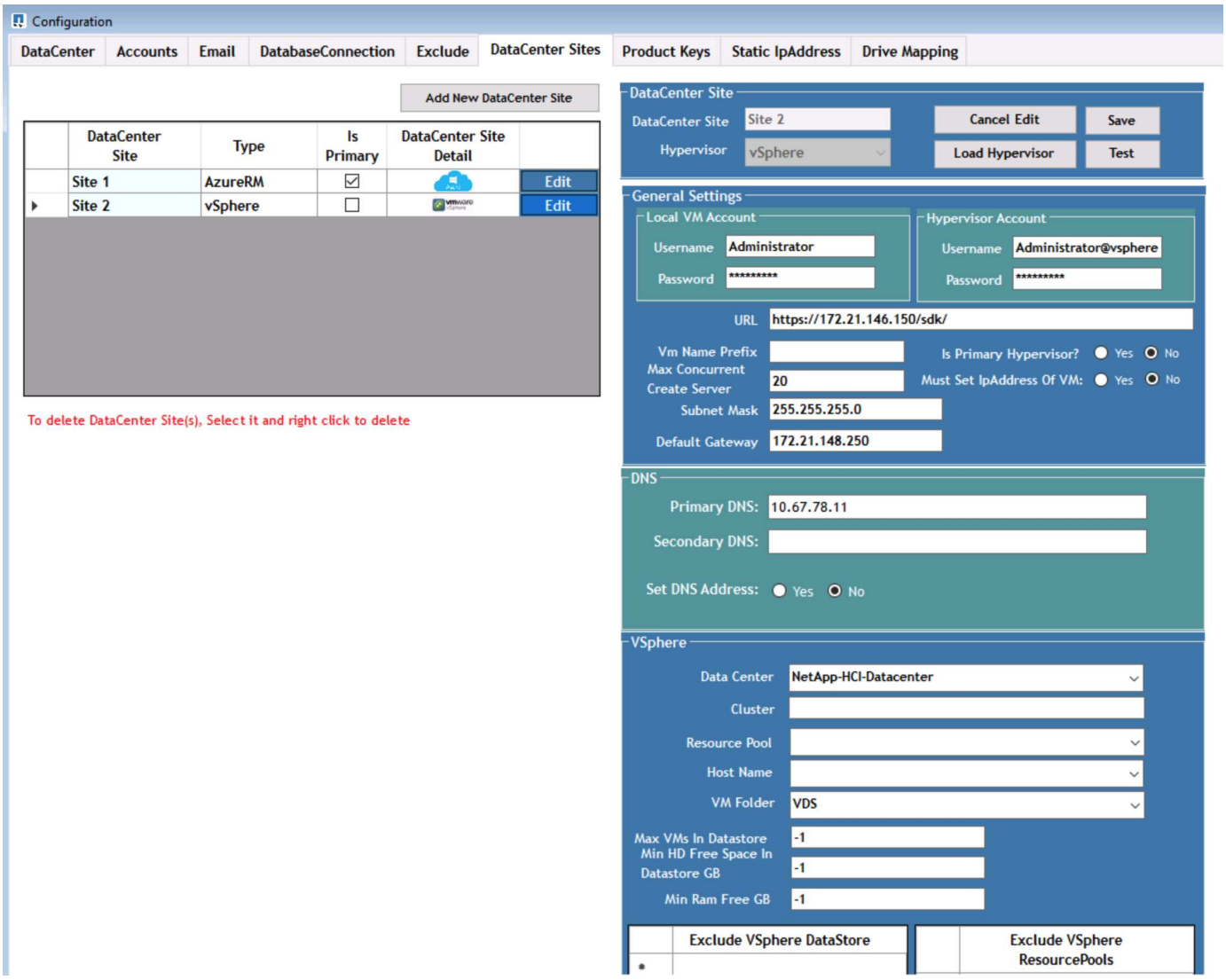
For this Hybrid VDS solution validation, we initially deployed to Microsoft Azure and added an additional site with vSphere. The advantage with this approach is that platform services were deployed to Microsoft Azure and were then readily backed up using the portal. Services can then be easily accessed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

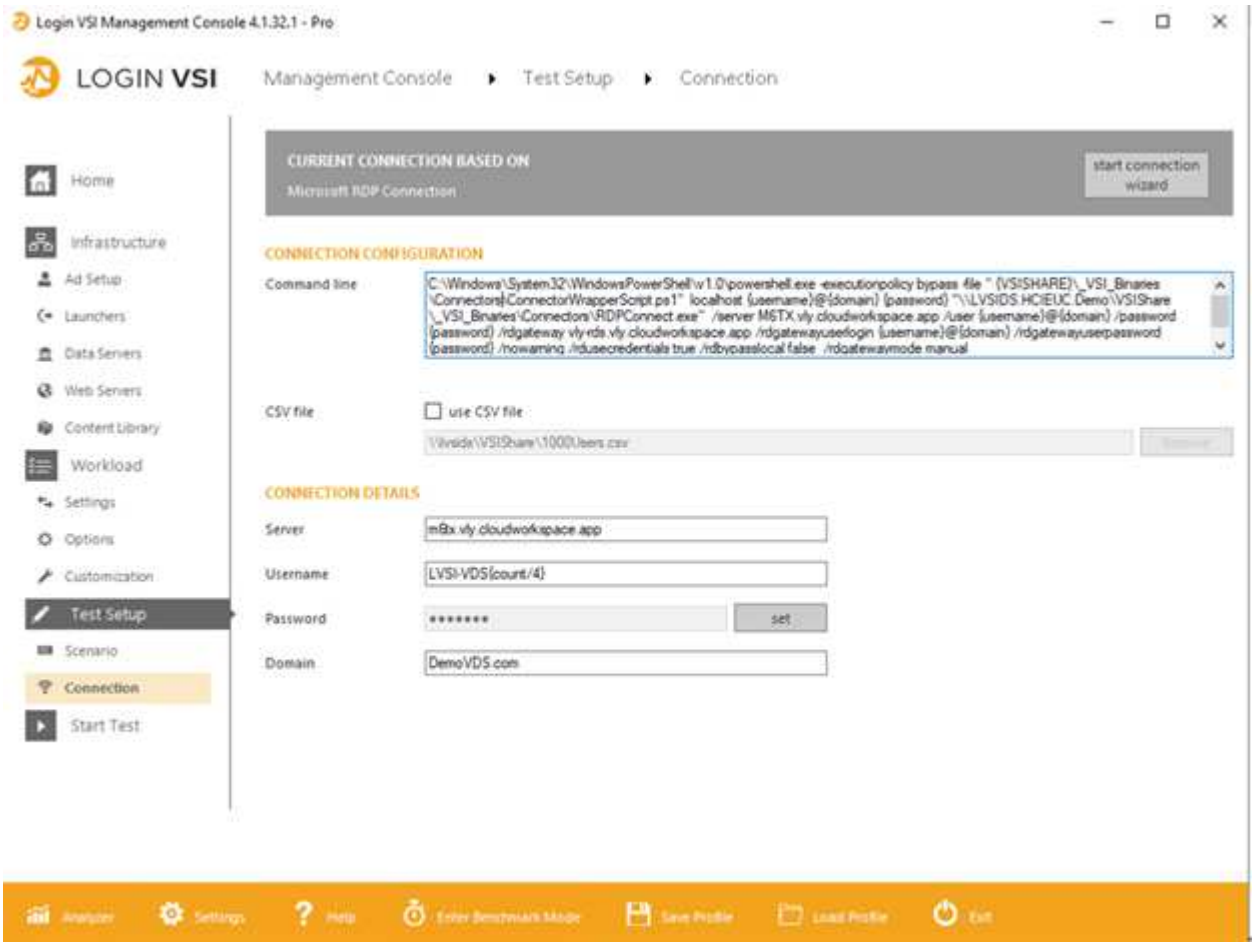
product	Description
NetApp VDS 5.4	Orchestration
VM Template Windows 2019 1809	Server OS for RDSH
Login VSI	4.1.32.1
VMware vSphere 6.7 Update 3	Hypervisor
VMware vCenter 6.7 Update 3f	VMware management tool

The Login VSI test results are as follows:

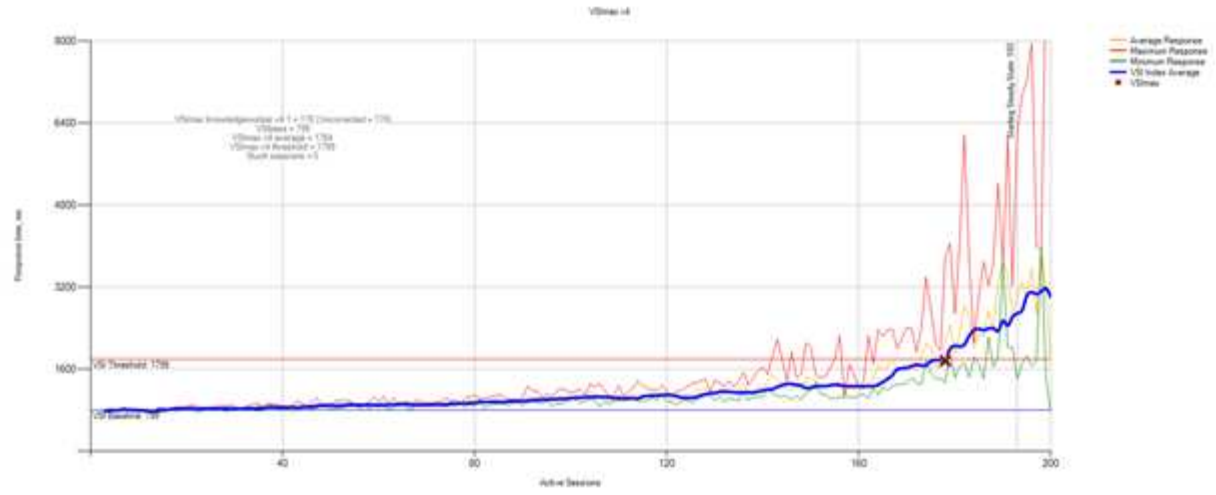
Model	VM configuration	Login VSI baseline	Login VSI Max
H610C	8 vCPU, 48GB RAM, 75GB disk, 8Q vGPU profile	799	178
H615C	12 vCPU, 128GB RAM, 75GB disk	763	272

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

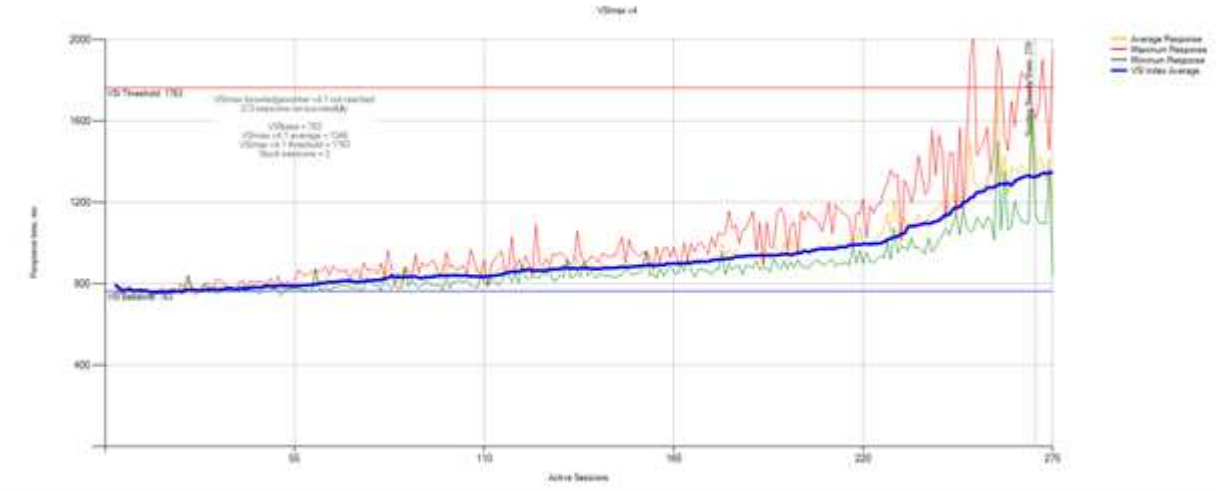
We used 10 launcher VMs on the H610C, which used the RDP protocol to connect to the user session. The following figure depicts the Login VSI connection information.



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.

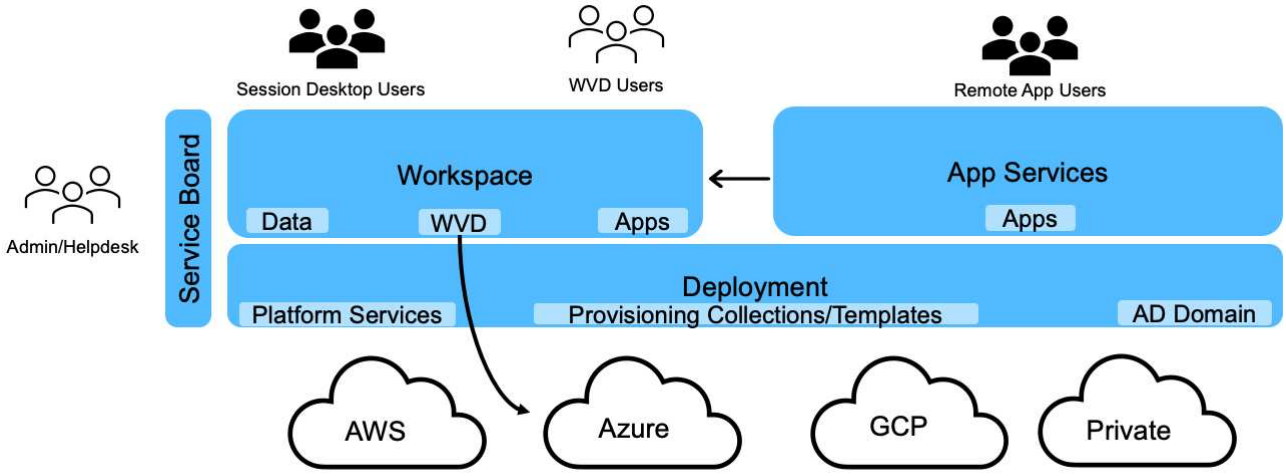
Next: User Management

User Management

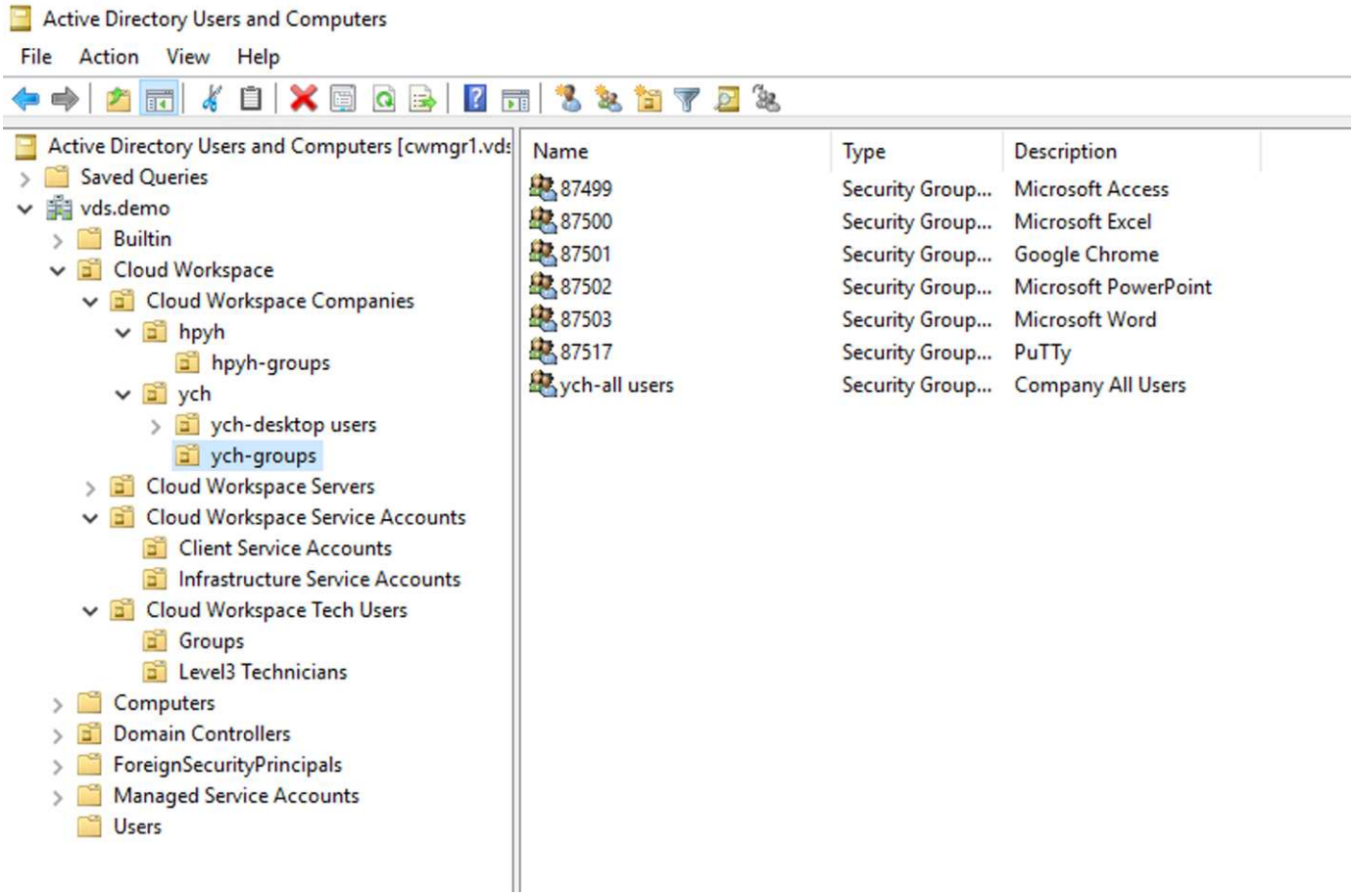
NetApp VDS uses Azure Active Directory for identity authentication and Azure Active Directory Domain Services for NTLM/Kerberos authentication. The ADConnect tool can be used to sync an on-prem Active Directory domain with Azure Active Directory.

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.



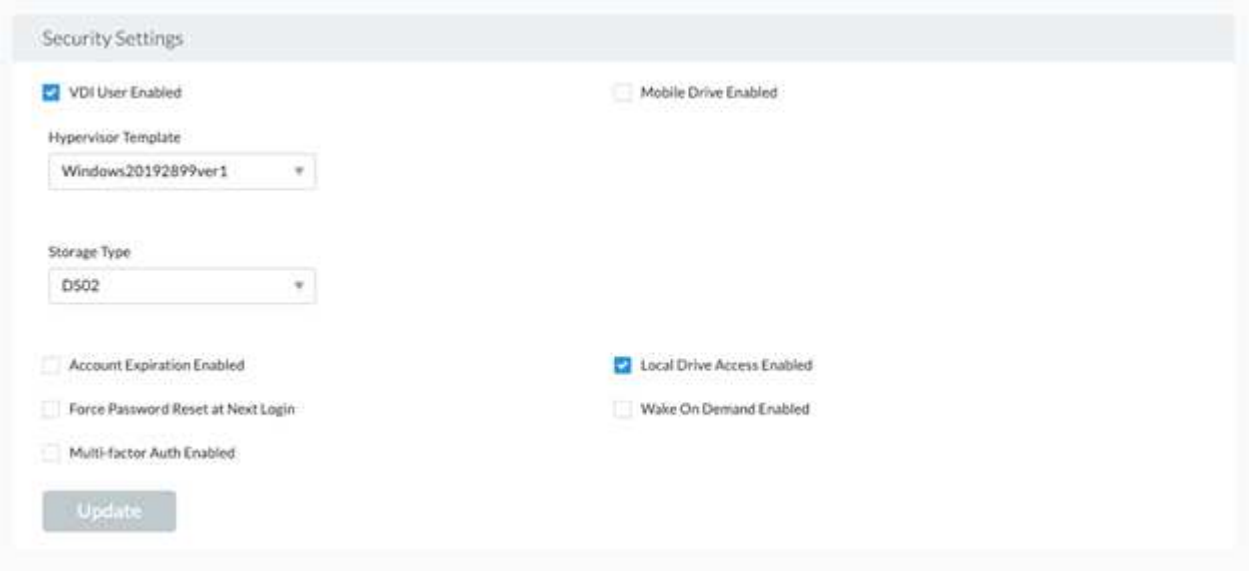
Each workspace resides in its own Active Directory organization unit (OU) under the Cloud Workspace OU as shown in the following figure.



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.

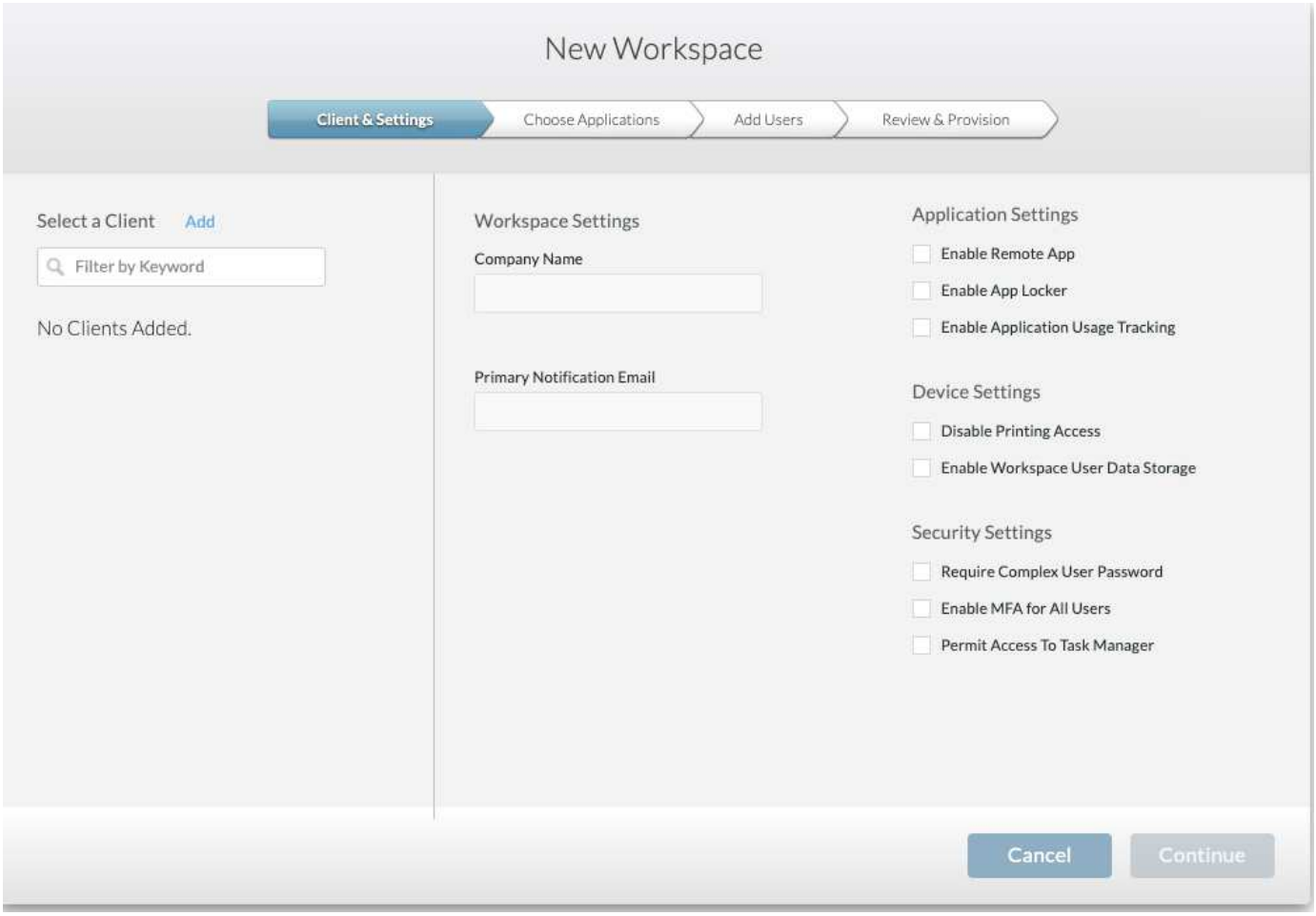
If VDI User Enabled is checked, VDS creates a single-session RDS machine dedicated to that user. It prompts for the template and the datastore to provision.



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.

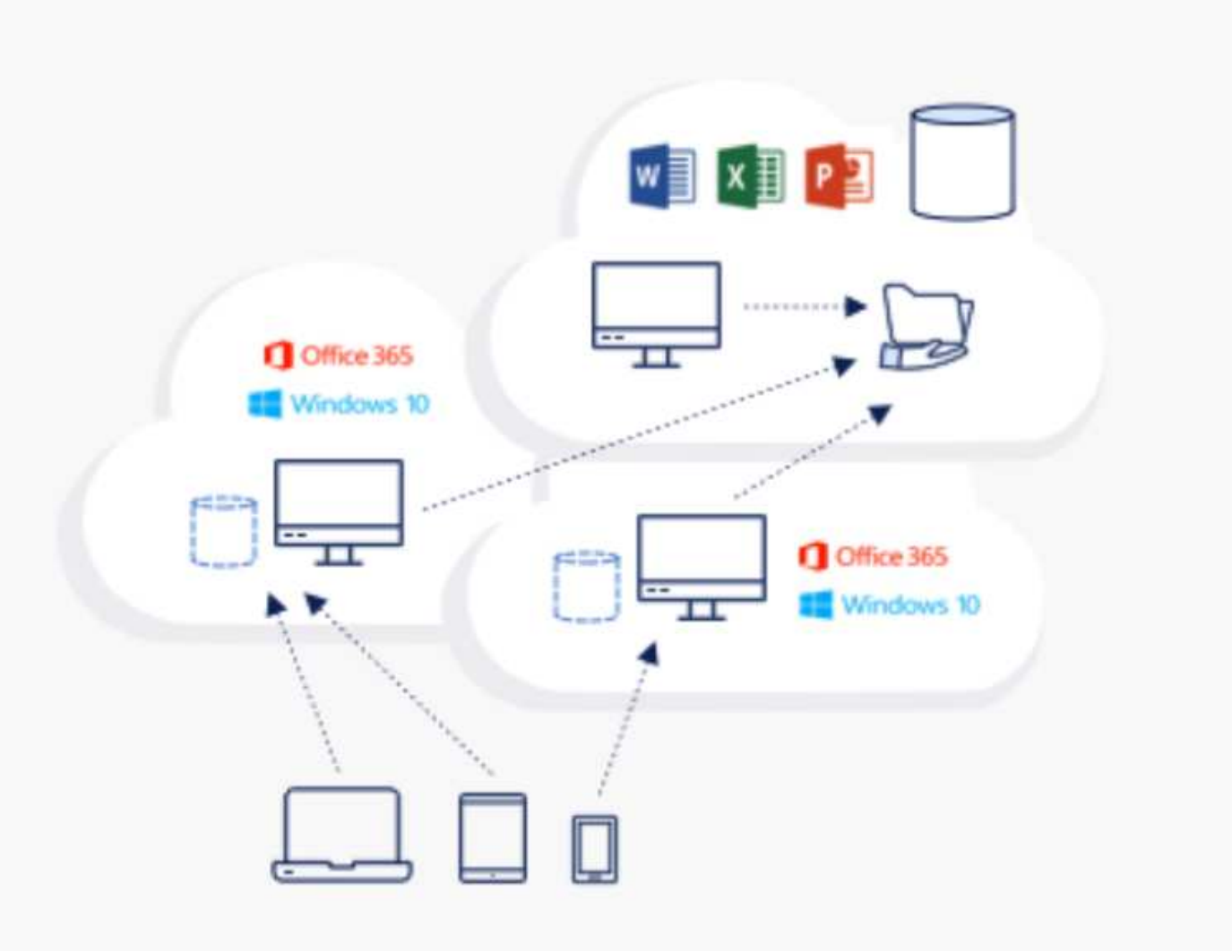
Next: Data Management

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:

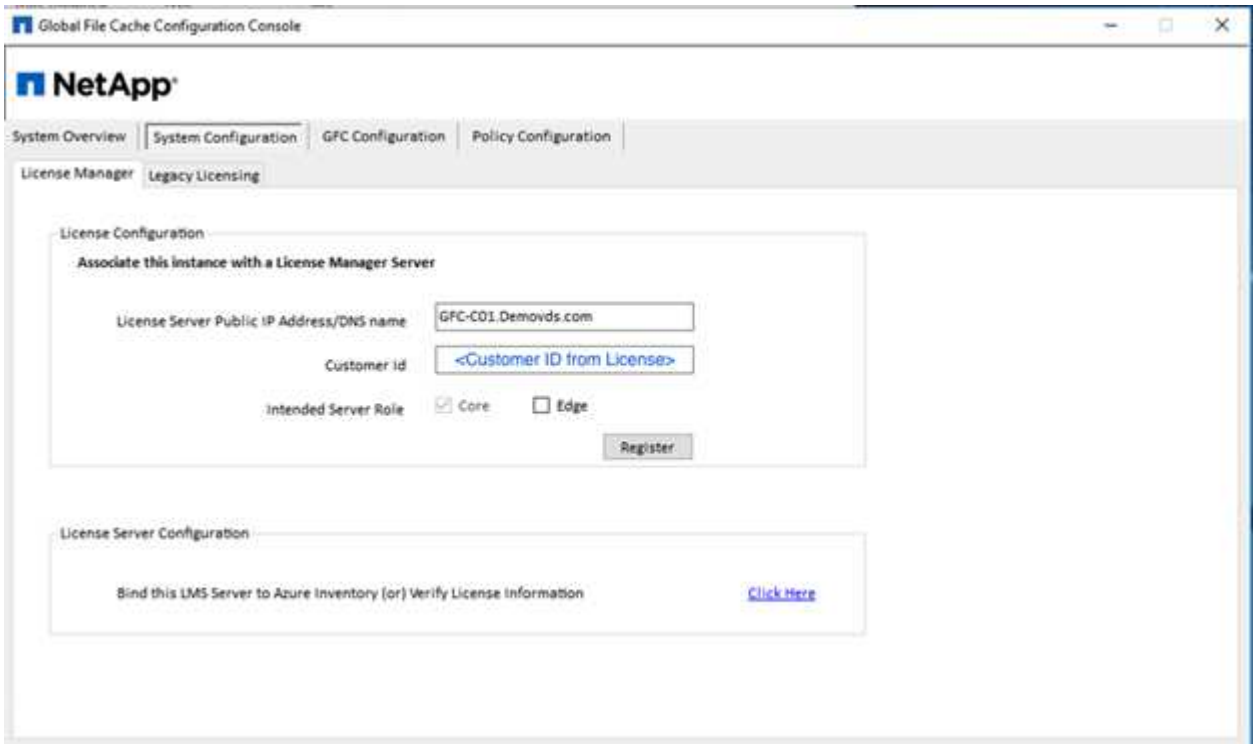
- Management server (License Management Server)
- Core

- Edge with enough disk capacity to cache the data

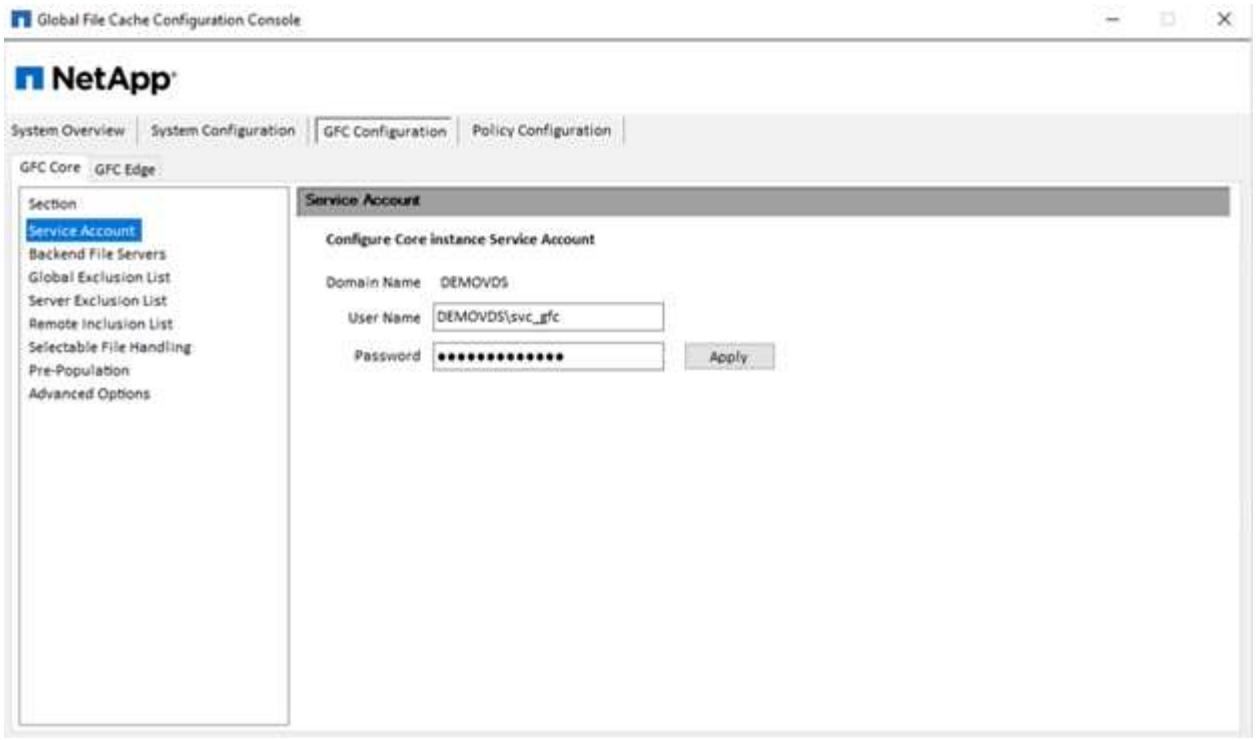
To download the software and to calculate the disk cache capacity for Edge, see the GFC documentation.

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:

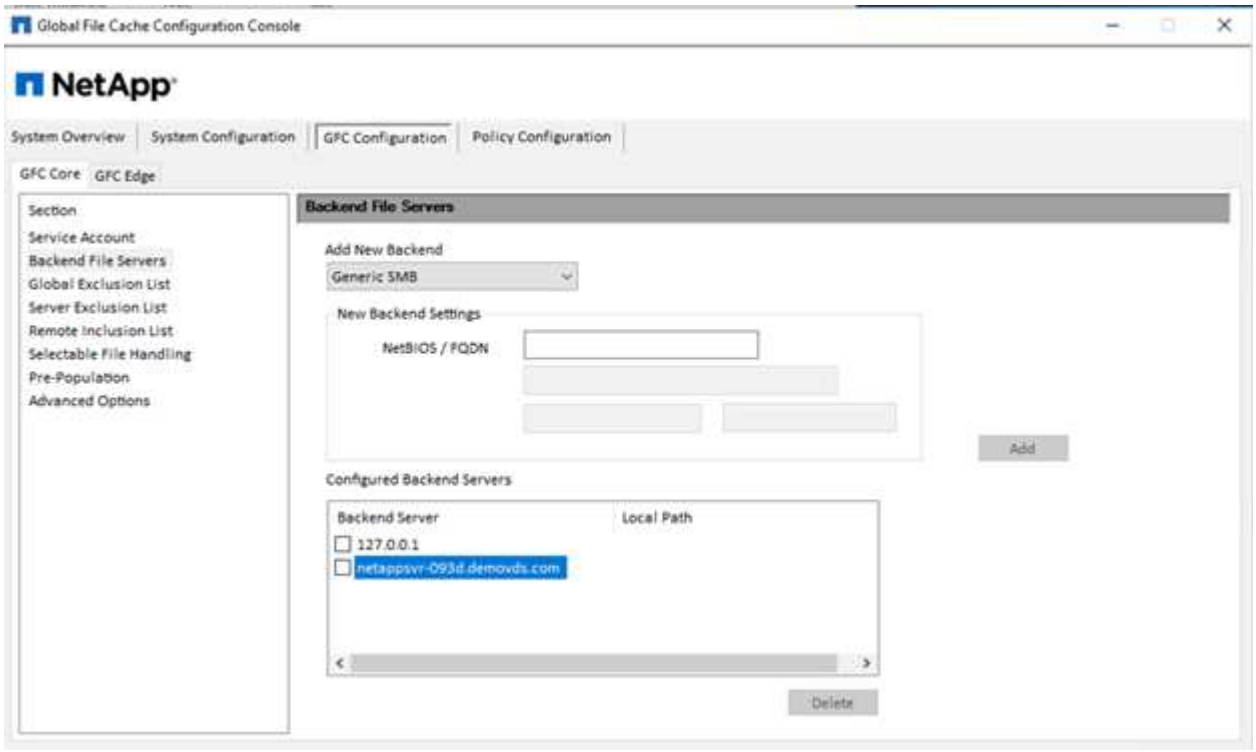
1. Under the License Configuration section, use the link Click Here to complete the license activation. Then register the core.



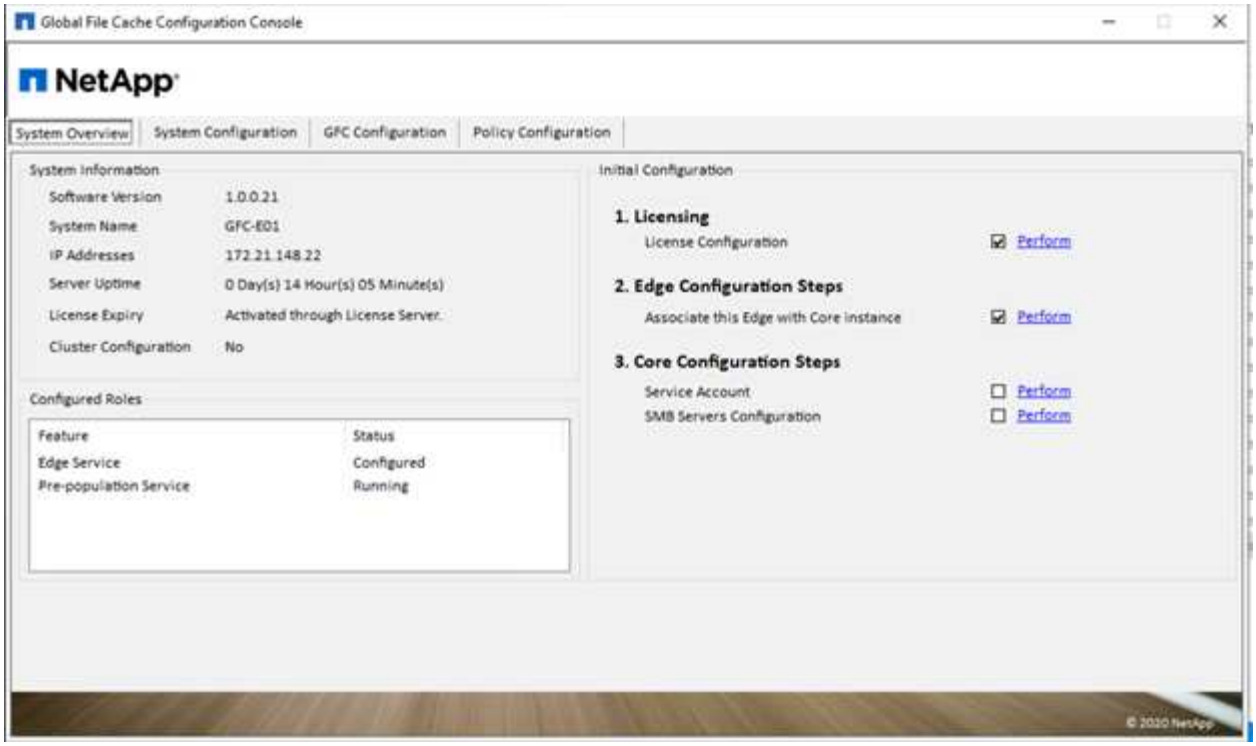
2. Provide the service account to be used for the Global File Cache. For the required permissions for this account, see the GFC documentation.



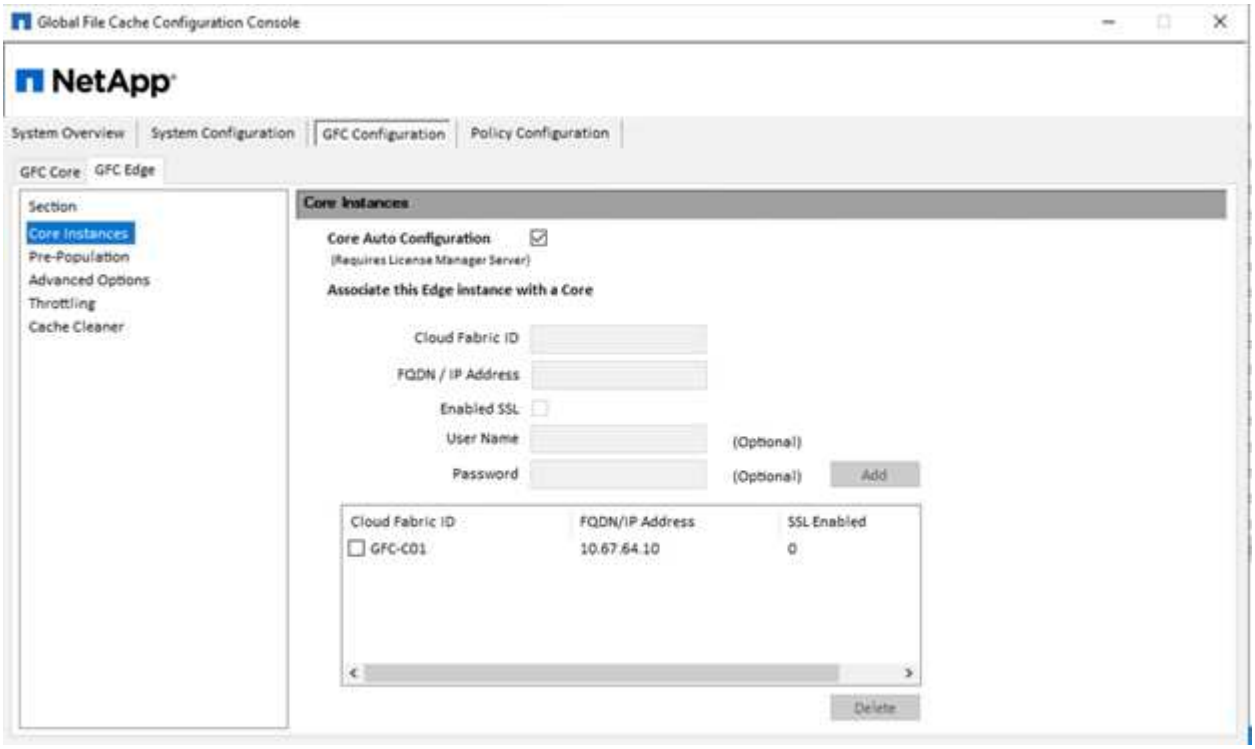
3. Add a new backend file server and provide the file server name or IP.



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.



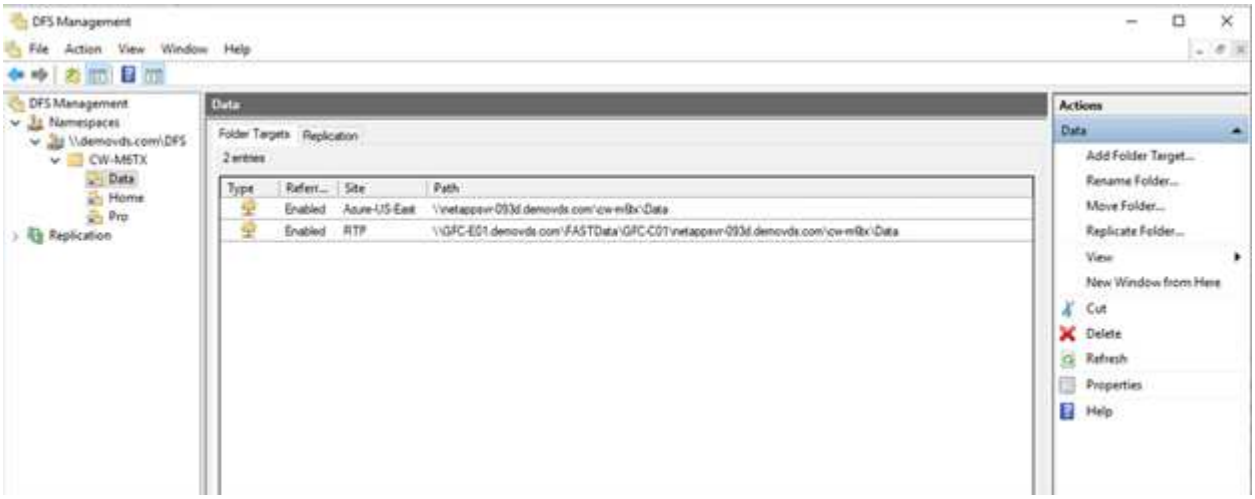
If core auto-configuration is enabled, core information is retrieved from the license management server automatically.



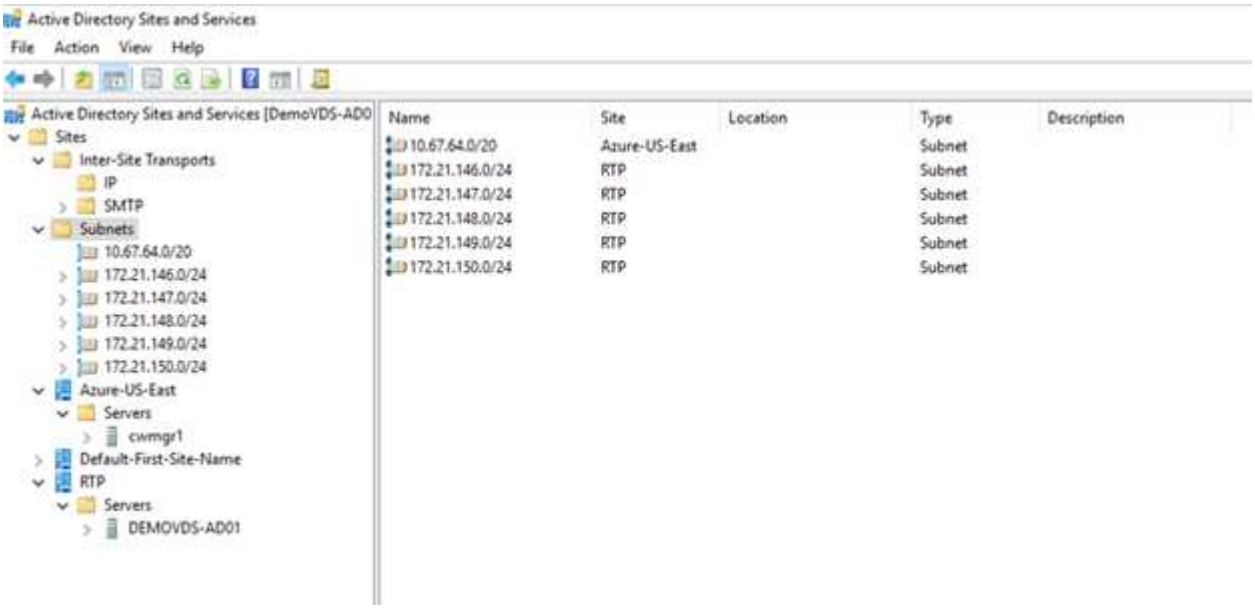
From any client machine, the administrators that used to access the share on the file server can access it with GFC edge using UNC Path `\\<edge server name>\FASTDATA\<core server name>\<backend file server name>\<share name>`. Administrators can include this path in user logonscript or GPO for users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

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

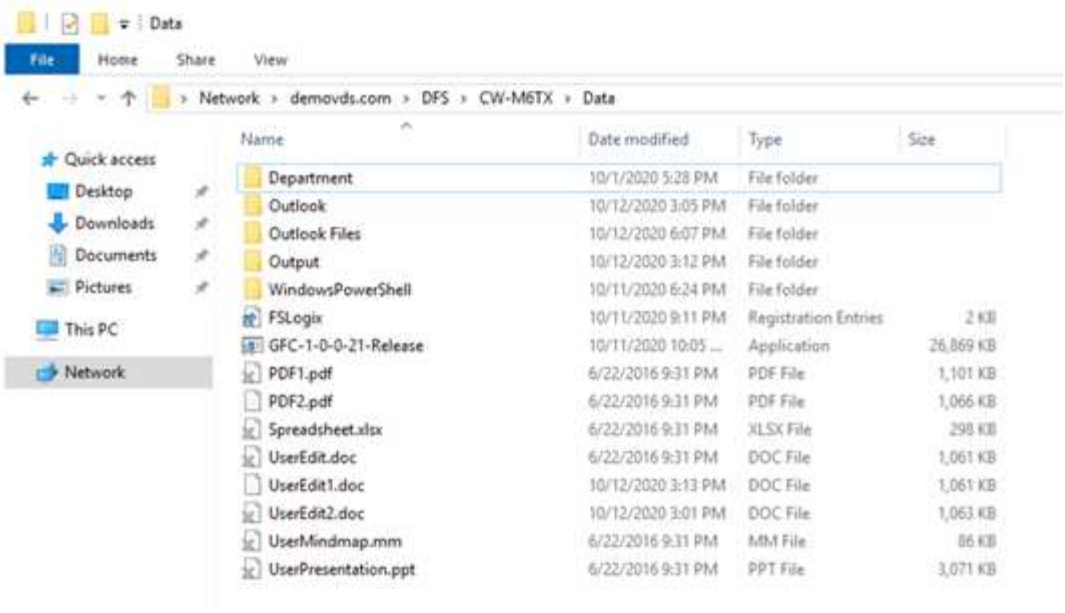
Filesystem (DFS) with links pointing to file server shares and to edge locations.



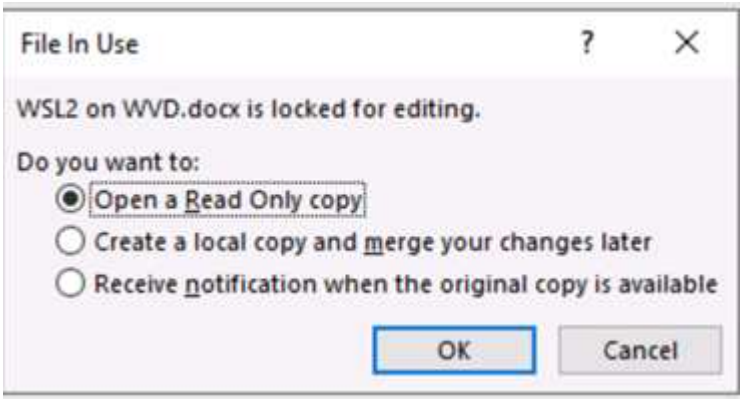
When users log in with Active Directory credentials based on the subnets associated with the site, the appropriate link is utilized by the DFS client to access the data.



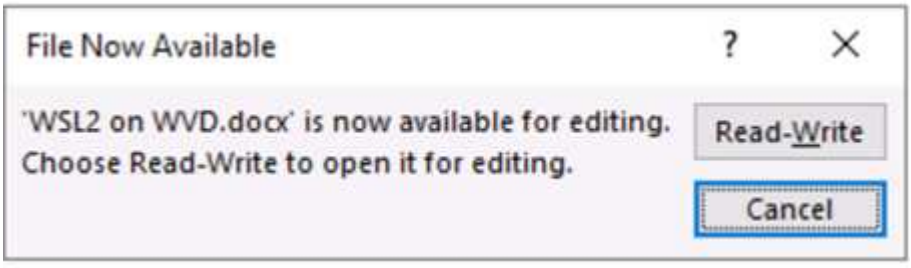
File icons change depending on whether a file is cached; files that are not cached have a grey X on the lower left corner of the icon. After a user in an edge location accesses a file, that file is cached, and the icon changes.



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:



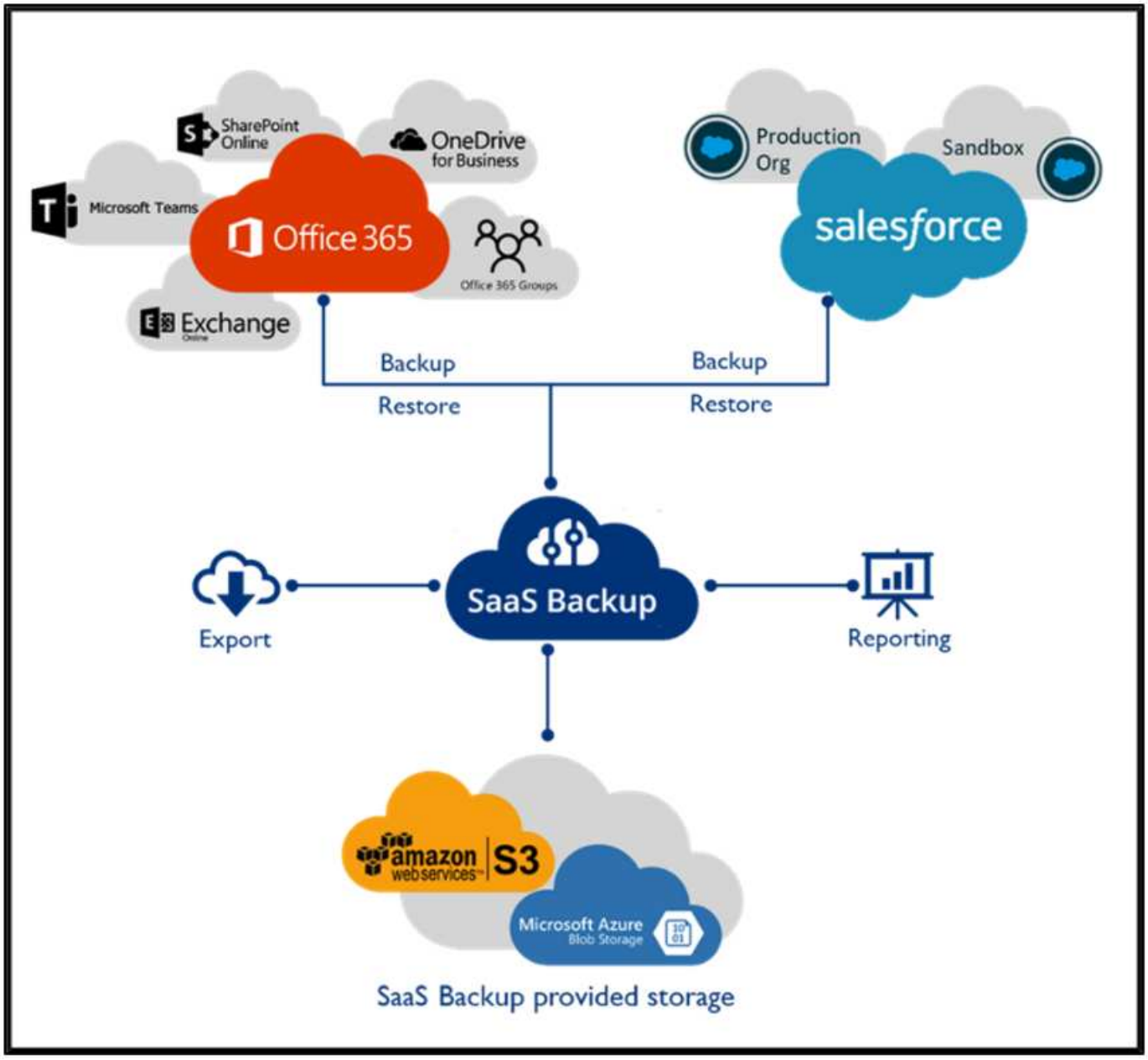
If the user selects the option to receive a notification when the original copy is available, the user is notified as follows:



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.

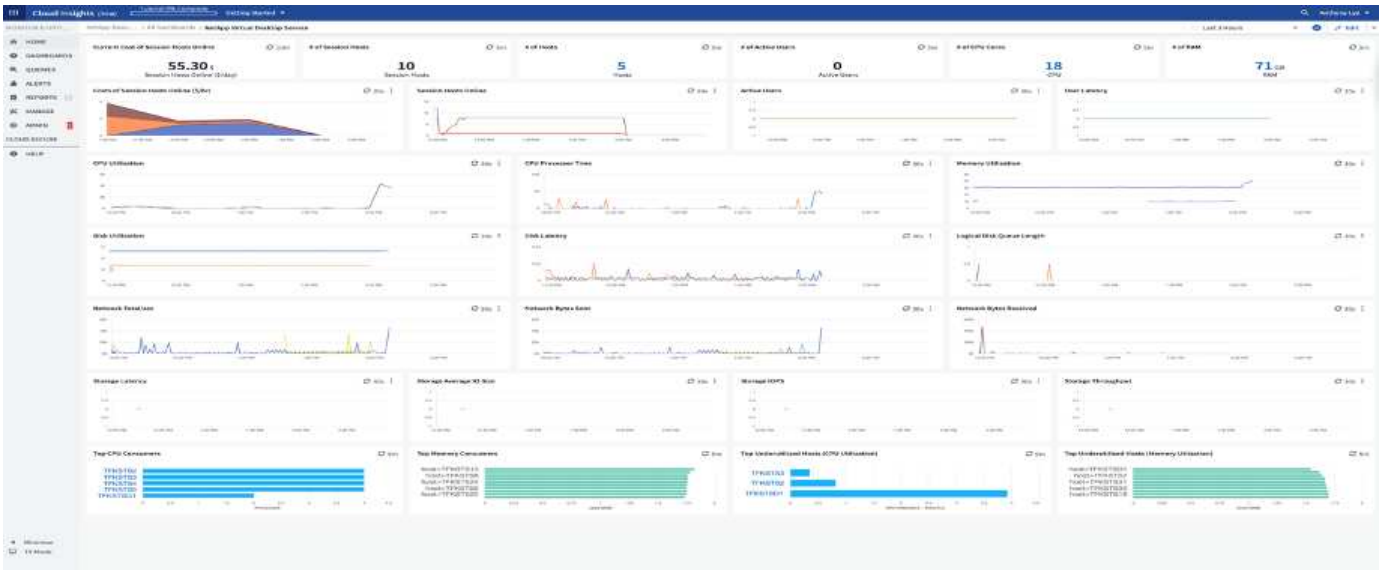
To identify the gateway address to manually configure the client, see the End User Requirements page.

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.



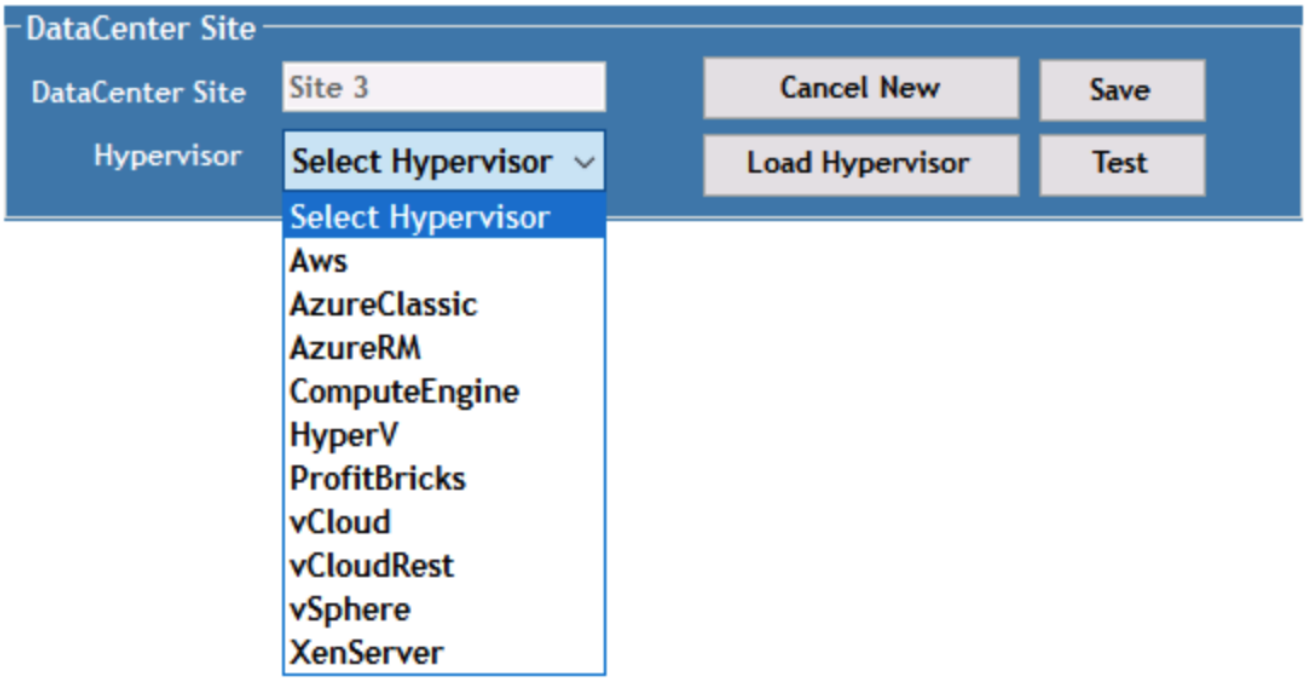
For more info on NetApp Cloud Insights, see this video.

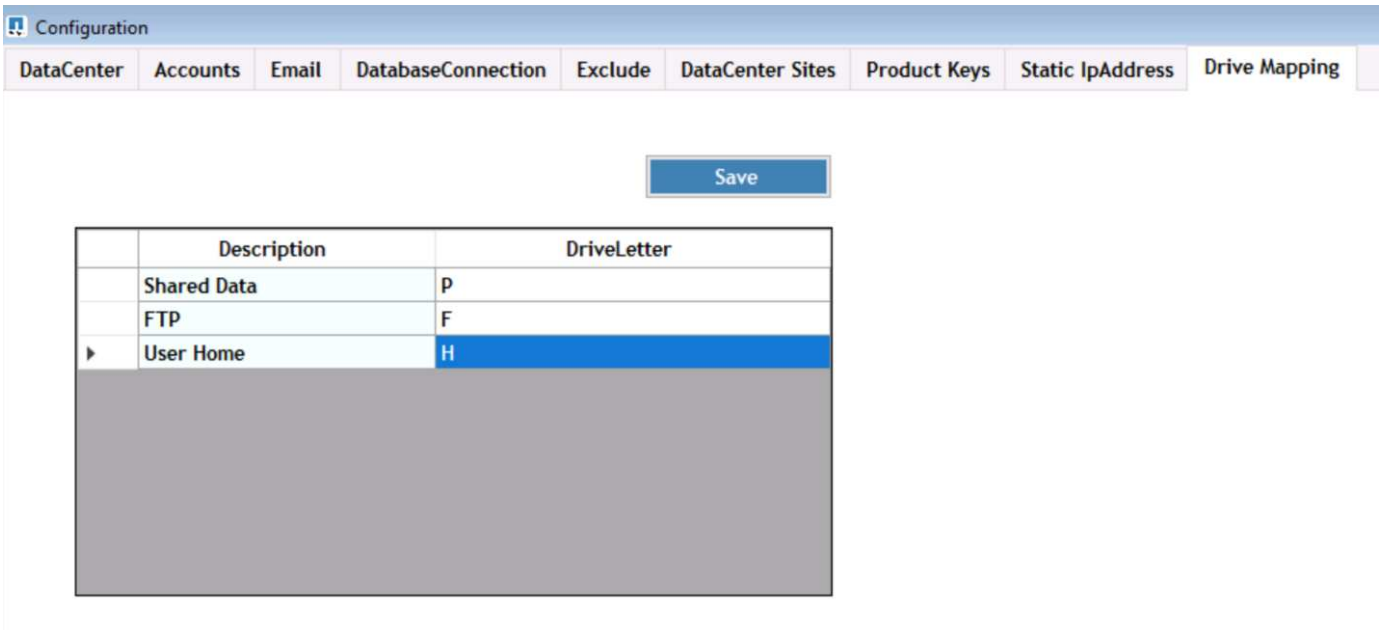
Next: Tools and logs

Tools and Logs

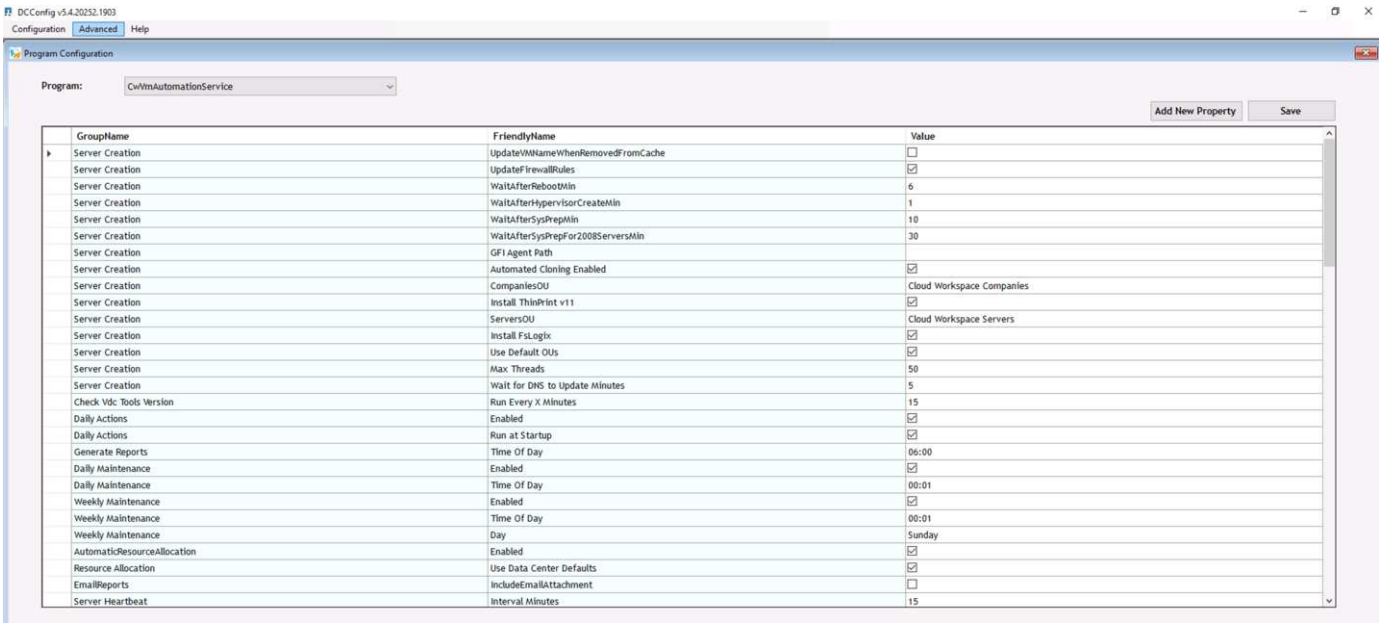
DCConfig Tool

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.



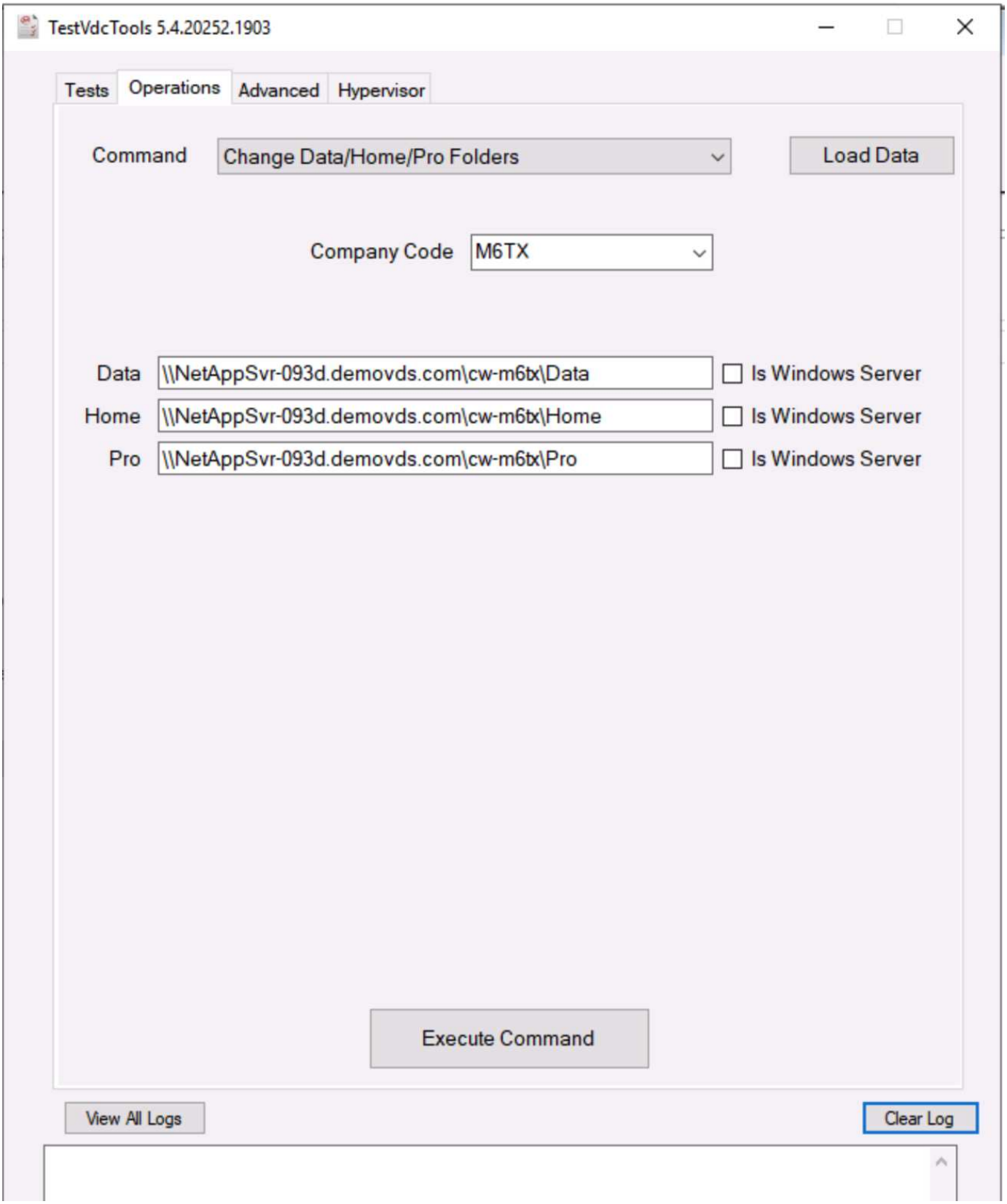
GroupName	FriendlyName	Value
Server Creation	UpdateVMNameWhenRemovedFromCache	☐
Server Creation	UpdateFirewallRules	☑
Server Creation	WaitAfterRebootMin	6
Server Creation	WaitAfterHypervisorCreateMin	1
Server Creation	WaitAfterSysPrepMin	10
Server Creation	WaitAfterSysPrepFor2008ServersMin	30
Server 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)

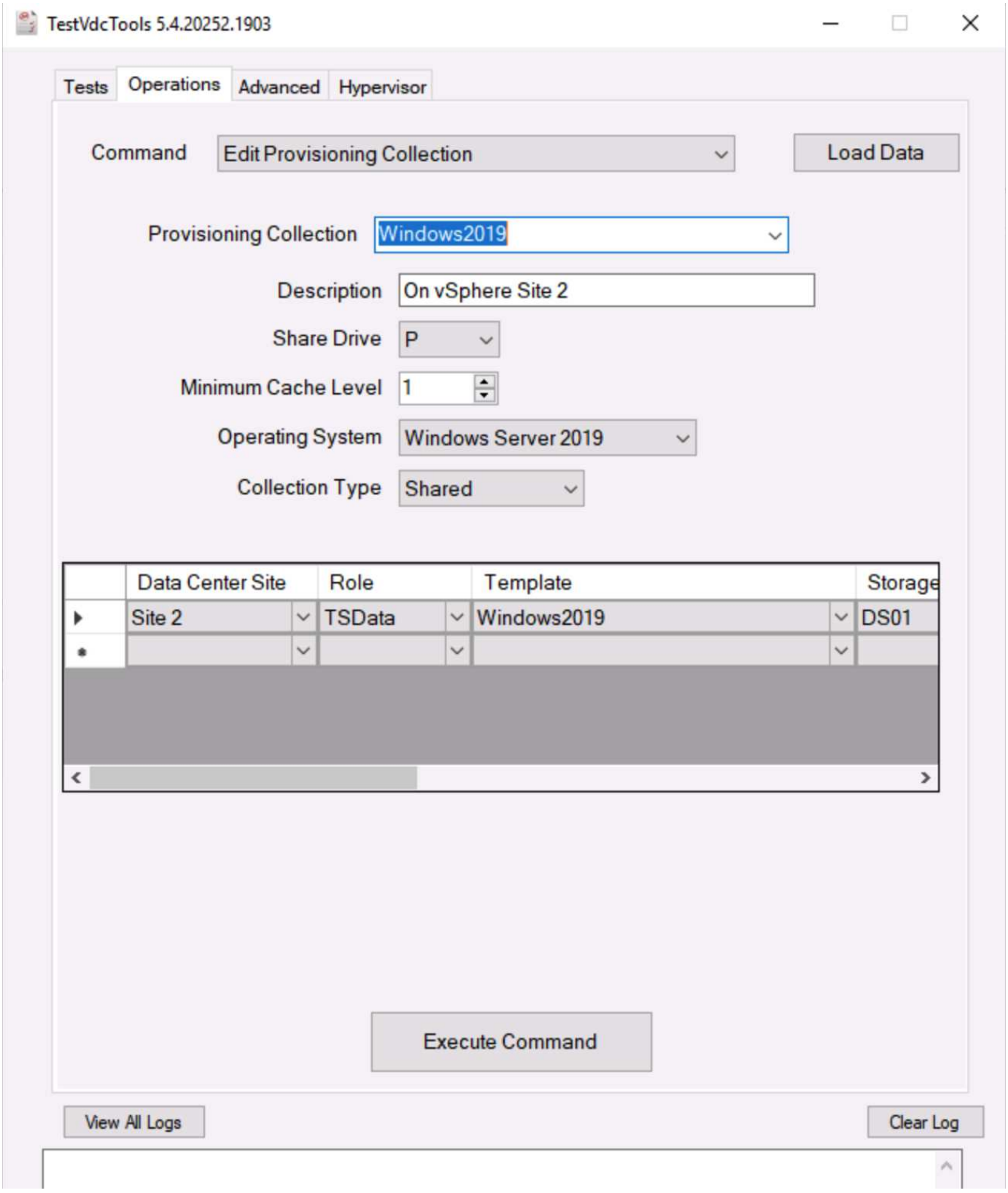
To launch Command Center and the required role, see the Command Center Overview.

You can perform the following operations:

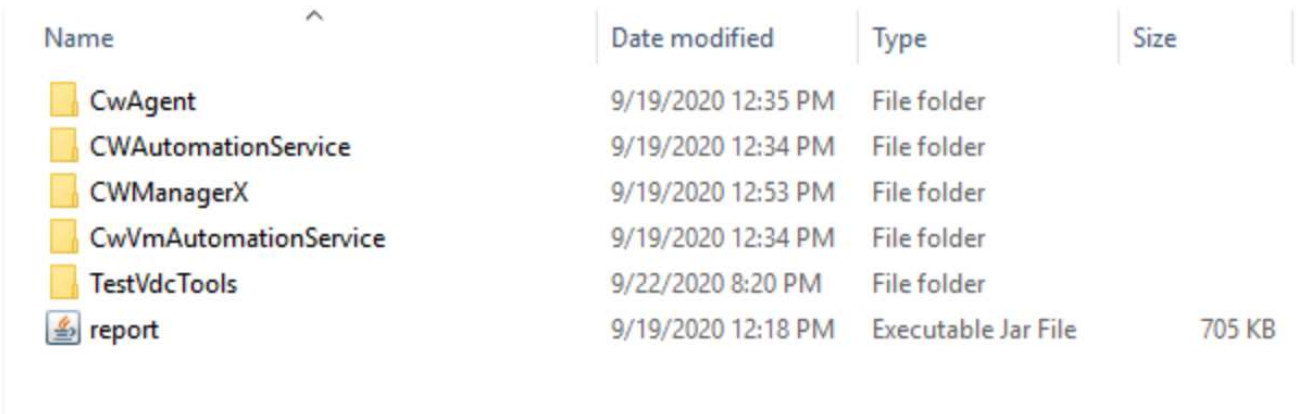
- Change the SMB Path for a workspace.



- 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.

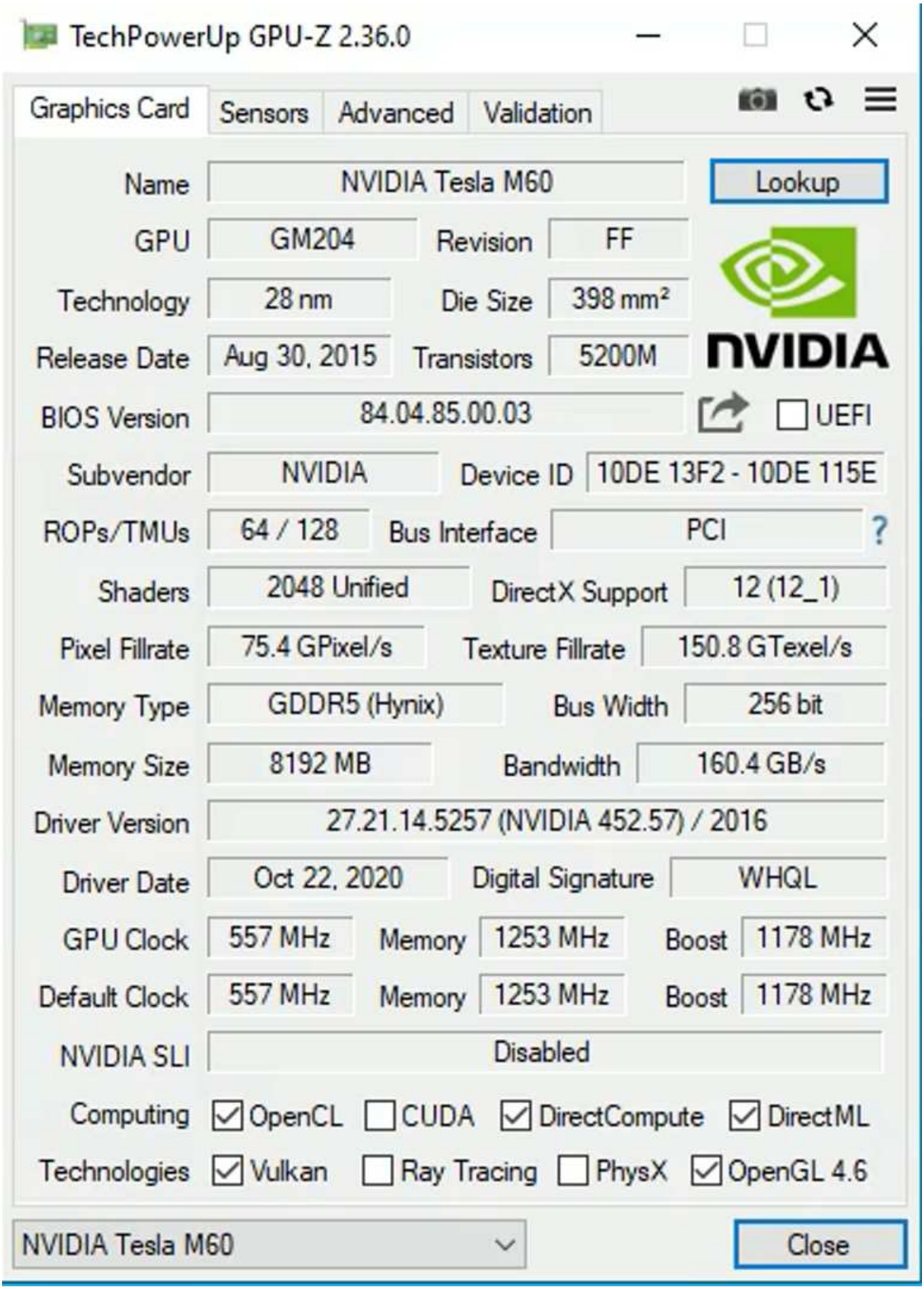
Next: Conclusion

GPU considerations

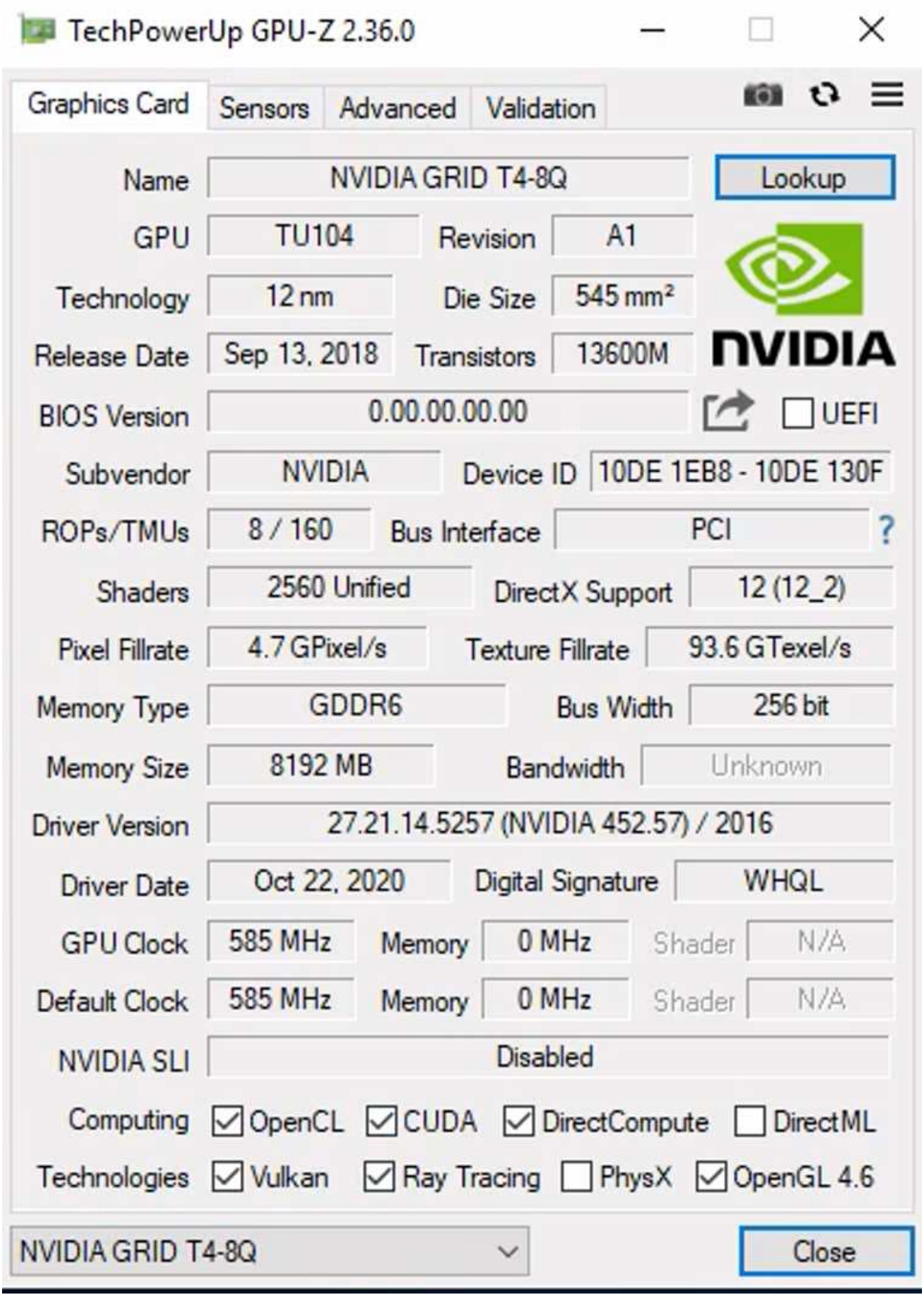
GPUs are typically used for graphic visualization (rendering) by performing repetitive arithmetic calculations. This repetitive compute capability is often used for AI and deep learning use cases.

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.

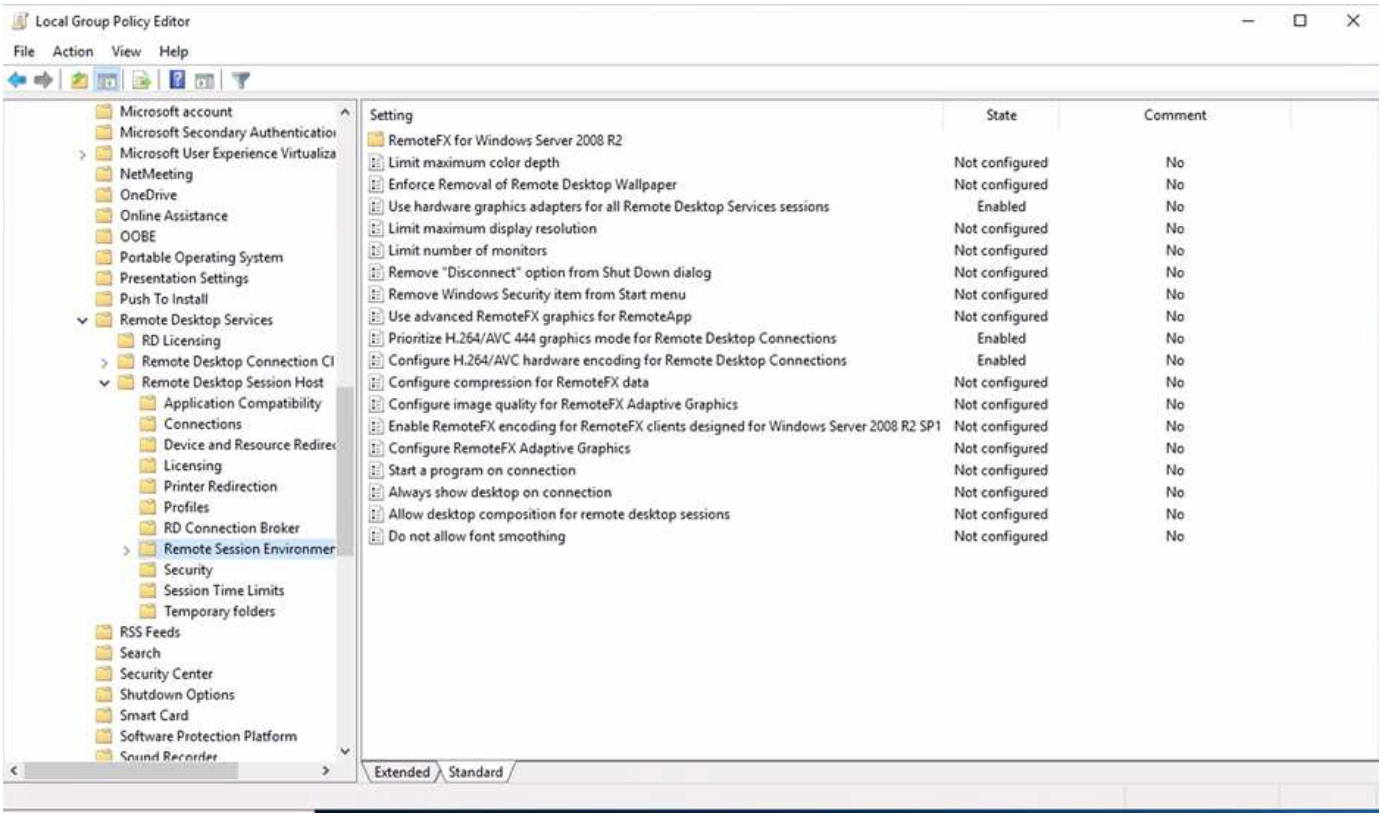
An NVIDIA license is included with the NV series.


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

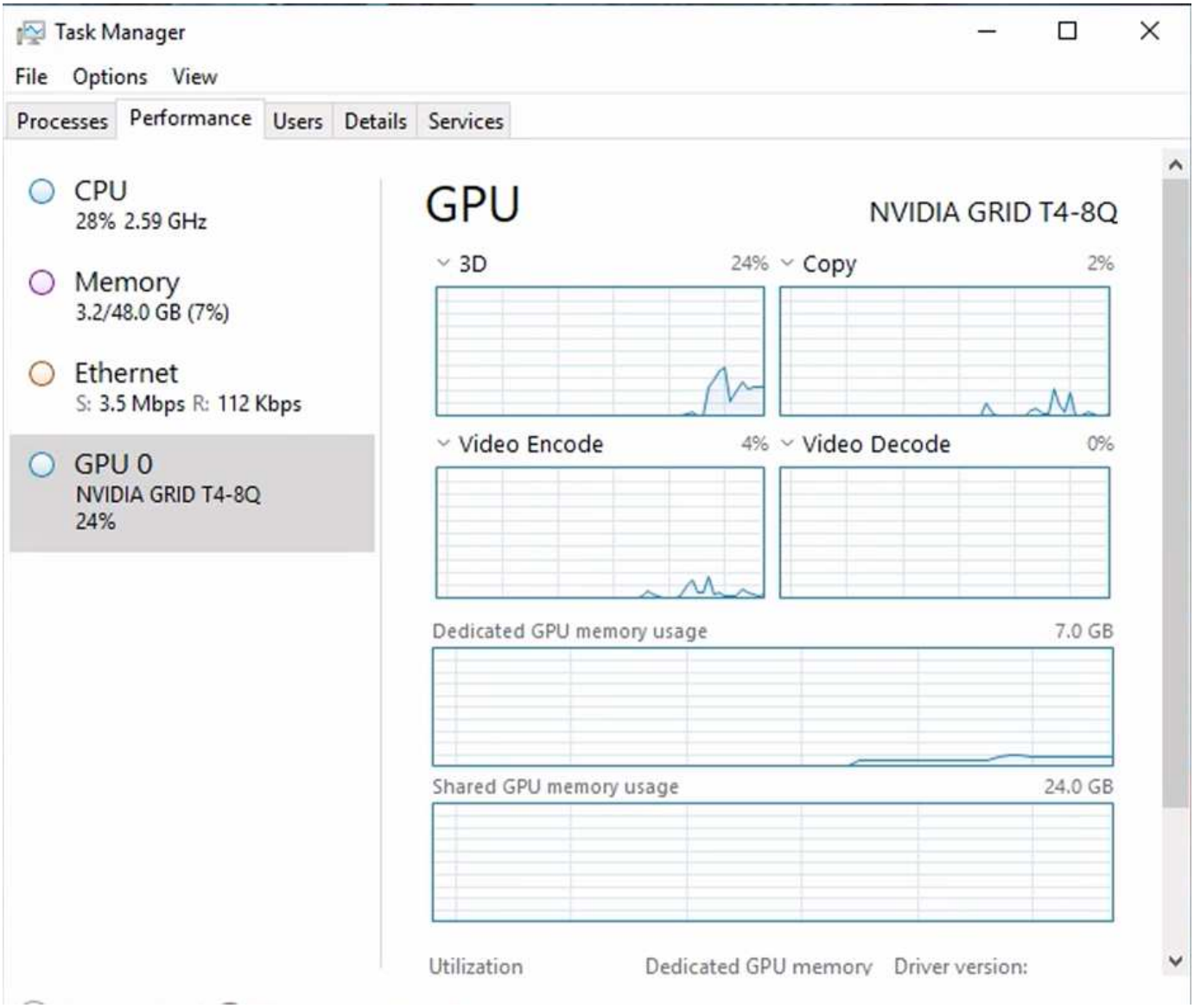
With NetApp HCI, the H615C GPU contains three NVIDIA Tesla T4 cards. Each NVIDIA Tesla T4 card has a Touring-based GPU with 16GB of GDDR6 memory. When used in a VMware vSphere environment, virtual machines are able to share the GPU, with each VM having dedicated frame buffer memory. Ray tracing is available 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

Demos and Tutorials

Hybrid Cloud, Virtualization and Containers Videos and Demos

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

NetApp SnapCenter and 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

► https://docs.netapp.com/us-en/netapp-solutions/media/scv_prereq_overview.mp4 *(video)*

SnapCenter Plug-in for VMware vSphere - Deployment

► https://docs.netapp.com/us-en/netapp-solutions/media/scv_deployment.mp4 *(video)*

SnapCenter Plug-in for VMware vSphere - Backup Workflow

► https://docs.netapp.com/us-en/netapp-solutions/media/scv_backup_workflow.mp4 *(video)*

SnapCenter Plug-in for VMware vSphere - Restore Workflow

► https://docs.netapp.com/us-en/netapp-solutions/media/scv_restore_workflow.mp4 *(video)*

SnapCenter - SQL Restore Workflow

► https://docs.netapp.com/us-en/netapp-solutions/media/scv_sql_restore.mp4 *(video)*

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.

NetApp with VMware Tanzu Videos

- 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

NetApp with Red Hat OpenShift

Red Hat OpenShift, an enterprise Kubernetes platform, enables you to run container-based applications with an open hybrid-cloud strategy. Available as a cloud service on leading public clouds or as self-managed software, Red Hat OpenShift provides customers with the flexibility they need when designing their container-based solution.

For more information regarding Red Hat OpenShift, see this Red Hat OpenShift Overview. You can also review the product documentation and deployment options to learn more about Red Hat OpenShift.

NetApp with Red Hat OpenShift videos

- Workload Migration - Red Hat OpenShift with NetApp
- Red Hat OpenShift Deployment on RHV: Red Hat OpenShift with NetApp

Blogs

NetApp and VMware Cloud Foundation (VCF)