



NetApp Hybrid Multi-Cloud with VMware

NetApp Solutions

NetApp
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NetApp Hybrid Multi-Cloud Solutions

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.

NOTE:

NetApp storage as a datastore is currently available as Public preview for AWS/VMC and Azure/AVS and Private preview for GCP/GSVE. Please visit the following links for more information.

AWS press release for FSx ONTAP as a native datastore COMING SOON!

[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.

NOTE:

NetApp storage as a datastore is currently available as Public preview for AWS/VMC and Azure/AVS and Private preview for GCP/GSVE. Please visit the following links for more information.

AWS press release for FSx ONTAP as a native datastore COMING SOON!

[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 guest 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 datastore¹

View the detailed [guest connect storage options for VMC](#).

Read more about FSx ONTAP as a native datastore public preview from the AWS Press Release (COMING SOON!).

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 datastore¹

View the detailed [guest connect storage options for AVS](#).

Read more about [Azure NetApp Files \(ANF\) as a native datastore - Public 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 datastore¹

View the detailed [guest connect storage options for GCVE](#).

Read more about [Cloud Volumes Service \(CVS\) as a native datastore¹](#).



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 Press Release coming soon!
Azure	CVO ANF Details	ANF Details ¹
GCP	CVO CVS Details	CVS Details ²

NOTE:

1 - Currently in Public Preview

2 - 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.

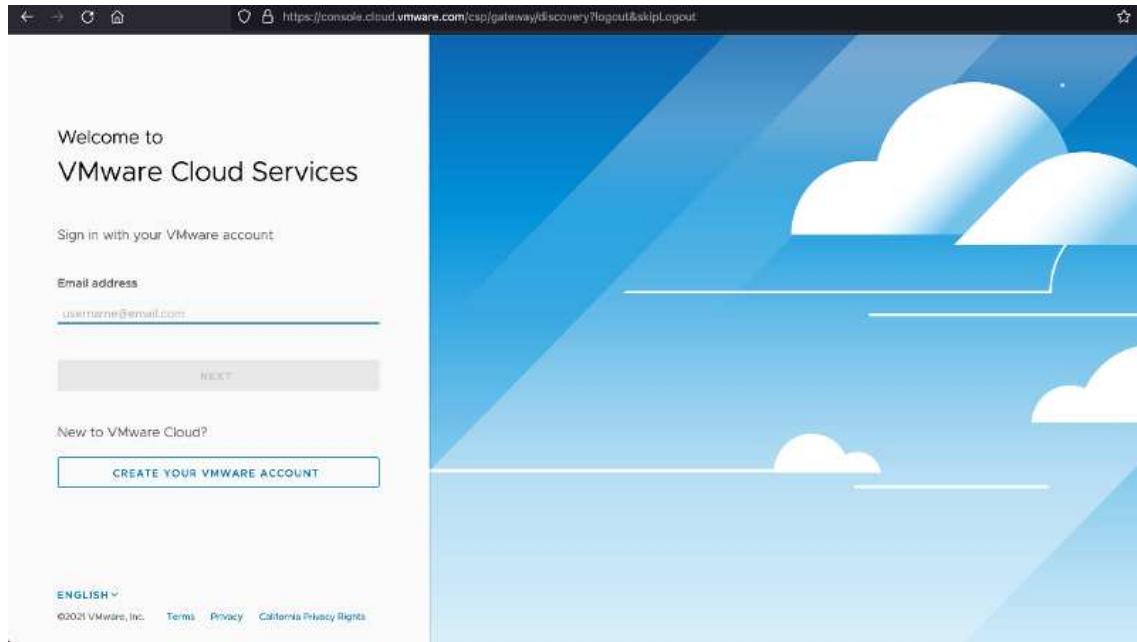
For access to VMware's cloud portfolio (including VMware Cloud on AWS), you need a VMware customer account or a My VMware account. If you have not already done so, create a VMware account [here](#).



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.

The screenshot shows the AWS CloudFormation 'Quick create stack' interface. At the top, there's a header bar with the AWS logo, navigation links like 'Services', a search bar, and user information. Below the header, the main title is 'Quick create stack'.

Template

Template URL: <https://vmware-sddc.s3.us-west-2.amazonaws.com/1eb9d184-a706-4489-abb8-692aad0e25d0/mq5ijphtleoh85b75tegq9icc4bdd7ifq07nv716fk36>

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-9a3dahd197b7

Stack name can include letters (A-Z and a-z), numbers (0-9), and dashes (-).

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-9a3dahd197b7

Stack name can include letters (A-Z and a-z), numbers (0-9), and dashes (-).

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

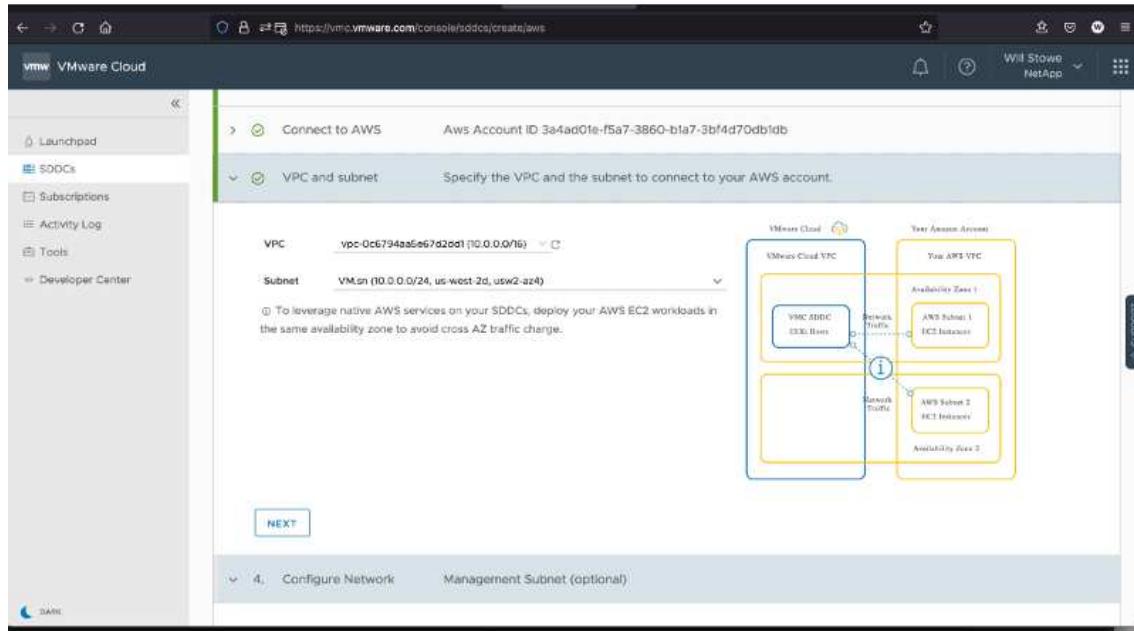
The screenshot shows the VMware Cloud SDDC creation interface. On the left, a sidebar lists options like Launchpad, SDDCs, Subscriptions, Activity Log, Tools, and Developer Center. The main area displays a progress bar with two steps completed: 'SDDC Properties' and 'Connect to AWS'. Step 2, 'Connect to AWS', is currently active, with a sub-instruction: 'Specify the AWS account that you want to connect your SDDC with.' A note below states: 'This step gives VMware permission to set up networking correctly for your SDDC on your AWS infrastructure using cross-account rules.' There are two buttons: 'Skip for now' and 'Connect to AWS now'. The 'Connect to AWS now' button is selected. Below it, there's a dropdown menu labeled 'Choose an AWS account' with a redacted value. A progress indicator shows 'Established time remaining: 60 seconds' with a circular progress bar. At the bottom, a large 'NEXT' button is visible.

The screenshot shows the same interface after the connection has been established. The 'Choose an AWS account' dropdown now shows a green checkmark and the message 'Congratulations! Your connection is successfully established.' It also displays the 'CF Stack' name as 'vmware-iddc-formation-a8731c9-e5ac-4bb4-9dfe-9a3dab097b7' and the 'AWS Account ID' as a redacted value. To the right, there's a small diagram illustrating the connection between AWS and VMware. The 'NEXT' button is still present at the bottom.

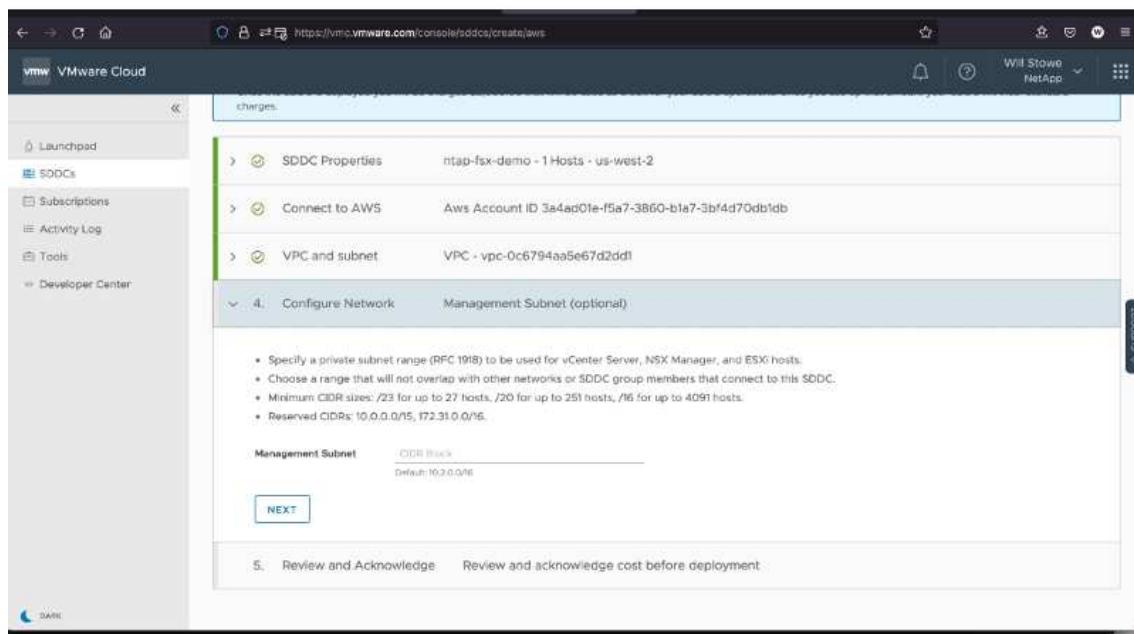


Single-host configuration is used in this validation.

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.

The screenshot shows the VMware Cloud interface for managing Software-Defined Data Centers (SDDCs). The main title is "Software-Defined Data Centers (SDDC)". On the left, a sidebar lists "Launched", "SDDCs", "Subscriptions", "Activity Log", "Tools", and "Developer Center". The "SDDCs" item is selected, showing a list of SDDCs. One SDDC is highlighted: "ntap-fsx-demo". The status is "Ready" with a progress bar showing "Express in 60 days". Key details include:

Region	Clusters	Hosts	Virtual Machines
US West (Oregon)	1	1	36
Type	VMC on AWS SDDC		
Availability Zones	us-west-2a, us-west-2b, us-west-2c		
	VMC on AWS SDDC		

Resource summary:

CPU	Memory	Storage
82.8 GHz	512 GiB	10.37 TiB

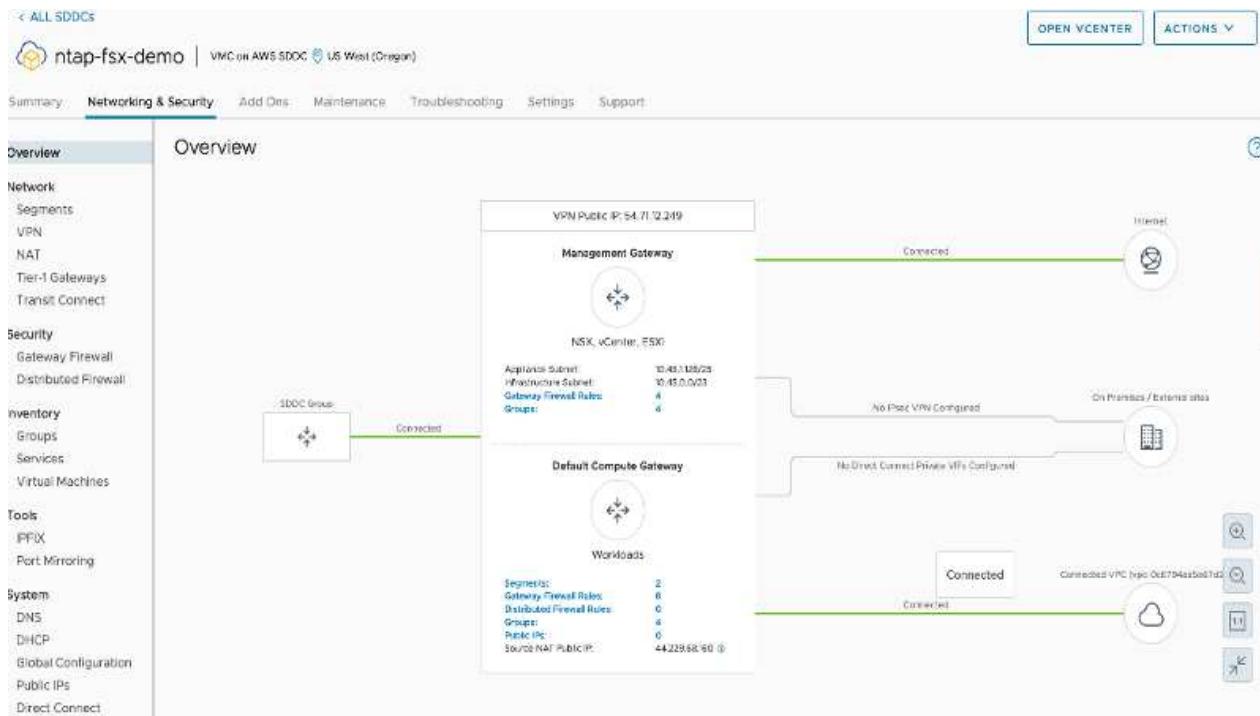
At the bottom, there are links for "VIEW DETAILS", "OPEN VCENTER", and "ACTIONS". Navigation links at the bottom right include "BACK TO TOP" and "GO TO GRID VIEW".

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:

- 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.



- 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

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

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
intap-lx-demo	829a6e22-92a1-42db-ad3d-9e4eb7a90fb6	US West (Oregon)	1.14.0.14	10.45.0.0/23
1				

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.



The screenshot shows the VMware Cloud interface with the URL <https://mc.vmware.com/core/sddc/groups/fe2c821-lcbf-80fc-a9bb-350a402f5a5c/connectivity>. The main content area displays the 'External VPC' tab for the SDDC group 'sddcgroup01'. On the left, there's a sidebar with options like 'Launchpad', 'Subscriptions', 'Activity Log', 'Tools', and 'Developer Center'. The main panel has tabs for 'Summary', 'vCenter Linking', 'Direct Connect', 'External VPC' (which is active), 'External TOW', 'Routing', and 'Support'. Below the tabs is a table with columns: 'AWS Account ID', 'Resource Share Name', 'State', and 'VPC Status'. One row is visible, showing an AWS account ID (redacted), Resource Share Name 'VMC-Group-dc0930e15e7-4fb5-b016-ee01768e86', State 'ASSOCIATED', and VPC Status '...'. There's also an 'ADD ACCOUNT' button.

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.

The screenshot shows the AWS Resource Access Manager (RAM) console at the URL <https://us-west-2.console.aws.amazon.com/home?region=us-west-2#/home>. The left sidebar shows 'Shared by me' (Resource shares, Shared resources, Principals) and 'Shared with me' (Resource shares 1, Shared resources, Principals). The main content area features the title 'AWS Resource Access Manager' and a sub-section 'How it works' with a diagram illustrating the process: 'AWS Resource Access Manager - Share resources across AWS accounts or AWS Organizations by creating a Resource Share', 'Select Resources - Select the resource(s) that you would like to add to a Resource Share.', 'Specify Principals - Specify account ID, ARN, or Organization identifier who can access the resources via the Resource Share.', and 'Share Resources - The specified principals will now have access to resources in the Resource Share.' To the right, there's a callout 'Start sharing your AWS resources with other accounts' with a 'Create a resource share' button, a 'Pricing' section stating 'AWS RAM is offered at no additional charge. There are no setup fees or upfront commitments.', a 'More resources' section with links to 'What is AWS Resource Access Manager?', 'Getting started', and 'Documentation', and a 'Your AZ ID' section with a note about AZ IDs providing a consistent way of identifying resource locations across accounts.

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.

VPC ID	VMC on AWS Region	Transit Gateway Attachment ID	Routes	Status
vpc-0d1c764bcc495e805	US West (Oregon)	tgw-attach-0a4883d6f92c67d64	192.168.0.0/24	PENDING

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.

VPC ID	VMC on AWS Region	Transit Gateway Attachment ID	Routes	Status
vpc-0d1c764bcc495e805	US West (Oregon)	tgw-attach-0a4883d6f92c67d64	192.168.0.0/24	AVAILABLE

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:

Name	ID	Sources	Destinations	Services	Applied To	Action
allow Internet fro...	1019	vmc-addc vmc-addc-2	Any	Any	All Uplinks	Allow
allow VMC to VPC	1017	vmc-addc vmc-addc-2	Connected...	Any	All Uplinks	Allow
allow VPC to VMC	1016	Connected...	vmc-addc	Any	All Uplinks	Allow
allow to vmch2...	1022	vmc-addc vmc-addc-2	vmcf2.v...	Any	All Uplinks	Allow
all from vmch2...	1023	vmcf2.v...	vmc-addc-2 vmc-addc	Any	All Uplinks	Allow
Default VTI Rule	1012	Any	Any	Any	VPN Tunnel In...	Allow
Default Uplink Ru...		Any	Any	Any	All Uplinks	Drop

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.



Provider	Status
Microsoft.OperationsManagement	Registered
Microsoft.Compute	Registered
Microsoft.ContainerService	Registered
Microsoft.ManagedIdentity	Registered
Microsoft.AVS	Registered
Microsoft.OperationalInsights	Registered
Microsoft.GuestConfiguration	Registered

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.

Create a private cloud

Prerequisites **Basics** Tags Review and Create

Project details

Subscription * **SaaS Backup Production**
Resource group * **(New) NimoAVSDemo**
[Create new](#)

Private cloud details

Resource name * **nimoavsppriv**
Location * **(US) East US 2**
Size of host * **AV36 Trial**
Number of hosts * **3**
Find out how many hosts you need

There is no metering for the selected subscription, region, and SKU. No cost data to display.

CIDR address block
Provide IP address for private cloud for cluster management. Make sure these are unique and do not overlap with any other Azure vnets or on-premise networks.

Address block for private cloud * **10.21.0.0/22**

[Review and Create](#) [Previous](#) [Next : Tags >](#)

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.

Home >

nimoavsppriv AVS Private cloud

Search (Ctrl+ /)

Overview

Activity log

Access control (IAM)

Tags

Diagnose and solve problems

Settings

Locks

Manage

Connectivity

Identity

Clusters

Essentials

Resource group (change) NimoAVSDemo	Address block for private cloud 10.21.0.0/22
Status Succeeded	Primary peering subnet 10.21.0.232/30
Location East US 2	Secondary peering subnet 10.21.0.236/30
Subscription (change) SaaS Backup Production	Private Cloud Management network 10.21.0.0/26
Subscription ID b58a041a-e464-4497-8be9-9048369ee8e1	vMotion network 10.21.1.128/25
Tags (change) Click here to add tags	Number of hosts 3

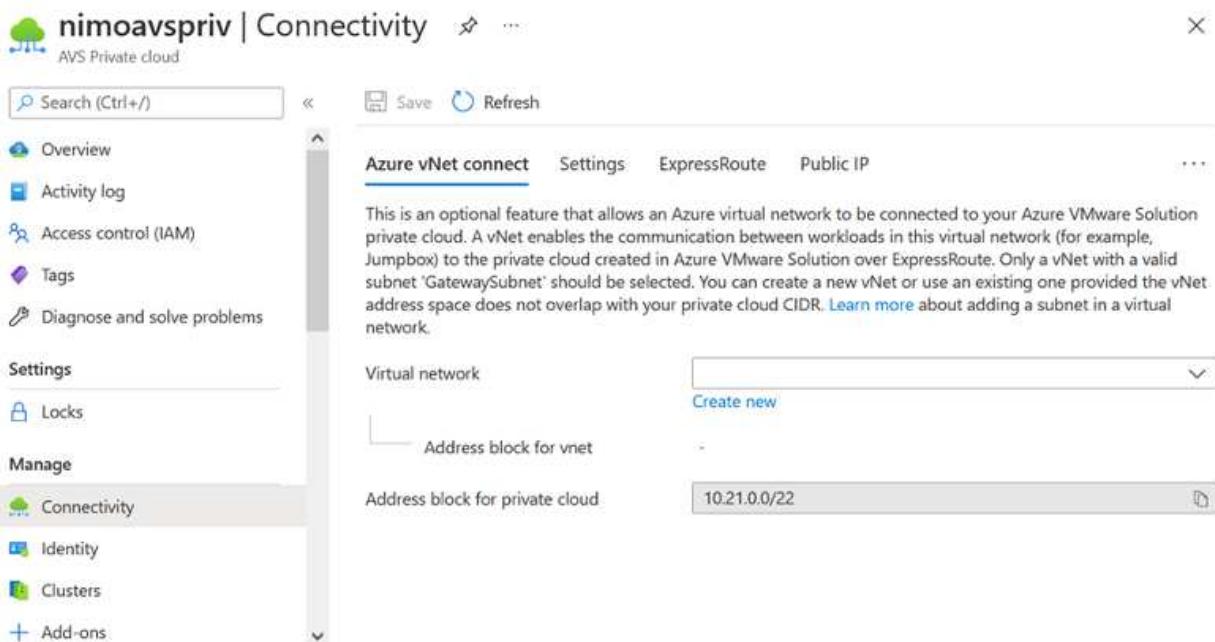
Connect to a new or existing ExpressRoute virtual network gateway

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.

Create virtual network

X

This virtual network enables the communication between workloads in this virtual network (e.g. a Jumphost) to the private cloud created in Azure VMware Solution over an Express route. A default address range and a subnet is selected for this virtual network. For changing the default address range and subnet of this virtual network, follow these steps: Step 1: Change the "Address Range" to desired range (e.g. 172.16.0.0/16). Step 2: Add a subnet under "Subnets" with the name as "GatewaySubnet" and provide subnet's address range in CIDR notation (e.g. 172.16.1.0/24). [Learn more about virtual networks](#)

Name *

nimoavspiv-vnet

Address space

The virtual network's address space specified as one or more address prefixes in CIDR notation (e.g. 10.0.0.0/16).

<input type="checkbox"/> Address range	Addresses	Overlap	
<input type="checkbox"/> 172.24.0.0/16	172.24.0.4 - 172.24.255.254 (65531 addresses)	None	
	(0 Addresses)	None	

Subnets

The subnet's address range in CIDR notation (e.g. 10.0.0.0/24). It must be contained by the address space of the virtual network.

<input type="checkbox"/> Subnet name	Address range	Addresses	
<input type="checkbox"/> GatewaySubnet	172.24.0.0/24	172.24.0.4 - 172.24.0.254 (251 addresses)	
		(0 Addresses)	

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.

Create a virtual machine

Basics Disks Networking Management Advanced Tags Review + create

Create a virtual machine that runs Linux or Windows. Select an image from Azure marketplace or use your own customized image. Complete the Basics tab then Review + create to provision a virtual machine with default parameters or review each tab for full customization. [Learn more](#)

Project details

Select the subscription to manage deployed resources and costs. Use resource groups like folders to organize and manage all your resources.

Subscription * SaaS Backup Production

Resource group * NimoAVSDemo [Create new](#)

Instance details

Virtual machine name * nimAVSRH

Region * (US) East US 2

Availability options No infrastructure redundancy required

Image * Windows Server 2012 R2 Datacenter - Gen2 [See all images](#)

Azure Spot instance

Size * Standard_D2s_v3 - 2 vcpus, 8 GiB memory (\$130.67/month) [See all sizes](#)

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

The screenshot shows the Azure portal interface for a virtual machine named 'nimAVSJH'. On the left, there's a sidebar with various navigation options like Overview, Activity log, Access control (IAM), Tags, Diagnose and solve problems, Settings, Networking, Connect, Disks, and Size. The 'Connect' option is currently selected. The main pane is titled 'nimAVSJH | Connect' and shows the 'Virtual machine' section. It includes a search bar, a warning message about enabling just-in-time access, and tabs for RDP, SSH, and BASTION. Under the RDP tab, there's a section titled 'Connect with RDP' with fields for 'IP address' (set to 'Public IP address (52.138.103.135)') and 'Port number' (set to '3389'). A blue button labeled 'Download RDP File' is also present.

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.

The screenshot shows the Azure portal interface for an AVS Private cloud named 'nimoavsppriv'. The left sidebar has sections for Access control (IAM), Tags, Diagnose and solve problems, Settings, Locks, Manage, Connectivity, Identity (which is selected), Clusters, Placement policies (preview), and Add-ons. The main pane is titled 'nimoavsppriv | Identity' and shows 'AVS Private cloud' details. It has a 'Login credentials' section with 'vCenter credentials' and 'NSX-T Manager credentials' subsections. For vCenter, the Web client URL is 'https://10.21.0.2/' and the Admin username is 'cloudadmin@vsphere.local'. For NSX-T Manager, the Web client URL is 'https://10.21.0.3/' and the Admin username is 'admin'. Each credential has a copy icon next to its value.

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 screenshot shows two parts of the VMware vSphere interface. The top part is the 'Login' screen, which includes fields for 'Email' (clouadmin@vsphere.local), 'Password', and a checkbox for 'Use Windows session authentication'. The bottom part is the main vSphere Client interface, showing the summary page for a cluster named 'vc.beeb9fd29eab4cbea81e62.eastus2.avs.azure.com'. The summary shows 0 virtual machines and 3 hosts. Resource usage metrics are displayed for CPU, Memory, and Storage.

CPU	Used: 231.73 GHz	Capacity: 247.75 GHz
Memory	Used: 18.02 GiB	Capacity: 1.44 TiB
Storage	Used: 246.81 GiB	Capacity: 1.88 TiB
	Used: 7.6 TiB	Capacity: 41.92 TiB

Recent Tasks

Task Name	Target	Status	Details	Initiator	Queued For	Start Time	Completion Time	Server
Undeploy plug-in	vc.beeb9fd29...	Completed	VMware vRops Client Plugin	VSPHERE.LOCAL...	8 ms	08/12/2021, 11:38:11 AM	08/12/2021, 11:38:11 AM	vc.beeb9fd29eb...

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.

Google Cloud VMware Engine

Create Private Cloud

Private Cloud name *

NIMoGCVE

Location *

us-east4 > v-zone-a > VE Placement Group 2

Node type *

ve1-standard-72
2x2.6 GHz, 36 Cores (72 HT), 768 GB RAM
19.2 TB Raw, 3.2 TB Cache (All-Flash)

Node count *

3
(3 to 3)

vSphere/vSAN subnets CIDR range *

192.168.100.0 / 22

IP Range: 192.168.100.0 - 192.168.103.255

HCX Deployment Network CIDR range

192.168.104.0 / 26

IP Range: 192.168.104.0 - 192.168.104.63

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 Project ID	Service	Region	Routing Mode	Peered Project ID	Peered VPC	VPC Peering Status	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](#).

The image shows two screenshots of the VMware vSphere interface. The top screenshot is the login screen, which includes fields for 'solution-user-01@gve.local' and a password, a checkbox for 'Use Windows session authentication', and a 'LOGIN' button. The background features a large, abstract blue and white geometric pattern. The bottom screenshot shows the vSphere Client interface for a cluster named 'vcsa-57901.f7458c8f.europe-west3.gve.goog'. The left sidebar shows a tree view of the environment, including a Datacenter node with a Cluster node containing several ESXi hosts (esxi-57898, esxi-57902, esxi-62642, esxi-71844). Other nodes listed include HCX Management, Workload, and various VMs (nimvmm01, nimvmm02, nimvmm02clone, nimvmmongodb, nimVMSQL03, nimVMSQL03-clone). The main pane displays the cluster summary, showing version 7.0.1, build 18392253, last updated on Sep 22, 2021, at 6:49 AM, and a last file-based backup that has not been scheduled. It also shows resource usage statistics: CPU (Used: 15.03 GHz, Free: 358.9 GHz), Memory (Used: 2.35 TB, Capacity: 2.99 TB), and Storage (Used: 78.67 TB, Capacity: 769.88 TB). Below the summary are sections for Custom Attributes and Health Status, both of which are currently set to 'Good'.

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 datastore¹

View the detailed [guest connect storage options for VMC](#).

Read more about FSx ONTAP as a native datastore public preview from the AWS Press Release (COMING SOON!).

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 datastore¹

View the detailed [guest connect storage options for AVS](#).

Read more about [Azure NetApp Files \(ANF\) as a native datastore - Public 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 datastore¹

View the detailed [guest connect storage options for GCVE](#).

Read more about [Cloud Volumes Service \(CVS\) as a native datastore¹](#).



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.

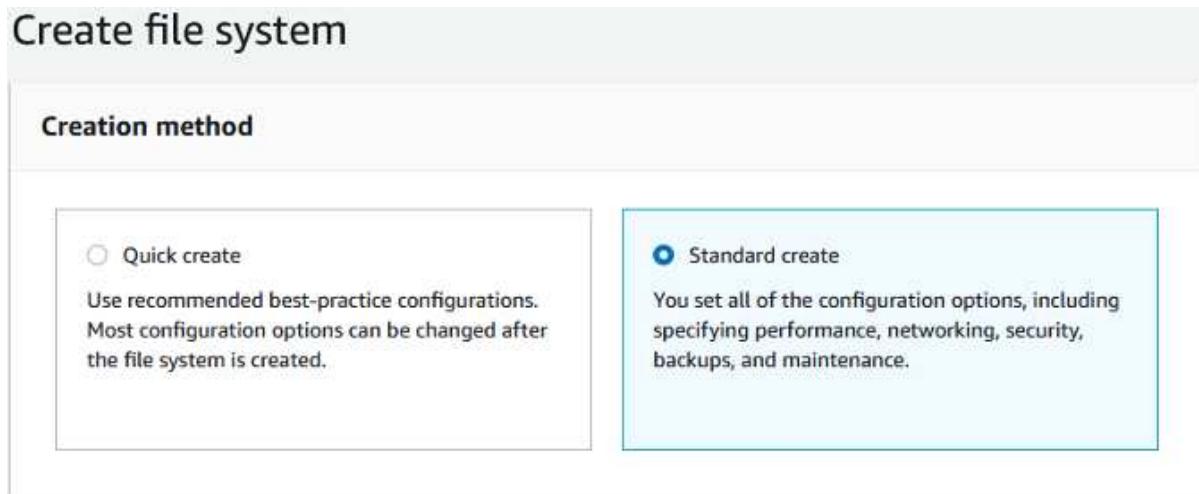
Create and mount Amazon FSx for ONTAP volumes

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.

File system details

File system name - optional [Info](#)

vmcfsxval2

Maximum of 256 Unicode letters, whitespace, and numbers, plus + - = . _ : /

SSD storage capacity [Info](#)

1024

Minimum 1024 GB; Maximum 192 TB.

Provisioned SSD IOPS

Amazon FSx provides 3 IOPS per GB of storage capacity. You can also provision additional SSD IOPS as needed.

Automatic (3 IOPS per GB of SSD storage)

User-provisioned

Throughput capacity [Info](#)

The sustained speed at which the file server hosting your file system can serve data. The file server can also burst to higher speeds for periods of time.

512 MB/s (Recommended)

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.

Network & security

Virtual Private Cloud (VPC) [Info](#)

Specify the VPC from which your file system is accessible.

vmcfsx2.vpc | vpc-0d1c764bcc495e805

VPC Security Groups [Info](#)

Specify VPC Security Groups to associate with your file system's network interface.

Choose VPC security group(s)

sg-018896ea218164ccb (default)

Preferred subnet [Info](#)

Specify the preferred subnet for your file system.

subnet02.sn | subnet-013675849a5b99b3c (us-west-2b)

Standby subnet

subnet01.sn | subnet-0ef956cebf539f970 (us-west-2a)

VPC route tables

Specify the VPC route tables associated with your file system.

VPC's default route table

Select one or more VPC route tables

Endpoint IP address range

Specify the IP address range in which the endpoints to access your file system will be created

No preference

Select an IP address range



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.

Security & encryption

Encryption key [Info](#)

AWS Key Management Service (KMS) encryption key that protects your file system data at rest.

aws/fsx (default)

Description	Account	KMS key ID
Default master key that protects my FSx resources when no other key is defined	139763910815	72745367-7bb0-499c-acc0-4f2c0a80e7c5

File system administrative password

Password for this file system's "fsxadmin" user, which you can use to access the ONTAP CLI or REST API.

- Don't specify a password
 Specify a password

Password

Confirm password

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.

Default storage virtual machine configuration

Storage virtual machine name

vmcfsxval2svm

SVM administrative password

Password for this SVM's "vsadmin" user, which you can use to access the ONTAP CLI or REST API.

- Don't specify a password
- Specify a password

Password

Confirm password

Active Directory

Joining an Active Directory enables access from Windows and MacOS clients over the SMB protocol.

- Do not join an Active Directory
- Join an Active Directory

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.

Default volume configuration

Volume name

vol1

Maximum of 203 alphanumeric characters, plus _.

Junction path

/vol1

The location within your file system where your volume will be mounted.

Volume size

1024



Minimum 20 MiB; Maximum 104857600 MiB

Storage efficiency

Select whether you would like to enable ONTAP storage efficiencies on your volume: deduplication, compression, and compaction.

- Enabled (recommended)
- Disabled

Capacity pool tiering policy

You can optionally enable automatic tiering of your data to lower-cost capacity pool storage.

Auto



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

10. Click Create File System.

Screenshot of the AWS FSx console showing the creation of a Storage Virtual Machine (SVM).

Left Navigation Pane:

- Amazon FSx
- File systems
- Backups
- ONTAP
 - Storage virtual machines
 - Volumes
- Windows File Server
- Lustre
 - Data repository tasks
- FSx on Service Quotas

Main Content Area - File Systems:

File systems (3)

File system name	File system ID	Status	Deployment type	Storage type	Size
fsxntapcifs	fs-014c28399be9c1f9f	Available	Multi-AZ	SSD	1.0 TB
vmcfsxval2	fs-040eacc5d0ac31017	Available	Multi-AZ	SSD	1.0 TB
fsxntapsql	fs-0ab4b447ebd6082aa	Available	Multi-AZ	SSD	2.0 TB

Main Content Area - Storage virtual machines:

Storage virtual machines (SVMs) (2)

SVM name	SVM ID	Status	Creation time	Active Directory
fsxsmbtesting01	svm-075dcfbe2cfa2ece9	Created	2021-10-19 15:17:08 UTC +01:00	FSXTESTING.LOCAL
vmcfsxval2svm	svm-095db076341561212	Created	2021-10-15 15:16:54 UTC +01:00	-

Detail View for SVM fsxsmbtesting01:

fsxsmbtesting01 (svm-075dcfbe2cfa2ece9)

Summary		
SVM ID svm-075dcfbe2cfa2ece9	Creation time 2021-10-19T15:17:08+01:00	Active Directory FSXTESTING.LOCAL
SVM name fsxsmbtesting01	Lifecycle state Created	Net BIOS name FSXSMBTESTING01
UUID 4a50e659-30e7-11ec-ac4f-f3ad92a6a735	Subtype DEFAULT	Fully qualified domain name FSXTESTING.LOCAL
File system ID fs-040eacc5d0ac31017		Service account username administrator
		Organizational unit distinguished name CN=Computers

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:

The screenshot shows the 'Create volume' dialog box with the following settings:

- File system:** fs-040eacc5d0ac31017 | vmcfsv12
- Storage virtual machine:** svm-095db076341561212 | vmcfsv12svm
- Volume name:** nfsdemovol01
- Junction path:** /nfsdemovol01
- Volume size:** 1024
- Storage efficiency:** Enabled (recommended) is selected.
- Capacity pool tiering policy:** Auto

At the bottom right, there are 'Cancel' and 'Confirm' buttons, with 'Confirm' being highlighted.

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.



```
root@ubuntu01:/fsx/nfsdemovol01# df  
Filesystem 1K-blocks Used Available Use% Mounted on  
tmpfs 814396 1176 813220 1% /run  
/dev/mapper/ubuntu--vg-ubuntu--lv 15412160 3666428 10943132 26% /  
tmpfs 4071960 0 4071960 0% /dev/shm  
tmpfs 5120 0 5120 0% /run/lock  
tmpfs 4096 0 4096 0% /sys/fs/cgroup  
/dev/sda2 599320 254996 675512 28% /boot  
tmpfs 814392 4 814388 1% /run/user/1000  
172.16.0.2:/nfsdemovol01 9961472 4241732 5719680 43% /fsx/vcatesting01/nfsdemovol01  
root@ubuntu01:/fsx/nfsdemovol01# cd /fsx/nfsdemovol01/  
root@ubuntu01:/fsx/nfsdemovol01# ls  
nfsnull1.txt  
root@ubuntu01:/fsx/nfsdemovol01#
```

► 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, FSXSMBTTESTING01.FSXTESTING.LOCAL is used in this example.



To 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.

Endpoints

Management DNS name svm-075dcfbe2cfa2ece9.fs-040eacc5d0ac31017.fsx.us-west-2.amazonaws.com	Management IP address 198.19.254.9
NFS DNS name svm-075dcfbe2cfa2ece9.fs-040eacc5d0ac31017.fsx.us-west-2.amazonaws.com	NFS IP address 198.19.254.9
SMB DNS name FSXSMBTTESTING01.FSXTESTING.LOCAL	SMB IP address 198.19.254.9
iSCSI DNS name iscsi.svm-075dcfbe2cfa2ece9.fs-040eacc5d0ac31017.fsx.us-west-2.amazonaws.com	iSCSI IP addresses 10.222.2.224, 10.222.1.94



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

Computer Management

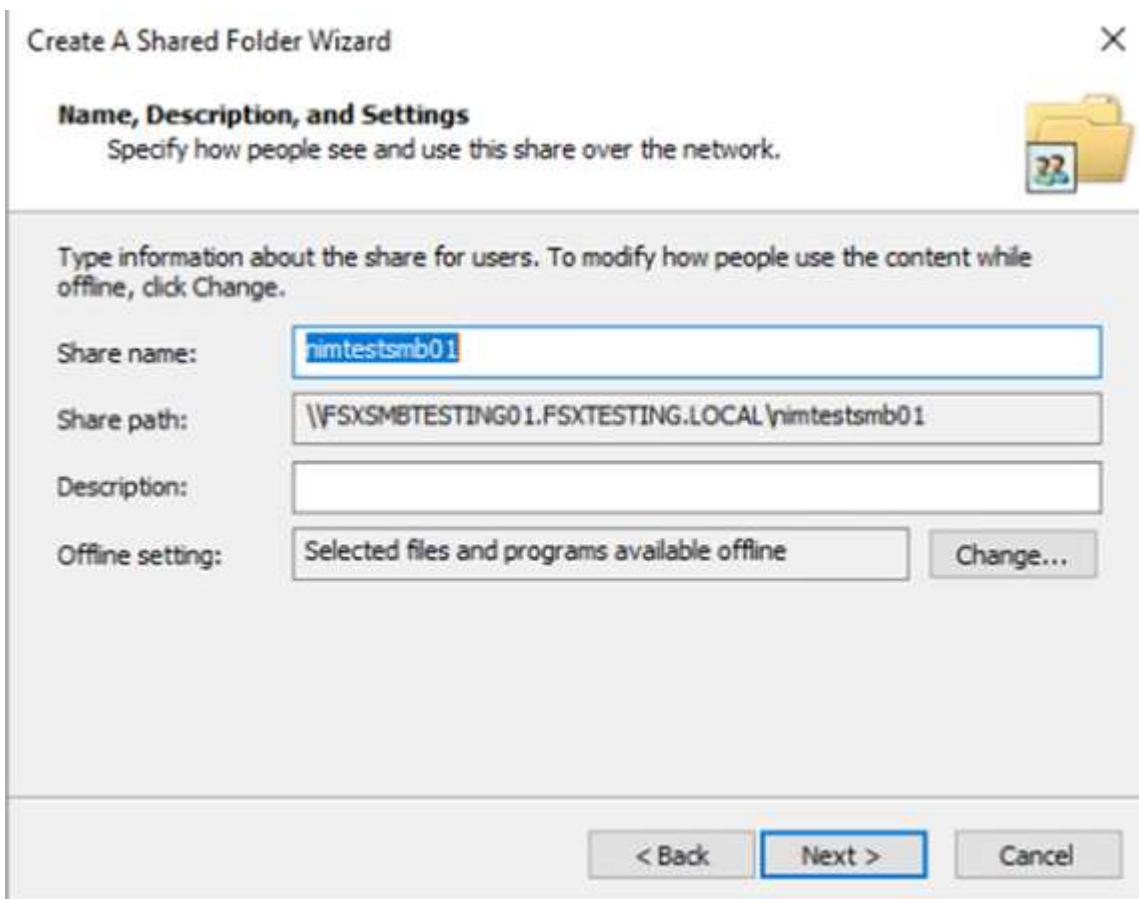
File Action View Help

Computer Management (FSXMBTESTING01.FSXTESTING.LOCAL)

- System Tools
 - Task Scheduler
 - Event Viewer
 - Shared Folders
 - Shares
 - Sessions
 - Open Files
 - Local Users and Groups
 - Performance
 - Device Manager
- Storage
 - Windows Server Backup
 - Disk Management
- Services and Applications

Share Name	Folder Path	Type	# Client Connections	Description
c\$	C:\	Windows	0	
ipc\$		Windows	1	
smbdemo...	C:\smbdemovol01	Windows	1	
testnimvol	C:\testnimvol	Windows	0	

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



Create A Shared Folder Wizard

X

Sharing was Successful

Status:

You have successfully completed the Share a Folder Wizard.

Summary:

You have selected the following share settings on \\FSXSMBTESTING01.FSXTESTING.LOCAL:
Folder path: C:\\nimtestsmb01
Share name: nimtestsmb01
Share path: \\FSXSMBTESTING01.FSXTESTING.LOCAL\\nimtestsmb01

When I click Finish, run the wizard again to share another folder

To close this wizard, click Finish.

Finish

Cancel

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

- 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 nimofsslun01 -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::> igrup create -vserver vmcfsxval2svm  
-igroup winIG -protocol iscsi -ostype windows -initiator  
iqn.1991-05.com.microsoft:vmcdc01.fsxtesting.local
```

```
FsxId040eacc5d0ac31017::> igrup 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 to a Windows host residing on VMware cloud on AWS SDDC, complete the following steps:

- RDP to the Windows VM hosted on the VMware Cloud on AWS SDDC.
- Navigate to Server Manager > Dashboard > Tools > iSCSI Initiator to open the iSCSI Initiator Properties dialog box.
- From the Discovery tab, click Discover Portal or Add Portal and then enter the IP address of the iSCSI target port.
- From the Targets tab, select the target discovered and then click Log On or Connect.
- 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 your 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](#).

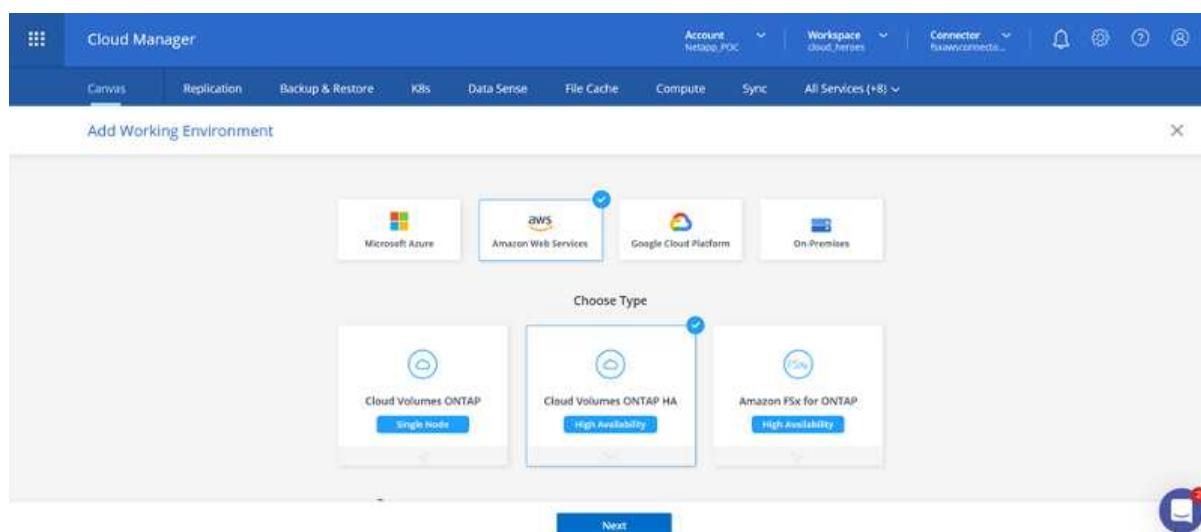


Use the [Cloud Volumes ONTAP sizer](#) to accurately size the Cloud Volumes ONTAP instances. Also, monitor on-premises performance to use as inputs in the Cloud Volumes ONTAP sizer.

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.

Create a New Working Environment

Details and Credentials

↑ Previous Step	Instance Profile Credential Name	139763910815 Account ID	netapp.com-cloud-volumes-... Marketplace Subscription	Edit Credentials													
<table border="1"><tr><td>Details</td><td>Credentials</td></tr><tr><td>Working Environment Name (Cluster Name) <input type="text" value="fsxvcvtesting01"/></td><td>User Name <input type="text" value="admin"/></td></tr><tr><td>+ Add Tags Optional Field Up to four tags</td><td>Password <input type="password" value="*****"/></td></tr><tr><td></td><td>Confirm Password <input type="password" value="*****"/></td></tr><tr><td colspan="5" style="text-align: center;">Continue</td></tr></table>					Details	Credentials	Working Environment Name (Cluster Name) <input type="text" value="fsxvcvtesting01"/>	User Name <input type="text" value="admin"/>	+ Add Tags Optional Field Up to four tags	Password <input type="password" value="*****"/>		Confirm Password <input type="password" value="*****"/>	Continue				
Details	Credentials																
Working Environment Name (Cluster Name) <input type="text" value="fsxvcvtesting01"/>	User Name <input type="text" value="admin"/>																
+ Add Tags Optional Field Up to four tags	Password <input type="password" value="*****"/>																
	Confirm Password <input type="password" value="*****"/>																
Continue																	

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

Create a New Working Environment

Services

 Data Sense & Compliance	<input checked="" type="checkbox"/>
 Backup to Cloud	<input checked="" type="checkbox"/>
 Monitoring	<input checked="" type="checkbox"/>
Continue	

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

Create a New Working Environment

HA Deployment Models

↑ Previous Step	<table border="1"><tr><td>Multiple Availability Zones</td></tr><tr><td> Provides maximum protection against AZ failures.</td></tr><tr><td> Enables selection of 3 availability zones.</td></tr><tr><td> An HA node serves data if its partner goes offline.</td></tr><tr><td>Extended Info</td></tr></table>	Multiple Availability Zones	 Provides maximum protection against AZ failures.	 Enables selection of 3 availability zones.	 An HA node serves data if its partner goes offline.	Extended Info	<table border="1"><tr><td>Single Availability Zone</td></tr><tr><td> Protects against failures within a single AZ.</td></tr><tr><td> Single availability zone. HA nodes are in a placement group, spread across distinct underlying hardware.</td></tr><tr><td> An HA node serves data if its partner goes offline.</td></tr><tr><td>Extended Info</td></tr></table>	Single Availability Zone	 Protects against failures within a single AZ.	 Single availability zone. HA nodes are in a placement group, spread across distinct underlying hardware.	 An HA node serves data if its partner goes offline.	Extended Info
Multiple Availability Zones												
 Provides maximum protection against AZ failures.												
 Enables selection of 3 availability zones.												
 An HA node serves data if its partner goes offline.												
Extended Info												
Single Availability Zone												
 Protects against failures within a single AZ.												
 Single availability zone. HA nodes are in a placement group, spread across distinct underlying hardware.												
 An HA node serves data if its partner goes offline.												
Extended Info												
Continue												

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

Create a New Working Environment

Region & VPC

↑ Previous Step

AWS Region	VPC	Security group
US West Oregon	vpc-0d1c764bcc495e805 - 10.222.0.0/16	Use a generated security group

Node 1:	Node 2:	Mediator:
Availability Zone	Availability Zone	Availability Zone
us-west-2a	us-west-2b	us-west-2c
Subnet	Subnet	Subnet
10.222.1.0/24	10.222.2.0/24	10.222.3.0/24

Continue

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

Create a New Working Environment

Connectivity & SSH Authentication

↑ Previous Step

Nodes	Mediator
SSH Authentication Method	Security Group
Password	Use a generated security group
	Key Pair Name
	nimokey
	Internet Connection Method
	Public IP address

Continue

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

Create a New Working Environment

Floating IPs

↑ Previous Step

Floating IP addresses are required for cluster and SVM access and for NFS and CIFS data access. These floating IPs can migrate between HA nodes if failures occur. To access the data from outside the VPC, [you can set up an AWS transit gateway](#).

You must specify IP addresses that are outside of the CIDR blocks for all VPCs in the selected AWS region.

Floating IP address for cluster management	172.16.0.1
Floating IP address 1 for NFS and CIFS data	172.16.0.2
Floating IP address 2 for NFS and CIFS data	172.16.0.3
Floating IP address for SVM management (Optional)	172.16.0.4

Continue

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

Create a New Working Environment

Route Tables

↑ Previous Step

Select the route tables that should include routes to the floating IP addresses. This enables client access to the Cloud Volumes ONTAP HA pair. If you leave a route table unselected, clients that are associated with the route table cannot access the HA pair.

Additional information ⓘ

Name	Main	ID	Associate with Subnet	Tags
<input checked="" type="checkbox"/>	Yes	rtb-00b2d30c3f68fdbdd	0 Subnets	1 Tags

1 Route Tables | The main route table is the default for the VPC

Continue

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

Create a New Working Environment

Data Encryption

↑ Previous Step

 AWS Managed Encryption

AWS is responsible for data encryption and decryption operations. Key management is handled by AWS key management services.

Default Master Key: aws/ebs

 Change Key

Continue

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.

Create a New Working Environment Cloud Volumes ONTAP Charging Methods & NSS Account

Cloud Volumes ONTAP Charging Methods

Learn more about our charging methods

Pay-As-You-Go by the hour

Bring your own license

NetApp Support Site Account (*Optional*)

Learn more about NetApp Support Site (NSS) accounts

To register this Cloud Volumes ONTAP to support, you should add NetApp Support Site Account.

Don't have a NetApp Support Site account? Select go to finish deploying this system. After it's created, use the [Support Registration option](#) to create an NSS account.

Continue

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.

Create a New Working Environment

Preconfigured Packages

Select a preconfigured Cloud Volumes ONTAP system that best matches your needs, or create your own configuration. Preconfigured settings can be modified at a later time.

Change Configuration

POC and small workloads
Up to 500GB of storage

Database and application data production workloads

Cost effective DR
Up to 500GB of storage

Highest performance production workloads

Continue

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

Create a New Working Environment

Review & Approve

Previous Step [tsxcvotesting](#) Show API request

AWS | us-west-2 | HA

This Cloud Volumes ONTAP instance will be registered with NetApp support under the NSS Account mchad.

I understand that Cloud Manager will allocate the appropriate AWS resources to comply with my above requirements. [More information >](#)

Overview	Networking	Storage	
Storage System:	Cloud Volumes ONTAP HA	HA Deployment Model:	Multiple Availability Zones
License Type:	Cloud Volumes ONTAP Explore	Encryption:	AWS Managed
Capacity Limit:	2TB	Customer Master Key:	aws/ebs

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) ▾

Go to Tabular View

Add Working Environment

vmhseval2
15a for ONTAP
9 Volumes 26.49 GB Capacity AWS

fsxvotesting01
Cloud Volumes ONTAP
46.08 Capacity AWS

Amazon S3
4 Buckets 2 Regions AWS

fsxvotesting01 Cloud Volumes ONTAP On

Cloud Volumes ONTAP | AWS | HA

DETAILS

SERVICES

Replication Off Enable

Backup & Restore Loading...

Additional configurations for SMB volumes

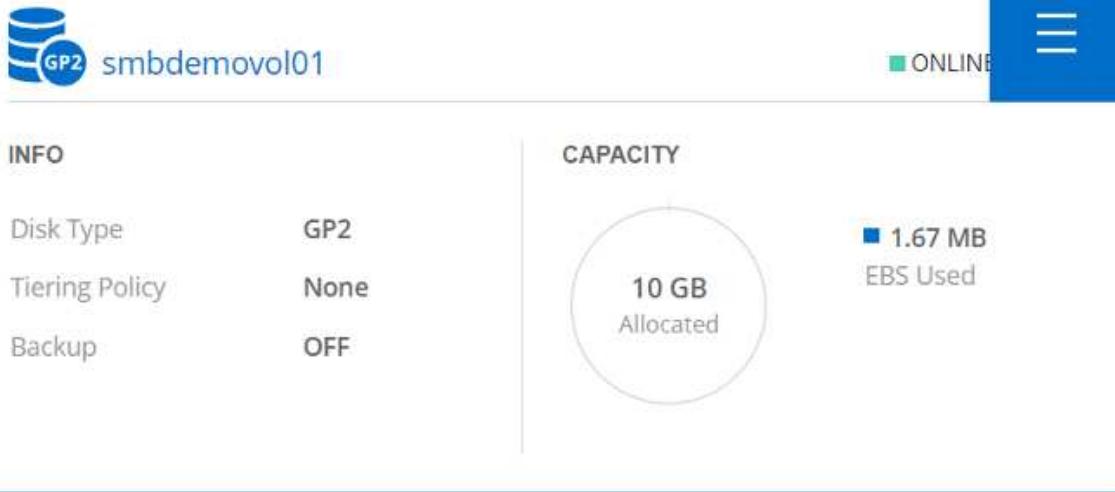
1. After the working environment is ready, make sure the CIFS server is configured with the appropriate DNS and Active Directory configuration parameters. This step is required before you can create the SMB volume.

The screenshot shows the 'Create a CIFS server' configuration page. It includes fields for 'DNS Primary IP Address' (192.168.1.3), 'Active Directory Domain to join' (fsxtesting.local), 'DNS Secondary IP Address (Optional)', 'Credentials authorized to join the domain' (Username and Password), and 'Save' and 'Cancel' buttons.

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.

The screenshot shows the 'Volume Details, Protection & Protocol' configuration page. It has two main sections: 'Details & Protection' and 'Protocol'. In 'Details & Protection', fields include 'Volume Name' (smbdemovol01), 'Size (GB)' (100), and 'Snapshot Policy' (default). In 'Protocol', the 'CIFS' tab is selected, showing 'Share name' (smbdemovol01_share), 'Permissions' (Full Control), 'Users / Groups' (Everyone), and a note about valid users separated by a semicolon. A 'Continue' button is at the bottom.

3. After the volume is provisioned, it is available 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.

fsxvotesting01 (Multiple AZs)

AWS | AWS

Volumes HA Status Cost Replications

Mount Volume smbdemovol01

Access from inside the VPC using Floating IP

Auto failover between nodes
The IP address automatically migrates between nodes if failures occur

Go to your machine and enter this command

\\172.16.0.2\smbdemovol01_share Copy

Access from outside the VPC using AWS Private IP

No auto failover between nodes
The IP address does not migrate between nodes if failures occur

To avoid traffic between nodes, mount the volume by using the primary node's IP address:

\\10.222.1.100\smbdemovol01_share Copy

If the primary node goes offline, mount the volume by using the HA partner's IP address:

VMware Cloud - ntap-fsx-demo X vsphere - vmcd01 - Summary X vmcd01 X NetApp Cloud Manager X +

https://vcenter.sddc-S2-37-127-104.vmwarevmc.com/ui/webconsole.html?vmid=vm-1005&vmName=vmcd01 80% ☆

Getting Started EC2 Management Con... New Tab Other Bookmarks

vmcd01

Server Manager • Dashboard

WELCOME TO SERVER MANAGER

File Home Share View

Dashboard Local Server All Servers AD DS DNS File and Storage Services

QUICKSTART

AD DS

SEARCH NOW

The PC - smbdemovol01_share (172.16.0.2) (Z)

Name Date modified Type Size

name01 10/22/2023 11:11 AM File folder

name02 10/22/2023 11:11 AM File folder

name03 10/22/2023 11:11 AM File folder

name04 10/22/2023 11:11 AM File folder

Quick access Desktop Downloads Documents Pictures The PC DVD Drive (D) (S0_0) Network

ROLES AND SERVER GRID Active 1 | Server groups 1 |

AD DS Manageability Events Services Performance DPA results

Manage Task View Help

Enforce US Keyboard Layout View Fullscreen Send Ctrl+Alt+Delete

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.

The screenshot shows two windows side-by-side. The top window is titled 'Volume Details, Protection & Protocol' and is part of the 'Create new volume in fsxvotesting01' process. It has tabs for 'Details & Protection' and 'Protocol'. Under 'Protocol', the 'iSCSI' tab is selected. The 'Initiator Group' section contains a radio button for 'Map Existing Initiator Groups' and a checkbox for 'Create Initiator Group'. The 'Operating System Type' dropdown is set to 'Windows'. Below these, a 'Select Initiator Groups:' section shows '1 (of 3) Groups' with a checkbox for 'winIG | windows' and the IQN 'iqn.1991-05.com.microsoft:vmcdc01.fsxtesting01'. The bottom right of this window has a 'Continue' button. The bottom window is a 'Server Manager - Dashboard' window for 'vmcdc01'. It shows the 'File and Storage Services' role is installed. A file browser window is open showing a folder structure with files named 'monkey1', 'monkey2', and 'monkey3'. The status bar at the bottom of the dashboard window indicates the time as 7:25 AM and the date as Wednesday, October 20, 2021.

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
```

The screenshot shows a terminal window titled 'ubuntu01' running on a VMware host. The terminal displays the command 'root@ubuntu01:/fsx# mount -t nfs 172.16.0.2:/nfsdemovol01 /fsxcvotesting01/nfsdemovol01'. Below this, the 'df' command output is shown, indicating the mounted volume at '/fsxcvotesting01/nfsdemovol01'. A red arrow points to the mounted directory in the 'df' output.

```
root@ubuntu01:/fsx# mount -t nfs 172.16.0.2:/nfsdemovol01 /fsxcvotesting01/nfsdemovol01_
root@ubuntu01:~# df
Filesystem      1K-blocks   Used Available Use% Mounted on
tmpfs            814396    116    813280  1% /run
/dev/mapper/ubuntu--vg-ubuntu--1V 15412168 3666428 10943132 2% /
tmpfs            4071960     0  4071960  0% /dev/shm
tmpfs             5120     0   5120  0% /run/lock
tmpfs              4096     0   4096  0% /sys/fs/cgroup
/dev/sda2        999320 254996  675512 28% /boot
tmpfs            814392     4  814388  1% /run/user/1000
172.16.0.2:/nfsdemovol01  9361472 4241792  5195680 43% /fsxcvotesting01/nfsdemovol01
192.16.254.239:/nfsdemovol01  536160    512   995648  1% /fsx/nfsdemovol01
root@ubuntu01:/fsx/nfsdemovol01# cd /fsx/nfsdemovol01/
root@ubuntu01:/fsx/nfsdemovol01# ls
n1now111.txt
root@ubuntu01:/fsx/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.

The screenshot shows the 'New NetApp account' creation interface in the Azure portal. On the left, there's a sidebar with a 'Create' button and a 'Manage view' dropdown. The main area has fields for 'Name' (set to 'nimoAVSANFdemo'), 'Subscription' (set to 'SaaS Backup Production'), 'Resource group' (set to 'NimoAVSDemo'), and 'Location' (set to 'East US 2'). At the bottom, there are 'Create' and 'Download a template for automation' buttons.

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](#).

The screenshot shows the Azure NetApp Files portal. On the left, there's a sidebar with options like 'Create', 'Manage view', and a search bar. The main area is titled 'nimoAVSANFdemo | Capacity pools'. It has a table with columns 'Name', 'Capacity', and 'Service level'. Below the table, it says 'You don't have any capacity pools. Click Add pool to get started'. On the right, a modal window titled 'New capacity pool' is open. It contains fields for 'Name' (set to 'nimcappool'), 'Service level' (set to 'Standard'), 'Size (TiB)' (set to '4'), and 'QoS type' (set to 'Auto'). At the bottom of the modal are 'Create' and 'Discard' buttons.

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](#).

The screenshot shows the Azure portal with a virtual network named 'nimoavspriv-vnet'. On the left, there's a sidebar with options like 'Overview', 'Activity log', 'Access control (IAM)', 'Tags', 'Diagnose and solve problems', 'Address space', 'Connected devices', 'Subnets' (which is selected), 'DDoS protection', 'Firewall', and 'Security'. The main area is titled 'nimoavspriv-vnet | Subnets'. It shows a table with columns 'Name', 'GatewaySubnet', 'VMSubnet', and 'StorageSubnet'. Below the table, there's a button to 'Add subnet'. A modal window titled 'Add subnet' is open. It contains fields for 'Name' (set to 'anf.del'), 'Subnet address range' (set to '172.24.3.0/28'), and other options like 'Add IPv6 address space' (unchecked), 'NAT gateway' (set to 'None'), 'Network security group' (set to 'None'), and 'Route table' (set to 'None'). At the bottom of the modal are 'Save' and 'Cancel' buttons.

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.

nimoAVSANFdemo | Active Directory connections

Join Refresh

DNS AD DNS Domain SMB Server

No currently joined Active Directories.

Primary DNS * 172.24.1.5

Secondary DNS

AD DNS Domain Name * nimodemo.com

AD Site Name

SMB Server (Computer Account) Prefix * nim smb

Organizational Unit Path

Join

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

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

Create a volume

Basics Protocol Tags Review + create

This page will help you create an Azure NetApp Files volume in your subscription and enable you to access the volume from within your virtual network. [Learn more about Azure NetApp Files](#).

Volume details

Volume name * nimvoltest1

Capacity pool * nimcappool

Available quota (GiB) 4096 4 TiB

Quota (GiB) * 100 100 GiB

Review + create < Previous Next : Protocol >

The screenshot shows the Azure portal interface for managing NetApp volumes. On the left, there's a sidebar with options like Quota, Properties, Locks, Azure NetApp Files, and Active Directory connections. The main area is titled 'nimoAVSANFDemo | Volumes' and contains a table with the following data:

Name	Quota	Throughput	Protocol type	Mount path	Service level	Capacity p
nimsmbvol2	100 GiB	1.6 MiB/s	SMB	\\\nimsmb-7c1c.nimodr	Standard	nimcappoo
nimvoltest1	100 GiB	1.6 MiB/s	NFSv3	172.24.3.4/nimvoltest1	Standard	nimcappoo

To learn more about Azure NetApp Files volume performance by size or quota, see [Performance considerations for Azure NetApp Files](#).

- 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.





- 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:/nimodemofsv1 /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-themes/1515
/dev/loop1        224256   224256          0 100% /snap/gnome-3-34-1804/72
/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/VMware Tools
172.24.3.4:/nimodemofsv1 104857600          0 104857600   0% /home/nimoadmin/nimodemo11
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 your 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.

The screenshot shows the NetApp Cloud Manager interface. The top navigation bar includes 'Cloud Manager', 'Account CVOAVSDemo', 'Workspace Workspace-1', 'Connector N/A', and various icons. Below the navigation bar, a horizontal menu bar has tabs for 'Canvas', 'Replication', 'Backup & Restore', 'K8s', 'Data Sense', 'File Cache', 'Compute', 'Sync', and 'All Services (+8)'. A large blue button labeled 'Canvas' is positioned below the tabs. In the center of the page, there is a circular icon with a cloud and a plus sign, and the text 'Let's Add Your First Working Environment'. A small note below it says 'This is how you deploy, allocate or discover your cloud storage. (Cloud Volumes ONTAP, Cloud Volumes Service, on-prem ONTAP or S3 buckets.)'. At the bottom, a blue button says 'Add Working Environment'.

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.



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



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

Create a New Working Environment		Details and Credentials	
Managed Service Ide...	SaaS Backup Prod...	CMCVOSub	Edit Credentials
Credential Name	Azure Subscription	Marketplace Subscription	
Details Working Environment Name (Cluster Name) <input type="text" value="nimavscvo"/>		Credentials User Name <input type="text" value="admin"/> Password <input type="password"/>	
Continue			

- 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.

Create a New Working Environment Details and Credentials

Working Environment Name (Cluster Name)	User Name
nimavsCVO	admin
Add Resource Group Tags Optional Field	
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.

Create a New Working Environment Services

Data Sense & Compliance	On
Backup to Cloud	On
Monitoring	On
Continue	

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

Create a New Working Environment Location & Connectivity

Azure Region East US 2	Resource Group <input checked="" type="radio"/> Create a new group nimavsCVO-rg
Availability Zone Select an Availability Zone	
VNet nimoavspiv-vnet NimoAVSDemo	Security Group <input checked="" type="radio"/> Generated security group
Subnet 172.24.2.0/24	<input checked="" type="checkbox"/> I have verified network connectivity between the Cloud Manager server and the selected VNet.
Continue	

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.

Create a New Working Environment Cloud Volumes ONTAP Charging Methods & NSS Account

Cloud Volumes ONTAP Charging Methods

[Learn more about our charging methods](#)



Pay-As-You-Go by the hour



Bring your own license

NetApp Support Site Account (*Optional*)

[Learn more about NetApp Support Site \(NSS\) accounts](#)

To register this Cloud Volumes ONTAP to support, you should add NetApp Support Site Account.

Don't have a NetApp Support Site account? Select go to finish deploying this system. After it's created, use the [Support Registration option](#) to create an NSS account.

[Continue](#)

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

Create a New Working Environment

Preconfigured Packages

Select a preconfigured Cloud Volumes ONTAP system that best matches your needs, or create your own configuration.
Preconfigured settings can be modified at a later time.

[Change Configuration](#)



POC and small workloads
Up to 500GB of storage



Database and application data production workloads



Cost effective DR
Up to 500GB of storage



Highest performance production workloads

[Continue](#)

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

Create a New Working Environment

Review & Approve

nimavscVO

Azure | East US 2

- I understand that in order to activate support, I must first register Cloud Volumes ONTAP with NetApp. [More information](#) >
- I understand that Cloud Manager will allocate the appropriate Azure resources to comply with my above requirements. [More information](#) >

[Overview](#)

[Networking](#)

[Storage](#)

[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) ▾

Go to Tabular View

Add Working Environment

Cloud Volumes ONTAP

Freemium

nimavscVO

On

DETAILS

Cloud Volumes ONTAP | Azure | Single

SERVICES

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.

The screenshot shows the 'Create a CIFS server' configuration page in the Nimav CVO interface. It includes fields for DNS Primary IP Address (172.24.1.5), Active Directory Domain to join (nimodemo.com), DNS Secondary IP Address (Optional) (Example: 127.0.0.1), and Credentials authorized to join the domain (nimoadmin). There is also a 'Advanced' button.

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.

The screenshot shows the 'Volume Details, Protection & Protocol' configuration page. Under 'Details & Protection', the Volume Name is 'nimavssmbvol1' and the Size (GB) is 50. Under 'Protocol', the protocol is set to CIFS. The Share name is 'nimavssmbvol1_share' and the Permissions are 'Full Control'. The Users / Groups field contains 'Everyone;'. A 'Continue' button is at the bottom.

3. After the volume is provisioned, it will be available 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.

Volumes Replications

Volumes

1 Volume | 50 GB Allocated | 1.74 MB Total Used (1.74 MB In Disk, 0 KB In Blob)

nimavssmbvol1 ONLINE

INFO	
Disk Type	PREMIUM_LRS
Tiering Policy	Auto
Backup	OFF

CAPACITY

Category	Value
Disk Used	1.74 MB
Blob Used	0 GB

- 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.
- Copy the following path and use the Map Network Drive option to mount the volume on the VM running on Azure VMware Solution SDDC.

Volumes Replications

Mount Volume nimavssmbvol1

Go to your machine and enter this command

```
\\"172.24.2.8\\nimavssmbvol1_share
```

File Home Share View

\\172.24.2.8\\nimavssmbvol1_share

Name	Date modified	Type	Size
Desktop			
Downloads			
Documents			
Pictures			
This PC			
Network			

This folder is empty.

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.

The screenshot shows the 'New Volume' wizard interface. The 'Protocol' tab is selected, indicating iSCSI. The 'Volume Name' field contains 'nimavsscsi1'. The 'Size (GB)' field is set to '500'. Under 'Snapshot Policy', 'default' is selected. In the 'Initiator Group' section, 'Create Initiator Group' is chosen, and the initiator group name is 'avsvmlIG'. A 'Continue' button is visible at the bottom.

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.

Volume	Layout	Type	File System	Status	Capacity	Free Space	% Free
(C)	Simple	Basic	NTFS	Healthy (Boot, Page File, Crash Dump, Primary Partition)	39.51 GB	24.99 GB	63 %
SSD_X64FREE_EN-US_DV9 (D)	Simple	Basic	UDF	Healthy (Primary Partition)	6.49 GB	0 MB	0 %
System Reserved	Simple	Basic	NTFS	Healthy (System, Active, Primary Partition)	500 MB	169 MB	34 %

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 your 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)

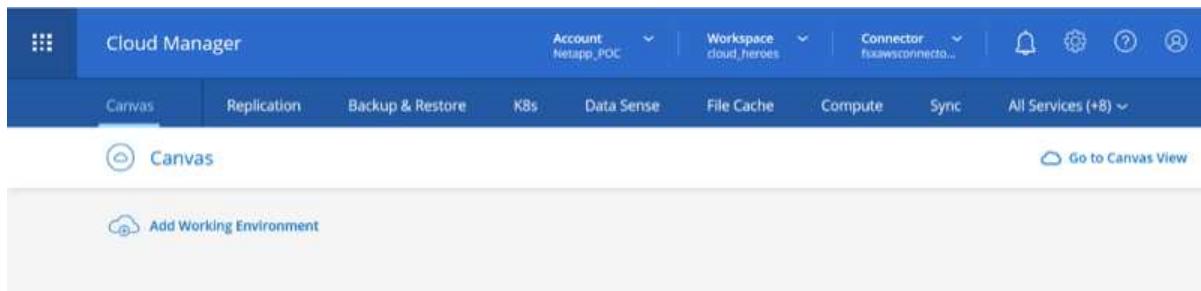
Cloud Volumes ONTAP shares and LUNs can be mounted from VMs that are created in the GCVE private cloud environment. The volumes can also be mounted on the Linux client and on Windows client and LUNS can be accessed on Linux or Windows clients as block devices when mounted over iSCSI because Cloud Volumes 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](#).

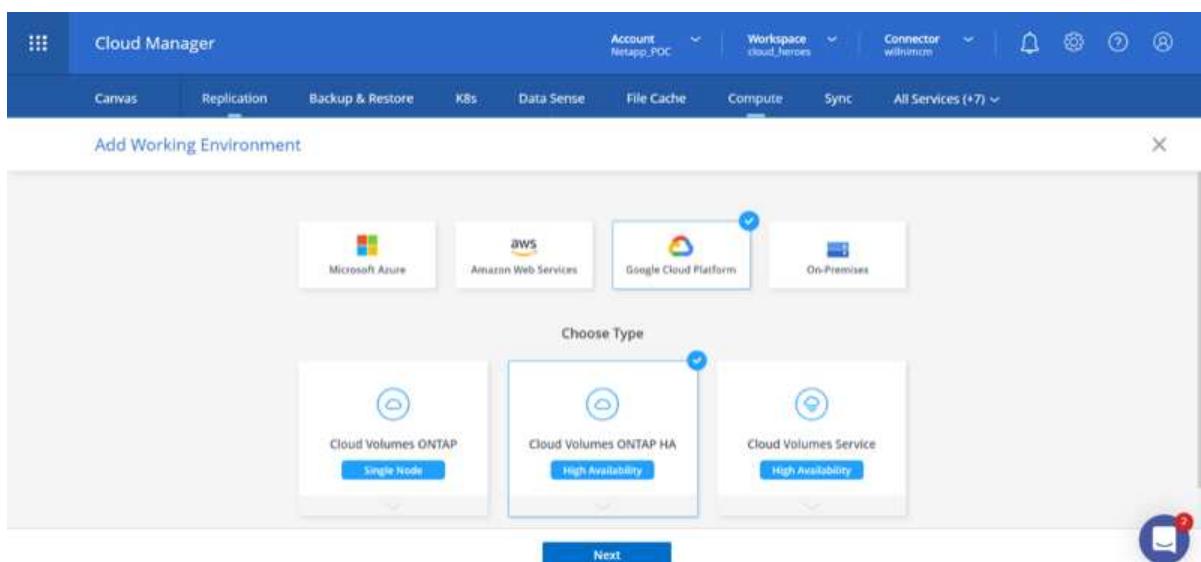


Use [Cloud Volumes ONTAP sizer](#) to accurately size the Cloud Volumes ONTAP instances. Also monitor on-premises performance to use as inputs in the Cloud Volumes ONTAP sizer.

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.

[↑ Previous Step](#)

CV-Performance-Testing

Google Cloud Project

HCLMainBillingAccountSubs...

Marketplace Subscription

[Edit Project](#)

Details

Working Environment Name (Cluster Name)

cvogcveva

Service Account



! **Notice:** A Google Cloud service account is required to use two features: backing up data using Backup

Credentials

User Name

admin

Password

.....

Confirm Password

.....

[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.

[↑ Previous Step](#)

Data Sense & Compliance



Backup to Cloud



⚠ **WARNING:** By turning off Backup to Cloud, future data recovery will not be possible in case of data corruption or loss

[Continue](#)

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

Create a New Working Environment

Location & Connectivity

[↑ Previous Step](#) Location

GCP Region

europe-west3

Connectivity

VPC

cloud-volumes-vpc

GCP Zone

europe-west3-c

Subnet

10.0.6.0/24

I have verified connectivity between the target VPC and Google Cloud storage.

Firewall Policy

 Generated firewall policy Use existing firewall policy[Continue](#)

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.

Create a New Working Environment

Cloud Volumes ONTAP Charging Methods & NSS Account

[↑ Previous Step](#)

Cloud Volumes ONTAP Charging Methods

[Learn more about our charging methods](#) Pay-As-You-Go by the hour Bring your own license Freemium (Up to 500GB)

NetApp Support Site Account

[Learn more about NetApp Support Site \(NSS\) accounts](#)

NetApp Support Site Account

mchad

To add a new NetApp Support Site account, go to the Support - NSS Management tab.

[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.

Create a New Working Environment

Preconfigured Packages



Select a preconfigured Cloud Volumes ONTAP system that best matches your needs, or create your own configuration.
Preconfigured settings can be modified at a later time.

[Change Configuration](#)

POC and small workloads

Up to 500GB of storage



Database and application data production workloads



Cost effective DR

Up to 500GB of storage



Highest performance production workloads

[Continue](#)

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

The screenshot shows the 'Review & Approve' step of a wizard. At the top left is a link to 'Create a New Working Environment'. The main area displays configuration details for a 'cvogcveval' instance in 'GCP | europe-west3'. A note states: 'This Cloud Volumes ONTAP instance will be registered with NetApp support under the NSS Account mchad.' A checkbox is checked, indicating agreement to resource allocation. Below the note are three tabs: 'Overview' (selected), 'Networking', and 'Storage'. Under 'Overview', the following details are listed:

Storage System:	Cloud Volumes ONTAP	Cloud Volumes ONTAP runs on:	n2-standard-4
License Type:	Cloud Volumes ONTAP Freemium	Encryption:	Google Cloud Managed
Capacity Limit:	500GB	Write Speed:	Normal

A large blue 'Go' button is centered at the bottom of the configuration section.

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

The screenshot shows the 'Canvas' tab in the Cloud Manager interface. The top navigation bar includes 'Account: NetApp_POC', 'Workspace: cloud_tieries', 'Connector: wellnimmci', and various icons for notifications, settings, and help. Below the navigation is a search bar with 'Canvas' and a 'Go to Tabular View' link. The main area features two clouds representing environments:

- cvogcveval**: 'Cloud Volumes ONTAP' (Freemium license) with a GCP icon.
- DatacenterDude**: 'Azure NetApp Files' with a Microsoft Azure icon. It shows 31 volumes and 9.71 TiB capacity.

To the right, a 'Working Environments' sidebar lists the provisioned resources:

- 1 Cloud Volumes ONTAP 43.05 GiB Provisioned Capacity
- 1 FSx for ONTAP (High-Availability) 0 B Provisioned Capacity
- 1 Azure NetApp Files 9.71 TiB Provisioned Capacity

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 (°), 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.

Create new volume in cvogcve01 Volume Details, Protection & Protocol

The screenshot shows the 'Volume Details, Protection & Protocol' configuration page. It has two main sections: 'Details & Protection' and 'Protocol'. In 'Details & Protection', fields include Volume Name (cvogcvesmbvol01), Size (GB) (10), and Snapshot Policy (default). In 'Protocol', the CIFS tab is selected, showing Share name (cvogcvesmbvol01_share), Permissions (Full Control), and Users / Groups (Everyone). A note below says 'Valid users and groups separated by a semicolon'. A 'Continue' button is at the bottom.

3. After the volume is provisioned, it will be available 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 (°) to display its options.



cvogcvesmbvol01

ONLINE



INFO

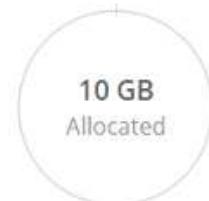
Disk Type

PD-SSD

Tiering Policy

None

CAPACITY



1.84 MB

Disk Used

- 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.



cvogcve01

Volumes

Replications

 [Mount Volume cvogcvesmbvol01](#)

Go to your machine and enter this command

\\\10.0.6.251\cvogcvesmbvol01_share

Copy

- 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.

Specify the drive letter for the connection and the folder that you want to connect to:

Drive:

Y:



Folder:

\\\10.0.6.251\cvogcvesmbvol01_share

Browse...

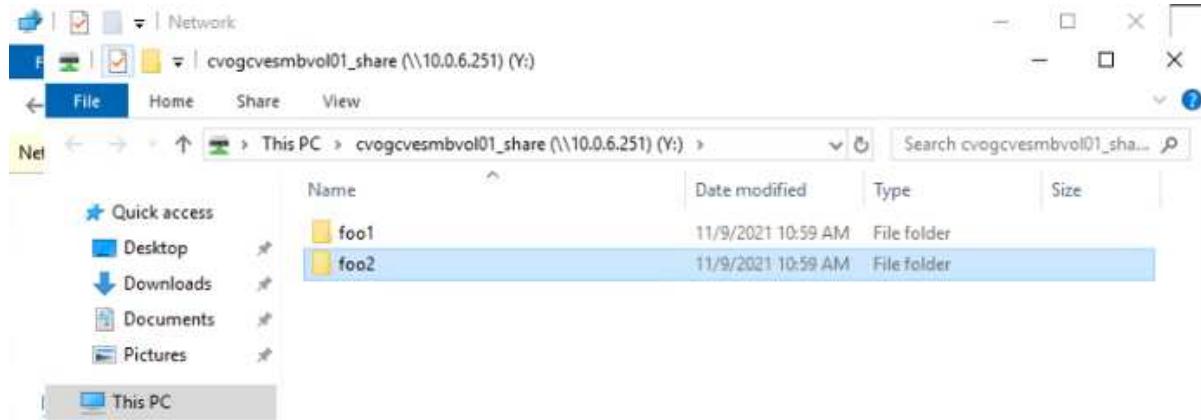
Example: \\\server\share

 Reconnect at sign-in Connect using different credentials[Connect to a Web site that you can use to store your documents and pictures.](#)

Finish

Cancel

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.

The top section shows the 'Create new volume in cvogcve01' screen with the following details:

- Volume Name:** cvogcvescsilun01
- Size (GB):** 10
- Protocol:** NFS, CIFS, **iSCSI** (selected)
- Snapshot Policy:** default
- Default Policy:** (radio button selected)
- Initiator Group:** WinIG
- Operating System Type:** Windows

The bottom section shows the Windows Server Manager dashboard with the following information:

- Dashboard:** Local Server, All Servers, AD DS, DNS, File and Storage Services.
- WELCOME TO SERVER M...** (orange box)
- ROLES AND SERVER GRO...** (AD DS)
- File and Storage Services:** This PC > embdenm001_share (172.16.0.2) (E)
- File Explorer:** Shows contents of the share including 'Analyze01', 'analyse01', 'memtest01', and 'memtest02'.

3. After the volume is provisioned, select the volume menu (°), 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.

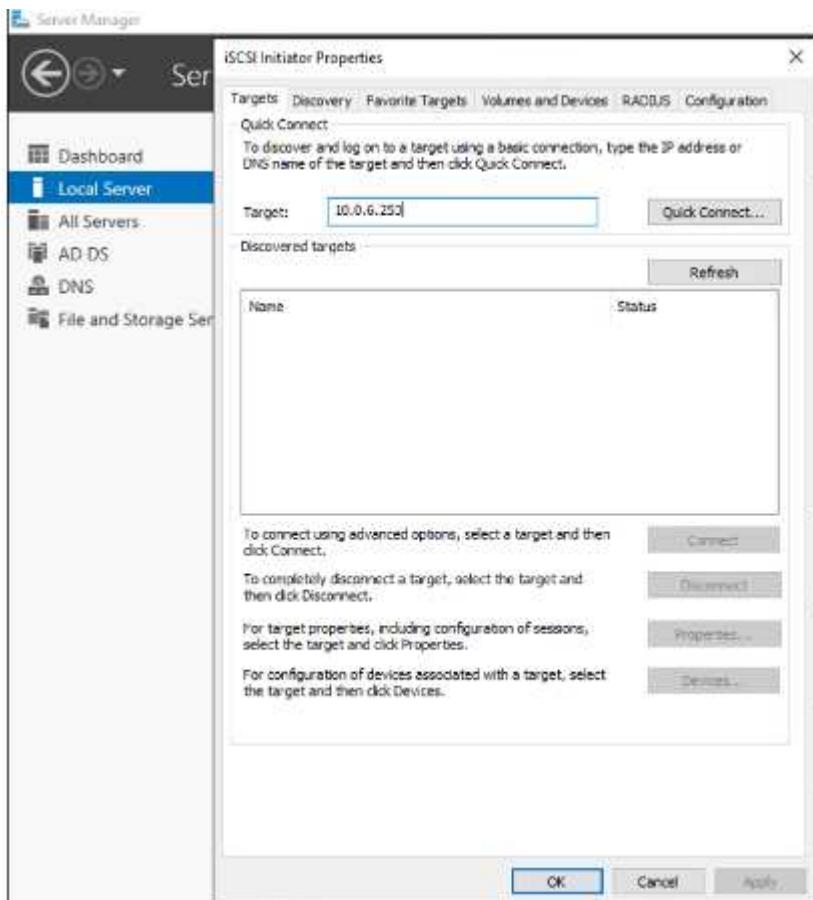
To accomplish the same for the host residing on Google Cloud VMware Engine:

- 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.

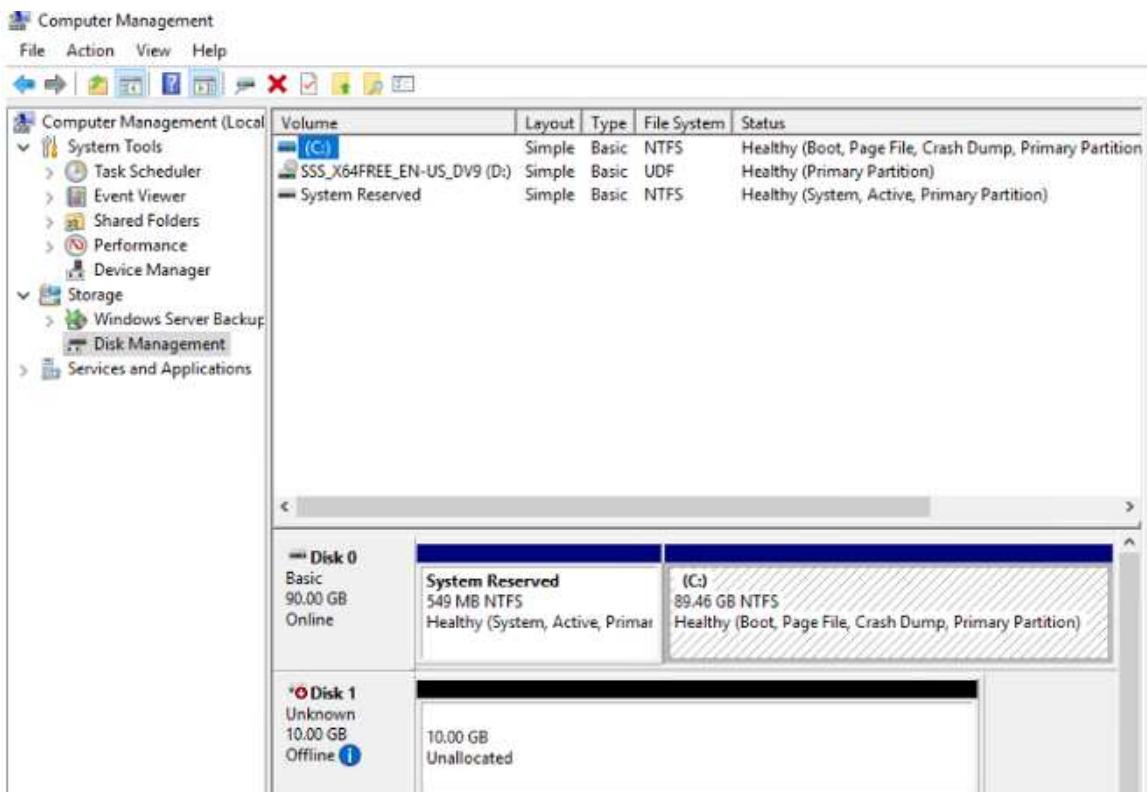


The Windows host must have an iSCSI connection to each node in the cluster.
The native DSM selects the best paths to use.



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 (°), and then click Mount Command.

Volumes Replications

[Mount Volume cvogcvenfsvol01](#)

Go to your Linux machine and enter this mount command

```
mount 10.0.6.251:/cvogcvenfsvol01 <dest_dir>
```

Copy

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
```

```
root@nimubu01:~# sudo mount -t nfs 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.

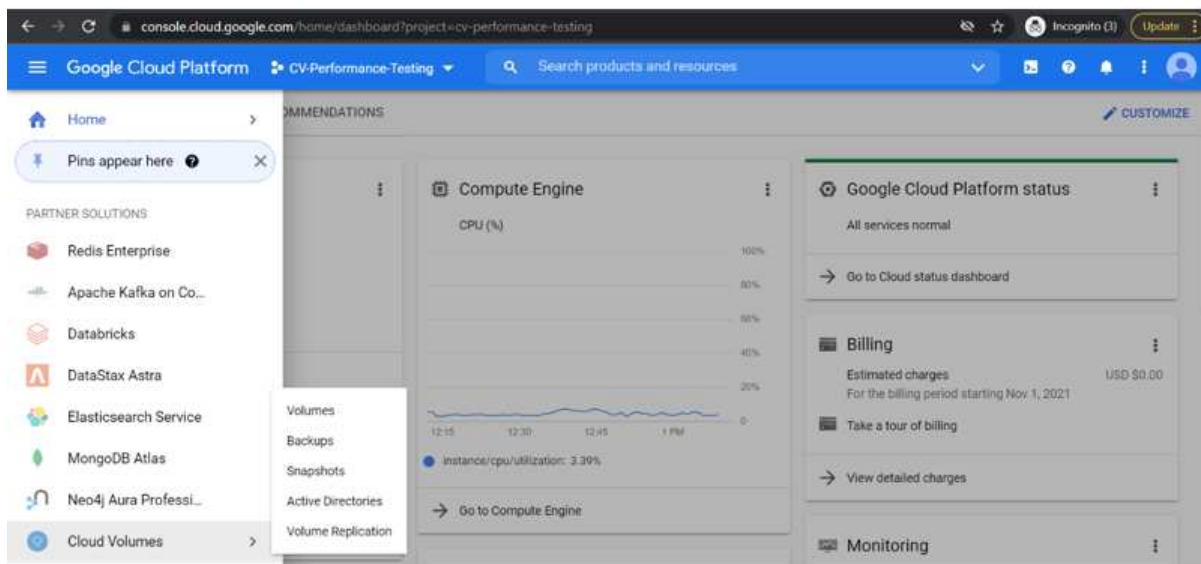
Cloud Volume Service and Google Cloud VMware Engine private cloud must be in the same region.

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

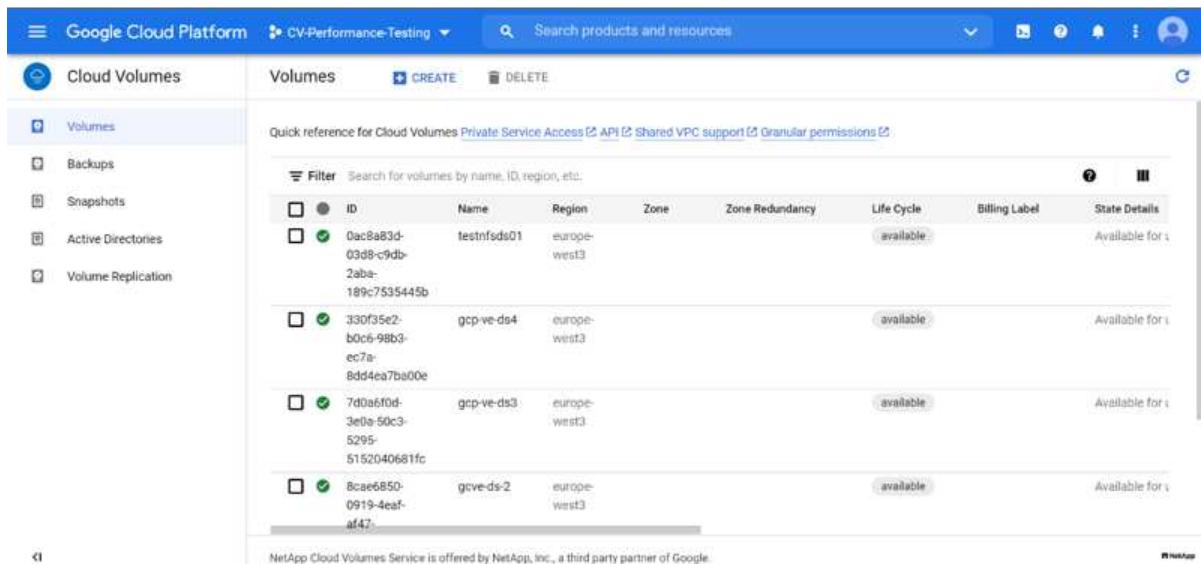
To create and mount NFS volumes, complete the following steps:

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



The screenshot shows the Google Cloud Platform dashboard for the project 'CV-Performance-Testing'. On the left, there's a sidebar with 'PARTNER SOLUTIONS' including Redis Enterprise, Apache Kafka on Co..., Databricks, DataStax Astra, Elasticsearch Service, MongoDB Atlas, Neo4j Aura Professional, and Cloud Volumes. The 'Cloud Volumes' item is highlighted with a mouse cursor. The main content area displays 'RECOMMENDATIONS' for Compute Engine, showing CPU utilization over time. To the right are sections for 'Google Cloud Platform status', 'Billing' (with estimated charges of USD \$0.00), and 'Monitoring'.

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



The screenshot shows the 'Volumes' page within the Cloud Volumes section of the Google Cloud Platform. At the top, there are 'CREATE' and 'DELETE' buttons. The main area lists existing volumes with columns for ID, Name, Region, Zone, Zone Redundancy, Life Cycle, Billing Label, and State Details. The volumes listed are: testnfsds01 (ID: 0ac8a83d-03d8-c9db-2ab4-189c7535445b, Name: testnfsds01, Region: europe-west3, Zone: available, Billing Label: Available for), gcp-ve-ds4 (ID: 330f35e2-b0c6-98b3-ec7a-8dd4ea7ba00e, Name: gcp-ve-ds4, Region: europe-west3, Zone: available, Billing Label: Available for), gcp-ve-ds3 (ID: 7d0a610d-3e0a-50c3-5295-5152040681fc, Name: gcp-ve-ds3, Region: europe-west3, Zone: available, Billing Label: Available for), and gcvve-ds-2 (ID: 8cae6850-0919-4eaf-af47-, Name: gcvve-ds-2, Region: europe-west3, Zone: available, Billing Label: Available for).

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

 Cloud Volumes <ul style="list-style-type: none">  Volumes  Backups  Snapshots  Active Directories  Volume Replication 	← Create File System <p>Volume Name</p> <p>Name * <input type="text" value="nimCVNFSvol01"/></p> <p>A human readable name used for display purposes.</p> <p>Billing Labels</p> <p>Label your volumes for billing reports, queries. Supported with CVS-Performance service type; can be set with CVS service type but not available for billing at this time.</p> <p>+ ADD LABEL</p>
---	---

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.

 Cloud Volumes <ul style="list-style-type: none">  Volumes  Backups  Snapshots  Active Directories  Volume Replication 	← Create File System <p>Service Type</p> <p>Cloud Volumes Service is offered as two service types: CVS and CVS-Performance. Select the service type that matches your workload needs. Region availability varies by service type. Learn more</p> <p><input checked="" type="radio"/> CVS Offers volumes created with zonal high availability.</p> <p><input checked="" type="radio"/> CVS-Performance Offers 3 performance levels and improved latency to address higher performance application requirements.</p> <p>Volume Replication</p> <p><input type="checkbox"/> Secondary Select to create volume as a destination target for volume replication. Applicable only to CVS-performance volumes.</p>
---	---

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)

 Cloud Volumes <ul style="list-style-type: none">  Volumes  Backups  Snapshots  Active Directories  Volume Replication 	← Create File System <p>Region</p> <p>Region availability varies by service type.</p> <p>Region * <input type="text" value="europe-west3"/></p> <p>Volume will be provisioned in the region you select.</p> <p>Volume Path * <input type="text" value="nimCVSNFSvol01"/></p> <p>Must be unique to the project.</p>
---	--

6. Select the level of performance for the volume.

The screenshot shows the 'Create File System' wizard. On the left, a sidebar lists 'Cloud Volumes' options: Volumes (selected), Backups, Snapshots, Active Directories, and Volume Replication. The main panel title is 'Create File System'. Under 'Service Level', it says 'Select the performance level required for your workload.' with three radio button options: 'Standard' (selected, up to 16 MiB/s per TiB), 'Premium' (up to 64 MiB/s per TiB), and 'Extreme' (up to 128 MiB/s per TiB). Below this is a dropdown menu labeled 'Snapshot' with the sub-option 'The snapshot to create the volume from.'

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

The screenshot shows the 'Create File System' wizard. The sidebar is identical to the previous screenshot. The main panel title is 'Create File System'. Under 'Volume Details', it shows 'Allocated Capacity *' set to '1024 GiB'. A note below says 'Allocated size must be between 1 TiB (1024 GiB) and 100 TiB (102400 GiB)'. Below this is a dropdown menu labeled 'Protocol Type *' with 'NFSv3' selected. At the bottom are two optional checkboxes: 'Make snapshot directory (.snapshot) visible' (which makes the .snapshot directory visible to clients) and 'Enable LDAP' (which enables user look up from AD LDAP server for your NFS volumes).

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.

Cloud Volumes

Volumes

Network Details

Shared VPC configuration
Provide the host project name when deploying in a shared VPC service project.

VPC Network Name *

Select the VPC Network from which the volume will be accessible. This cannot be changed later.

Use Custom Address Range
Reserved Address range

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.

Cloud Volumes

Volumes

Export Policy

Rules

Item 1

Allowed Clients 1 *

Access

Read & Write
 Read Only

Root Access

On
 Off

Protocol Type (Select at least 1 of the below options)

Must select for Protocol type NFSv3. Optional for Protocol Type Both. Do not select for NFSv4.1

Allows Matching Clients for NFSv3

10. Click Save to create the volume.

	4b8ed9d9- bc6d-f3d5- 5a0f- 7da26aed3ed0	nimnfsdemods02	europe-west3	Available for use	CFS- Performance	Primary	Extreme	NFSv3 : 10.53.0.4/nimnfsdemods02
<input type="checkbox"/>								

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:

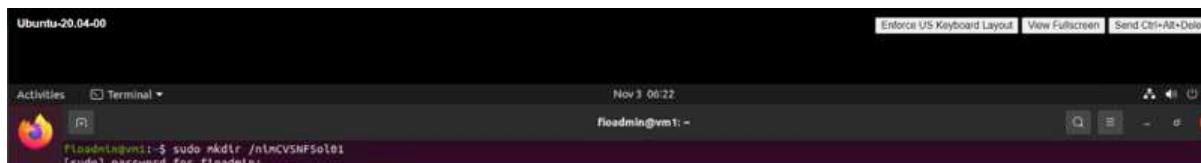
```
sudo yum install -y nfs-utils
```

- b. On an Ubuntu or Debian instance:

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

3. Create a new directory on the instance, such as "/nimCVSNFS01":

```
sudo mkdir /nimCVSNFS01
```



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

```
sudo mount -t nfs -o rw,hard,rsize=65536,wszie=65536,vers=3,tcp  
10.53.0.4:/nimCVSNFS01 /nimCVSNFS01
```

```
root@vm1:~# sudo mkdir /nimCVSNFS01  
root@vm1:~# sudo mount -t nfs -o rw,hard,rsize=65536,wszie=65536,vers=3,tcp 10.53.0.4:/nimCVSNFS01 /nimCVSNFS01
```

```
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.

The screenshot shows a table of Active Directory connections. There is one entry:

Username	Domain	DNS Servers	NetBIOS Prefix	OU Path	AD Server Name	KDC IP	Region	Status
administrator	nimgcveval.com	192.168.0.16	nimsmb	CN=Computers			europe-west3	In Use

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.

[←](#) Create File System

Volume Name

Name * nimCVSMBvol01

A human readable name used for display purposes.

Billing Label

Label your volumes for billing reports, queries.

Supported with CVS-Performance service type; can be set with CVS service type but not available for billing at this time.

[+ ADD LABEL](#)

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.

[Create File System](#)

Service Type

Cloud Volumes Service is offered as two service types: CVS and CVS-Performance.

Select the service type that matches your workload needs. [Region availability](#) varies by service type. [Learn more](#)

CVS

Offers volumes created with zonal high availability.

CVS-Performance

Offers 3 performance levels and improved latency to address higher performance application requirements.

Volume Replication

Secondary

Select to create volume as a destination target for volume replication. Applicable only to CVS-performance volumes.

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)

[Create File System](#)

Region

Region availability varies by service type.

Region * —

europe-west3



Volume will be provisioned in the region you select.

Volume Path * —

nimCVSMBvol01



Must be unique to the project.

5. Select the level of performance for the volume.

[←](#) Create File System

Service Level

Select the performance level required for your workload.

Standard

Up to 16 MiB/s per TiB

Premium

Up to 64 MiB/s per TiB

Extreme

Up to 128 MiB/s per TiB

Snapshot



The snapshot to create the volume from.

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

[←](#) Create File System

Volume Details

Allocated Capacity *

1024

GiB

Allocated size must be between 1 TiB (1024 GiB) and 100 TiB (102400 GiB)

Protocol Type *

SMB



Make snapshot directory (.snapshot) visible

Makes .snapshot directory visible to clients. For NFSv4.1 volumes (CVS-Performance only), the directory itself will not be listed but can be accessed to list contents, etc.

Enable SMB Encryption

Enable this option only if you require encryption of your SMB data traffic.

Enable CA share support for SQL Server, FSLogix

Enable this option only for SQL Server and FSLogix workloads that require continuous availability.

Hide SMB Share

Enable this option to make SMB shares non-browsable

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](#).

Network Details

Shared VPC configuration

Provide the host project name when deploying in a shared VPC service project.

VPC Network Name *

cloud-volumes-vpc

Select the VPC Network from which the volume will be accessible. This cannot be changed later.

Use Custom Address Range

Reserved Address range

netapp-addresses

SHOW SNAPSHOT POLICY

SAVE

CANCEL

8. Click Save to create the volume.

	6a4552ed-7378-7302-be2b-21a169374f28	nimCVSMBvol01	europe-west3	Available for use	CVS-Performance	Primary	Standard	SMB : \\nimsmb-3830.nimgcveval.com\\nimCVSMBvol01
<input type="checkbox"/>								

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



What network folder would you like to map?

Specify the drive letter for the connection and the folder that you want to connect to:

Drive: Z:

Folder: \\10.53.0.4\ nimcvsmbvol01

Example: \\server\share

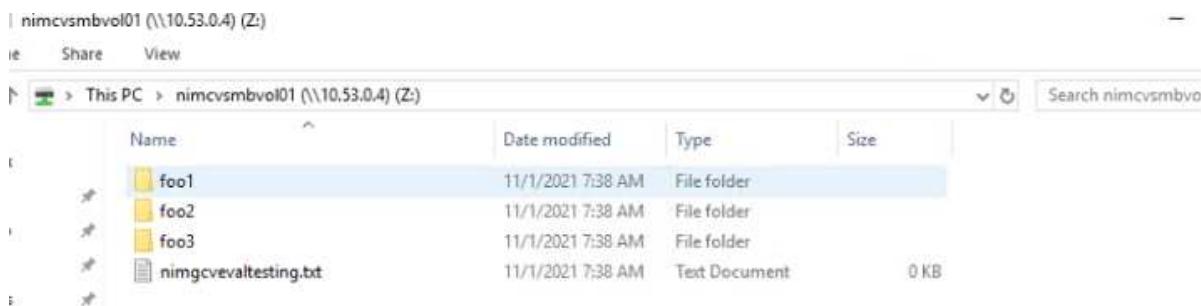
Reconnect at sign-in

Connect using different credentials

[Connect to a Web site that you can use to store your documents and pictures.](#)

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

5. Click Finish.



Region Availability for NFS datastores on AWS / VMC, Azure / AVS, and GCP / GCVE

Learn more about the Global Region support for NFS datastores on AWS, Azure and Google Cloud Platform (GCP).

AWS Region Availability

Americas

AWS Region	VMC Availability	FSx ONTAP Availability	NFS Datastore Availability
US East (Northern Virginia)	Yes	Yes	Yes
US East (Ohio)	Yes	Yes	Yes
US West (Northern California)	Yes	No	No
US West (Oregon)	Yes	Yes	Yes
GovCloud (US West)	Yes	Yes	Yes
Canada (Central)	Yes	Yes	Yes
South America (Sao Paulo)	Yes	Yes	Yes

Last updated on: June 2, 2022.

EMEA

AWS Region	VMC Availability	FSx ONTAP Availability	NFS Datastore Availability
Europe (Ireland)	Yes	Yes	Yes
Europe (London)	Yes	Yes	Yes
Europe (Frankfurt)	Yes	Yes	Yes
Europe (Paris)	Yes	Yes	Yes
Europe (Milan)	Yes	Yes	Yes
Europe (Stockholm)	Yes	Yes	Yes

Last updated on: June 2, 2022.

Asia Pacific

AWS Region	VMC Availability	FSx ONTAP Availability	NFS Datastore Availability
Asia Pacific (Sydney)	Yes	Yes	Yes
Asia Pacific (Tokyo)	Yes	Yes	Yes
Asia Pacific (Osaka)	Yes	No	No
Asia Pacific (Singapore)	Yes	Yes	Yes
Asia Pacific (Seoul)	Yes	Yes	Yes
Asia Pacific (Mumbai)	Yes	Yes	Yes
Asia Pacific (Jakarta)	No	No	No
Asia Pacific (Hong Kong)	No	Yes	No

Last updated on: June 2, 2022.

Azure Region Availability

Americas

Azure Region	AVS Availability	ANF Availability	NFS Datastore Availability
Central US	Yes	Yes	Yes
East US	Yes	Yes	Yes
East US 2	No	Yes	No
North Central US	Yes	Yes	Yes
South Central US	Yes	Yes	Yes
West Central US	No	No	No
West US	Yes	Yes	Yes
West US2	No	Yes	No
West US3	GA: H1-2023	Yes	Yes
Canada Central	Yes	Yes	Yes
Canada East	Yes	Yes	Yes
Brazil South	Yes	Yes	Yes
Brazil Southeast	No	GA: Q2-2022	No

Last updated on: June 7, 2022.

EMEA

Azure Region	AVS Availability	ANF Availability	NFS Datastore Availability
North Europe	Yes	Yes	Yes
West Europe	No	Yes	No
France Central	Yes	Yes	Yes
France South	No	GA: H2-2022	No
Germany North	No	Yes	No
Germany West Central	Yes	Yes	Yes
Norway East	No	Yes	No
Norway West	No	Yes	No
Sweden Central	GA: Q2-2022	GA: Q2-2022	No
Sweden South	No	No	No
Switzerland North	No	Yes	No
Switzerland West	No	Yes	No
UAE Central	No	Yes	No
UAE North	No	Yes	No
UK South	Yes	Yes	Yes

UK West

Yes

Yes

Yes

Last updated on: June 7, 2022.

Asia Pacific

Azure Region	AVS Availability	ANF Availability	NFS Datastore Availability
Australia East	Yes	Yes	Yes
Australia Southeast	Yes	Yes	Yes
Australia Central	No	Yes	No
Japan East	Yes	Yes	No
Japan West	Yes	Yes	Yes
East Asia	No	Yes	No
Southeast Asia	Yes	Yes	Yes
Central India	No	Yes	No
South India	No	Yes	No
Korea Central	No	Yes	No

Last updated on: June 20, 2022.

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.

NetApp Solutions for Amazon VMware Managed Cloud (VMC)

Learn more about the solutions that NetApp brings to AWS.

VMware defines the cloud workloads into one of three categories:

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

Browse the available solutions in the following sections.

Protect

COMING SOON!!

Migrate

COMING SOON!!

Extend

COMING SOON!!

NetApp Solutions for Azure VMware Solution (AVS)

Learn more about the solutions that NetApp brings to Azure.

VMware defines the cloud workloads into one of three categories:

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

Browse the available solutions in the following sections.

Protect

COMING SOON!!

Migrate

COMING SOON!!

Extend

COMING SOON!!

NetApp Solutions for Google Cloud Virtualization Engine (GCVE)

Learn more about the solutions that NetApp brings to GCP.

VMware defines the cloud workloads into one of three categories:

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

Browse the available solutions in the following sections.

Protect

COMING SOON!!

Migrate

COMING SOON!!

Extend

COMING SOON!!

NetApp Hybrid Multi-Cloud Solutions for AWS / VMC

Region Availability – NFS datastore for VMC

Learn more about the Global Region support for AWS, VMC and FSx ONTAP.



NFS datastore will be available in regions where both services (VMC and FSx ONTAP) are available.

Americas

AWS Region	VMC Availability	FSx ONTAP Availability	NFS Datastore Availability
US East (Northern Virginia)	Yes	Yes	Yes
US East (Ohio)	Yes	Yes	Yes
US West (Northern California)	Yes	No	No
US West (Oregon)	Yes	Yes	Yes
GovCloud (US West)	Yes	Yes	Yes
Canada (Central)	Yes	Yes	Yes
South America (Sao Paulo)	Yes	Yes	Yes

Last updated on: June 2, 2022.

EMEA

AWS Region	VMC Availability	FSx ONTAP Availability	NFS Datastore Availability
Europe (Ireland)	Yes	Yes	Yes
Europe (London)	Yes	Yes	Yes
Europe (Frankfurt)	Yes	Yes	Yes
Europe (Paris)	Yes	Yes	Yes
Europe (Milan)	Yes	Yes	Yes
Europe (Stockholm)	Yes	Yes	Yes

Last updated on: June 2, 2022.

Asia Pacific

AWS Region	VMC Availability	FSx ONTAP Availability	NFS Datastore Availability
Asia Pacific (Sydney)	Yes	Yes	Yes
Asia Pacific (Tokyo)	Yes	Yes	Yes
Asia Pacific (Osaka)	Yes	No	No
Asia Pacific (Singapore)	Yes	Yes	Yes
Asia Pacific (Seoul)	Yes	Yes	Yes
Asia Pacific (Mumbai)	Yes	Yes	Yes
Asia Pacific (Jakarta)	No	No	No
Asia Pacific (Hong Kong)	No	Yes	No

Last updated on: June 2, 2022.

NetApp Hybrid Multi-Cloud Solutions for Azure / AVS

NetApp Hybrid Multi-Cloud Solutions for GCP / GCVE

Security overview - NetApp Cloud Volumes Service (CVS) in Google Cloud

TR-4918: Security overview - NetApp Cloud Volumes Service in Google Cloud

Oliver Krause, Justin Parisi, NetApp

Document scope

Security, particularly in the cloud where infrastructure is outside of the control of storage administrators, is paramount to trusting your data to service offerings provided by cloud providers. This document is an overview of the security offerings that NetApp [Cloud Volumes Service provides in Google Cloud](#).

Intended audience

This document's intended audience includes, but is not limited to, the following roles:

- Cloud providers
- Storage administrators
- Storage architects
- Field resources
- Business decision makers

If you have questions about the content of this technical report, see the section "[Contact us.](#)"

Abbreviation	Definition
CVS-SW	Cloud Volumes Service, Service Type CVS
CVS-Performance	Cloud Volume Service, Service Type CVS-Performance
PSA	

[Next: How Cloud Volumes Service in Google Cloud secures your data.](#)

How Cloud Volumes Service in Google Cloud secures your data

[Previous: Overview.](#)

Cloud Volumes Service in Google Cloud provides a multitude of ways to natively secure your data.

Secure architecture and tenancy model

Cloud Volumes Service provides a secure architecture in Google Cloud by segmenting the service management (control plane) and the data access (data plane) across different endpoints so that neither can impact the other (see the section "[Cloud Volumes Service architecture](#)"). It uses Google's [private services access](#) (PSA) framework to provide the service. This framework distinguishes between the service producer, which is provided and operated by NetApp, and the service consumer, which is a Virtual Private Cloud (VPC) in

a customer project, hosting the clients that want to access Cloud Volumes Service file shares.

In this architecture, tenants (see the section “[Tenancy model](#)”) are defined as Google Cloud projects that are completely isolated from each other unless explicitly connected by the user. Tenants allow complete isolation of data volumes, external name services, and other essential pieces of the solution from other tenants using the Cloud Volumes Service volume platform. Because the Cloud Volumes Service platform is connected through VPC peering, that isolation applies to it also. You can enable sharing of Cloud Volumes Service volumes between multiple projects by using a shared-VPC (see the section “[Shared VPCs](#)”). You can apply access controls to SMB shares and NFS exports to limit who or what can view or modify datasets.

Strong identity management for the control plane

In the control plane where Cloud Volumes Service configuration takes place, identity management is managed by using [Identity Access Management \(IAM\)](#). IAM is a standard service that enables you to control authentication (logins) and authorization (permissions) to Google Cloud project instances. All configuration is performed with Cloud Volumes Service APIs over a secure HTTPS transport using TLS 1.2 encryption, and authentication is performed by using JWT tokens for added security. The Google console UI for Cloud Volumes Service translates user input into Cloud Volumes Service API calls.

Security hardening - Limiting attack surfaces

Part of effective security is limiting the number of attack surfaces available in a service. Attack surfaces can include a variety of things, including data at-rest, in-flight transfers, logins, and the datasets themselves.

A managed service removes some of the attack surfaces inherently in its design. Infrastructure management, as described in the section “[Service operation](#),” is handled by a dedicated team and is automated to reduce the number of times a human actually touches configurations, which helps reduce the number of intentional and unintentional errors. Networking is fenced off so that only necessary services can access one another. Encryption is baked into the data storage and only the data plane needs security attention from Cloud Volumes Service administrators. By hiding most of the management behind an API interface, security is achieved by limiting the attack surfaces.

Zero Trust model

Historically, IT security philosophy has been to trust but verify, and manifested as relying solely on external mechanisms (such as firewalls and intrusion detection systems) to mitigate threats. However, attacks and breaches evolved to bypass the verification in environments through phishing, social engineering, insider threats and other methods that provide the verification to enter networks and wreak havoc.

Zero Trust has become a new methodology in security, with the current mantra being “trust nothing while still verifying everything.” Therefore, nothing is allowed access by default. This mantra is enforced in a variety of ways, including standard firewalls and intrusion detection systems (IDS) and also with the following methods:

- Strong authentication methods (such as AES-encrypted Kerberos or JWT tokens)
- Single strong sources of identities (such as Windows Active Directory, Lightweight Directory Access Protocol (LDAP), and Google IAM)
- Network segmentation and secure multitenancy (only tenants are allowed access by default)
- Granular access controls with Least Privileged Access policies
- Small exclusive lists of dedicated, trusted administrators with digital audit and paper trails

Cloud Volumes Service running in Google Cloud adheres to the Zero Trust model by implementing the "trust nothing, verify everything" stance.

Encryption

Encrypt data at-rest (see the section “[Data encryption at rest](#)”) by using XTS-AES-256 ciphers with NetApp Volume Encryption (NVE) and in-flight with “[SMB encryption](#)” or NFS Kerberos 5p support. Rest easy knowing cross-region replication transfers are protected by TLS 1.2 encryption (see the section “[Cross-region replication](#)”). In addition, Google networking also provides encrypted communications (see the section “[Data encryption in transit](#)”) for an added layer of protection against attacks. For more information about transport encryption, see the section “[Google Cloud network](#)”.

Data protection and backups

Security isn’t just about the prevention of attacks. It is also about how we recover from attacks if or when they occur. This strategy includes data protection and backups. Cloud Volumes Service provides methods to replicate to other regions in case of outages (see the section “[Cross-region replication](#)”) or if a dataset is affected by a ransomware attack. It can also perform asynchronous backups of data to locations outside of the Cloud Volumes Service instance by using [Cloud Volumes Service backup](#). With regular backups, mitigation of security events can take less time and save money and angst for administrators.

Fast ransomware mitigation with industry leading Snapshot copies

In addition to data protection and backups, Cloud Volumes Service provides support for immutable Snapshot copies (see the section “[Immutable Snapshot copies](#)”) of volumes that allow recovery from ransomware attacks (see the section “[Service operation](#)”) within seconds of discovering the issue and with minimal disruption. Recovery time and effects depend on the Snapshot schedule, but you can create Snapshot copies that provide as little as one-hour deltas in ransomware attacks. Snapshot copies have a negligible effect on performance and capacity usage and are a low-risk, high-reward approach to protecting your datasets.

[Next: Security considerations and attack surfaces.](#)

Security considerations and attack surfaces

[Previous: How Cloud Volumes Service in Google Cloud secures your data.](#)

The first step in understanding how to secure your data is identifying the risks and potential attack surfaces. These include (but are not limited to) the following:

- Administration and logins
- Data at rest
- Data in flight
- Network and firewalls
- Ransomware, malware, and viruses

Understanding attack surfaces can help you to better secure your environments. Cloud Volumes Service in Google Cloud already considers many of these topics and implements security functionality by default, without any administrative interaction.

Ensuring secure logins

When securing your critical infrastructure components, it is imperative to make sure that only approved users can log in and manage your environments. If bad actors breach your administrative credentials, then they have the keys to the castle and can do anything they want—change configurations, delete volumes and backups, create backdoors, or disable Snapshot schedules.

Cloud Volumes Service for Google Cloud provides protection against unauthorized administrative logins

through the obfuscation of storage as a service (StaaS). Cloud Volumes Service is completely maintained by the cloud provider with no availability to login externally. All setup and configuration operations are fully automated, so a human administrator never has to interact with the systems except in very rare circumstances.

If login is required, Cloud Volumes Service in Google Cloud secures logins by maintaining a very short list of trusted administrators that have access to log in to the systems. This gatekeeping helps reduce the number of potential bad actors with access. Additionally, the Google Cloud networking hides the systems behind layers of network security and exposes only what is needed to the outside world. For information about the Google Cloud, Cloud Volumes Service architecture, see the section “[Cloud Volumes Service architecture](#).”

Cluster administration and upgrades

Two areas with potential security risks include cluster administration (what happens if a bad actor has admin access) and upgrades (what happens if a software image is compromised).

Storage administration protection

Storage provided as a service removes the added risk of exposure to administrators by removing that access to end users outside of the cloud data center. Instead, the only configuration done is for the data access plane by customers. Each tenant manages their own volumes, and no tenant can reach other Cloud Volumes Service instances. The service is managed by automation, with a very small list of trusted administrators given access to the systems through the processes covered in the section “[Service operation](#).”

The CVS-Performance service type offers cross-region replication as an option to provide data protection to a different region in the event of a region failure. In those cases, Cloud Volumes Service can be failed over to the unaffected region to maintain data access.

Service upgrades

Updates help protect vulnerable systems. Each update provides security enhancements and bug fixes that minimize attack surfaces. Software updates are downloaded from centralized repositories and are validated before the updates are allowed to verify that official images are used and that the upgrades are not compromised by bad actors.

With Cloud Volumes Service, updates are handled by the cloud provider teams, which removes risk exposure for administrator teams by providing experts well versed in configuration and upgrades that have automated and fully tested the process. Upgrades are nondisruptive, and Cloud Volumes Service maintains the latest updates for best overall results.

For information about the administrator team that performs these service upgrades, see the section “[Service operation](#).”

Securing data at-rest

Data-at-rest encryption is important to protect sensitive data in the event of a disk that is stolen, returned, or repurposed. Data in Cloud Volumes Service is protected at rest by using software-based encryption.

- Google-generated keys are used for CVS-SW.
- For CVS-Performance, the per-volume keys are stored in a key manager built into Cloud Volumes Service, which uses NetApp ONTAP CryptoMod to generate AES-256 encryption keys. CryptoMod is listed on the CMVP FIPS 140-2 validated modules list. See [FIPS 140-2 Cert #4144](#).

Starting in November 2021, preview Customer-managed Encryption (CMEK) functionality was made available for CVS-Performance. This functionality allows you to encrypt the per-volume keys with per-project, per-region master-keys that are hosted in Google Key Management Service (KMS). KMS enables you to attach external

key managers.

For details about how to configure KMS for CVS-Performance, see the [Cloud Volumes Service documentation](#).

For more information about architecture, see the section [“Cloud Volumes Service architecture.”](#)

Securing data in-flight

In addition to securing data at rest, you must also be able to secure data when it is in flight between the Cloud Volumes Service instance and a client or replication target. Cloud Volumes Service provides encryption for in-flight data over NAS protocols by using encryption methods such as SMB encryption using Kerberos, the signing/sealing of packets, and NFS Kerberos 5p for end-to-end encryption of data transfers.

Replication of Cloud Volumes Service volumes uses TLS 1.2, which takes advantage of AES-GCM encryption methods.

Most insecure in-flight protocols such as telnet, NDMP, and so on are disabled by default. DNS, however, is not encrypted by Cloud Volumes Service (no DNS Sec support) and should be encrypted by using external network encryption when possible. See the section [“Data encryption in transit”](#) for more information about securing data in-flight.

For information about NAS protocol encryption, see the section [“NAS protocols.”](#)

Users and groups for NAS permissions

Part of securing your data in the cloud involves proper user and group authentication, where the users accessing the data are verified as real users in the environment and the groups contain valid users. These users and groups provide initial share and export access, as well as permission validation for files and folders in the storage system.

Cloud Volumes Service uses standard Active Directory-based Windows user and group authentication for SMB shares and Windows-style permissions. The service can also leverage UNIX identity providers such as LDAP for UNIX users and groups for NFS exports, NFSv4 ID validation, Kerberos authentication, and NFSv4 ACLs.



Currently only Active Directory LDAP is supported with Cloud Volumes Service for LDAP functionality.

Detection, prevention and mitigation of ransomware, malware, and viruses

Ransomware, malware, and viruses are a persistent threat to administrators, and detection, prevention, and mitigation of those threats are always top of mind for enterprise organizations. A single ransomware event on a critical dataset can potentially cost millions of dollars, so it is beneficial to do what you can to minimize the risk.

Although Cloud Volumes Service currently doesn't include native detection or prevention measures, such as antivirus protection or [automatic ransomware detection](#), there are ways to quickly recover from a ransomware event by enabling regular Snapshot schedules. Snapshot copies are immutable and read only pointers to changed blocks in the file system, are near instantaneous, have minimal impact on performance, and only use up space when data is changed or deleted. You can set schedules for Snapshot copies to match your desired acceptable recovery point objective (RPO)/recovery time objective (RTO) and can keep up to 1,024 Snapshot copies per volume.

Snapshot support is included at no additional cost (beyond data storage charges for changed blocks/data retained by Snapshot copies) with Cloud Volumes Service and, in the event of a ransomware attack, can be used to roll back to a Snapshot copy before the attack occurred. Snapshot restores take just seconds to complete, and you then can get back to serving data as normal. For more information, see [The NetApp](#)

Solution for Ransomware.

Preventing ransomware from affecting your business requires a multilayered approach that includes one or more of the following:

- Endpoint protection
- Protection against external threats through network firewalls
- Detection of data anomalies
- Multiple backups (onsite and offsite) of critical datasets
- Regular restore tests of backups
- Immutable read-only NetApp Snapshot copies
- Multifactor authentication for critical infrastructure
- Security audits of system logins

This list is far from exhaustive but is a good blueprint to follow when dealing with the potential of ransomware attacks. Cloud Volumes Service in Google Cloud provides several ways to protect against ransomware events and reduce their effects.

Immutable Snapshot copies

Cloud Volumes Service natively provides immutable read-only Snapshot copies that are taken on a customizable schedule for quick point-in-time recovery in the event of data deletion or if an entire volume has been victimized by a ransomware attack. Snapshot restores to previous good Snapshot copies are fast and minimize data loss based on the retention period of your Snapshot schedules and RTO/RPO. The performance effect with Snapshot technology is negligible.

Because Snapshot copies in Cloud Volumes Service are read-only, they cannot be infected by ransomware unless the ransomware has proliferated into the dataset unnoticed and Snapshot copies have been taken of the data infected by ransomware. This is why you must also consider ransomware detection based on data anomalies. Cloud Volumes Service does not currently provide detection natively, but you can use external monitoring software.

Backups and restores

Cloud Volumes Service provides standard NAS client backup capabilities (such as backups over NFS or SMB).

- CVS-Performance offers cross-region volume replication to other CVS-Performance volumes. For more information, see [volume replication](#) in the Cloud Volumes Service documentation.
- CVS-SW offers service-native volume backup/restore capabilities. For more information, see [cloud backup](#) in the Cloud Volumes Service documentation.

Volume replication provides an exact copy of the source volume for fast failover in the case of a disaster, including ransomware events.

Cross-region replication

CVS-Performance enables you to securely replicate volumes across Google Cloud regions for data protection and archive use cases by using TLS1.2 AES 256 GCM encryption on a NetApp-controlled backend service network using specific interfaces used for replication running on Google's network. A primary (source) volume contains the active production data and replicates to a secondary (destination) volume to provide an exact replica of the primary dataset.

Initial replication transfers all blocks, but updates only transmit the changed blocks in a primary volume. For instance, if a 1TB database that resides on a primary volume is replicated to the secondary volume, then 1TB of space is transferred on the initial replication. If that database has a few hundred rows (hypothetically, a few MB) that change between the initialization and the next update, only the blocks with the changed rows are replicated to the secondary (a few MB). This helps to make sure that the transfer times remain low and keeps replication charges down.

All permissions on files and folders are replicated to the secondary volume, but share access permissions (such as export policies and rules or SMB shares and share ACLs) must be handled separately. In the case of a site failover, the destination site should leverage the same name services and Active Directory domain connections to provide consistent handling of user and group identities and permissions. You can use a secondary volume as a failover target in the event of a disaster by breaking the replication relationship, which converts the secondary volume to read-write.

Volume replicas are read-only, which provides an immutable copy of data offsite for quick recovery of data in instances where a virus has infected data or ransomware has encrypted the primary dataset. Read-only data won't be encrypted, but, if the primary volume is affected and replication occurs, the infected blocks also replicate. You can use older, non-affected Snapshot copies to recover, but SLAs might fall out of range of the promised RTO/RPO depending on how quickly an attack is detected.

In addition, you can prevent malicious administrative actions, such as volume deletions, Snapshot deletions, or Snapshot schedule changes, with cross-region replication (CRR) management in Google Cloud. This is done by creating custom roles that separate volume administrators, who can delete source volumes but not break mirrors and therefore cannot delete destination volumes, from CRR administrators, who cannot perform any volume operations. See [Security Considerations](#) in the Cloud Volumes Service documentation for permissions allowed by each administrator group.

Cloud Volumes Service backup

Although Cloud Volumes Service provides high data durability, external events can cause data loss. In the event of a security event such as a virus or ransomware, backups and restores become critical for resumption of data access in a timely manner. An administrator might accidentally delete a Cloud Volumes Service volume. Or users simply want to retain backup versions of their data for many months and keeping the extra Snapshot copy space inside the volume becomes a cost challenge. Although Snapshot copies should be the preferred way to keep backup versions for the last few weeks to restore lost data from them, they are sitting inside the volume and are lost if the volume goes away.

For all these reasons, NetApp Cloud Volumes Service offers backup services through [Cloud Volumes Service backup](#).

Cloud Volumes Service backup generates a copy of the volume on Google Cloud Storage (GCS). It only backs up the actual data stored within the volume, not the free space. It works as incremental forever, meaning it transfers the volume content once and from there on continues backing up changed data only. Compared to classical backup concepts with multiple full backups, it saves large amounts of backup storage, reducing cost. Because the monthly price of backup space is lower compared to a volume, it is an ideal place to keep backup versions longer.

Users can use a Cloud Volumes Service backup to restore any backup version to the same or a different volume within the same region. If the source volume is deleted, the backup data is retained and needs to be managed (for example, deleted) independently.

Cloud Volumes Service backup is built into Cloud Volumes Service as option. Users can decide which volumes to protect by activating Cloud Volumes Service backup on a per-volume basis. See the [Cloud Volumes Service backup documentation](#) for information about backups, the [number of maximum backup versions supported](#), scheduling, and [pricing](#).

All backup data of a project is stored within a GCS bucket, which is managed by the service and not visible to the user. Each project uses a different bucket. Currently, the buckets are in same region as the Cloud Volumes Service volumes, but more options are being discussed. Consult the documentation for the latest status.

Data transport from a Cloud Volumes Service bucket to GCS uses service-internal Google networks with HTTPS and TLS1.2. Data is encrypted at-rest with Google-managed keys.

To manage Cloud Volumes Service backup (creating, deleting, and restoring backups), a user must have the [roles/netappcloudvolumes.admin](#) role.

[Next: Architecture overview.](#)

Architecture

Overview

[Previous: Security considerations and attack surfaces.](#)

Part of trusting a cloud solution is understanding the architecture and how it is secured. This section calls out different aspects of the Cloud Volumes Service architecture in Google to help alleviate potential concerns about how data is secured, as well as call out areas where additional configuration steps might be required to obtain the most secure deployment.

The general architecture of Cloud Volumes Service can be broken down into two main components: the control plane and the data plane.

Control plane

The control plane in Cloud Volumes Service is the backend infrastructure managed by Cloud Volumes Service administrators and NetApp native automation software. This plane is completely transparent to end users and includes networking, storage hardware, software updates, and so on to help deliver value to a cloud-resident solution such as Cloud Volumes Service.

Data plane

The data plane in Cloud Volumes Service includes the actual data volumes and the overall Cloud Volumes Service configuration (such as access control, Kerberos authentication, and so on). The data plane is entirely under the control of the end users and the consumers of the Cloud Volumes Service platform.

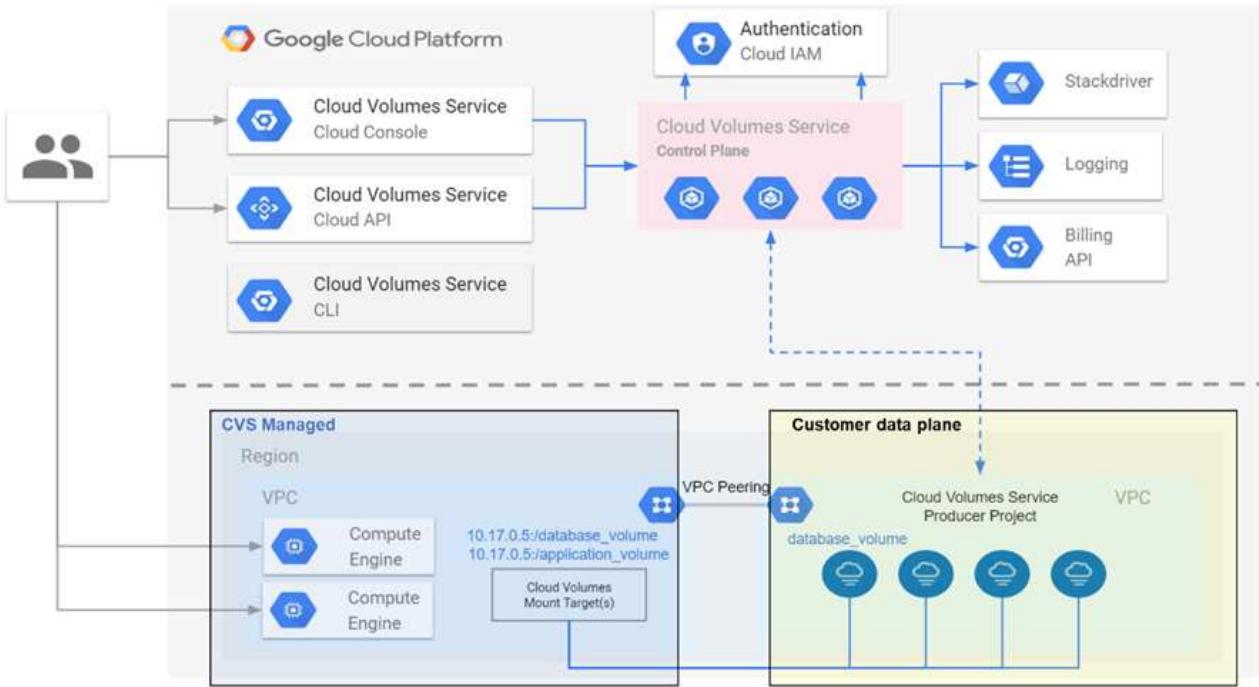
There are distinct differences in how each plane is secured and managed. The following sections cover these differences, starting with a Cloud Volumes Service architecture overview.

[Next: Cloud Volumes Service architecture.](#)

Cloud Volumes Service architecture

In a manner similar to other Google Cloud native services such as CloudSQL, Google Cloud VMware Engine (GCVE), and FileStore, Cloud Volumes Service uses [Google PSA](#) to deliver the service. In PSA, services are built inside a service producer project, which uses [VPC network peering](#) to connect to the service consumer. The service producer is provided and operated by NetApp, and the service consumer is a VPC in a customer project, hosting the clients that want to access Cloud Volumes Service file shares.

The following figure, referenced from the [architecture section](#) of the Cloud Volumes Service documentation, shows a high-level view.



The part above the dotted line shows the control plane of the service, which controls the volume lifecycle. The part below the dotted line shows the data plane. The left blue box depicts the user VPC (service consumer), the right blue box is the service producer provided by NetApp. Both are connected through VPC peering.

Tenancy model

In Cloud Volumes Service, individual projects are considered unique tenants. This means that manipulation of volumes, Snapshot copies, and so on are performed on a per-project basis. In other words, all volumes are owned by the project that they were created in and only that project can manage and access the data inside of them by default. This is considered the control plane view of the service.

Shared VPCs

On the data plane view, Cloud Volumes Service can connect to a shared VPC. You can create volumes in the hosting project or in one of the service projects connected to the shared VPC. All projects (host or service) connected to that shared VPC are able to reach the volumes at the network layer (TCP/IP). Because all clients with network connectivity on the shared- VPC can potentially access the data through NAS protocols, access control on the individual volume (such as user/group access control lists (ACLs) and hostnames/IP addresses for NFS exports) must be used to control who can access the data.

You can connect Cloud Volumes Service to up to five VPCs per customer project. On the control plane, the project enables you to manage all created volumes, no matter which VPC they are connected to. On the data plane, VPCs are isolated from one another, and each volume can only be connected to one VPC.

Access to the individual volumes is controlled by protocol specific (NFS/SMB) access control mechanisms.

In other words, on the network layer, all projects connected to the shared VPC are able to see the volume, while, on the management side, the control plane only allows the owner project to see the volume.

VPC Service Controls

VPC Service Controls establish an access control perimeter around Google Cloud services that are attached to

the internet and are accessible worldwide. These services provide access control through user identities but cannot restrict which network location requests originate from. VPC Service Controls close that gap by introducing the capabilities to restrict access to defined networks.

The Cloud Volumes Service data plane is not connected to the external internet but to private VPCs with well-defined network boundaries (perimeters). Within that network, each volume uses protocol-specific access control. Any external network connectivity is explicitly created by Google Cloud project administrators. The control plane, however, does not provide the same protections as the data plane and can be accessed by anyone from anywhere with valid credentials ([JWT tokens](#)).

In short, the Cloud Volumes Service data plane provides the capability of network access control, without the requirement to support VPC Service Controls and does not explicitly use VPC Service Controls.

Packet sniffing/trace considerations

Packet captures can be useful for troubleshooting network issues or other problems (such as NAS permissions, LDAP connectivity, and so on), but can also be used maliciously to gain information about network IP addresses, MAC addresses, user and group names, and what level of security is being used on endpoints. Because of the way Google Cloud networking, VPCs, and firewall rules are configured, unwanted access to network packets should be difficult to obtain without user login credentials or [JWT tokens](#) into the cloud instances. Packet captures are only possible on endpoints (such as virtual machines (VMs)) and only possible on endpoints internal to the VPC unless a shared VPC and/or external network tunnel/IP forwarding is in use to explicitly allow external traffic to endpoints. There is no way to sniff traffic outside of the clients.

When shared VPCs are used, in-flight encryption with NFS Kerberos and/or [SMB encryption](#) can mask much of the information gleaned from traces. However, some traffic is still sent in plaintext, such as [DNS](#) and [LDAP queries](#). The following figure shows a packet capture from a plaintext LDAP query originating from Cloud Volumes Service and the potential identifying information that is exposed. LDAP queries in Cloud Volumes Service currently do not support encryption or LDAP over SSL. Both CVS-SW and CVS-Performance support LDAP signing.

IP addresses of the LDAP server and CVS instance			LDAP base DN and search type, search result			
No.	Time	Source	Destination	Protocol	Length	Info
2320...	366.244071	10.194.0.6	10.10.0.11	LDAP	225	searchRequest(2) "DC=cvsdemo,DC=local" wholeSubtree
2320...	366.244381	10.10.0.11	10.194.0.6	LDAP	330	searchResRef(2) searchResRef(2) searchResRef(2) searchResDone(2) success [0 results]
<pre>▼ searchRequest baseObject: DC=cvsdemo,DC=local scope: wholeSubtree (2) derefAliases: neverDerefAliases (0) sizeLimit: 0 timeLimit: 3 typesOnly: False ▼ Filter: (&(objectClass=User)(uidNumber=1025)) ▼ filter: and (0) ▼ and: (&(objectClass=User)(uidNumber=1025)) ▼ and: 2 items ▼ Filter: (objectClass=User) ▼ and: item: equalityMatch (3) ▼ equalityMatch attributeDesc: objectClass assertionValue: User ▼ Filter: (uidNumber=1025) ▼ and: item: equalityMatch (3) ▼ equalityMatch attributeDesc: uidNumber assertionValue: 1025 ▼ attributes: 7 items AttributeDescription: uid AttributeDescription: uidNumber AttributeDescription: gidNumber AttributeDescription: unixUserPassword AttributeDescription: name AttributeDescription: unixHomeDirectory AttributeDescription: loginShell</pre>						

- Filters used in the query
- Usernames
 - Numeric IDs
 - Group names
 - Group IDs

Attributes queried



unixUserPassword is queried by LDAP and is not sent in plaintext but instead in a salted hash. By default, Windows LDAP does not populate the unixUserPassword fields. This field is only required if you need to leverage Windows LDAP for interactive logins through LDAP to clients. Cloud Volumes Service does not support interactive LDAP logins to the instances.

The following figure shows a packet capture from an NFS Kerberos conversation next to a capture of NFS over AUTH_SYS. Note how the information available in a trace differs between the two and how enabling in-flight encryption offers greater overall security for NAS traffic.

IP addresses of the NFS client and CVS instance						Generalized NFS call/reply	
No.	Time	Source	Destination	Protocol	Length	Info	
380	9.218014	10.193.67.225	10.193.67.219	NFS	346	V4 Call (Reply In 381)	
381	9.218480	10.193.67.219	10.193.67.225	NFS	426	V4 Reply (Call In 380)	
382	9.218641	10.193.67.225	10.193.67.219	NFS	370	V4 Call (Reply In 397)	
397	9.369035	10.193.67.219	10.193.67.225	NFS	458	V4 Reply (Call In 382)	

> Frame 381: 426 bytes on wire (3408 bits), 426 bytes captured (3408 bits)
> Ethernet II, Src: IntelCor_7f:da:bc (90:e2:ba:7f:da:bc), Dst: VMware_a0:2c:2d (00:50:56:a0:2c:2d)
> Internet Protocol Version 4, Src: 10.193.67.219, Dst: 10.193.67.225
> Transmission Control Protocol, Src Port: 2049, Dst Port: 738, Seq: 6305, Ack: 6569, Len: 360
> Remote Procedure Call, Type:Reply XID:0xef5e998d

▼ GSS-Wrap
Length: 300
GSS Data: 050407ff000000000000000025913451ee1d43d298cf3031...
 > krb5_blob: 050407ff000000000000000025913451ee1d43d298cf3031...
▼ Network File System
[Program Version: 4]
[V4 Procedure: COMPOUND (1)]

GSS wrapped NFS calls/replies with no other identifying information

IP addresses of the NFS client and CVS instance						Detailed NFS call types and file handle information	
No.	Time	Source	Destination	Protocol	Length	Info	
33	0.958480	10.193.67.201	10.193.67.204	NFS	458	V4 Reply (Call In 32) OPEN StateID: 0x0481	
34	0.958784	10.193.67.204	10.193.67.201	NFS	306	V4 Call (Reply In 35) SETATTR FH: 0x6c07918a	
35	0.959284	10.193.67.201	10.193.67.204	NFS	350	V4 Reply (Call In 34) SETATTR	

> Opcode: PUTFH (22)
> Opcode: SETATTR (34)
▼ Opcode: GETATTR (9)
 Status: NFS4_OK (0)
 ▼ Attr mask[0]: 0x0010011a (Type, Change, Size, FSID, fileId)
 > reqd_attr: Type (1)
 > reqd_attr: Change (3)
 > reqd_attr: Size (4)
 > reqd_attr: FSID (8)
 ▼ reco_attr: fileId (20) File ID
 fileId: 9232254136597092620
 ▼ Attr mask[1]: 0x00b00a03a (Mode, NumLinks, Owner, Owner_Group, Space_Used, Time_Access, Time_Metadata, Time_Modify, Mounted_on_FileId)
 ▼ reco_attr: Mode (33) Permission information
 > mode: 0644, Name: Unknown, Read permission for owner, Write permission for owner, Read permission for group, Read permission for others
 > reco_attr: NumLinks (35)
 ▼ reco_attr: Owner (36) Owner and group ID strings
 > fattr4_owner: root@NTAP.LOCAL
 ▼ reco_attr: Owner_Group (37)
 > fattr4_owner_group: root@NTAP.LOCAL
 > reco_attr: Space_Used (45)
 > reco_attr: Time_Access (47)
 > reco_attr: Time_Metadata (52)
 > reco_attr: Time_Modify (53)
 > reco_attr: Mounted_on_FileId (55)

VM network interfaces

One trick attackers might attempt is to add a new network interface card (NIC) to a VM in **promiscuous mode** (port mirroring) or enable promiscuous mode on an existing NIC in order to sniff all traffic. In Google Cloud, adding a new NIC requires a VM to be shut down entirely, which creates alerts, so attackers cannot do this

unnoticed.

In addition, NICs cannot be set to promiscuous mode at all and will trigger alerts in Google Cloud.

[Next: Control plane architecture.](#)

Control plane architecture

[Previous: Cloud Volumes Service architecture.](#)

All management actions to Cloud Volumes Service are done through API. Cloud Volumes Service management integrated into the GCP Cloud Console also uses the Cloud Volumes Service API.

Identity and Access Management

Identity and Access Management ([IAM](#)) is a standard service that enables you to control authentication (logins) and authorization (permissions) to Google Cloud project instances. Google IAM provides a full audit trail of permissions authorization and removal. Currently Cloud Volumes Service does not provide control plane auditing.

Authorization/permission overview

IAM offers built-in, granular permissions for Cloud Volumes Service. You can find a [complete list of granular permissions here](#).

IAM also offers two predefined roles called `netappcloudvolumes.admin` and `netappcloudvolumes.viewer`. These roles can be assigned to specific users or service accounts.

Assign appropriate roles and permission to allow IAM users to manage Cloud Volumes Service.

Examples for using granular permissions include the following:

- Build a custom role with only `get/list/create/update` permissions so that users cannot delete volumes.
- Use a custom role with only `snapshot.*` permissions to create a service account that is used to build application-consistent Snapshot integration.
- Build a custom role to delegate `volumereplication.*` to specific users.

Service accounts

To make Cloud Volumes Service API calls through scripts or [Terraform](#), you must create a service account with the `roles/netappcloudvolumes.admin` role. You can use this service account to generate the JWT tokens required to authenticate Cloud Volumes Service API requests in two different ways:

- Generate a JSON key and use Google APIs to derive a JWT token from it. This is the simplest approach, but it involves manual secrets (the JSON key) management.
- Use [Service account impersonation](#) with `roles/iam.serviceAccountTokenCreator`. The code (script, Terraform, and so on.) runs with [Application Default Credentials](#) and impersonates the service account to gain its permissions. This approach reflects Google security best practices.

See [Creating your service account and private key](#) in the Google cloud documentation for more information.

Cloud Volumes Service API

Cloud Volumes Service API uses a REST-based API by using HTTPS (TLSv1.2) as the underlying network transport. You can find the latest API definition [here](#) and information about how to use the API at [Cloud Volumes APIs in the Google cloud documentation](#).

The API endpoint is operated and secured by NetApp using standard HTTPS (TLSv1.2) functionality.

JWT tokens

Authentication to the API is performed with JWT bearer tokens ([RFC-7519](#)). Valid JWT tokens must be obtained by using Google Cloud IAM authentication. This must be done by fetching a token from IAM by providing a service account JSON key.

Audit logging

Currently, no user-accessible control plane audit logs are available.

[Next: Data plane architecture.](#)

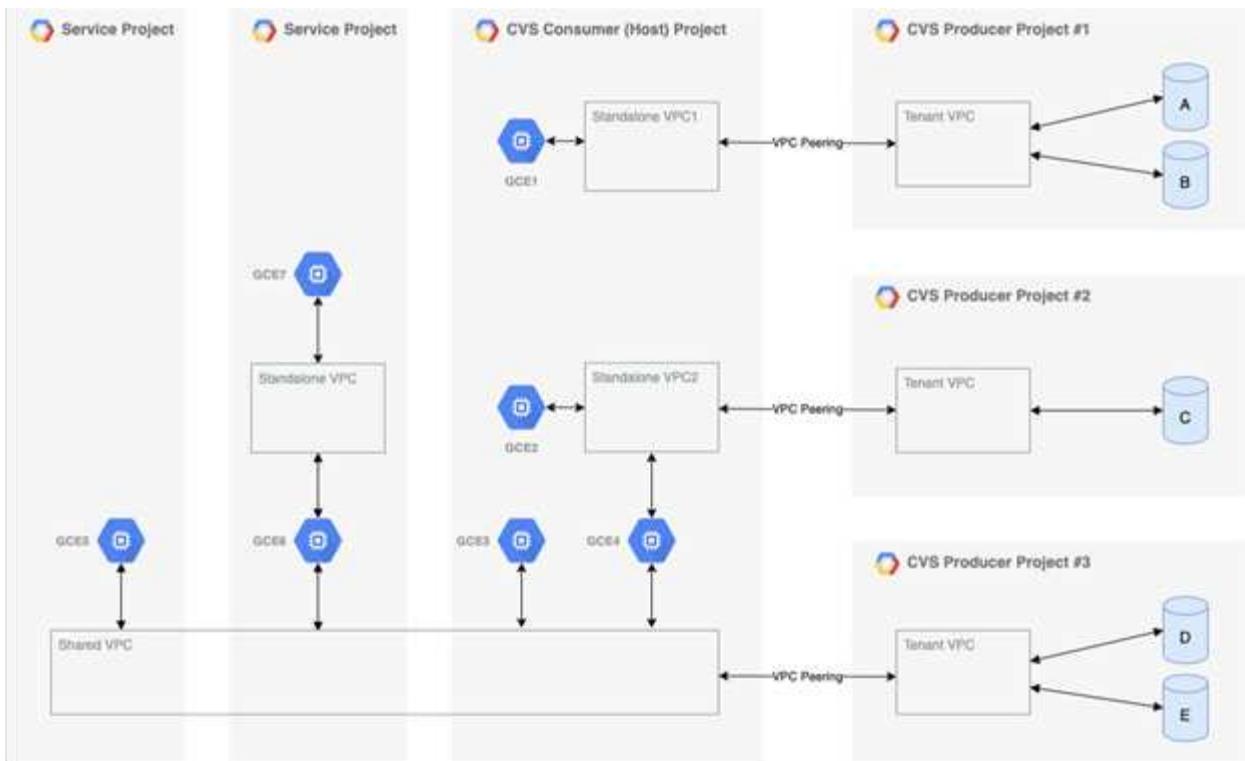
Data plane architecture

[Previous: Control plane architecture.](#)

Cloud Volumes Service for Google Cloud leverages the Google Cloud [private services access](#) framework. In this framework, users can connect to the Cloud Volumes Service. This framework uses Service Networking and VPC peering constructs like other Google Cloud services, ensuring complete isolation between tenants.

For an architecture overview of Cloud Volumes Service for Google Cloud, see [Architecture for Cloud Volumes Service](#).

User VPCs (standalone or shared) are peered to VPCs within Cloud Volumes Service managed tenant projects, which hosts the volumes.



The preceding figure shows a project (the CVS consumer project in the middle) with three VPC networks connected to Cloud Volumes Service and multiple Compute Engine VMs (GCE1-7) sharing volumes:

- VPC1 allows GCE1 to access volumes A and B.
- VPC2 allows GCE2 and GCE4 to access volume C.
- The third VPC network is a shared VPC, shared with two service projects. It allows GCE3, GCE4, GCE5, and GCE6 to access volumes D and E. Shared VPC networks are only supported for volumes of the CVS-Performance service type.



GCE7 cannot access any volume.

Data can be encrypted both in-transit (using Kerberos and/or SMB encryption) and at-rest in Cloud Volumes Service.

[Next: Data encryption in transit.](#)

Data encryption in transit

[Previous: Data plane architecture.](#)

Data in transit can be encrypted at the NAS protocol layer, and the Google Cloud network itself is encrypted, as described in the following sections.

Google Cloud network

Google Cloud encrypts traffic on the network level as described in [Encryption in transit](#) in the Google documentation. As mentioned in the section “Cloud Volumes Services architecture,” Cloud Volumes Service is delivered out of a NetApp-controlled PSA producer project.

In case of CVS-SW, the producer tenant runs Google VMs to provide the service. Traffic between user VMs

and Cloud Volumes Service VMs is encrypted automatically by Google.

Although the data path for CVS-Performance isn't fully encrypted on the network layer, NetApp and Google use a combination of [IEEE 802.1AE encryption \(MACSec\)](#), [encapsulation](#) (data encryption), and physically restricted networks to protect data in transit between the Cloud Volumes Service CVS-Performance service type and Google Cloud.

NAS protocols

NFS and SMB NAS protocols provide optional transport encryption at the protocol layer.

SMB encryption

[SMB encryption](#) provides end-to-end encryption of SMB data and protects data from eavesdropping occurrences on untrusted networks. You can enable encryption for both the client/server data connection (only available to SMB3.x capable clients) and the server/domain controller authentication.

When SMB encryption is enabled, clients that do not support encryption cannot access the share.

Cloud Volumes Service supports RC4-HMAC, AES-128-CTS-HMAC-SHA1, and AES-256-CTS-HMAC-SHA1 security ciphers for SMB encryption. SMB negotiates to the highest supported encryption type by the server.

NFSv4.1 Kerberos

For NFSv4.1, CVS-Performance offers Kerberos authentication as described in [RFC7530](#). You can enable Kerberos on a per-volume basis.

The current strongest available encryption type for Kerberos is AES-256-CTS-HMAC-SHA1. NetApp Cloud Volumes Service supports AES-256-CTS-HMAC-SHA1, AES-128-CTS-HMAC-SHA1, DES3, and DES for NFS. It also supports ARCFour-HMAC (RC4) for CIFS/SMB traffic, but not for NFS.

Kerberos provides three different security levels for NFS mounts that offer choices for how strong the Kerberos security should be.

As per RedHat's [Common Mount Options](#) documentation:

```
sec=krb5 uses Kerberos V5 instead of local UNIX UIDs and GIDs to authenticate users.  
sec=krb5i uses Kerberos V5 for user authentication and performs integrity checking of NFS operations using secure checksums to prevent data tampering.  
sec=krb5p uses Kerberos V5 for user authentication, integrity checking, and encrypts NFS traffic to prevent traffic sniffing. This is the most secure setting, but it also involves the most performance overhead.
```

As a general rule, the more the Kerberos security level has to do, the worse the performance is, as the client and server spend time encrypting and decrypting NFS operations for each packet sent. Many clients and NFS servers provide support for AES-NI offloading to the CPUs for a better overall experience, but the performance impact of Kerberos 5p (full end-to-end encryption) is significantly greater than the impact of Kerberos 5 (user authentication).

The following table shows differences in what each level does for security and performance.

Security level	Security	Performance
NFSv3—sys	<ul style="list-style-type: none"> Least secure; plain text with numeric user IDs/group IDs Able to view UID, GID, client IP addresses, export paths, file names, permissions in packet captures 	<ul style="list-style-type: none"> Best for most cases
NFSv4.x—sys	<ul style="list-style-type: none"> More secure than NFSv3 (client IDs, name string/domain string matching) but still plain text Able to view UID, GID, client IP addresses, name strings, domain IDs, export paths, file names, permissions in packet captures 	<ul style="list-style-type: none"> Good for sequential workloads (such as VMs, databases, large files) Bad with high file count/high metadata (30-50% worse)
NFS—krb5	<ul style="list-style-type: none"> Kerberos encryption for credentials in every NFS packet—wraps UID/GID of users/groups in RPC calls in GSS wrapper User requesting access to mount needs a valid Kerberos ticket (either through username/password or manual key tab exchange); ticket expires after a specified time period and user must reauthenticate for access No encryption for NFS operations or ancillary protocols like mount/portmapper/nlm (can see export paths, IP addresses, file handles, permissions, file names, atime/mtime in packet captures) 	<ul style="list-style-type: none"> Best in most cases for Kerberos; worse than AUTH_SYS

Security level	Security	Performance
NFS—krb5i	<ul style="list-style-type: none"> • Kerberos encryption for credentials in every NFS packet—wraps UID/GID of users/groups in RPC calls in GSS wrapper • User requesting access to mount needs a valid Kerberos ticket (either via username/password or manual key tab exchange); ticket expires after a specified time period and user must reauthenticate for access • No encryption for NFS operations or ancillary protocols like mount/portmapper/nlm (can see export paths, IP addresses, file handles, permissions, file names, atime/mtime in packet captures) • Kerberos GSS checksum is added to every packet to ensure nothing intercepts the packets. If checksums match, conversation is allowed. 	<ul style="list-style-type: none"> • Better than krb5p because the NFS payload is not encrypted; only added overhead compared to krb5 is the integrity checksum. Performance of krb5i won't be much worse than krb5 but will see some degradation.

Security level	Security	Performance
NFS – krb5p	<ul style="list-style-type: none"> • Kerberos encryption for credentials in every NFS packet—wraps UID/GID of users/groups in RPC calls in GSS wrapper • User requesting access to mount needs a valid Kerberos ticket (either via username/password or manual keytab exchange); ticket expires after specified time period and user must reauthenticate for access • All of the NFS packet payloads are encrypted with the GSS wrapper (cannot see file handles, permissions, file names, atime/mtime in packet captures). • Includes integrity check. • NFS operation type is visible (FSINFO, ACCESS, GETATTR, and so on). • Ancillary protocols (mount, portmap, nlm, and so on) are not encrypted - (can see export paths, IP addresses) 	<ul style="list-style-type: none"> • Worst performance of the security levels; krb5p has to encrypt/decrypt more. • Better performance than krb5p with NFSv4.x for high file count workloads.

In Cloud Volumes Service, a configured Active Directory server is used as Kerberos server and LDAP server (to lookup user identities from an RFC2307 compatible schema). No other Kerberos or LDAP servers are supported. NetApp highly recommends that you use LDAP for identity management in Cloud Volumes Service. For information on how NFS Kerberos is shown in packet captures, see the section [“Packet sniffing/trace considerations.”](#)

[Next: Data encryption at rest.](#)

Data encryption at rest

[Previous: Data encryption in transit.](#)

All volumes in Cloud Volumes Service are encrypted-at-rest using AES-256 encryption, which means all user data written to media is encrypted and can only be decrypted with a per-volume key.

- For CVS-SW, Google-generated keys are used.
- For CVS-Performance, the per-volume keys are stored in a key manager built into the Cloud Volumes Service.

Starting in November 2021, preview customer-managed encryption keys (CMEK) functionality was made available. This enables you to encrypt the per-volume keys with a per-project, per-region master key that is

hosted in [Google Key Management Service \(KMS\)](#). KMS enables you to attach external key managers.

For information about configuring KMS for CVS-Performance, see [Setting up customer-managed encryption keys](#).

Next: [Firewall](#).

Firewall

Previous: [Data encryption at rest](#).

Cloud Volumes Service exposes multiple TCP ports to serve NFS and SMB shares:

- [Ports required for NFS access](#)
- [Ports required for SMB access](#)

Additionally, SMB, NFS with LDAP including Kerberos, and dual-protocol configurations require access to a Windows Active Directory domain. Active Directory connections must be [configured](#) on a per-region basis. Active Directory Domain controllers (DC) are identified by using [DNS-based DC discovery](#) using the specified DNS servers. Any of the DCs returned are used. The list of eligible DCs can be limited by specifying an Active Directory site.

Cloud Volumes Service reaches out with IP addresses from the CIDR range allocated with the `gcloud compute address` command while [on-boarding the Cloud Volumes Service](#). You can use this CIDR as source addresses to configure inbound firewalls to your Active Directory domain controllers.

Active Directory Domain Controllers must [expose ports to the Cloud Volumes Service CIDRs as mentioned here](#).

Next: [NAS protocols overview](#).

NAS protocols

NAS protocols overview

Previous: [Firewall](#).

NAS protocols include NFS (v3 and v4.1) and SMB/CIFS (2.x and 3.x). These protocols are how CVS allows shared access to data across multiple NAS clients. In addition, Cloud Volumes Service can provide access to NFS and SMB/CIFS clients simultaneously (dual-protocol) while honoring all of the identity and permission settings on files and folders in the NAS shares. To maintain the highest possible data transfer security, Cloud Volumes Service supports protocol encryption in flight using SMB encryption and NFS Kerberos 5p.



Dual-protocol is available with CVS-Performance only.

Next: [Basics of NAS protocols](#).

Basics of NAS protocols

Previous: [NAS protocols overview](#).

NAS protocols are ways for multiple clients on a network to access the same data on a storage system, such as Cloud Volumes Service on GCP. NFS and SMB are the defined NAS protocols and operate on a client/server basis where Cloud Volumes Service acts as the server. Clients send access, read, and write

requests to the server, and the server is responsible for coordinating the locking mechanisms for files, storing permissions and handling identity and authentication requests.

For example, the following general process is followed if a NAS client wants to create a new file in a folder.

1. The client asks the server for information about the directory (permissions, owner, group, file ID, available space, and so on); the server responds with the information if the requesting client and user have the necessary permissions on the parent folder.
2. If the permissions on the directory allow access, the client then asks the server if the file name being created already exists in the file system. If the file name is already in use, creation fails. If the file name does not exist, the server lets the client know it can proceed.
3. The client issues a call to the server to create the file with the directory handle and file name and sets the access and modified times. The server issues a unique file ID to the file to make sure that no other files are created with the same file ID.
4. The client sends a call to check file attributes before the WRITE operation. If permissions allow it, the client then writes the new file. If locking is used by the protocol/application, the client asks the server for a lock to prevent other clients from accessing the file while locked to prevent data corruption.

[Next: NFS.](#)

NFS

[Previous: Basics of NAS protocols _ overview.](#)

NFS is a distributed file system protocol that is an open IETF standard defined in Request for Comments (RFC) that allows anyone to implement the protocol.

Volumes in Cloud Volumes Service are shared out to NFS clients by exporting a path that is accessible to a client or set of clients. Permissions to mount these exports are defined by export policies and rules, which are configurable by Cloud Volumes Service administrators.

The NetApp NFS implementation is considered a gold standard for the protocol and is used in countless enterprise NAS environments. The following sections cover NFS and specific security features available in Cloud Volumes Service and how they are implemented.

Default local UNIX users and groups

Cloud Volumes Service contains several default UNIX users and groups for various basic functionalities. These users and groups cannot currently be modified or deleted. New local users and groups cannot currently be added to Cloud Volumes Service. UNIX users and groups outside of the default users and groups need to be provided by an external LDAP name service.

The following table shows the default users and groups and their corresponding numeric IDs. NetApp recommends not creating new users or groups in LDAP or on the local clients that re-use these numeric IDs.

Default users: numeric IDs	Default groups: numeric IDs
<ul style="list-style-type: none">• root:0• pcuser:65534• nobody:65535	<ul style="list-style-type: none">• root:0• daemon:1• pcuser:65534• nobody:65535



When using NFSv4.1, the root user might display as nobody when running directory listing commands on NFS clients. This is due to the client's ID domain mapping configuration. See the section called [NFSv4.1 and the nobody user/group](#) for details on this issue and how to resolve it.

The root user

In Linux, the root account has access to all commands, files, and folders in a Linux-based file system. Because of the power of this account, security best practices often require the root user to be disabled or restricted in some fashion. In NFS exports, the power a root user has over the files and folders can be controlled in Cloud Volumes Service through export policies and rules and a concept known as root squash.

Root squashing ensures that the root user accessing an NFS mount is squashed to the anonymous numeric user 65534 (see the section “[The anonymous user](#)”) and is currently only available when using CVS-Performance by selecting Off for root access during export policy rule creation. If the root user is squashed to the anonymous user, it no longer has access to run chown or [setuid/setgid commands \(the sticky bit\)](#) on files or folders in the NFS mount, and files or folders created by the root user show the anon UID as the owner/group. In addition, NFSv4 ACLs cannot be modified by the root user. However, the root user still has access to chmod and deleted files that it does not have explicit permissions for. If you want to limit access to a root user’s file and folder permissions, consider using a volume with NTFS ACLs, creating a Windows user named `root`, and applying the desired permissions to the files or folders.

The anonymous user

The anonymous (anon) user ID specifies a UNIX user ID or username that is mapped to client requests that arrive without valid NFS credentials. This can include the root user when root squashing is used. The anon user in Cloud Volumes Service is 65534.

This UID is normally associated with the username `nobody` or `nfsnobody` in Linux environments. Cloud Volumes Service also uses 65534 as the local UNIX user ‘pcuser’ (see the section “[Default local UNIX users and groups](#)”), which is also the default fallback user for Windows to UNIX name mappings when no valid matching UNIX user can be found in LDAP.

Because of the differences in usernames across Linux and Cloud Volumes Service for UID 65534, the name string for users mapped to 65534 might not match when using NFSv4.1. As a result, you might see `nobody` as the user on some files and folders. See the section “[NFSv4.1 and the nobody user/group](#)” for information about this issue and how to resolve it.

Access control/exports

Initial export/share access for NFS mounts is controlled through host- based export policy rules contained within an export policy. A host IP, host name, subnet, netgroup, or domain is defined to allow access to mount the NFS share and the level of access allowed to the host. Export policy rule configuration options depend on the Cloud Volumes Service level.

For CVS-SW, the following options are available for export-policy configuration:

- **Client match.** Comma-separated list of IP addresses, comma-separated list of hostnames, subnets, netgroups, domain names.
- **RO/RW access rules.** Select read/write or read only to control level of access to export.CVS-Performance provides the following options:
- **Client match.** Comma-separated list of IP addresses, comma-separated list of hostnames, subnets, netgroups, domain names.

- **RO/RW access rules.** Select read/write or read only to control level of access to export.
- **Root access (on/off).** Configures root squash (see the section “[The root user](#)” for details).
- **Protocol type.** This limits access to the NFS mount to a specific protocol version. When specifying both NFSv3 and NFSv4.1 for the volume, either leave both blank or check both boxes.
- **Kerberos security level (when Enable Kerberos is selected).** Provides the options of krb5, krb5i, and/or krb5p for read-only or read-write access.

Change ownership (chown) and change group (chgrp)

NFS on Cloud Volumes Service only allows the root user to run chown/chgrp on files and folders. Other users see an Operation not permitted error—even on files they own. If you use root squash (as covered in the section “[The root user](#)”), the root is squashed to a nonroot user and is not allowed access to chown and chgrp. There are currently no workarounds in Cloud Volumes Service to allow chown and chgrp for non-root users. If ownership changes are required, consider using dual protocol volumes and set the security style to NTFS to control permissions from the Windows side.

Permission management

Cloud Volumes Service supports both mode bits (such as 644, 777, and so on for rwx) and NFSv4.1 ACLs to control permissions on NFS clients for volumes that use the UNIX security style. Standard permission management is used for these (such as chmod, chown, or nfs4_setfacl) and work with any Linux client that supports them.

Additionally, when using dual protocol volumes set to NTFS, NFS clients can leverage Cloud Volumes Service name mapping to Windows users, which then are used to resolve the NTFS permissions. This requires an LDAP connection to Cloud Volumes Service to provide numeric-ID-to-username translations because Cloud Volumes Service requires a valid UNIX username to map properly to a Windows username.

Providing granular ACLs for NFSv3

Mode bit permissions cover only owner, group, and everyone else in the semantics—meaning that there are no granular user access controls in place for basic NFSv3. Cloud Volumes Service does not support POSIX ACLs, nor extended attributes (such as chattr), so granular ACLs are only possible in the following scenarios with NFSv3:

- NTFS security style volumes (CIFS server required) with valid UNIX to Windows user mappings.
- NFSv4.1 ACLs applied using an admin client mounting NFSv4.1 to apply ACLs.

Both methods require an LDAP connection for UNIX identity management and a valid UNIX user and group information populated (see the section “[LDAP](#)”) and are only available with CVS-Performance instances. To use NTFS security style volumes with NFS, you must use dual-protocol (SMB and NFSv3) or dual-protocol (SMB and NFSv4.1), even if no SMB connections are made. To use NFSv4.1 ACLs with NFSv3 mounts, you must select Both (NFSv3/NFSv4.1) as the protocol type.

Regular UNIX mode bits don’t provide the same level of granularity in permissions that NTFS or NFSv4.x ACLs provide. The following table compares the permission granularity between NFSv3 mode bits and NFSv4.1 ACLs. For information about NFSv4.1 ACLs, see [nfs4_acl - NFSv4 Access Control Lists](#).

NFSv3 mode bits	NFSv4.1 ACLs
<ul style="list-style-type: none"> • Set user ID on execution • Set group ID on execution • Save swapped text (not defined in POSIX) • Read permission for owner • Write permission for owner • Execute permission for owner on a file; or look up (search) permission for owner in directory • Read permission for group • Write permission for group • Execute permission for group on a file; or look up (search) permission for group in directory • Read permission for others • Write permission for others • Execute permission for others on a file; or look up (search) permission for others in directory 	<p>Access control entry (ACE) types (Allow/Deny/Audit)</p> <ul style="list-style-type: none"> * Inheritance flags * directory-inherit * file-inherit * no-propagate-inherit * inherit-only <p>Permissions</p> <ul style="list-style-type: none"> * read-data (files) / list-directory (directories) * write-data (files) / create-file (directories) * append-data (files) / create-subdirectory (directories) * execute (files) / change-directory (directories) * delete * delete-child * read-attributes * write-attributes * read-named-attributes * write-named-attributes * read-ACL * write-ACL * write-owner * Synchronize

Finally, NFS group membership (in both NFSv3 and NFSV4.x) is limited to a default maximum of 16 for AUTH_SYS as per the RPC packet limits. NFS Kerberos provides up to 32 groups and NFSv4 ACLs remove the limitation by way of granular user and group ACLs (up to 1024 entries per ACE).

Additionally, Cloud Volumes Service provides extended group support to extend the maximum supported groups up to 32. This requires an LDAP connection to an LDAP server that contains valid UNIX user and group identities. For more information about configuring this, see [Creating and managing NFS volumes](#) in the Google documentation.

NFSv3 user and group IDs

NFSv3 user and group IDs come across the wire as numeric IDs rather than names. Cloud Volumes Service does no username resolution for these numeric IDs with NFSv3, with UNIX security style volumes using just mode bits. When NFSv4.1 ACLs are present, a numeric ID lookup and/or name string lookup is needed to resolve the ACL properly—even when using NFSv3. With NTFS security style volumes, Cloud Volumes Service must resolve a numeric ID to a valid UNIX user and then map to a valid Windows user to negotiate access rights.

Security limitations of NFSv3 user and group IDs

With NFSv3, the client and server never have to confirm that the user attempting a read or write with a numeric ID is a valid user; it is just implicitly trusted. This opens the file system up to potential breaches simply by spoofing any numeric ID. To prevent security holes like this, there are a few options available to Cloud Volumes Service.

- Implementing Kerberos for NFS forces users to authenticate with a username and password or keytab file to get a Kerberos ticket to allow access into a mount. Kerberos is available with CVS-Performance instances and only with NFSv4.1.

- Limiting the list of hosts in your export policy rules limits which NFSv3 clients have access to the Cloud Volumes Service volume.
- Using dual-protocol volumes and applying NTFS ACLs to the volume forces NFSv3 clients to resolve numeric IDs to valid UNIX usernames to authenticate properly to access mounts. This requires enabling LDAP and configuring UNIX user and group identities.
- Squashing the root user limits the damage a root user can do to an NFS mount but does not completely remove risk. For more information, see the section “[The root user](#).”

Ultimately, NFS security is limited to what the protocol version you are using offers. NFSv3, while more performant in general than NFSv4.1, does not provide the same level of security.

NFSv4.1

NFSv4.1 provides greater security and reliability as compared to NFSv3, for the following reasons:

- Integrated locking through a lease-based mechanism
- Stateful sessions
- All NFS functionality over a single port (2049)
- TCP only
- ID domain mapping
- Kerberos integration (NFSv3 can use Kerberos, but only for NFS, not for ancillary protocols such as NLM)

NFSv4.1 dependencies

Because of the additional security features in NFSv4.1, there are some external dependencies involved that were not needed to use NFSv3 (similar to how SMB requires dependencies such as Active Directory).

NFSv4.1 ACLs

Cloud Volumes Service offers support for NFSv4.x ACLs, which deliver distinct advantages over normal POSIX-style permissions, such as the following:

- Granular control of user access to files and directories
- Better NFS security
- Improved interoperability with CIFS/SMB
- Removal of the NFS limitation of 16 groups per user with AUTH_SYS security
- ACLs bypass the need for group ID (GID) resolution, which effectively removes the GID limitNFSv4.1 ACLs are controlled from NFS clients—not from Cloud Volumes Service. To use NFSv4.1 ACLs, be sure your client’s software version supports them and the proper NFS utilities are installed.

Compatibility between NFSv4.1 ACLs and SMB clients

NFSv4 ACLs are different from Windows file-level ACLs (NTFS ACLs) but carry similar functionality. However, in multiprotocol NAS environments, if NFSv4.1 ACLs are present and you are using dual-protocol access (NFS and SMB on the same datasets), clients using SMB2.0 and later won’t be able to view or manage ACLs from Windows security tabs.

How NFSv4.1 ACLs work

For reference, the following terms are defined:

- **Access control list (ACL).** A list of permissions entries.
- **Access control entry (ACE).** A permission entry in the list.

When a client sets an NFSv4.1 ACL on a file during a SETATTR operation, Cloud Volumes Service sets that ACL on the object, replacing any existing ACL. If there is no ACL on a file, then the mode permissions on the file are calculated from OWNER@, GROUP@, and EVERYONE@. If there are any existing SUID/Sgid/STICKY bits on the file, they are not affected.

When a client gets an NFSv4.1 ACL on a file during the course of a GETATTR operation, Cloud Volumes Service reads the NFSv4.1 ACL associated with the object, constructs a list of ACEs, and returns the list to the client. If the file has an NT ACL or mode bits, then an ACL is constructed from mode bits and is returned to the client.

Access is denied if a DENY ACE is present in the ACL; access is granted if an ALLOW ACE exists. However, access is also denied if neither of the ACEs is present in the ACL.

A security descriptor consists of a security ACL (SACL) and a discretionary ACL (DACL). When NFSv4.1 interoperates with CIFS/SMB, the DACL is one-to-one mapped with NFSv4 and CIFS. The DACL consists of the ALLOW and the DENY ACEs.

If a basic chmod is run on a file or folder with NFSv4.1 ACLs set, existing user and group ACLs are preserved, but the default OWNER@, GROUP@, EVERYONE@ ACLs are modified.

A client using NFSv4.1 ACLs can set and view ACLs for files and directories on the system. When a new file or subdirectory is created in a directory that has an ACL, that object inherits all ACEs in the ACL that have been tagged with the appropriate [inheritance flags](#).

If a file or directory has an NFSv4.1 ACL, that ACL is used to control access no matter which protocol is used to access the file or directory.

Files and directories inherit ACEs from NFSv4 ACLs on parent directories (possibly with appropriate modifications) as long as the ACEs have been tagged with the correct inheritance flags.

When a file or directory is created as the result of an NFSv4 request, the ACL on the resulting file or directory depends on whether the file creation request includes an ACL or only standard UNIX file access permissions. The ACL also depends on whether the parent directory has an ACL.

- If the request includes an ACL, that ACL is used.
- If the request includes only standard UNIX file access permissions and the parent directory does not have an ACL, the client file mode is used to set standard UNIX file access permissions.
- If the request includes only standard UNIX file access permissions and the parent directory has a noninheritable ACL, a default ACL based on the mode bits passed into the request is set on the new object.
- If the request includes only standard UNIX file access permissions but the parent directory has an ACL, the ACEs in the parent directory's ACL are inherited by the new file or directory as long as the ACEs have been tagged with the appropriate inheritance flags.

ACE permissions

NFSv4.1 ACLs permissions uses a series of upper- and lower-case letter values (such as `rxtncy`) to control access. For more information about these letter values, see [HOW TO: Use NFSv4 ACL](#).

NFSv4.1 ACL behavior with umask and ACL inheritance

NFSv4 ACLs provide the ability to offer ACL inheritance. ACL inheritance means that files or folders created beneath objects with NFSv4.1 ACLs set can inherit the ACLs based on the configuration of the [ACL inheritance flag](#).

[Umask](#) is used to control the permission level at which files and folders are created in a directory without administrator interaction. By default, Cloud Volumes Service allows umask to override inherited ACLs, which is expected behavior as per [RFC 5661](#).

ACL formatting

NFSv4.1 ACLs have specific formatting. The following example is an ACE set on a file:

```
A:::ldapuser@domain.netapp.com:rwtTnNcCy
```

The preceding example follows the ACL format guidelines of:

```
type:flags:principal:permissions
```

A type of `A` means “allow.” The inherit flags are not set in this case, because the principal is not a group and does not include inheritance. Also, because the ACE is not an AUDIT entry, there is no need to set the audit flags. For more information about NFSv4.1 ACLs, see http://linux.die.net/man/5/nfs4_acl.

If the NFSv4.1 ACL is not set properly (or a name string cannot be resolved by the client and server), the ACL might not behave as expected, or the ACL change might fail to apply and throw an error.

Sample errors include:

```
Failed setxattr operation: Invalid argument
Scanning ACE string 'A:: user@rwaDxtTnNcCy' failed.
```

Explicit DENY

NFSv4.1 permissions can include explicit DENY attributes for OWNER, GROUP, and EVERYONE. That is because NFSv4.1 ACLs are default-deny, which means that if an ACL is not explicitly granted by an ACE, then it is denied. Explicit DENY attributes override any ACCESS ACEs, explicit or not.

DENY ACEs are set with an attribute tag of `D`.

In the example below, `GROUP@` is allowed all read and execute permissions, but denied all write access.

```
sh-4.1$ nfs4_getfacl /mixed
A::ldapuser@domain.netapp.com:ratTnNcCy
A::OWNER@:rwaDxtTnNcCy
D::OWNER@:
A:g:GROUP@:rxtncy
D:g:GROUP@:waDTC
A::EVERYONE@:rxtncy
D::EVERYONE@:waDTC
```

DENY ACEs should be avoided whenever possible because they can be confusing and complicated; ALLOW ACLs that are not explicitly defined are implicitly denied. When DENY ACEs are set, users might be denied access when they expect to be granted access.

The preceding set of ACEs is equivalent to 755 in mode bits, which means:

- The owner has full rights.
- Groups have read only.
- Others have read only.

However, even if permissions are adjusted to the 775 equivalent, access can be denied because of the explicit DENY set on EVERYONE.

NFSv4.1 ID domain mapping dependencies

NFSv4.1 leverages ID domain mapping logic as a security layer to help verify that a user attempting access to an NFSv4.1 mount is indeed who they claim to be. In these cases, the username and group name coming from the NFSv4.1 client appends a name string and sends it to the Cloud Volumes Service instance. If that username/group name and ID string combination does not match, then the user and/or group is squashed to the default nobody user specified in the `/etc/idmapd.conf` file on the client.

This ID string is a requirement for proper permission adherence, especially when NFSv4.1 ACLs and/or Kerberos are in use. As a result, name service server dependencies such as LDAP servers are necessary to ensure consistency across clients and Cloud Volumes Service for proper user and group name identity resolution.

Cloud Volumes Service uses a static default ID domain name value of `defaultv4iddomain.com`. NFS clients default to the DNS domain name for its ID domain name settings, but you can manually adjust the ID domain name in `/etc/idmapd.conf`.

If LDAP is enabled in Cloud Volumes Service, then Cloud Volumes Service automates the NFS ID domain to change to what is configured for the search domain in DNS and clients won't need to be modified unless they use different DNS domain search names.

When Cloud Volumes Service can resolve a username or group name in local files or LDAP, the domain string is used and non-matching domain IDs squash to nobody. If Cloud Volumes Service cannot find a username or group name in local files or LDAP, the numeric ID value is used and the NFS client resolves the name properly (this is similar to NFSv3 behavior).

Without changing the client's NFSv4.1 ID domain to match what the Cloud Volumes Service volume is using, you see the following behavior:

- UNIX users and groups with local entries in Cloud Volumes Service (such as root, as defined in local UNIX users and groups) are squashed to the nobody value.
- UNIX users and groups with entries in LDAP (if Cloud Volumes Service is configured to use LDAP) squashes to nobody if DNS domains are different between NFS clients and Cloud Volumes Service.
- UNIX users and groups with no local entries or LDAP entries use the numeric ID value and resolve to the name specified on the NFS client. If no name exists on the client, only the numeric ID is shown.

The following shows the results of the preceding scenario:

```
# ls -la /mnt/home/prof1/nfs4/
total 8
drwxr-xr-x 2 nobody nobody 4096 Feb  3 12:07 .
drwxrwxrwx 7 root   root   4096 Feb  3 12:06 ..
-rw-r--r-- 1 9835 9835     0 Feb  3 12:07 client-user-no-name
-rw-r--r-- 1 nobody nobody    0 Feb  3 12:07 ldap-user-file
-rw-r--r-- 1 nobody nobody    0 Feb  3 12:06 root-user-file
```

When the client and server ID domains match, this is how the same file listing looks:

```
# ls -la
total 8
drwxr-xr-x 2 root   root      4096 Feb  3 12:07 .
drwxrwxrwx 7 root   root      4096 Feb  3 12:06 ..
-rw-r--r-- 1 9835      9835     0 Feb  3 12:07 client-user-no-name
-rw-r--r-- 1 apache   apache-group 0 Feb  3 12:07 ldap-user-file
-rw-r--r-- 1 root   root      0 Feb  3 12:06 root-user-file
```

For more information about this issue and how to resolve it, see the section “[NFSv4.1 and the nobody user/group](#).”

Kerberos dependencies

If you plan to use Kerberos with NFS, you must have the following with Cloud Volumes Service:

- Active Directory domain for Kerberos Distribution Center services (KDC)
- Active Directory domain with user and group attributes populated with UNIX information for LDAP functionality (NFS Kerberos in Cloud Volumes Service requires a user SPN to UNIX user mapping for proper functionality.)
- LDAP enabled on the Cloud Volumes Service instance
- Active Directory domain for DNS services

NFSv4.1 and the nobody user/group

One of the most common issues seen with an NFSv4.1 configuration is when a file or folder is shown in a listing using `ls` as being owned by the `user:group` combination of `nobody:nobody`.

For example:

```
sh-4.2$ ls -la | grep prof1-file
-rw-r--r-- 1 nobody nobody 0 Apr 24 13:25 prof1-file
```

And the numeric ID is 99.

```
sh-4.2$ ls -lan | grep prof1-file
-rw-r--r-- 1 99 99 0 Apr 24 13:25 prof1-file
```

In some instances, the file might show the correct owner but `nobody` as the group.

```
sh-4.2$ ls -la | grep newfile1
-rw-r--r-- 1 prof1 nobody 0 Oct 9 2019 newfile1
```

Who is `nobody`?

The `nobody` user in NFSv4.1 is different from the `nfsnobody` user. You can view how an NFS client sees each user by running the `id` command:

```
# id nobody
uid=99(nobody) gid=99(nobody) groups=99(nobody)
# id nfsnobody
uid=65534(nfsnobody) gid=65534(nfsnobody) groups=65534(nfsnobody)
```

With NFSv4.1, the `nobody` user is the default user defined by the `idmapd.conf` file and can be defined as any user you want to use.

```
# cat /etc/idmapd.conf | grep nobody
#Nobody-User = nobody
#Nobody-Group = nobody
```

Why does this happen?

Because security through name string mapping is a key tenet of NFSv4.1 operations, the default behavior when a name string does not match properly is to squash that user to one that won't normally have any access to files and folders owned by users and groups.

When you see `nobody` for the user and/or group in file listings, this generally means something in NFSv4.1 is misconfigured. Case sensitivity can come into play here.

For example, if `user1@CVSDEMO.LOCAL` (uid 1234, gid 1234) is accessing an export, then Cloud Volumes Service must be able to find `user1@CVSDEMO.LOCAL` (uid 1234, gid 1234). If the user in Cloud Volumes Service is `USER1@CVSDEMO.LOCAL`, then it won't match (uppercase USER1 versus lowercase user1). In

many cases, you can see the following in the messages file on the client:

```
May 19 13:14:29 centos7 nfsidmap[17481]: nss_getpwnam: name  
'root@defaultv4iddomain.com' does not map into domain 'CVSDEMO.LOCAL'  
May 19 13:15:05 centos7 nfsidmap[17534]: nss_getpwnam: name 'nobody' does  
not map into domain 'CVSDEMO.LOCAL'
```

The client and server must both agree that a user is indeed who they are claiming to be, so you must check the following to ensure that the user that the client sees has the same information as the user that Cloud Volumes Service sees.

- **NFSv4.x ID domain.** Client: `idmapd.conf` file; Cloud Volumes Service uses `defaultv4iddomain.com` and cannot be changed manually. If using LDAP with NFSv4.1, Cloud Volumes Service changes the ID domain to what the DNS search domain is using, which is the same as the AD domain.
- **User name and numeric IDs.** This determines where the client is looking for user names and leverages the name service switch configuration—client: `nsswitch.conf` and/or local `passwd` and `group` files; Cloud Volumes Service does not allow modifications to this but automatically adds LDAP to the configuration when it is enabled.
- **Group name and numeric IDs.** This determines where the client is looking for group names and leverages the name service switch configuration—client: `nsswitch.conf` and/or local `passwd` and `group` files; Cloud Volumes Service does not allow modifications to this but automatically adds LDAP to the configuration when it is enabled.

In almost all cases, if you see `nobody` in user and group listings from clients, the issue is user or group name domain ID translation between Cloud Volumes Service and the NFS client. To avoid this scenario, use LDAP to resolve user and group information between clients and Cloud Volumes Service.

Viewing name ID strings for NFSv4.1 on clients

If you are using NFSv4.1, there is a name-string mapping that takes place during NFS operations, as previously described.

In addition to using `/var/log/messages` to find an issue with NFSv4 IDs, you can use the `nfsidmap -l` command on the NFS client to view which usernames have properly mapped to the NFSv4 domain.

For example, this is output of the command after a user that can be found by the client and Cloud Volumes Service accesses an NFSv4.x mount:

```
# nfsidmap -l  
4 .id_resolver keys found:  
  gid:daemon@CVSDEMO.LOCAL  
  uid:nfs4@CVSDEMO.LOCAL  
  gid:root@CVSDEMO.LOCAL  
  uid:root@CVSDEMO.LOCAL
```

When a user that does not map properly into the NFSv4.1 ID domain (in this case, `netapp-user`) tries to access the same mount and touches a file, they are assigned `nobody:nobody`, as expected.

```
# su netapp-user
sh-4.2$ id
uid=482600012(netapp-user), 2000(secondary)
sh-4.2$ cd /mnt/nfs4/
sh-4.2$ touch newfile
sh-4.2$ ls -la
total 16
drwxrwxrwx 5 root root 4096 Jan 14 17:13 .
drwxr-xr-x 8 root root 81 Jan 14 10:02 ..
-rw-r--r-- 1 nobody nobody 0 Jan 14 17:13 newfile
drwxrwxrwx 2 root root 4096 Jan 13 13:20 qtree1
drwxrwxrwx 2 root root 4096 Jan 13 13:13 qtree2
drwxr-xr-x 2 nfs4 daemon 4096 Jan 11 14:30 testdir
```

The `nfsidmap -l` output shows the user `pcuser` in the display but not `netapp-user`; this is the anonymous user in our export-policy rule (65534).

```
# nfsidmap -l
6 .id_resolver keys found:
gid:pcuser@CVSDEMO.LOCAL
uid:pcuser@CVSDEMO.LOCAL
gid:daemon@CVSDEMO.LOCAL
uid:nfs4@CVSDEMO.LOCAL
gid:root@CVSDEMO.LOCAL
uid:root@CVSDEMO.LOCAL
```

[Next: SMB.](#)

SMB

[Previous: NFS.](#)

SMB is a network file sharing protocol developed by Microsoft that provides centralized user/group authentication, permissions, locking, and file sharing to multiple SMB clients over an Ethernet network. Files and folders are presented to clients by way of shares, which can be configured with a variety of share properties and offers access control through share-level permissions. SMB can be presented to any client that offers support for the protocol, including Windows, Apple, and Linux clients.

Cloud Volumes Service provides support for the SMB 2.1 and 3.x versions of the protocol.

Access control/SMB shares

- When a Windows username requests access to the Cloud Volumes Service volume, Cloud Volumes Service looks for a UNIX username using the methods configured by Cloud Volumes Service administrators.
- If an external UNIX identity provider (LDAP) is configured and Windows/UNIX usernames are identical, then Windows usernames will map 1:1 to UNIX usernames without any additional configuration needed.

When LDAP is enabled, Active Directory is used to host those UNIX attributes for user and group objects.

- If Windows names and UNIX names do not match identically, then LDAP must be configured to allow Cloud Volumes Service to use the LDAP name mapping configuration (see the section “[Using LDAP for asymmetric name mapping](#)”).
- If LDAP is not in use, then Windows SMB users map to a default local UNIX user named `pcuser` in Cloud Volumes Service. This means files written in Windows by users that map to the `pcuser` show UNIX ownership as `pcuser` in multiprotocol NAS environments. `pcuser` here is effectively the `nobody` user in Linux environments (UID 65534).

In deployments with SMB only, the `pcuser` mapping still occurs, but it won’t matter, because Windows user and group ownership is correctly displayed and NFS access to the SMB-only volume is not allowed. In addition, SMB-only volumes do not support conversion to NFS or dual-protocol volumes after they are created.

Windows leverages Kerberos for username authentication with the Active Directory domain controllers, which requires a username/password exchange with the AD DCs, which is external to the Cloud Volumes Service instance. Kerberos authentication is used when the `\\\$ERVERNAME` UNC path is used by the SMB clients and the following is true:

- DNS A/AAAA entry exists for SERVERNAME
- A valid SPN for SMB/CIFS access exists for SERVERNAME

When a Cloud Volumes Service SMB volume is created, the machine account name is created as defined in the section “[How Cloud Volumes Service shows up in Active Directory](#).” That machine account name also becomes the SMB share access path because Cloud Volumes Service leverages Dynamic DNS (DDNS) to create the necessary A/AAAA and PTR entries in DNS and the necessary SPN entries on the machine account principal.



For PTR entries to be created, the reverse lookup zone for the Cloud Volumes Service instance IP address must exist on the DNS server.

For example, this Cloud Volumes Service volume uses the following UNC share path: `\\\cvs-east-433d.cvsdemo.local`.

In Active Directory, these are the Cloud Volumes Service-generated SPN entries:

```
PS C:\> setspn /L CVS-EAST-433D
Registered ServicePrincipalNames for CN=CVS-EAST-433D,CN=Computers,DC=cvsdemo,DC=local:
HOST/cvs-east-433d.cvsdemo.local
HOST/CSV-EAST-433D
```

This is the DNS forward/reverse lookup result:

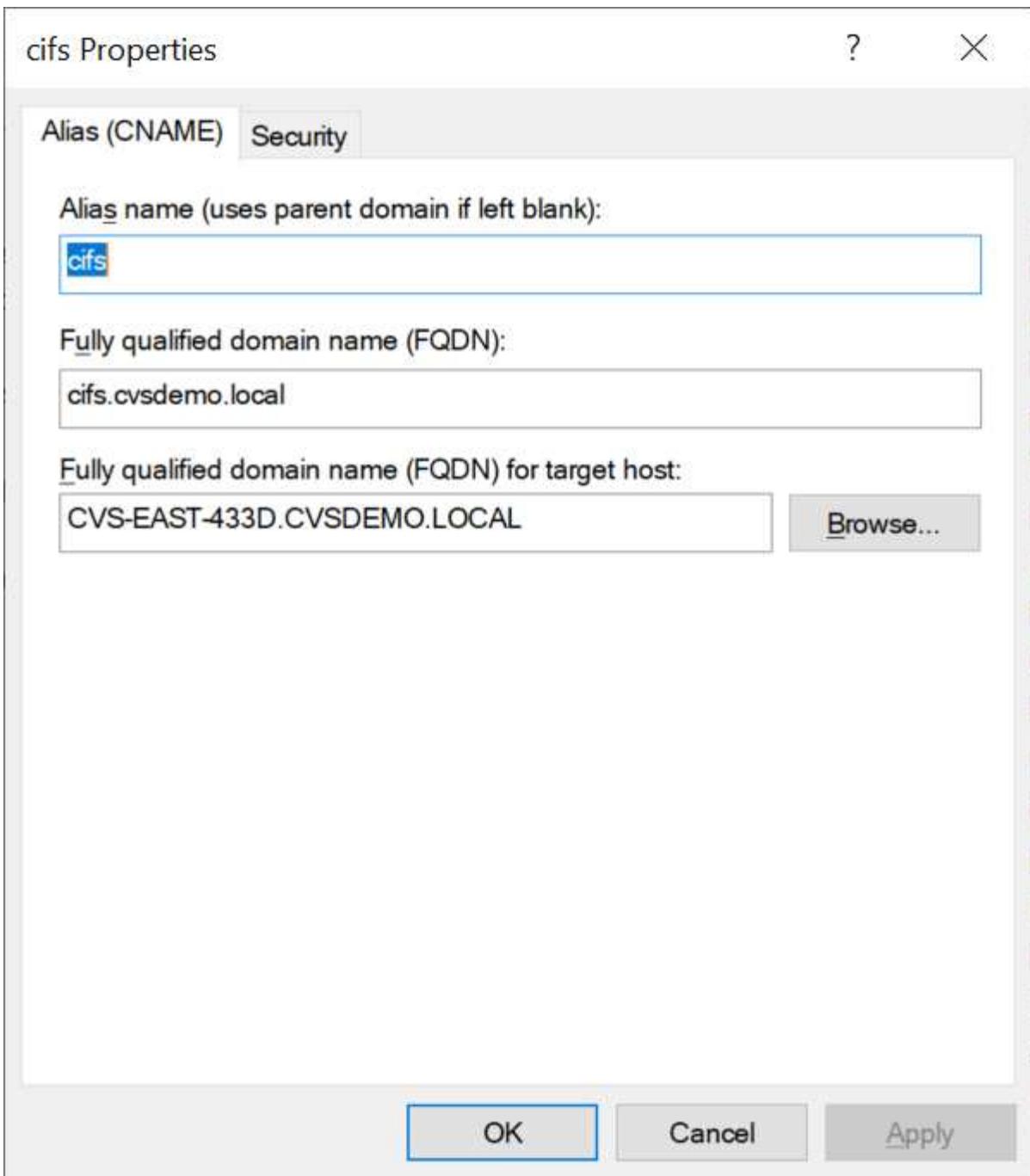
```
PS C:\> nslookup CVS-EAST-433D
Server: activedirectory. region. lab. internal
Address: 10. xx.0. xx
Name: CVS-EAST-433D.cvsdemo.local
Address: 10. xxx.0. x
PS C:\> nslookup 10. xxx.0. x
Server: activedirectory.region.lab.internal
Address: 10.xx.0.xx
Name: CVS-EAST-433D.CVSDEMO.LOCAL
Address: 10. xxx.0. x
```

Optionally, more access control can be applied by enabling/requiring SMB encryption for SMB shares in Cloud Volumes Service. If SMB encryption isn't supported by one of the endpoints, then access is not allowed.

Using SMB name aliases

In some cases, it might be a security concern for end users to know the machine account name in use for Cloud Volumes Service. In other cases, you might simply want to provide a simpler access path to your end users. In those cases, you can create SMB aliases.

If you want to create aliases for the SMB share path, you can leverage what is known as a CNAME record in DNS. For example, if you want to use the name \\CIFS to access shares instead of \\cvs-east-433d.cvsdemo.local, but you still want to use Kerberos authentication, a CNAME in DNS that points to the existing A/AAAA record and an additional SPN added to the existing machine account provides Kerberos access.



This is the resulting DNS forward lookup result after adding a CNAME:

```
PS C:\> nslookup cifs
Server:  ok-activedirectory.us-east4-a.c.cv-solution-architect-
lab.internal
Address: 10. xx.0. xx
Name:    CVS-EAST-433D.cvsdemo.local
Address: 10. xxx.0. x
Aliases: cifs.cvsdemo.local
```

This is the resulting SPN query after adding new SPNs:

```
PS C:\> setspn /L CVS-EAST-433D
Registered ServicePrincipalNames for CN=CVS-EAST-433D,CN=Computers,DC=cvsdemo,DC=local:
  cifs/cifs.cvsdemo.local
  cifs/cifs
  HOST/cvs-east-433d.cvsdemo.local
  HOST/CVS-EAST-433D
```

In a packet capture, we can see the Session Setup Request using the SPN tied to the CNAME.

431 4.156722	SMB2	308 Negotiate Protocol Response
432 4.156785	SMB2	232 Negotiate Protocol Request
434 4.158108	SMB2	374 Negotiate Protocol Response
435 4.160977	SMB2	1978 Session Setup Request
437 4.166224	SMB2	322 Session Setup Response
438 4.166891	SMB2	152 Tree Connect Request Tree: \\cifs\IPC\$
439 4.168063	SMB2	138 Tree Connect Response

realm: CVSDEMO.LOCAL
▼ sname
name-type: kRB5-NT-SRV-INST (2)
▼ sname-string: 2 items
SNameString: cifs
SNameString: cifs
▼ enc-part
etype: eTYPE-ARCFOUR-HMAC-MD5 (23)

SMB authentication dialects

Cloud Volumes Service supports the following [dialects](#) for SMB authentication:

- LM
- NTLM
- NTLMv2
- Kerberos

Kerberos authentication for SMB share access is the most secure level of authentication you can use. With AES and SMB encryption enabled, the security level is further increased.

Cloud Volumes Service also supports backward compatibility for LM and NTLM authentication. When Kerberos is misconfigured (such as when creating SMB aliases), share access falls back to weaker authentication methods (such as NTLMv2). Because these mechanisms are less secure, they are disabled in some Active Directory environments. If weaker authentication methods are disabled and Kerberos is not configured properly, share access fails because there is no valid authentication method to fall back to.

For information about configuring/viewing your supported authentication levels in Active Directory, see [Network security: LAN Manager authentication level](#).

Permission models

NTFS/File permissions

NTFS permissions are the permissions applied to files and folders in file systems adhering to NTFS logic. You can apply NTFS permissions in Basic or Advanced and can be set to Allow or Deny for access control.

Basic permissions include the following:

- Full Control
- Modify
- Read & Execute
- Read
- Write

When you set permissions for a user or group, referred to as an ACE, it resides in an ACL. NTFS permissions use the same read/write/execute basics as UNIX mode bits, but they can also extend to more granular and extended access controls (also known as Special Permissions), such as Take Ownership, Create Folders/Append Data, Write Attributes, and more.

Standard UNIX mode bits do not provide the same level of granularity as NTFS permissions (such as being able to set permissions for individual user and group objects in an ACL or setting extended attributes). However, NFSv4.1 ACLs do provide the same functionality as NTFS ACLs.

NTFS permissions are more specific than share permissions and can be used in conjunction with share permissions. With NTFS permission structures, the most restrictive applies. As such, explicit denials to a user or group overrides even Full Control when defining access rights.

NTFS permissions are controlled from Windows SMB clients.

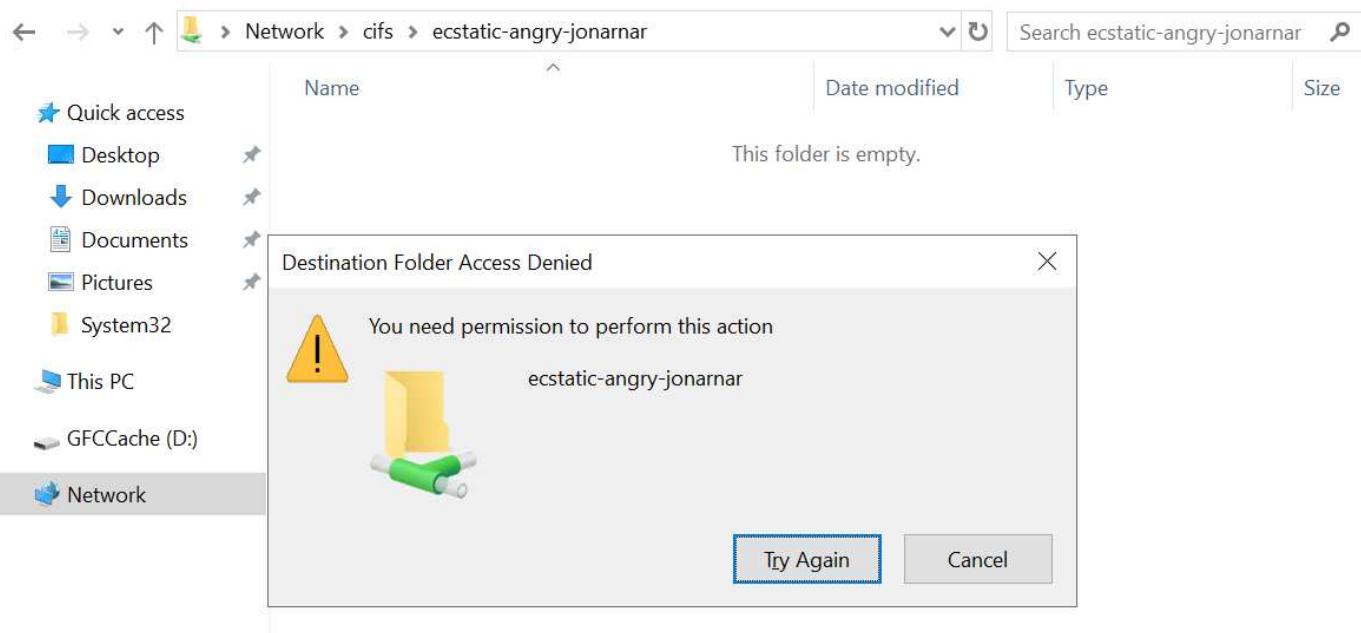
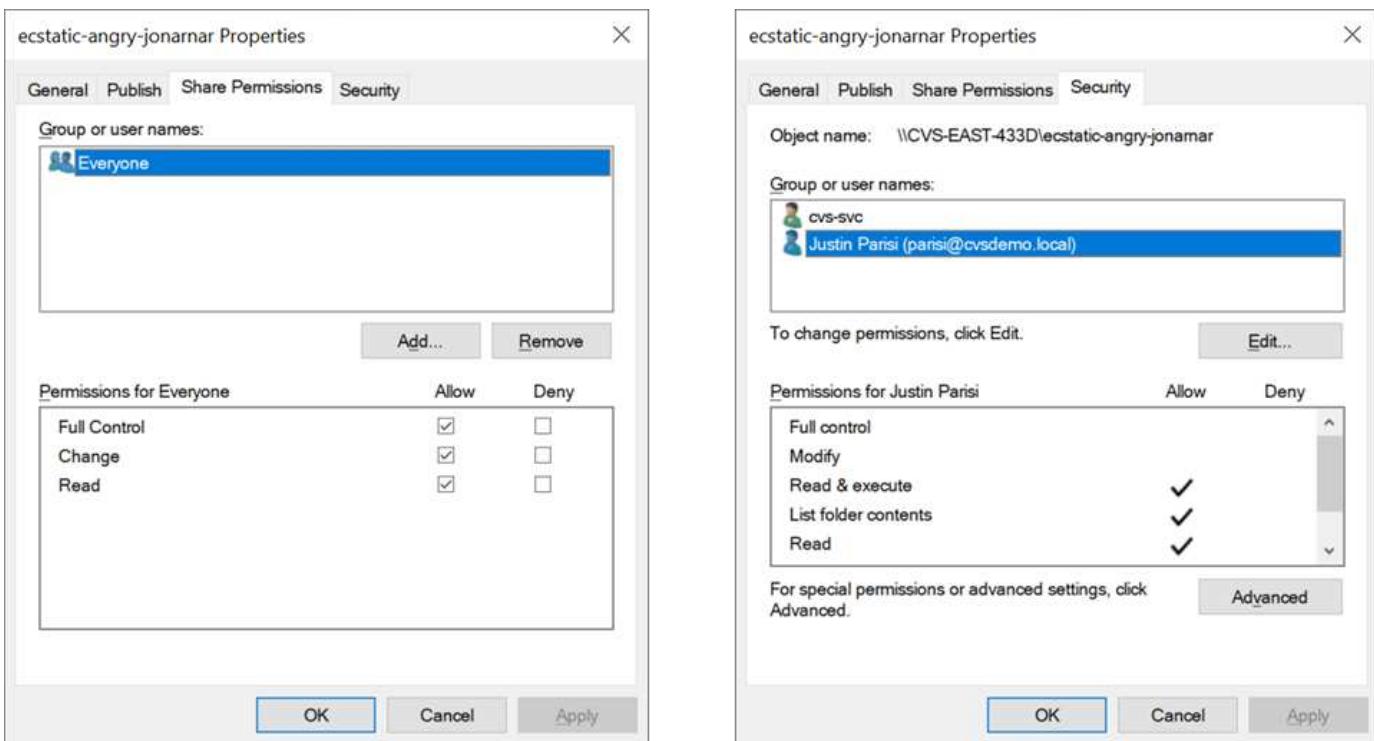
Share permissions

Share permissions are more general than NTFS permissions (Read/Change/Full Control only) and control the initial entry into an SMB share—similar to how NFS export policy rules work.

Although NFS export policy rules control access through host-based information such as IP addresses or host names, SMB share permissions can control access by using user and group ACEs in a share ACL. You can set share ACLs either from the Windows client or from the Cloud Volumes Service management UI.

By default, share ACLs and initial volume ACLs include Everyone with Full Control. The file ACLs should be changed but share permissions are overruled by the file permissions on objects in the share.

For instance, if a user is only allowed Read access to the Cloud Volumes Service volume file ACL, they are denied access to create files and folders even though the share ACL is set to Everyone with Full Control, as shown in the following figure.



For best security results, do the following:

- Remove Everyone from the share and file ACLs and instead set share access for users or groups.
- Use groups for access control instead of individual users for ease of management and faster removal/addition of users to share ACLs through group management.
- Allow less restrictive, more general share access to the ACEs on the share permissions and lock down access to users and groups with file permissions for more granular access control.
- Avoid general use of explicit deny ACLs, because they override allow ACLs. Limit use of explicit deny ACLs for users or groups that need to be restricted from access to a file system quickly.
- Make sure that you pay attention to the [ACL inheritance](#) settings when modifying permissions; setting the inheritance flag at the top level of a directory or volume with high file counts means that each file below that

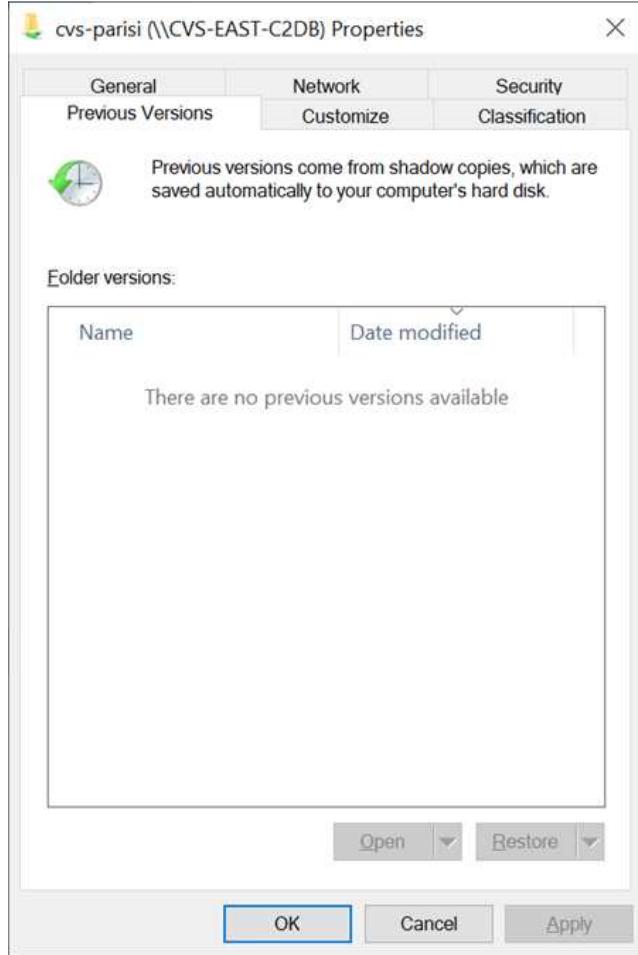
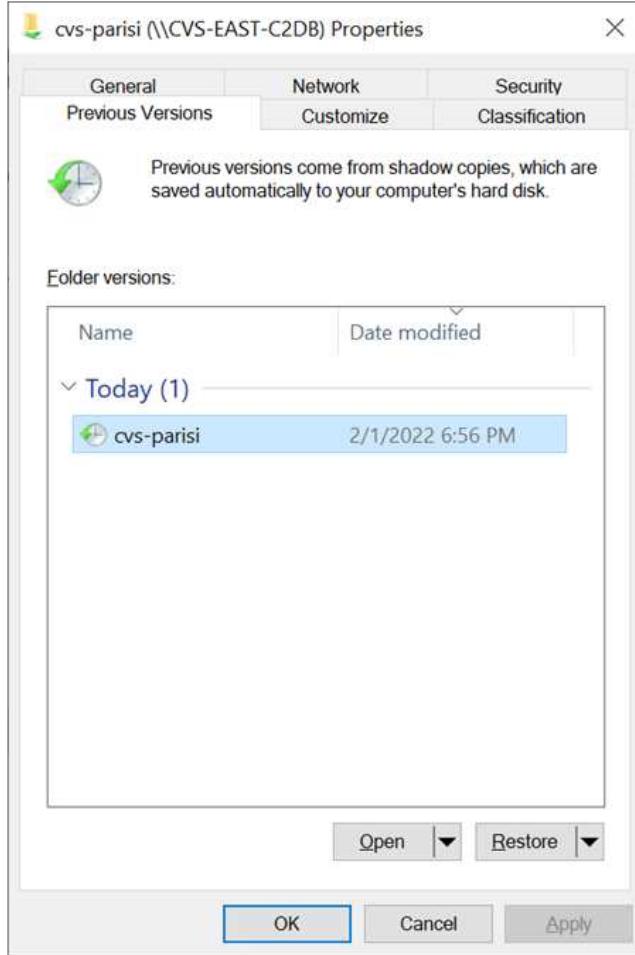
directory or volume has inherited permissions added to it, which can create unwanted behavior such as unintended access/denial and long churn of permission modification as each file is adjusted.

SMB share security features

When you first create a volume with SMB access in Cloud Volumes Service, you are presented with a series of choices for securing that volume.

Some of these choices depend on the Cloud Volumes Service level (Performance or Software) and choices include:

- **Make snapshot directory visible (available for both CVS-Performance and CVS-SW).** This option controls whether or not SMB clients can access the Snapshot directory in an SMB share (\server\share\~snapshot and/or Previous Versions tab). The default setting is Not Checked, which means that the volume defaults to hiding and disallowing access to the ~snapshot directory, and no Snapshot copies appear in the Previous Versions tab for the volume.

Snapshot directory visible: Unchecked			Snapshot directory visible: Checked												
 cvs-parisi (\CVS-EAST-C2DB) Properties			 cvs-parisi (\CVS-EAST-C2DB) Properties												
General		Network	General		Network										
Previous Versions		Customize	Previous Versions		Customize										
<p>Previous versions come from shadow copies, which are saved automatically to your computer's hard disk.</p> <p>Folder versions:</p> <table border="1"><thead><tr><th>Name</th><th>Date modified</th></tr></thead><tbody><tr><td colspan="2">There are no previous versions available</td></tr></tbody></table> <p>Open ▾ Restore ▾</p> <p>OK Cancel Apply</p>			Name	Date modified	There are no previous versions available		<p>Previous versions come from shadow copies, which are saved automatically to your computer's hard disk.</p> <p>Folder versions:</p> <table border="1"><thead><tr><th>Name</th><th>Date modified</th></tr></thead><tbody><tr><td>Today (1)</td><td></td></tr><tr><td>cvs-parisi</td><td>2/1/2022 6:56 PM</td></tr></tbody></table> <p>Open ▾ Restore ▾</p> <p>OK Cancel Apply</p>			Name	Date modified	Today (1)		cvs-parisi	2/1/2022 6:56 PM
Name	Date modified														
There are no previous versions available															
Name	Date modified														
Today (1)															
cvs-parisi	2/1/2022 6:56 PM														

Hiding Snapshot copies from end users might be desired for security reasons, performance reasons (hiding these folders from AV scans) or preference. Cloud Volumes Service Snapshots are read-only, so even if these Snapshots are visible, end users cannot delete or modify files in the Snapshot directory. File permissions on the files or folders at the time the Snapshot copy was taken apply. If a file or folder's permissions change between Snapshot copies, then the changes also apply to the files or folders in the Snapshot directory. Users and groups can gain access to these files or folders based on permissions. While deletes or modifications of files in the Snapshot directory are not possible, it is possible to copy files or folders out of the Snapshot

directory.

- **Enable SMB encryption (available for both CVS-Performance and CVS-SW).** SMB encryption is disabled on the SMB share by default (unchecked). Checking the box enables SMB encryption, which means traffic between the SMB client and server is encrypted in-flight with the highest supported encryption levels negotiated. Cloud Volumes Service supports up to AES-256 encryption for SMB. Enabling SMB encryption does carry a performance penalty that might or might not be noticeable to your SMB clients—roughly in the 10-20% range. NetApp strongly encourages testing to see if that performance penalty is acceptable.
- **Hide SMB share (available for both CVS-Performance and CVS-SW).** Setting this option hides the SMB share path from normal browsing. This means that clients that do not know the share path cannot see the shares when accessing the default UNC path (such as \\CVS-SMB). When the checkbox is selected, only clients that explicitly know the SMB share path or have the share path defined by a Group Policy Object can access it (security through obfuscation).
- **Enable access-based enumeration (ABE) (CVS-SW only).** This is similar to hiding the SMB share, except the shares or files are only hidden from users or groups that do not have permissions to access the objects. For instance, if Windows user joe is not allowed at least Read access through the permissions, then the Windows user joe cannot see the SMB share or files at all. This is disabled by default, and you can enable it by selecting the checkbox. For more information on ABE, see the NetApp Knowledge Base article [How does Access Based Enumeration \(ABE\) work?](#)
- **Enable Continuously Available (CA) share support (CVS-Performance only).** [Continuously Available SMB shares](#) provide a way to minimize application disruptions during failover events by replicating lock states across nodes in the Cloud Volumes Service backend system. This is not a security feature, but it does offer better overall resiliency. Currently, only SQL Server and FSLogix applications are supported for this functionality.

Default hidden shares

When an SMB server is created in Cloud Volumes Service, there are [hidden administrative shares](#) (using the \$ naming convention) that are created in addition to the data volume SMB share. These include C\$ (namespace access) and IPC\$ (sharing named pipes for communication between programs, such as the remote procedure calls (RPC) used for Microsoft Management Console (MMC) access).

The IPC\$ share contains no share ACLs and cannot be modified—it is strictly used for RPC calls and [Windows disallows anonymous access to these shares by default](#).

The C\$ share allows BUILTIN/Administrators access by default, but Cloud Volumes Service automation removes the share ACL and does not allow access to anyone because access to the C\$ share allows visibility into all mounted volumes in the Cloud Volumes Service file systems. As a result, attempts to navigate to \\SERVER\C\$ fail.

Accounts with local/BUILTIN administrator/backup rights

Cloud Volumes Service SMB servers maintain similar functionality to regular Windows SMB servers in that there are local groups (such as BUILTIN\Administrators) that apply access rights to select domain users and groups.

When you specify a user to be added to Backup Users, the user is added to the BUILTIN\Backup Operators group in the Cloud Volumes Service instance that uses that Active Directory connection, which then gets the [SeBackupPrivilege](#) and [SeRestorePrivilege](#).

When you add a user to Security Privilege Users, the user is given the SeSecurityPrivilege, which is useful in some application use cases, such as [SQL Server on SMB shares](#).

Backup Users

Provide a comma separated list of domain users or a domain group name that require elevated privileges to access volumes created by Cloud Volumes Service.

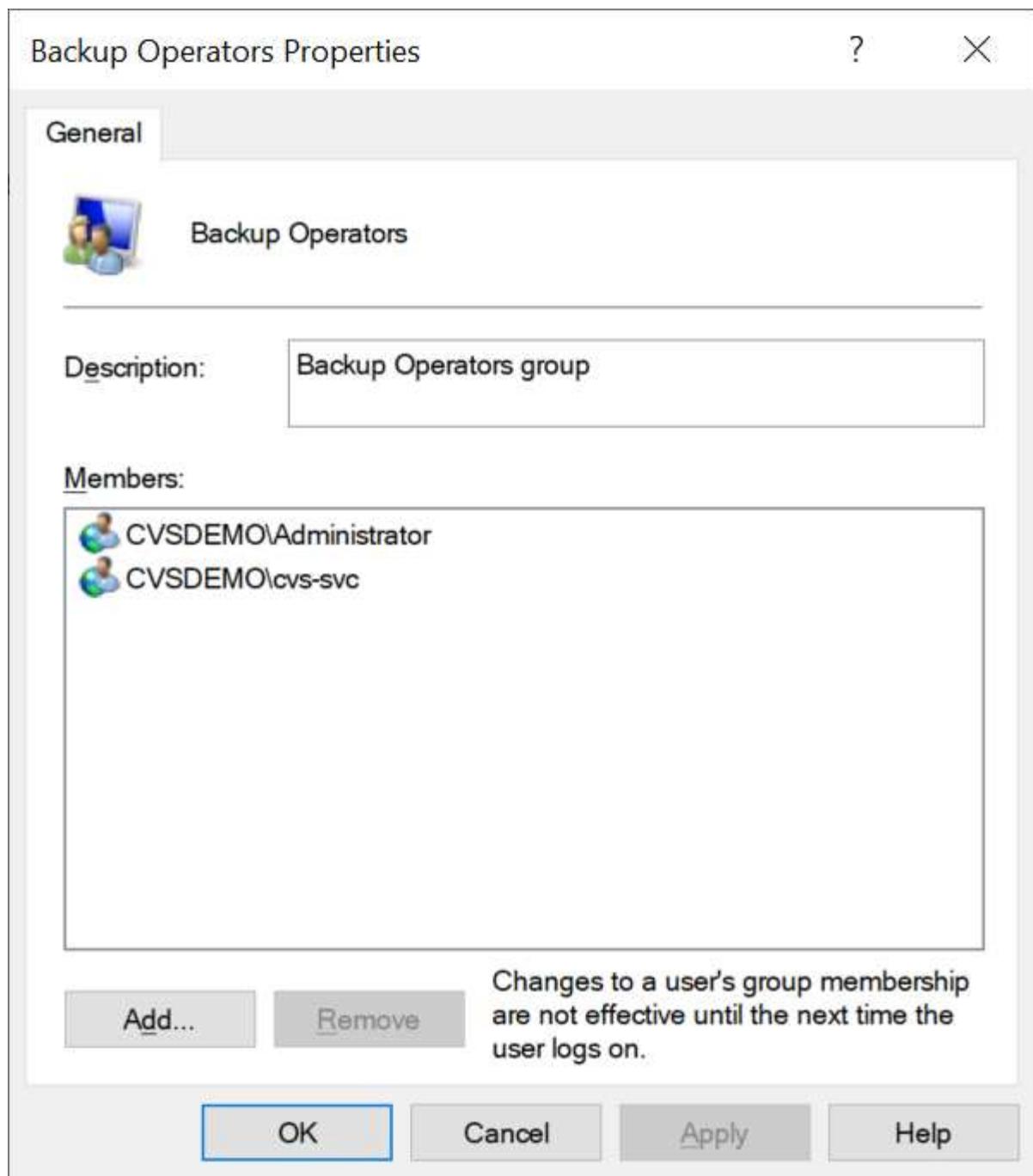
Accountnames —
administrator,cvs-svc

Security Privilege Users

Provide a list of comma separated domain user accounts that require elevated privileges to manage security log for the Active Directory associated with Cloud Volumes Service.

Accountnames —
administrator,cvs-svc

You can view Cloud Volumes Service local group memberships through the MMC with the proper privileges. The following figure shows users that have been added by using the Cloud Volumes Service console.



The following table shows the list of default BUILTIN groups and what users/groups are added by default.

Local/BUILTIN group	Default members
BUILTIN\Administrators*	DOMAIN\Domain Admins
BUILTIN\Backup Operators*	None
BUILTIN\Guests	DOMAIN\Domain Guests
BUILTIN\Power Users	None
BUILTIN\Domain Users	DOMAIN\Domain Users

*Group membership controlled in Cloud Volumes Service Active Directory connection configuration.

You can view local users and groups (and group memberships) in the MMC window, but you cannot add or delete objects or change group memberships from this console. By default, only the Domain Admins group and Administrator are added to the BUILTIN\Administrators group in Cloud Volumes Service. Currently, you cannot modify this.

Computer Management (CVS-EAST-C2DB)	Name	Full Name	Description
System Tools Task Scheduler Event Viewer Shared Folders Shares Sessions Open Files Local Users and Groups Users Groups	Administrator		Built-in administrator account

Computer Management (CVS-EAST-C2DB)	Name	Description
System Tools Task Scheduler Event Viewer Shared Folders Shares Sessions Open Files Local Users and Groups Users Groups	Administrators	Built-in Administrators group
	Users	All users
	Guests	Built-in Guests Group
	Power Users	Restricted administrative privileges
	Backup Operators	Backup Operators group

Administrators Properties

General

Administrators

Description: Built-in Administrators group

Members:

Administrator
CVSDEMO\Domain Admins

Add... Remove

Changes to a user's group membership are not effective until the next time the user logs on.

OK Cancel Apply Help

MMC/Computer Management access

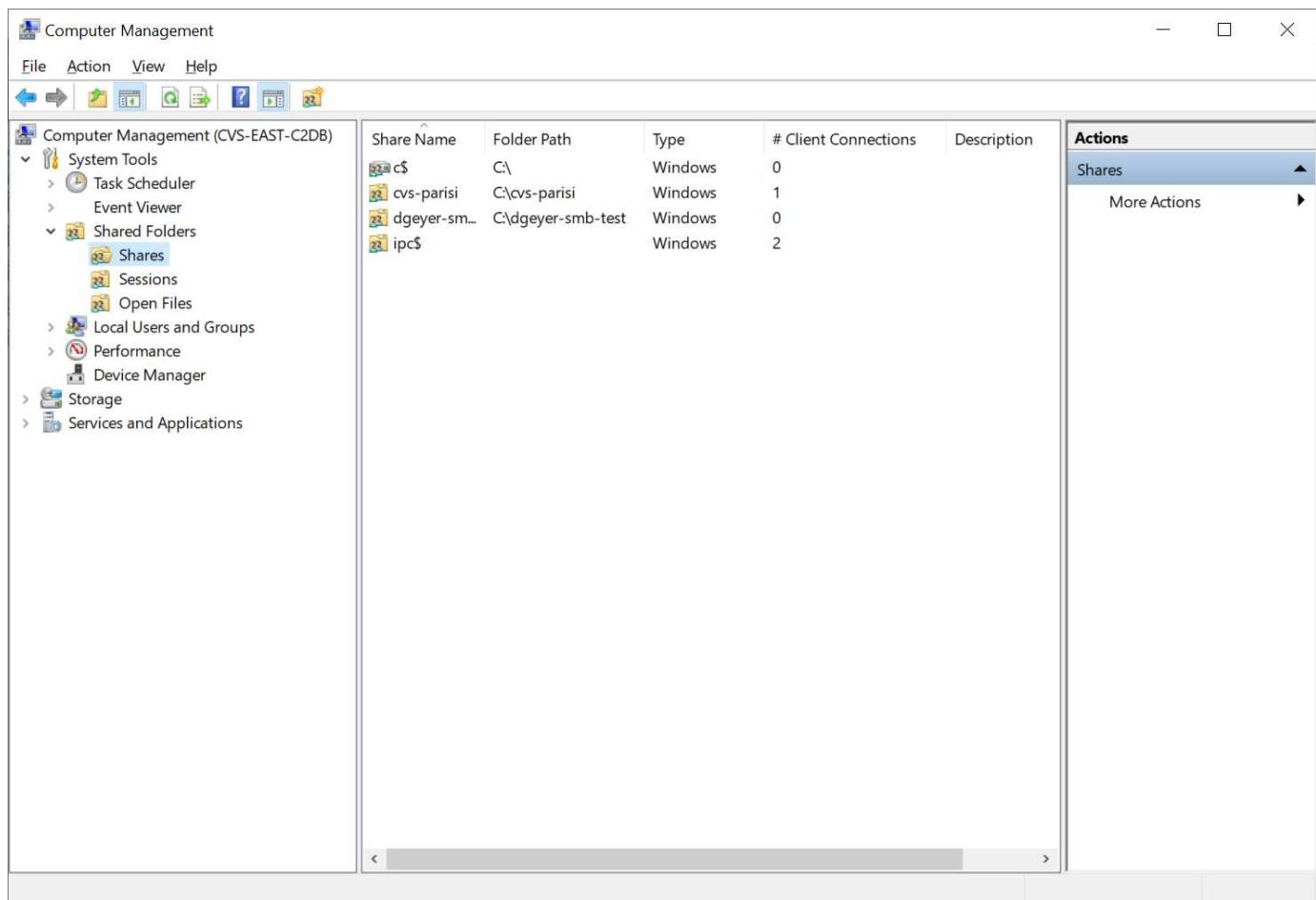
SMB access in Cloud Volumes Service provides connectivity to the Computer Management MMC, which allows you to view shares, manage share ACLs, and view/manage SMB sessions and open files.

To use the MMC to view SMB shares and sessions in Cloud Volumes Service, the user logged in currently must be a domain administrator. Other users are allowed access to view or manage the SMB server from MMC and receive a You Do Not Have Permissions dialog box when attempting to view shares or sessions on the Cloud Volumes Service SMB instance.

To connect to the SMB server, open Computer Management, right click Computer Management and then select Connect To Another Computer. This opens the Select Computer dialog box where you can enter the SMB server name (found in the Cloud Volumes Service volume information).

When you view SMB shares with the proper permissions, you see all available shares in the Cloud Volumes Service instance that share the Active Directory connection. To control this behavior, set the Hide SMB Shares option on the Cloud Volumes Service volume instance.

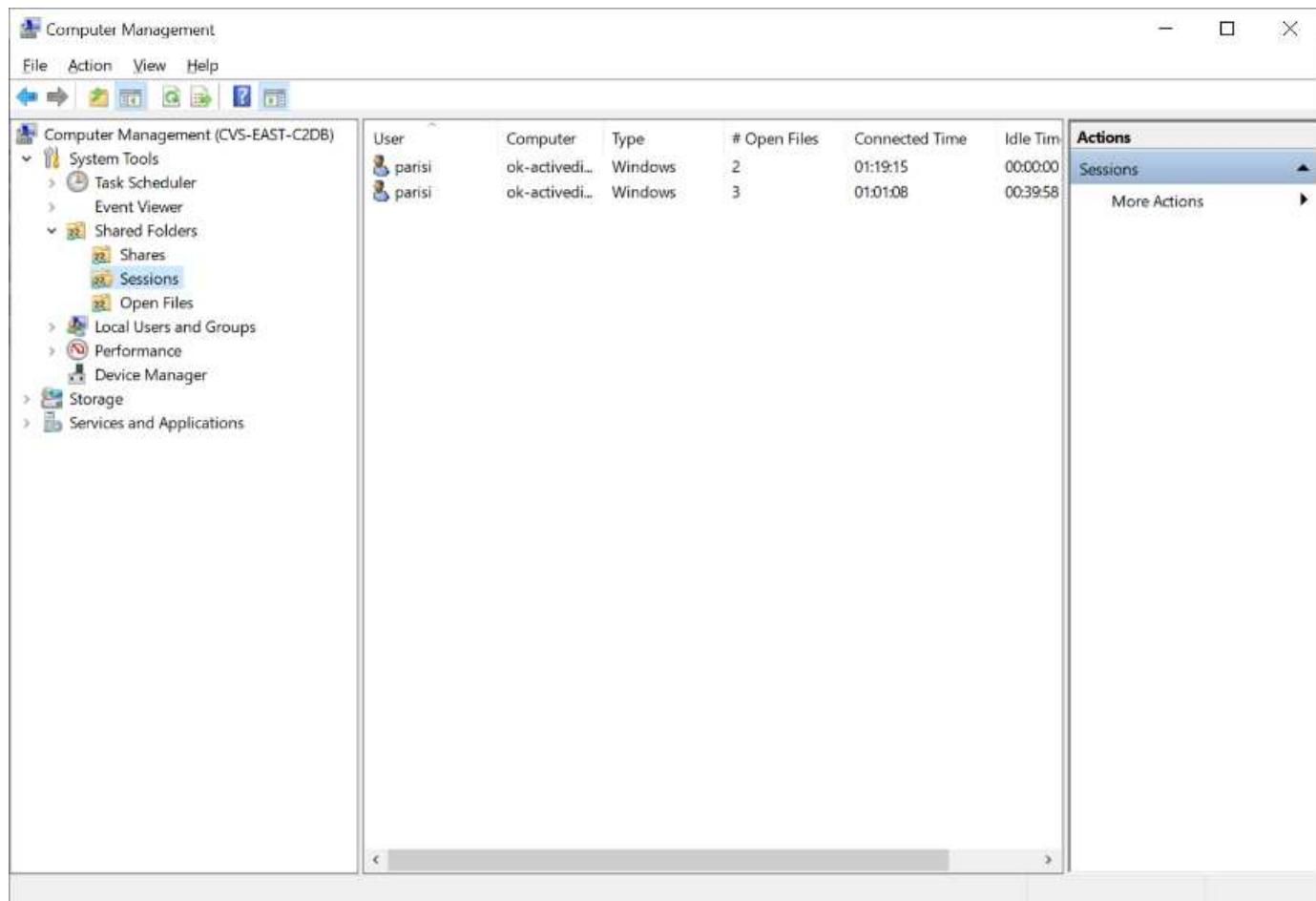
Remember, only one Active Directory connection is allowed per region.



The screenshot shows the Windows Computer Management console window. The left pane displays a tree view of system tools, with 'Shared Folders' expanded to show 'Shares', 'Sessions', and 'Open Files'. The right pane displays a table of SMB shares:

Share Name	Folder Path	Type	# Client Connections	Description
c\$	C:\	Windows	0	
cvs-parisi	C\cvs-parisi	Windows	1	
dgeyer-sm...	C\dgeyer-smb-test	Windows	0	
ipc\$		Windows	2	

The 'Shares' item in the Actions column is selected. A 'More Actions' button is visible in the bottom right corner of the table area.



The following table shows a list of supported/unsupported functionality for the MMC.

Supported functions	Unsupported functions
<ul style="list-style-type: none"> View shares View active SMB sessions View open files View local users and groups View local group memberships Enumerate the list of sessions, files, and tree connections in the system Close open files in the system Close open sessions Create/manage shares 	<ul style="list-style-type: none"> Creating new local users/groups Managing/viewing existing local user/groups View events or performance logs Managing storage Managing services and applications

SMB server security information

The SMB server in Cloud Volumes Service uses a series of options that define security policies for SMB connections, including things such as Kerberos clock skew, ticket age, encryption, and more.

The following table contains a list of those options, what they do, the default configurations, and if they can be modified with Cloud Volumes Service. Some options do not apply to Cloud Volumes Service.

Security option	What it does	Default value	Can change?
Maximum Kerberos Clock Skew (minutes)	Maximum time skew between Cloud Volumes Service and domain controllers. If the time skew exceeds 5 minutes, Kerberos authentication fails. This is set to the Active Directory default value.	5	No
Kerberos Ticket Lifetime (hours)	Maximum time a Kerberos ticket remains valid before requiring a renewal. If no renewal occurs before the 10 hours, you must obtain a new ticket. Cloud Volumes Service performs these renewals automatically. 10 hours is the Active Directory default value.	10	No
Maximum Kerberos Ticket Renewal (days)	Maximum number of days that a Kerberos ticket can be renewed before a new authorization request is needed. Cloud Volumes Service automatically renews tickets for SMB connections. Seven days is the Active Directory default value.	7	No
Kerberos KDC Connection Timeout (secs)	The number of seconds before a KDC connection times out.	3	No
Require Signing for Incoming SMB Traffic	Setting to require signing for SMB traffic. If set to true, clients that do not support signing fail connectivity.	False	
Require Password Complexity for Local User Accounts	Used for passwords on local SMB users. Cloud Volumes Service does not support local user creation, so this option does not apply to Cloud Volumes Service.	True	No

Security option	What it does	Default value	Can change?
Use start_tls for Active Directory LDAP Connections	Used to enable start TLS connections for Active Directory LDAP. Cloud Volumes Service does not currently support enabling this.	False	No
Is AES-128 and AES-256 Encryption for Kerberos Enabled	This controls whether AES encryption is used for Active Directory connections and is controlled with the Enable AES Encryption for Active Directory Authentication option when creating/modifying the Active Directory connection.	False	Yes
LM Compatibility Level	Level of supported authentication dialects for Active Directory connections. See the section “ SMB authentication dialects ” for more information.	ntlmv2-krb	No
Require SMB Encryption for Incoming CIFS Traffic	Requires SMB encryption for all shares. This is not used by Cloud Volumes Service; instead, set encryption on a per-volume basis (see the section “ SMB share security features ”).	False	No
Client Session Security	Sets signing and/or sealing for LDAP communication. This is not currently set in Cloud Volumes Service but might be needed in future releases to address . Remediation for LDAP authentication issues due to the Windows patch is covered in the section “ LDAP channel binding .”.	None	No
SMB2 enable for DC connections	Uses SMB2 for DC connections. Enabled by default.	System-default	No

Security option	What it does	Default value	Can change?
LDAP Referral Chasing	When using multiple LDAP servers, referral chasing allows the client to refer to other LDAP servers in the list when an entry is not found in the first server. This is currently not supported by Cloud Volumes Service.	False	No
Use LDAPS for Secure Active Directory Connections	Enables the use of LDAP over SSL. Currently not supported by Cloud Volumes Service.	False	No
Encryption is required for DC Connection	Requires encryption for successful DC connections. Disabled by default in Cloud Volumes Service.	False	No

[Next: Dual-protocol/multiprotocol.](#)

[Dual-protocol/multiprotocol](#)

[Previous: SMB.](#)

Cloud Volumes Service offers the ability to share the same datasets to both SMB and NFS clients while maintaining proper access permissions ([dual-protocol](#)). This is done by coordinating identity mapping between protocols and using a centralized backend LDAP server to provide the UNIX identities to Cloud Volumes Service. You can use Windows Active Directory to provide both Windows and UNIX users for ease of use.

Access control

- **Share access controls.** Determine which clients and/or user and groups can access a NAS share. For NFS, export policies and rules control client access to exports. NFS exports are managed from the Cloud Volumes Service instance. SMB makes use of CIFS/SMB shares and share ACLs to provide more granular control at the user and group level. You can only configure share-level ACLs from SMB clients by using [MMC/Computer Management](#) with an account that has administrator rights on the Cloud Volumes Service instance (see the section “[Accounts with local/BUILTIN administrator/backup rights.](#)”).
- **File access controls.** Control permissions at a file or folder level and are always managed from the NAS client. NFS clients can make use of traditional mode bits (rwx) or NFSv4 ACLs. SMB clients leverage NTFS permissions.

The access control for volumes that serve data to both NFS and SMB depends on the protocol in use. For information on permissions with dual protocol, see the section “[Permission model](#).”

User mapping

When a client accesses a volume, Cloud Volumes Service attempts to map the incoming user to a valid user in the opposite direction. This is necessary for proper access to be determined across protocols and to ensure that the user requesting access is indeed who they claim to be.

For example, if a Windows user named `joe` attempts access to a volume with UNIX permissions through SMB, then Cloud Volumes Service performs a search to find a corresponding UNIX user named `joe`. If one exists, then files that are written to an SMB share as Windows user `joe` appears as UNIX user `joe` from NFS clients.

Alternately, if a UNIX user named `joe` attempts access to a Cloud Volumes Service volume with Windows permissions, then the UNIX user must be able to map to a valid Windows user. Otherwise, access to the volume is denied.

Currently, only Active Directory is supported for external UNIX identity management with LDAP. For more information about configuring access to this service, see [Creating an AD connection](#).

Permission model

When using dual-protocol setups, Cloud Volumes Service makes use of security styles for volumes to determine the type of ACL. These security styles are set based on which NAS protocol is specified, or in the case of dual protocol, is a choice made at the time of Cloud Volumes Service volume creation.

- If you are only using NFS, Cloud Volumes Service volumes use UNIX permissions.
- If you are only using SMB, Cloud Volumes Service volumes use NTFS permissions.

If you are creating a dual-protocol volume, you can choose the ACL style at volume creation. This decision should be made based on the desired permissions management. If your users manage permissions from Windows/SMB clients, select NTFS. If your users prefer using NFS clients and chmod/chown, use UNIX security styles.

[Next: Considerations for creating Active Directory connections.](#)

Considerations for creating Active Directory connections

[Previous: Dual-protocol/multiprotocol.](#)

Cloud Volumes Service provides the ability to connect your Cloud Volumes Service instance to an external Active Directory server for identity management for both SMB and UNIX users. Creating an Active Directory connection is required to use SMB in Cloud Volumes Service.

The configuration for this provides several options that require some consideration for security. The external Active Directory server can be an on-premises instance or cloud native. If you are using an on-premises Active Directory server, don't expose the domain to the external network (such as with a DMZ or an external IP address). Instead, use secure private tunnels or VPNs, one-way forest trusts, or dedicated network connections to the on-premises networks with [Private Google Access](#). See the Google Cloud documentation for more information about [best practices using Active Directory in Google Cloud](#).

 CVS-SW requires Active Directory servers to be located in the same region. If a DC connection is attempted in CVS-SW to another region, the attempt fails. When using CVS-SW, be sure to create Active Directory sites that include the Active Directory DCs and then specify sites in Cloud Volumes Service to avoid cross-region DC connection attempts.

Active Directory credentials

When SMB or LDAP for NFS is enabled, Cloud Volumes Service interacts with the Active Directory controllers to create a machine account object to use for authentication. This is no different from how a Windows SMB client joins a domain and requires the same access rights to Organizational Units (OUs) in Active Directory.

In many cases, security groups do not allow the use of a Windows administrator account on external servers

such as Cloud Volumes Service. In some cases, the Windows Administrator user is disabled entirely as a security best practice.

Permissions needed to create SMB machine accounts

To add Cloud Volumes Service machine objects to an Active Directory, an account that either has administrative rights to the domain or has [delegated permissions to create and modify machine account objects](#) to a specified OU is required. You can do this with the Delegation of Control Wizard in Active Directory by creating a custom task that provides a user access to creation/deletion of computer objects with the following access permissions provided:

- Read/Write
- Create/Delete All Child Objects
- Read/Write All Properties
- Change/Reset Password

Doing this automatically adds a security ACL for the defined user to the OU in Active Directory and minimizes the access to the Active Directory environment. After a user has been delegated, that username and password can be provided as Active Directory Credentials in this window.



The username and password that is passed to the Active Directory domain leverages Kerberos encryption during the machine account object query and creation for added security.

Active Directory connection details

The [Active Directory Connection Details](#) provide fields for administrators to give specific Active Directory schema information for machine account placement, such as the following:

- **Active Directory Connection Type.** Used to specify whether the Active Directory connection in a region is used for volumes of either Cloud Volumes Service or CVS-Performance service type. If this is set incorrectly on an existing connection, it might not work properly when used or edited.
- **Domain.** The Active Directory domain name.
- **Site.** Limits Active Directory servers to a specific site for security and performance [considerations](#). This is necessary when multiple Active Directory servers span regions because Cloud Volumes Service does not currently support allowing Active Directory authentication requests to Active Directory servers in a different region than the Cloud Volumes Service instance. (For instance, the Active Directory domain controller is in a region that only CVS-Performance supports but you want an SMB share in a CVS-SW instance.)
- **DNS servers.** DNS servers to use in name lookups.
- **NetBIOS name (optional).** If desired, the NetBIOS name for the server. This what is used when new machine accounts are created using the Active Directory connection. For instance, if the NetBIOS name is set to CVS-EAST then the machine account names will be CVS-EAST-{1234}. See the section "[How Cloud Volumes Service shows up in Active Directory](#)" for more information.
- **Organizational Unit (OU).** The specific OU to create the computer account. This is useful if you're delegating control to a user for machine accounts to a specific OU.
- **AES Encryption.** You can also check or uncheck the Enable AES Encryption for AD Authentication checkbox. Enabling AES encryption for Active Directory authentication provides extra security for Cloud Volumes Service to Active Directory communication during user and group lookups. Before enabling this option, check with your domain administrator to confirm that the Active Directory domain controllers support AES authentication.



By default, most Windows servers do not disable weaker ciphers (such as DES or RC4-HMAC), but if you choose to disable weaker ciphers, confirm Cloud Volumes Service Active Directory connection has been configured to enable AES. Otherwise, authentication failures occur. Enabling AES encryption doesn't disable weaker ciphers but instead adds support for AES ciphers to the Cloud Volumes Service SMB machine account.

Kerberos realm details

This option does not apply to SMB servers. Rather, it is used when configuring NFS Kerberos for the Cloud Volumes Service system. When these details are populated, the NFS Kerberos realm is configured (similar to a krb5.conf file on Linux) and is used when NFS Kerberos is specified on the Cloud Volumes Service volume creation, as the Active Directory connection acts as the NFS Kerberos Distribution Center (KDC).



Non-Windows KDCs are currently unsupported for use with Cloud Volumes Service.

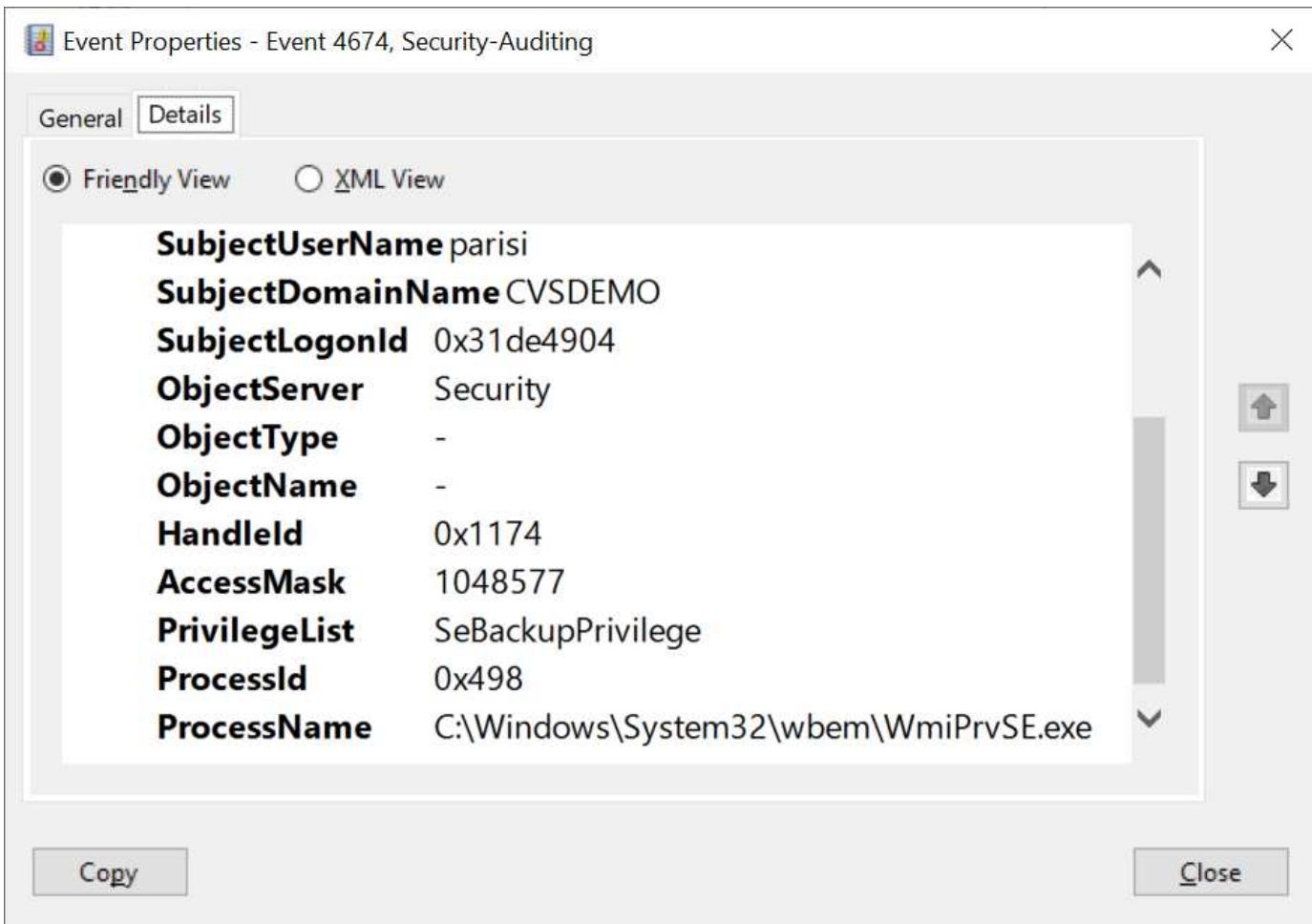
Region

A region enables you to specify the location where the Active Directory connection resides. This region must be the same region as the Cloud Volumes Service volume.

- **Local NFS Users with LDAP.** In this section, there is also an option to Allow Local NFS Users with LDAP. This option must be left unselected if you want to extend your UNIX user group membership support beyond the 16-group limitation of NFS (extended groups). However, using extended groups requires a configured LDAP server for UNIX identities. If you don't have an LDAP server, leave this option unselected. If you have an LDAP server and want to also use local UNIX users (such as root), select this option.

Backup users

This option enables you to specify Windows users that have backup permissions to the Cloud Volumes Service volume. Backup privileges (SeBackupPrivilege) are necessary for some applications to properly backup and restore data in NAS volumes. This user has a high level of access to data in the volume, so you should consider [enabling auditing of that user access](#). After it is enabled, audit events display in Event Viewer > Windows Logs > Security.



Security privilege users

This option enables you to specify Windows users that have security modification permissions to the Cloud Volumes Service volume. Security privileges (SeSecurityPrivilege) are necessary for some applications ([such as SQL Server](#)) to properly set permissions during installation. This privilege is needed to manage the security log. Although this privilege is not as powerful as SeBackupPrivilege, NetApp recommends [auditing user access of users](#) with this privilege level if needed.

For more information, see [Special privileges assigned to new logon](#).

How Cloud Volumes Service shows up in Active Directory

Cloud Volumes Service shows up in Active Directory as a normal machine account object. The naming conventions are as follows.

- CIFS/SMB and NFS Kerberos create separate machine account objects.
- NFS with LDAP enabled creates a machine account in Active Directory for Kerberos LDAP binds.
- Dual protocol volumes with LDAP share the CIFS/SMB machine account for LDAP and SMB.
- CIFS/SMB machine accounts use a naming convention of NAME-1234 (random four digit ID with hyphen appended to <10 character name) for the machine account. You can define NAME by the NetBIOS name setting on the Active Directory connection (see the section "[Active Directory connection details](#)").
- NFS Kerberos uses NFS-NAME-1234 as the naming convention (up to 15 characters). If more than 15 characters are used, the name is NFS-TRUNCATED-NAME-1234.

- NFS-only CVS-Performance instances with LDAP enabled create an SMB machine account for binding to the LDAP server with the same naming convention as CIFS/SMB instances.
- When an SMB machine account is created, default hidden admin shares (see the section “[Default hidden shares](#)”) are also created (c\$, admin\$, ipc\$), but those shares have no ACLs assigned and are inaccessible.
- The machine account objects are placed in CN=Computers by default, but you can specify a different OU when necessary. See the section “[Permissions needed to create SMB machine accounts](#)” for information about what access rights are needed to add/remove machine account objects for Cloud Volumes Service.

When Cloud Volumes Service adds the SMB machine account to Active Directory, the following fields are populated:

- cn (with the specified SMB server name)
- dNSHostName (with SMBserver.domain.com)
- msDS-SupportedEncryptionTypes (Allows DES_CBC_MD5, RC4_HMAC_MD5 if AES encryption is not enabled; if AES encryption is enabled, DES_CBC_MD5, RC4_HMAC_MD5, AES128_CTS_HMAC_SHA1_96, AES256_CTS_HMAC_SHA1_96 are allowed for Kerberos ticket exchange with the machine account for SMB)
- name (with the SMB server name)
- sAMAccountName (with SMBserver\$)
- servicePrincipalName (with host/smbserver.domain.com and host/smbserver SPNs for Kerberos)

If you want to disable weaker Kerberos encryption types (enctype) on the machine account, you can change the msDS-SupportedEncryptionTypes value on the machine account to one of the values in the following table to allow AES only.

msDS-SupportedEncryptionTypes value	Enctype enabled
2	DES_CBC_MD5
4	RC4_HMAC
8	AES128_CTS_HMAC_SHA1_96 only
16	AES256_CTS_HMAC_SHA1_96 only
24	AES128_CTS_HMAC_SHA1_96 and AES256_CTS_HMAC_SHA1_96
30	DES_CBC_MD5, RC4_HMAC, AES128_CTS_HMAC_SHA1_96 and AES256_CTS_HMAC_SHA1_96

To enable AES encryption for SMB machine accounts, click Enable AES Encryption for AD Authentication when creating the Active Directory connection.

To enable AES encryption for NFS Kerberos, [see the Cloud Volumes Service documentation](#).

[Next: Other NAS Infrastructure service dependencies \(KDC, LDAP, DNS\).](#)

[Other NAS Infrastructure service dependencies \(KDC, LDAP, and DNS\)](#)

[Previous: Considerations for creating Active Directory connections.](#)

When using Cloud Volumes Service for NAS shares, there might be external dependencies required for proper functionality. These dependencies are in play under specific circumstances. The following table shows various configuration options and what, if any, dependencies are required.

Configuration	Dependencies required
NFSv3 only	None
NFSv3 Kerberos only	Windows Active Directory: * KDC * DNS * LDAP
NFSv4.1 only	Client ID mapping configuration (/etc/idmap.conf)
NFSv4.1 Kerberos only	<ul style="list-style-type: none"> • Client ID mapping configuration (/etc/idmap.conf) • Windows Active Directory: KDC DNS LDAP
SMB only	Active Directory: * KDC * DNS
Multiprotocol NAS (NFS and SMB)	<ul style="list-style-type: none"> • Client ID mapping configuration (NFSv4.1 only; /etc/idmap.conf) • Windows Active Directory: KDC DNS LDAP

Kerberos keytab rotation/password resets for machine account objects

With SMB machine accounts, Cloud Volumes Service schedules periodic password resets for the SMB machine account. These password resets occur using Kerberos encryption and operate on a schedule of every fourth Sunday at a random time between 11PM and 1AM. These password resets change the Kerberos key versions, rotate the keytabs stored on the Cloud Volumes Service system, and help maintain a greater level of security for SMB servers running in Cloud Volumes Service. Machine account passwords are randomized and are not known to administrators.

For NFS Kerberos machine accounts, password resets take place only when a new keytab is created/exchanged with the KDC. Currently, this is not possible to do in Cloud Volumes Service.

Network ports for use with LDAP and Kerberos

When using LDAP and Kerberos, you should determine the network ports in use by these services. You can find a complete list of ports in use by Cloud Volumes Service in the [Cloud Volumes Service documentation on security considerations](#).

LDAP

Cloud Volumes Service acts as an LDAP client and uses standard LDAP search queries for user and group lookups for UNIX identities. LDAP is necessary if you intend to use users and groups outside the standard

default users provided by Cloud Volumes Service. LDAP is also necessary if you plan on using NFS Kerberos with user principals (such as user1@domain.com). Currently, only LDAP using Microsoft Active Directory is supported.

To use Active Directory as a UNIX LDAP server, you must populate the necessary UNIX attributes on users and groups you intend to use for UNIX identities. Cloud Volumes Service uses a default LDAP schema template that queries attributes based on [RFC-2307-bis](#). As a result, the following table shows the bare minimum necessary Active Directory attributes to populate for users and groups and what each attribute is used for.

For more information about setting LDAP attributes in Active Directory, see [Managing dual-protocol access](#).

Attribute	What it does
uid*	Specifies the UNIX user name
uidNumber*	Specifies the UNIX user's numeric ID
gidNumber*	Specifies the UNIX user's primary group numeric ID
objectClass*	Specifies what type of object is being used; Cloud Volumes Service requires “user” to be included in the list of object classes (is included in most Active Directory deployments by default).
name	General information about the account (real name, phone number, and so on—also known as gecos)
unixUserPassword	No need to set this; not used in UNIX identity lookups for NAS authentication. Setting this puts the configured unixUserPassword value in plaintext.
unixHomeDirectory	Defines path to UNIX home directories when a user authenticates against LDAP from a Linux client. Set this if you want to use LDAP for UNIX home directory functionality.
loginShell	Defines path to the bash/profile shell for Linux clients when a user authenticates against LDAP.

*Denotes attribute is required for proper functionality with Cloud Volumes Service. Remaining attributes are for client-side use only.

Attribute	What it does
cn*	Specifies the UNIX group name. When using Active Directory for LDAP, this is set when the object is first created, but it can be changed later. This name cannot be the same as other objects. For instance, if your UNIX user named user1 belongs to a group named user1 on your Linux client, Windows doesn't allow two objects with the same cn attribute. To work around this, rename the Windows user to a unique name (such as user1-UNIX); LDAP in Cloud Volumes Service uses the uid attribute for UNIX user names.
gidNumber*	Specifies the UNIX group numeric ID.

Attribute	What it does
objectClass*	Specifies what type of object is being used; Cloud Volumes Service requires group to be included in the list of object classes (this attribute is included in most Active Directory deployments by default).
memberUid	Specifies which UNIX users are members of the UNIX group. With Active Directory LDAP in Cloud Volumes Service, this field is not necessary. The Cloud Volumes Service LDAP schema uses the Member field for group memberships.
Member*	Required for group memberships/secondary UNIX groups. This field is populated by adding Windows users to Windows groups. However, if the Windows groups don't have UNIX attributes populated, they are not included in the UNIX user's group membership lists. Any groups that need to be available in NFS must populate the required UNIX group attributes listed in this table.

*Denotes attribute is required for proper functionality with Cloud Volumes Service. Remaining attributes are for client-side use only.

LDAP bind information

To query users in LDAP, Cloud Volumes Service must bind (login) to the LDAP service. This login has read-only permissions and is used to query LDAP UNIX attributes for directory lookups. Currently, LDAP binds are possible only by using an SMB machine account.

You can only enable LDAP for CVS-Performance instances and use it for NFSv3, NFSv4.1, or dual-protocol volumes. An Active Directory connection must be established in the same region as the Cloud Volumes Service volume for successful deployment of the LDAP-enabled volume.

When LDAP is enabled, the following occurs in specific scenarios.

- If only NFSv3 or NFSv4.1 is used for the Cloud Volumes Service project, then a new machine account is created in the Active Directory domain controller, and the LDAP client in Cloud Volumes Service binds to Active Directory by using the machine account credentials. No SMB shares are created for the NFS volume and default hidden administrative shares (see the section “[Default hidden shares](#)”) have share ACLs removed.
- If dual-protocol volumes are used for the Cloud Volumes Service project, then only the single machine account created for SMB access is used to bind the LDAP client in Cloud Volumes Service to Active Directory. No additional machine accounts are created.
- If dedicated SMB volumes are created separately (either before or after NFS volumes with LDAP are enabled), then the machine account for LDAP binds is shared with the SMB machine account.
- If NFS Kerberos is also enabled, two machine accounts are created—one for SMB shares and/or LDAP binds and one for NFS Kerberos authentication.

LDAP queries

Although LDAP binds are encrypted, LDAP queries are passed over the wire in plaintext by using the common LDAP port 389. This well-known port cannot currently be changed in Cloud Volumes Service. As a result,

someone with access to packet sniffing in the network can see user and group names, numeric IDs, and group memberships.

However, Google Cloud VMs cannot sniff other VM's unicast traffic. Only VMs actively participating in LDAP traffic (that is, being able to bind) can see traffic from the LDAP server. For more information about packet sniffing in Cloud Volumes Service, see the section "[Packet sniffing/trace considerations](#)".

LDAP client configuration defaults

When LDAP is enabled in a Cloud Volumes Service instance, an LDAP client configuration is created with specific configuration details by default. In some cases, options either do not apply to Cloud Volumes Service (not supported) or are not configurable.

LDAP client option	What it does	Default value	Can change?
LDAP Server List	Sets LDAP server names or IP addresses to use for queries. This is not used for Cloud Volumes Service. Instead, Active Directory Domain is used to define LDAP servers.	Not set	No
Active Directory Domain	Sets the Active Directory Domain to use for LDAP queries. Cloud Volumes Service leverages SRV records for LDAP in DNS to find LDAP servers in the domain.	Set to the Active Directory domain specified in the Active Directory connection.	No
Preferred Active Directory Servers	Sets the preferred Active Directory servers to use for LDAP. Not supported by Cloud Volumes Service. Instead, use Active Directory sites to control LDAP server selection.	Not set.	No
Bind using SMB Server Credentials	Binds to LDAP by using the SMB machine account. Currently, the only supported LDAP bind method in Cloud Volumes Service.	True	No
Schema Template	The schema template used for LDAP queries.	MS-AD-BIS	No
LDAP Server Port	The port number used for LDAP queries. Cloud Volumes Service currently uses only the standard LDAP port 389. LDAPS/port 636 is not currently supported.	389	No

LDAP client option	What it does	Default value	Can change?
Is LDAPS Enabled	Controls whether LDAP over Secure Sockets Layer (SSL) is used for queries and binds. Currently not supported by Cloud Volumes Service.	False	No
Query Timeout (sec)	Timeout for queries. If queries take longer than the specified value, queries fail.	3	No
Minimum Bind Authentication Level	The minimum supported bind level. Because Cloud Volumes Service uses machine accounts for LDAP binds and Active Directory does not support anonymous binds by default, this option does not come into play for security.	Anonymous	No
Bind DN	The user/distinguished name (DN) used for binds when simple bind is used. Cloud Volumes Service uses machine accounts for LDAP binds and does not currently support simple bind authentication.	Not set	No
Base DN	The base DN used for LDAP searches.	The Windows domain used for the Active Directory connection, in DN format (that is, DC=domain, DC=local).	No
Base search scope	The search scope for base DN searches. Values can include base, onelevel, or subtree. Cloud Volumes Service only supports subtree searches.	Subtree	No
User DN	Defines the DN where user searches start for LDAP queries. Currently not supported for Cloud Volumes Service, so all user searches start at the base DN.	Not set	No

LDAP client option	What it does	Default value	Can change?
User search scope	The search scope for user DN searches. Values can include base, onlevel, or subtree. Cloud Volumes Service does not support setting the user search scope.	Subtree	No
Group DN	Defines the DN where group searches start for LDAP queries. Currently not supported for Cloud Volumes Service, so all group searches start at the base DN.	Not set	No
Group search scope	The search scope for group DN searches. Values can include base, onlevel, or subtree. Cloud Volumes Service does not support setting the group search scope.	Subtree	No
Netgroup DN	Defines the DN where netgroup searches start for LDAP queries. Currently not supported for Cloud Volumes Service, so all netgroup searches start at the base DN.	Not set	No
Netgroup search scope	The search scope for netgroup DN searches. Values can include base, onlevel, or subtree. Cloud Volumes Service does not support setting the netgroup search scope.	Subtree	No
Use start_tls over LDAP	Leverages Start TLS for certificate based LDAP connections over port 389. Currently not supported by Cloud Volumes Service.	False	No
Enable netgroup-by-host lookup	Enables netgroup lookups by hostname rather than expanding netgroups to list all members. Currently not supported by Cloud Volumes Service.	False	No

LDAP client option	What it does	Default value	Can change?
Netgroup-by-host DN	Defines the DN where netgroup-by-host searches start for LDAP queries. Netgroup-by-host is currently not supported for Cloud Volumes Service.	Not set	No
Netgroup-by-host search scope	The search scope for netgroup-by-host DN searches. Values can include base, onlevel or subtree. Netgroup-by-host is currently not supported for Cloud Volumes Service.	Subtree	No
Client session security	Defines what level of session security is used by LDAP (sign, seal, or none). LDAP signing is supported by Cloud Volumes Service, but sealing is not currently supported.	None	No
LDAP referral chasing	When using multiple LDAP servers, referral chasing allows the client to refer to other LDAP servers in the list when an entry is not found in the first server. This is currently not supported by Cloud Volumes Service.	False	No
Group membership filter	Provides a custom LDAP search filter to be used when looking up group membership from an LDAP server. Not currently supported with Cloud Volumes Service.	Not set	No

Using LDAP for asymmetric name mapping

Cloud Volumes Service, by default, maps Windows users and UNIX users with identical usernames bidirectionally without special configuration. As long as Cloud Volumes Service can find a valid UNIX user (with LDAP), then 1:1 name mapping occurs. For instance, if Windows user `johndoe` is used, then, if Cloud Volumes Service can find a UNIX user named `johndoe` in LDAP, name mapping succeeds for that user, all files/folders created by `johndoe` show the correct user ownership, and all ACLs affecting `johndoe` are honored regardless of the NAS protocol in use. This is known as symmetric name mapping.

Asymmetric name mapping is when the Windows user and UNIX user identity don't match. For instance, if

Windows user `johndoe` has a UNIX identity of `jsmith`, Cloud Volumes Service needs a way to be told about the variation. Because Cloud Volumes Service currently doesn't support creation of static name mapping rules, LDAP must be used to look up the identity of the users for both Windows and UNIX identities to ensure proper ownership of files and folders and expected permissions.

By default, Cloud Volumes Service includes LDAP in the ns-switch of the instance for the name map database, so that to provide name mapping functionality by using LDAP for asymmetric names, you only need to modify some of the user/group attributes to reflect what Cloud Volumes Service looks for.

The following table shows what attributes must be populated in LDAP for asymmetric name mapping functionality. In most cases, Active Directory is already configured to do this.

Cloud Volumes Service attribute	What it does	Value used by Cloud Volumes Service for name mapping
Windows to UNIX objectClass	Specifies the type of object being used. (That is, user, group, posixAccount, and so on)	Must include user (can contain multiple other values, if desired.)
Windows to UNIX attribute	that defines the Windows username at creation. Cloud Volumes Service uses this for Windows to UNIX lookups.	No change needed here; sAMAccountName is the same as the Windows login name.
UID	Defines the UNIX username.	Desired UNIX username.

Cloud Volumes Service currently does not use domain prefixes in LDAP lookups, so multiple domain LDAP environments do not function properly with LDAP namemap lookups.

The following example shows a user with the Windows name `asymmetric`, the UNIX name `unix-user`, and the behavior it follows when writing files from both SMB and NFS.

The following figure shows how LDAP attributes look from the Windows server.

asymmetric Properties

?

X

Published Certificates		Member Of		Password Replication		Dial-in	Object									
Security		Environment		Sessions		Remote control										
General	Address	Account	Profile	Telephones	Organization											
Remote Desktop Services Profile			COM+		Attribute Editor											
Attributes:																
Attribute	Value															
name	asymmetric															
objectCategory	CN=Person,CN=Schema,CN=Configuration,															
objectClass	top; person; organizationalPerson; user															
objectGUID	de489556-dd7b-43a3-98fa-2722f79d67ed															
objectSid	S-1-5-21-3552729481-4032800560-2279794															
primaryGroupID	513 = (GROUP_RID_USERS)															
pwdLastSet	1/19/2017 1:56:34 PM Eastern Standard Time															
replPropertyMetaData	AttID	Ver	Loc.USN	Org.DSA												
sAMAccountName	asymmetric															
sAMAccountType	805306368 = (NORMAL_USER_ACCOUNT)															
uid	unix-user															
uidNumber	1207															

From an NFS client, you can query the UNIX name but not the Windows name:

```
# id unix-user
uid=1207(unix-user) gid=1220(sharedgroup) groups=1220(sharedgroup)
# id asymmetric
id: asymmetric: no such user
```

When a file is written from NFS as unix-user, the following is the result from the NFS client:

```
sh-4.2$ pwd
/mnt/home/ntfssh-4.2$ touch unix-user-file
sh-4.2$ ls -la | grep unix-user
-rwx----- 1 unix-user sharedgroup      0 Feb 28 12:37 unix-user-nfs
sh-4.2$ id
uid=1207(unix-user) gid=1220(sharedgroup) groups=1220(sharedgroup)
```

From a Windows client, you can see that the owner of the file is set to the proper Windows user:

```
PS C:\ > Get-Acl \\demo\home\ntfs\unix-user-nfs | select Owner  
Owner  
----  
NTAP\asymmetric
```

Conversely, files created by the Windows user `asymmetric` from an SMB client show the proper UNIX owner, as shown in the following text.

SMB:

```
PS Z:\ntfs> echo TEXT > asymmetric-user-smb.txt
```

NFS:

```
sh-4.2$ ls -la | grep asymmetric-user-smb.txt  
-rwx----- 1 unix-user sharedgroup 14 Feb 28 12:43 asymmetric-  
user-smb.txt  
sh-4.2$ cat asymmetric-user-smb.txt  
TEXT
```

LDAP channel binding

Because of a vulnerability with Windows Active Directory domain controllers, [Microsoft Security Advisory ADV190023](#) changes how DCs allow LDAP binds.

The impact for Cloud Volumes Service is the same as for any LDAP client. Cloud Volumes Service does not currently support channel binding. Because Cloud Volumes Service supports LDAP signing by default through negotiation, LDAP channel binding should not be an issue. If you do have issues binding to LDAP with channel binding enabled, follow the remediation steps in ADV190023 to allow LDAP binds from Cloud Volumes Service to succeed.

DNS

Active Directory and Kerberos both have dependencies on DNS for host name to IP/IP to host name resolution. DNS requires port 53 to be open. Cloud Volumes Service does not make any modifications to DNS records, nor does it currently support the use of [dynamic DNS](#) on network interfaces.

You can configure Active Directory DNS to restrict which servers can update DNS records. For more information, see [Secure Windows DNS](#).

Note that resources within a Google project default to using Google Cloud DNS, which isn't connected with Active Directory DNS. Clients using Cloud DNS cannot resolve UNC paths returned by Cloud Volumes Service. Windows clients joined to the Active Directory domain are configured to use Active Directory DNS and can resolve such UNC paths.

To join a client to Active Directory, you must configure its DNS configuration to use Active Directory DNS.

Optionally, you can configure Cloud DNS to forward requests to Active Directory DNS. See [Why can't my client resolve the SMB NetBIOS name?](#) for more information.



Cloud Volumes Service does not currently support DNSSEC and DNS queries are performed in plaintext.

File access auditing

Currently not supported for Cloud Volumes Service.

Antivirus protection

You must perform antivirus scanning in Cloud Volumes Service at the client to a NAS share. There is currently no native antivirus integration with Cloud Volumes Service.

[Next: Service operation.](#)

Service operation

[Previous: Other NAS Infrastructure service dependencies \(KDC, LDAP, DNS\).](#)

The Cloud Volumes Service team manages the backend services in Google Cloud and uses multiple strategies to secure the platform and prevent unwanted access.

Each customer gets their own unique subnet that has access fenced off from other customers by default, and every tenant in Cloud Volumes Service gets their own namespace and VLAN for total data isolation. After a user is authenticated, the Service Delivery Engine (SDE) can only read configuration data specific to that tenant.

Physical security

With proper preapproval, only onsite engineers and NetApp-badged Field Support Engineers (FSEs) have access to the cage and racks for physical work. Storage and network management is not permitted. Only these onsite resources are able to perform hardware maintenance tasks.

For onsite engineers, a ticket is raised for the statement of work (SOW) that includes the rack ID and device location (RU) and all other details are included in the ticket. For NetApp FSEs, a site visitation ticket must be raised with the COLO and the ticket includes the visitor's details, date, and time for auditing purposes. The SOW for the FSE is communicated internally to NetApp.

Operations team

The operations team for Cloud Volumes Service consists of Production Engineering and a Site Reliability Engineer (SRE) for Cloud Volume Services and NetApp Field Support Engineers and Partners for hardware. All operations team members are accredited for work in Google Cloud and detailed records of work are maintained for every ticket raised. In addition, there is a stringent change control and approval process in place to ensure each decision is appropriately scrutinized.

The SRE team manages the control plane and how the data is routed from UI requests to backend hardware and software in Cloud Volumes Service. The SRE team also manages system resources, such as volume and inode maximums. SREs are not allowed to interact with or have access to customer data. SREs also provide coordination with Return Material Authorizations (RMAs), such as new disk or memory replacement requests for the backend hardware.

Customer responsibilities

Customers of Cloud Volumes Service manage their organization's Active Directory and user role management as well as the volume and data operations. Customers can have administrative roles and can delegate permissions to other end users within the same Google Cloud project using the two predefined roles that NetApp and Google Cloud provide (Administrator and Viewer).

The administrator can peer any VPC within the customer project to Cloud Volumes Service that the customer determines to be appropriate. It is the responsibility of the customer to manage access to their Google Cloud marketplace subscription and to manage the VPCs that have access to the data plane.

Malicious SRE protection

One concern that could arise is how does Cloud Volumes Service protect against scenarios in which there is a malicious SRE or when SRE credentials have been compromised?

Access to the production environment is with a limited number of SRE individuals only. Administrative privileges are further restricted to a handful of experienced administrators. All actions performed by anyone in the Cloud Volumes Service production environment are logged and any anomalies to the baseline or suspicious activities are detected by our security information and event management (SIEM) threat intelligence platform. As a result, malicious actions can be tracked and mitigated before too much damage is done to the Cloud Volumes Service backend.

Volume life cycle

Cloud Volumes Service manages only the objects within the service—not the data within the volumes. Only clients accessing the volumes can manage the data, the ACLs, file owners, and so on. The data in these volumes is encrypted at rest and access is limited to tenants of the Cloud Volumes Service instance.

The volume lifecycle for Cloud Volumes Service is create-update-delete. Volumes retain Snapshot copies of volumes until the volumes are deleted, and only validated Cloud Volumes Service administrators can delete volumes in Cloud Volumes Service. When a volume deletion is requested by an administrator, an additional step of entering the volume name is required to verify the deletion. After a volume is deleted, the volume is gone and cannot be recovered.

In cases where a Cloud Volumes Service contract is terminated, NetApp marks volumes for deletion after a specific time period. Before that time period expires, you can recover volumes at the customer's request.

Certifications

Cloud Volumes Services for Google Cloud is currently certified to ISO/IEC 27001:2013 and ISO/IEC 27018:2019 standards. The service also recently received its SOC2 Type I attestation report. For information about the NetApp commitment to data security and privacy, see [Compliance: Data security and data privacy](#).

GDPR

Our commitments to privacy and compliance with GDPR are available in a number of our [customer contracts](#), such as our [Customer Data Processing Addendum](#), which includes the [Standard Contractual Clauses](#) provided by the European Commission. We also make these commitments in our Privacy Policy, backed by the core values set out in our corporate Code of Conduct.

[Next: Additional information, version history, and contact information.](#)

Additional information, version history, and contact information

[Previous: Service operation.](#)

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

- Google Cloud documentation for Cloud Volumes Service

<https://cloud.google.com/architecture/partners/netapp-cloud-volumes/>

- Google private service access

https://cloud.google.com/vpc/docs/private-services-access?hl=en_US

- NetApp product documentation

<https://www.netapp.com/support-and-training/documentation/>

- Cryptographic Validation Module Program—NetApp CryptoMod

<https://csrc.nist.gov/projects/cryptographic-module-validation-program/certificate/4144>

- The NetApp Solution for Ransomware

<https://www.netapp.com/pdf.html?item=/media/16716-sb-3938pdf.pdf&v=202093745>

- TR-4616: NFS Kerberos in ONTAP

<https://www.netapp.com/pdf.html?item=/media/19384-tr-4616.pdf>

Version history

Version	Date	Document version history
Version 1.0	May 2022	Initial release.

Contact us

Let us know how we can improve this technical report.

Contact us at doccomments@netapp.com. Include TECHNICAL REPORT 4918 in the subject line.

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