White Paper

Why your SAN needs NetApp for virtualization and enterprise apps

NetApp AFF storage for the hybrid multicloud

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1. Executive summary

For three decades, storage area networks (SANs) have provided high-speed data access for storage and servers. These dedicated storage networks offer more than just speed; a SAN provides a disaggregated architecture that enables servers and storage to scale independently. Multiprotocol is a part of SAN topologies, with options for NVMe, iSCSI, and Fibre Channel Protocols (FCPs) providing additional performance and scale to the storage network. Although there are other storage architectures, SAN storage systems have proven to be the most secure, resilient, and efficient for reliable data protection and recovery. Block storage systems dominate the on-premises storage landscape, making up about two-thirds of the total networked storage market. Principal market analyst Casey Quillin of Quillin Research estimates that there are more than 37 million Fibre Channel ports in use today.

What SAN means at NetApp

Tens of thousands of customers rely on NetApp for mission-critical SAN applications. Industry-leading NetApp® systems allow you to build a simplified SAN that gives you continuous access to mission-critical databases during both planned and unplanned events. NetApp AFF systems offer unified storage SAN and NAS storage, and NetApp AFF All SAN Array (ASA) systems offer SAN-only storage. Both include NetApp's storage efficiency, encryption, data protection, and ultra-fast response times to accelerate Oracle, SAP, and Microsoft applications.

NetApp SAN deployments enable you to:

- Meet strict performance and uptime service level objectives.
- Perform planned maintenance and upgrades with data services intact.
- Prevent business disruptions due to ransomware attacks, storage and fabric failures, application errors, and site disasters.
- Take advantage of unparalleled cloud connectivity for backup data protection, analytics, and automatic cold data storage.

The view from the top: Industry analyst's view of SAN storage

The Evaluator Group's SAN Storage Evaluation Guide gives IT professionals a tool to evaluate storage technology alternatives. This guide grades the vendors on 10 important criteria: Capacity, Price, Performance, Scaling, Security, Data Protection, Business Continuity, Economics, Technology, and Integration. NetApp AFF achieved better scores than Dell EMC PowerMax, PowerStore, and Unity XT in many of the 10 categories, and none of these Dell EMC products surpassed NetApp in any of the categories. For detailed results, see Figure 2, later in this paper.

This paper explores SAN solutions applied to a diverse set of customer workloads that involve virtualization (VMware vSphere, Microsoft Hyper-V, etc.) and enterprise applications (Oracle, SAP, SQL, etc.). SANs have successfully evolved to address these business-critical workloads.

NetApp can address the most diverse set of workloads by using SAN block (NVMe, iSCSI, Fibre Channel), NAS file (NFS, SMB), cloud object protocols (S3), and hybrid storage. The following NetApp portfolio of products and services addresses every workload requirement.

- **Hybrid multicloud storage**
  NetApp offers the most feature-rich hybrid cloud storage solution across multiple private and public clouds, including support for the big three public clouds. The solution addresses public cloud workloads with Microsoft (Azure NetApp Files), Amazon (Amazon FSx for NetApp ONTAP), and Google Cloud (Cloud Volumes Service for Google Cloud). It also supports private cloud workloads (NetApp ASA, AFF, FAS, and ONTAP® Select).

- **Cloud services for storage and data management**
  NetApp's robust, enterprise-class set of software manages storage across multiple private, public, and hybrid clouds, including:
  - **NetApp Cloud Manager.** Unified single-pane-of-glass management.
  - **NetApp Cloud Insights.** Monitor, troubleshoot, and optimize workloads.
  - **Cloud Sync.** Secure, fast, automated data synchronization.
  - **NetApp Cloud Data Sense.** Data discovery, mapping, and classification.
  - **NetApp Cloud Tiering.** Automated migration of cold data to S3 object storage.
  - **NetApp Cloud Backup.** Data protection and long-term archiving.
  - **NetApp SAS Backup.** Data protection for Microsoft 365.
  - **Global File Cache.** Performance optimization by caching active datasets across a global namespace.

- **Storage-as-a-service options**
  NetApp customers can deploy SAN storage arrays with either on-premises capital expenditures or operating expense as a service model. NetApp Keystone™ provides the flexibility of the right mix of payment, subscription, and usage-based services that can be managed by NetApp, by channel partners, or directly by the customer. Keystone Flex Pay is a capex-friendly, consumption-based payment solution to meet the customer's cash flow needs. Keystone Flex Subscription is an opex-friendly, pay-as-you-grow, subscription-based service that brings a cloudlike experience on premises. Keystone Flex Utility is a true utility service that aligns costs with actual usage, using one subscription for "on-premises" and cloud services.

NetApp best practices for SAN storage

NetApp offers a complementary tool called SAN Health that can perform a thorough health check of a customer's entire SAN environment to optimize and document the overall SAN infrastructure. The result is a report that includes insights into performance, storage components, configurations, bottlenecks, and even potential problems that can be avoided proactively before they impact production.

Several documents are available from NetApp that address best practices for SAN storage. The Best Practices for Modern SAN: ONTAP 9 technical report is an overview of the block protocols in ONTAP data management software as well as best-practice recommendations. Other relevant documents include the ONTAP 9 SAN Administration Guide and the ONTAP 9 SAN Configuration Guide. Refer to these and other documents for details about SAN best practices.

2. What differentiates SAN storage?

Introduction

Opinions about SAN storage differ based on many factors, so this section uses the Evaluator Group as a source of objective information, assessments, and opinions about NetApp and other products. The Evaluator Group, an independent analyst firm that delivers unbiased reports for information technology products, publishes a SAN Storage Evaluation Guide. This guide includes the Evaluator Group EvaluScale requirements and offers criteria and opinions for making product decisions.

References:

- Evaluator Group SAN Storage Evaluation Guide
- Evaluator Group Product Brief: NetApp AFF
- Evaluator Group Product Brief: Dell EMC PowerMax
- Evaluator Group Product Brief: Dell EMC PowerStore
- Evaluator Group Product Brief: Dell EMC Unity XT
- Evaluator Group SAN High-End Comparison Matrix
- Evaluator Group SAN Midrange Comparison Matrix
- Evaluator Group NAS System Matrix High-End Systems
- Evaluator Group NAS System Matrix Mid-Tier Systems

Evaluator Group's expectations for SAN storage

As the demands on SAN storage expand, so do expectations. EvaluScale for SAN Storage Systems shares Evaluator Group assessments about whether a product "exceeds requirements," "meets requirements," or is an "area for development" for each of 10 criteria, as shown in Figure 1.

Capacity	Price	Performance	Scaling	Security
Data Protection	Business Continuity	Economic Considerations	Storage Technology	Application/ System Integration

Figure 1) Evaluator Group EvaluScale criteria for SAN storage.

The Evaluator Group reports that NetApp AFF surpasses Dell EMC PowerMax in 3 of 10, PowerStore in 6 of 10, and Unity XT in 5 of 10 EvaluScale criteria, as shown in Figure 2. Unlike Dell EMC, NetApp AFF did not receive an "area for development" rating for any of the criteria, and Dell does not surpass NetApp in any of the categories. SAN is a mature architecture, so it's not surprising that EvaluScale opinions of industry-leading products are similar for some SAN storage criteria. Product briefs by the Evaluator Group for each product offer details for EvaluScale requirements, views (assessments), and explanations (opinions).

	Criteria	Description	NetApp AFF	Dell EMC PowerMax	Dell EMC PowerStore	Dell EMC Unity XT
1	Capacity	Current capacity of system to meet demand	Meets Requirements	Meets Requirements	Meets Requirements	Meets Requirements
2	Price	Cost of the system including the effect of data reduction	Exceeds Requirements	Meets Requirements	Meets Requirements	Meets Requirements
3	Performance	Latency, IOPS, and bandwidth	Meets Requirements	Area for development	Area for development	Area for development
4	Scaling	Ability to increase to meet future demands	Exceeds Requirements	Exceeds Requirements	Meets Requirements	Area for development
5	Security	Data-at-rest encryption and key management	Exceeds Requirements	Exceeds Requirements	Meets Requirements	Exceeds Requirements
6	Data Protection	Snapshots (large number), tiering to cloud, replication	Exceeds Requirements	Exceeds Requirements	Area for development	Exceeds Requirements
7	Business Continuity	Active-active stretched clusters	Meets Requirements	Meets Requirements	Area for development	Area for development
8	Economic Considerations	Warranty, power, space, updating, and simplicity	Exceeds Requirements	Meets Requirements	Exceeds Requirements	Meets Requirements
9	Storage Technology	Use of solid-state tech as storage and for caching	Exceeds Requirements	Exceeds Requirements	Meets Requirements	Meets Requirements
10	App/System integration	VMware and Microsoft integration	Exceeds Requirements	Exceeds Requirements	Exceeds Requirements	Exceeds Requirements

Figure 2) EvaluScale assessments for NetApp AFF, Dell EMC PowerStore, and Dell EMC Unity XT SAN storage.

NetApp versus Dell EMC: Reviewing advanced features for SAN storage criteria

After decades of functional development and technological advancement, SAN storage has evolved to offer rich collections of capabilities for diverse workloads running in cloud, core, and edge environments. Product feature lists generally available from brochures and datasheets show that capabilities differ among brands and models of SAN storage. Evaluator Group takes evaluation one crucial step further by reviewing advanced features of importance for SAN storage systems. As an example of vendor differentiation, the Evaluator Group cites two forms of data tiering as advanced features of importance. As shown in Figure 3, NetApp AFF natively delivers both, while Dell EMC PowerScale and Unity XT deliver neither, and PowerMax offers only one.

Advanced Features of Importance	NetApp AFF	Dell EMC PowerMax	Dell EMC PowerStore	Dell EMC Unity XT
Tiering between devices of different performance and cost	Yes	Yes	No	No
Tiering to cloud/object storage with LUNs assigned to cloud storage pools for data protection or storage expansion	Yes	No	No	No

Figure 3) Examples of Evaluator Group advanced features of importance, based on Evaluator Group SAN Storage Evaluation Guide, Evaluator Group SAN High-End Comparison Matrix, Evaluator Group SAN Midrange Comparison Matrix, Evaluator Group NAS System Matrix High-End Systems, and Evaluator Group NAS System Matrix Mid-Tier Systems.

NetApp versus Dell EMC: Storage workload comparison

The diversity of databases, applications, and services in use today generates many types of workloads for SAN storage. Typical SAN storage supports workloads by using block protocols like Fibre Channel (FC) and iSCSI. Advanced SAN storage goes beyond supporting FC and iSCSI to also support workloads by using more block storage protocols like NVMe “end to end,” across drives, controllers, networks, and hosts. These protocols use TCP and FC networks to deliver storage at lower latency than is possible with FC or iSCSI protocols. The use of NVMe protocols lowers CPU utilization, which is especially beneficial for latency-sensitive databases and applications and storage workloads with high levels of small-sized I/O. Modern unified storage goes even further to support the most diverse set of workloads by using SAN block, NAS file, and cloud object protocols.

Types of Storage Protocols and Sharing Support	NetApp AFF	Dell EMC PowerMax	Dell EMC PowerStore	Dell EMC Unity XT
NVMe end-to-end block	Yes	Yes	Yes *	No
Fibre Channel and iSCSI block	Yes	Yes	Yes	Yes
Native NFS and SMB file	Yes	No	Yes	Yes
Native S3 object	Yes	No	No	No

Figure 4) Comparison of supported storage workloads based on Evaluator Group SAN Storage Evaluation Guide, Evaluator Group SAN High-End Comparison Matrix, Evaluator Group SAN Midrange Comparison Matrix, Evaluator Group NAS System Matrix High-End Systems, and Evaluator Group NAS System Matrix Mid-Tier System.

* Supported when using internal NVMe drives only. External SAS drives do not support NVMe.

As shown in Figure 4, NetApp AFF is a modern unified storage system that supports all block, file, and object storage workloads. Dell EMC PowerMax, PowerStore, and Unity XT are typical SAN storage with basic NAS protocol support. In other words, NetApp AFF simultaneously provides storage for workloads as diverse as virtual machines and containers, plus traditional enterprise databases and modern workloads, analytics, and AI applications.

Summary

Research published by the Evaluator Group shows that NetApp AFF meets or exceeds the expectations of the EvaluScale criteria, outperforming Dell EMC PowerMax, PowerStore, and Unity XT on these criteria. These findings show why NetApp AFF is always worthy of consideration as a SAN storage solution, although the reasons for considering NetApp AFF increase when storage capabilities and workloads are considered.

NetApp AFF supports many essential capabilities (that is, the Evaluator Group advanced features of importance). These capabilities include data tiering between devices of different performance and cost, plus tiering to cloud/object storage with LUNs assigned to clouds storage pools for data protection or storage expansion. Also, NetApp AFF includes many features detailed in Evaluator Group product briefs that support more diverse workloads by using advanced SAN block storage with end-to-end NVMe, modern SAN block storage, and modern unified storage protocol support.

3. Virtual machine workloads

Introduction

In 2001, VMware released its ESX Server software (a hypervisor) for the x86 platform with the ability to consolidate multiple virtual (software-based) servers onto fewer physical (hardware-based) servers. The use of hypervisors and virtual machines became increasingly popular, and Microsoft (as Hyper-V), the Linux Foundation (as KVM), and others released hypervisors within a decade.

In contemporary information technology, a virtual machine (VM) is represented by specialized software (a hypervisor) that divides a physical computing device (for example, a server) into multiple logical devices, with each running a separate software package (workloads). This creates a virtual server infrastructure for database and application computing and a virtual desktop infrastructure (VDI) for end-user computing (EUC). The virtualization solutions from VMware, Microsoft, and others offer sophisticated capabilities for virtual machines, but they lack the matching enterprise storage and data management capabilities needed to support the growing size, complexity, and diversity of VM workloads.

NetApp offers a broad variety of public cloud and enterprise-grade solutions that are hypervisor agnostic to support all virtual machine workloads, including the following solutions, products, and services:

- NetApp Keystone storage as a service
- FlexPod converged infrastructure solutions from NetApp and Cisco
- NetApp ASA, AFF, and FAS storage system products
- NetApp ONTAP Select and NetApp MetroCluster SDS storage software products
- Azure NetApp Files, NetApp Cloud Volumes Service, and NetApp Cloud Volumes ONTAP storage services

Some of the largest public cloud and managed services providers rely on NetApp storage to deliver virtual machines to customers, including:

- Microsoft Azure with Azure NetApp Files for Azure Virtual Machines
- IBM Cloud with NetApp ONTAP Select for IBM Cloud for VMware Solutions
- Rackspace with managed NetApp Cloud Volumes for VMware Cloud on AWS

Validated converged infrastructure with NetApp storage for virtualization

IT managers find compelling value in using virtual machines to increase utilization of computing and storage resources. Converged infrastructure systems, which combine compute, storage, and network systems into a single optimized package, continue to be popular and to achieve operational efficiencies. The use of virtualization is shifting the focus on infrastructure from hardware to software, so it follows that converged infrastructure solutions like FlexPod with NetApp storage can help to complete this transition.

FlexPod offers businesses a broad portfolio that contains more than 190 Cisco Validated Designs, including CVD solutions for Citrix, Microsoft, Red Hat, and VMware virtualized environments. Without FlexPod, infrastructure architects, designers, engineers, and others have to integrate individual storage, server, and network products to meet the needs of virtual machine workloads.

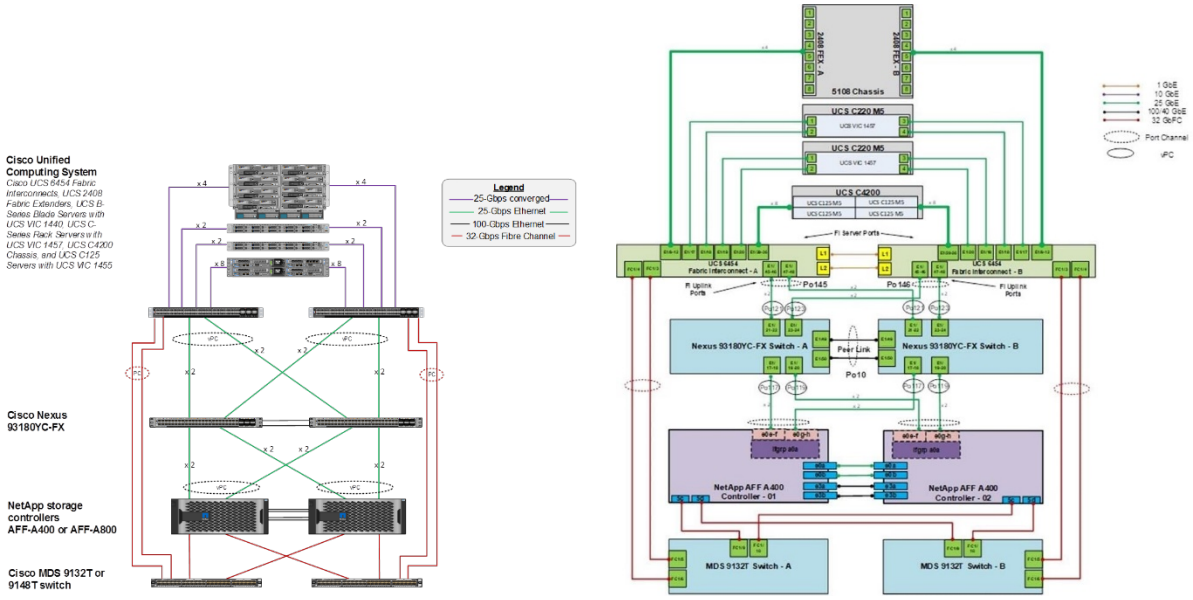

Figure 5) Example of a FlexPod converged infrastructure solution for VMware vSphere 7.

The example in Figure 5 illustrates a complete FlexPod converged infrastructure solution using a design validated by NetApp and Cisco. Hardware components include:

- NetApp AFF-A400 or AFF-A800 storage
- Cisco UCS C125 servers
- Cisco UCS 6454 fabric
- Cisco Nexus 93180 and MDS 9132T or 9148T switches

Not shown in Figure 5 are some essential NetApp software components, including NetApp SnapCenter® for vSphere, NetApp Virtual Storage Console for VMware vSphere, NetApp VASA Provider for ONTAP, NetApp Active IQ®, and NetApp NFS Plug-In for VMware VAAI. Also not shown are various Cisco and VMware software components, such as Cisco Intersight and VMware vSphere. For complete details for this example of a FlexPod solution, see the design guide FlexPod Datacenter with VMware vSphere 7.0, Cisco UCS C125 M5, and NetApp ONTAP 9.7. Other FlexPod validated designs for virtual machine workloads are available from NetApp here and from Cisco here.

Private and public cloud storage for SDDC

Many virtual machine workloads run with an on-premises infrastructure that uses software-defined data center (SDDC) architecture. SDDC extends the concept of software-based server virtualization to include networking and storage, effectively creating a virtual data center with capabilities mostly determined by the software platform in use, such as Citrix, Microsoft, Red Hat, or VMware. According to VMware, “the software-defined data center (SDDC) architecture enables a fully automated, zero-downtime infrastructure for any application, and any hardware, now and in the future. It is the ideal architecture for private, public, and hybrid clouds. SDDC extends the virtualization concepts you know—abstraction, pooling, and automation—to all data center resources and services.”

NetApp facilitates software-defined data centers by providing a storage platform with similar capabilities for storage and data management that supports workloads across data centers located on premises and in multiple public clouds. NetApp ASA, NetApp AFF, and NetApp FAS deliver powerful SAN and NAS storage for on-premises SDDC environments with high levels of integration with the SDDC software platform. When using a VMware-based SDDC, for example, NetApp on-premises storage integrates the following software tools:

- NetApp SnapCenter for vSphere
- NetApp Virtual Storage Console for VMware vSphere
- NetApp VASA Provider for ONTAP
- NetApp NFS Plug-in for VMware VAAI

Similar NetApp integration tools are available for the SDDC platforms of other vendors, including Citrix, Microsoft, and Red Hat. Additionally, NetApp storage includes native integration with multiple public clouds to support SDDC workloads wherever they run, as shown in Figure 6.

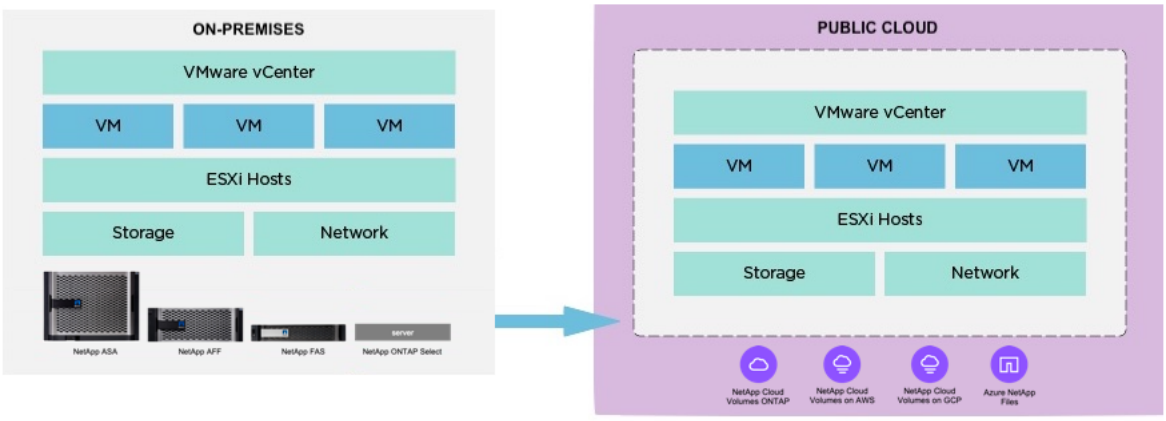

Figure 6) NetApp storage for VMware software-defined data centers on premises and in public clouds.

Delivering consistent EUC and VDI experiences to your remote workforce

Given the prevalence of personal mobile computing devices and the shift to work-from-home practices, it seems probable that more virtual machines run end-user workloads than database and application workloads. This trend is driving the need to deliver end-user computing (EUC) and virtual desktop infrastructure (VDI) experiences with service levels comparable to those when using company-issued computers and working on premises at company offices.

According to IDC, “the worldwide edge computing market will reach $250.6 billion in 2024 with a compound annual growth rate (CAGR) of 12.5% over the 2019–2024 forecast period. With the ability to place infrastructure and applications close to where data is generated and consumed, organizations of all types are looking to edge technology as a method of improving business agility and creating new customer experiences." This edge computing movement, coupled with the COVID-19-driven shift toward employees working remotely, makes it look likely that this trend will continue. A May 2021 Harris Poll found that 40% of workers prefer to work from home full time.

The challenges of using virtual machines to support end users differ from the challenges of using VMs to run databases and applications, and this fact changes the optimal infrastructure for EUC. Deploying a data center near every end user to run their desktop VM is not practical, and it becomes impossible for companies that have a global workforce. However, as shown in Figure 7, NetApp Cloud Volumes ONTAP runs on the global public cloud infrastructures of AWS, Google Cloud, and Microsoft Azure and delivers the performance needed to support the unique storage workloads of EUC and VDI.

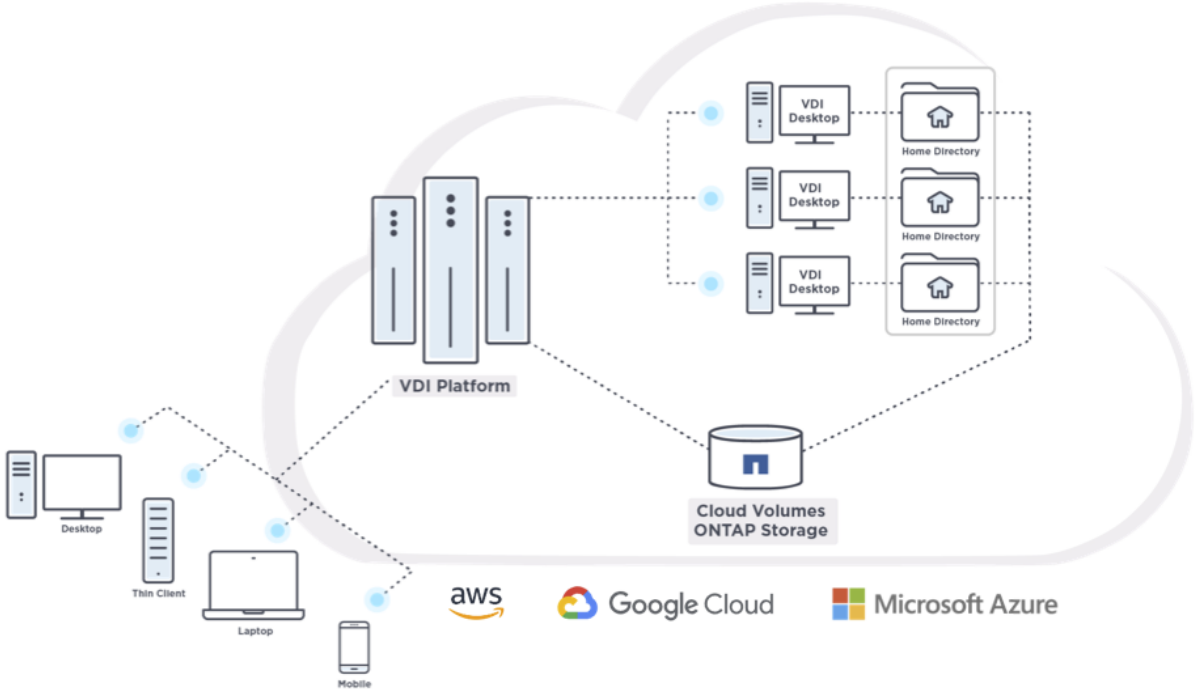

Figure 7) NetApp public cloud storage service for end-user computing and virtual desktop infrastructure.

NetApp supports EUC and VDI in many other ways that go far beyond storage alone. For example, NetApp delivers cloud services that include Spot PC by NetApp, fully managed and continuously optimized cloud desktops as a service; NetApp Virtual Desktop Managed Service (VDMS), which provides turnkey virtual desktops as a managed service; and NetApp Virtual Desktop Service (VDS) to orchestrate AWS, Azure, Google, Citrix, and VMware infrastructure. NetApp uniquely brings other cloud services as a complement to NetApp VDMS and VDS, including:

- Azure NetApp Files and NetApp Cloud Volumes storage services for file data
- NetApp Global File Cache to support shared user data at remote sites
- NetApp SaaS Backup to guard Microsoft 365 data with secure backup and restore
- NetApp Cloud Data Sense to discover, map, and classify data

Block, file, and object protocols: NetApp's modern unified storage

The diversity of virtual machine workloads often creates the need to store and manage different types of data, such as block, file, and object, by using multiple protocols, such as FC, iSCSI, SMB, NFS, and S3. For example, database administrators may prefer the isolation of dedicated block storage for their workloads, while application administrators may prefer the convenience of shared file storage. Both may prefer the scalability of object storage for data tiering, backup, and restore.

According to Eric Burgener, research vice president of IDC, "Historically, IT managers deployed dedicated block, file, and object storage silos—an approach that led to fragmented management and high administrative costs. The idea of unified storage that could simultaneously support multiple access methods on a single system, combined with the flexibility to configure the storage to meet individual application requirements, opens up significant possibilities to consolidate different workloads." Burgener goes on to say, "Workload consolidation is a notable trend in the enterprise, and that is a popular use case for object-based storage platforms. Object-based software and appliance revenues are growing at over four times the compound annual growth rate (CAGR) of enterprise storage overall and will crest $21.6 billion by 2023."

NetApp offers modern unified storage that simultaneously supports the block, file, and object storage needs of VM workloads. NetApp AFF and NetApp FAS systems deliver on-premises storage using the FC, iSCSI, NFS, SMB, and S3 protocols, for example, and Cloud Volumes ONTAP delivers multiple public cloud storage using the iSCSI, NFS, and SMB protocols. As shown in Figure 8, both support data tiering to Amazon S3, Azure Blob, and Google Cloud Storage object storage.

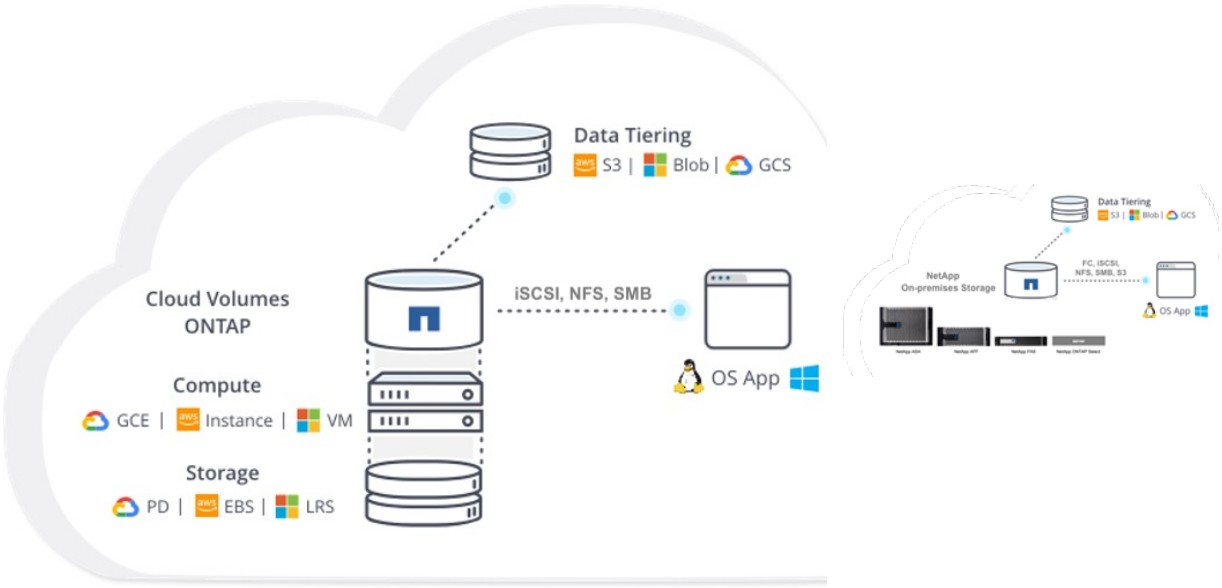

Figure 8) NetApp modern unified storage for VM workloads.

NetApp's modern unified storage probably does more than expected. However, the proven benefits of storage consolidation alone are so compelling that it might be the number 1 reason to use NetApp to provide block, file, and object storage for all VM workloads. Managing all business data on a single storage platform–regardless of where the data is located across remote offices, data centers, and public clouds–ensures higher return on investment and lower total cost of ownership.

Summary

NetApp delivers modern unified storage with block, file, and object storage for all virtual machine workloads.

Whether using sophisticated SDDC or a straightforward virtual infrastructure, the same NetApp ONTAP platform meets all requirements distributed across on-premises data centers and multiple public clouds. This is true regardless of whether the workloads support databases and applications only with a virtual server infrastructure, end users only with virtual desktop infrastructure, or both. With NetApp, customers have the flexibility to choose the most appropriate storage to run their virtual machines, including cloud-native storage services, hybrid cloud storage software, on-premises storage systems, and converged infrastructure solutions.

For example, SDDC environments can use NetApp ONTAP Select storage on premises and in the IBM Cloud to keep storage software-defined everywhere using the same SDS software. Dell EMC can't even begin to match this capability. PowerStore offers no support for software-defined or public cloud storage. UnityVSA for on-premises storage offers fixed capacities of 10, 20, or 50TB only, versus up to 400TB with NetApp ONTAP Select. Unity Cloud Edition requires the added expense of VMware Cloud, versus bare-metal storage with NetApp ONTAP Select. Finally, UnityVSA and Unity Cloud Edition are two different products that offer different capabilities to public cloud versus data center workloads.

On-premises virtualized environments running hypervisors like VMware vSphere or Microsoft Hyper-V, rather than full SDDC platforms, can use NetApp AFF and NetApp FAS to deliver modern unified storage to all VM workloads. This includes multiple protocol support with FC and iSCSI for block storage, SMB and NFS for file storage, and S3 for object storage. If the data center environment changes in the future, the same NetApp storage systems meet the new requirements by scaling out to increase storage capacity and performance demands and gaining capabilities with cloud-native services for storage and data management. This is true whether the change is due to evolution to SDDC or transformation to a hybrid multicloud environment. Dell EMC has demonstrated that major data center changes require storage system replacements, as demonstrated by the planned obsolescence of Unity XT and its replacement by PowerStore.

4. Traditional enterprise workloads

Introduction

Enterprise databases and applications, including those from Microsoft, Oracle, and SAP, are some of the most mission-critical workloads in use today. These “traditional” enterprise workloads frequently run with on-premises infrastructure deployed using tiered client-server architecture consisting of a presentation tier, an application tier, and a data tier. The infrastructure supporting this architecture frequently consists of a converged infrastructure that provides storage, networking, and computer resources, or separate SAN and server systems integrated by customers. A preference to run these workloads on a bare-metal infrastructure on premises persists even after the emergence of virtual machines, containers, and public cloud platforms.

According to IDC, among Windows-based workloads, a majority of supply chain management and data management workloads are expected to be deployed on cloud-based infrastructure by 2023. IDC expects this trend to continue, with enterprise workloads increasingly finding a home on cloud-based infrastructures.

Whether a business chooses to use converged infrastructure, separate systems, or both, NetApp offers solutions certified to support the most commonly used enterprise databases and applications, including those by Microsoft, Oracle, SAP, and others. Examples of these NetApp solutions and products include:

- NetApp Keystone storage as a service
- FlexPod converged infrastructure solutions from NetApp and Cisco
- NetApp ASA, AFF, and FAS storage system products
- Public cloud storage
- NetApp Cloud Volumes Service for Google Cloud public cloud storage
- Azure NetApp Files public cloud storage

NetApp technologies and storage power some of the largest deployments of enterprise databases and applications in the world. These deployments include those at IBM (IBM Cloud Block Storage and IBM Cloud File Storage for SAN and NAS workloads); at Microsoft (Azure NetApp Files for Windows and Linux enterprise workloads); and at SAP (data lake for HANA Enterprise Cloud database as a service). Key reasons for this wide adoption include native capabilities that are essential to enterprise data centers, such as business continuity with MetroCluster, disaster recovery with SnapMirror®, and data protection with SnapCenter. Another important factor is decades of NetApp strategic partnerships with Microsoft, Oracle, SAP, and other developers of enterprise databases and applications. NetApp has the deepest integration with the three largest hyperscalers, which provides the best environment for databases and makes it easier to implement a multicloud solution.

Validated converged infrastructure with NetApp storage for databases

Businesses that prefer proven designs of converged infrastructure have more than 100 options when choosing FlexPod for enterprise databases and applications, including options from Microsoft, Oracle, and SAP. FlexPod is backed by the NetApp Verified Architecture and Cisco Validated Designs programs. Every FlexPod design includes a specific formula of hardware and software, such as NetApp AFF or FAS storage plus Cisco UCS servers and Nexus switches.

IDC recently published the findings of their survey of FlexPod customers, which revealed the following benefits:

- 65% more time spent on innovation and new projects
- 61% improvement in application performance
- 60% decrease in the number of unplanned downtime incidents
- 34% decrease in data center floor space
- 29% reduction in power and cooling
- 24% saved in software capex

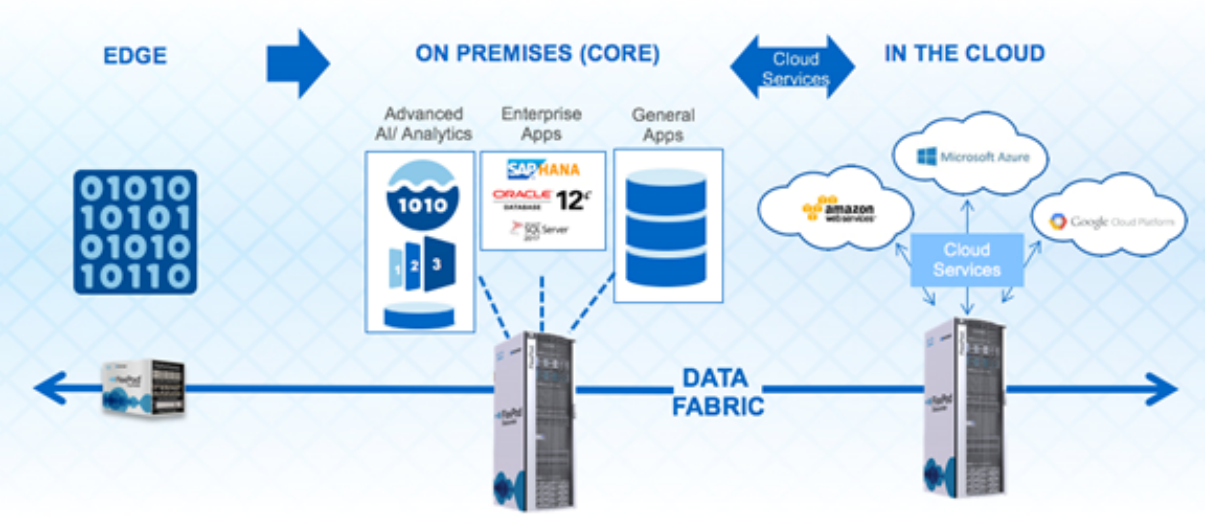

Figure 9) FlexPod converged infrastructure for edge, core, and cloud workloads.

As shown in Figure 9, the use of NetApp ONTAP based systems by FlexPod enables inherent enterprise capabilities for storage and data management, including but not limited to the following:

- Metro clustering using NetApp MetroCluster for continuous availability
- Business continuity using NetApp SnapMirror BC for synchronous replication
- Disaster recovery using NetApp SnapMirror for asynchronous replication
- Data protection using NetApp SnapCenter for DB- and app-aware backups, restores, and clones
- Data privacy using NetApp Volume Encryption for FIPS 140-2 Layer 2 data encryption
- Ransomware protection using NetApp SnapLock® for immutable NetApp Snapshot™ copies of data

All SAN storage with symmetric active-active paths from hosts to storage

NetApp AFF All SAN Array (ASA) systems are built on NetApp AFF systems for businesses that prefer a SAN-only storage solution to isolate workloads or that require symmetric active-active paths from hosts to storage. These ASA systems are ideal for mission-critical workloads that require the ultimate in storage availability, because their design eliminates All Paths Down (APD) client disruptions, even if a storage failover (SFO or takeover and giveback) occurs. See Figure 10.

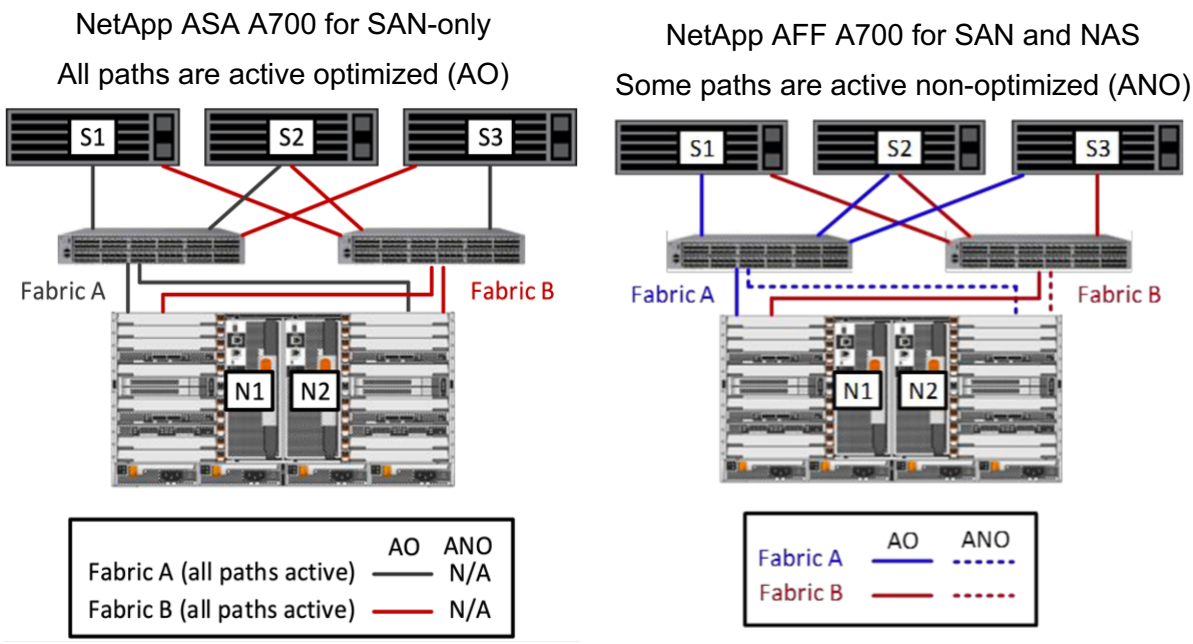

Figure 10) NetApp SAN path comparison of NetApp ASA versus NetApp AFF systems.

NetApp ASA systems use all controllers to present all paths between hosts and storage as active preferred (AP) or active optimized (AO). The practical effect is that hosts always have active paths and don't need to query for new paths if a storage failover occurs. This means that SLOs can be focused on reducing to an absolute minimum failover times and I/O resume times from the point of view of applications.

NetApp SnapMirror Business Continuity enables automated failovers, with the ability to test failover for each application, between two synchronously replicated sites to protect continuous availability against failures. It uses SnapMirror Synchronous to replicate applications between two sites, using application consistency groups to manage and replicate all application objects. This practice reduces outage durations and significantly lowers administrative costs associated with maintaining both mirrors and managing automated failovers. See Figure 11.

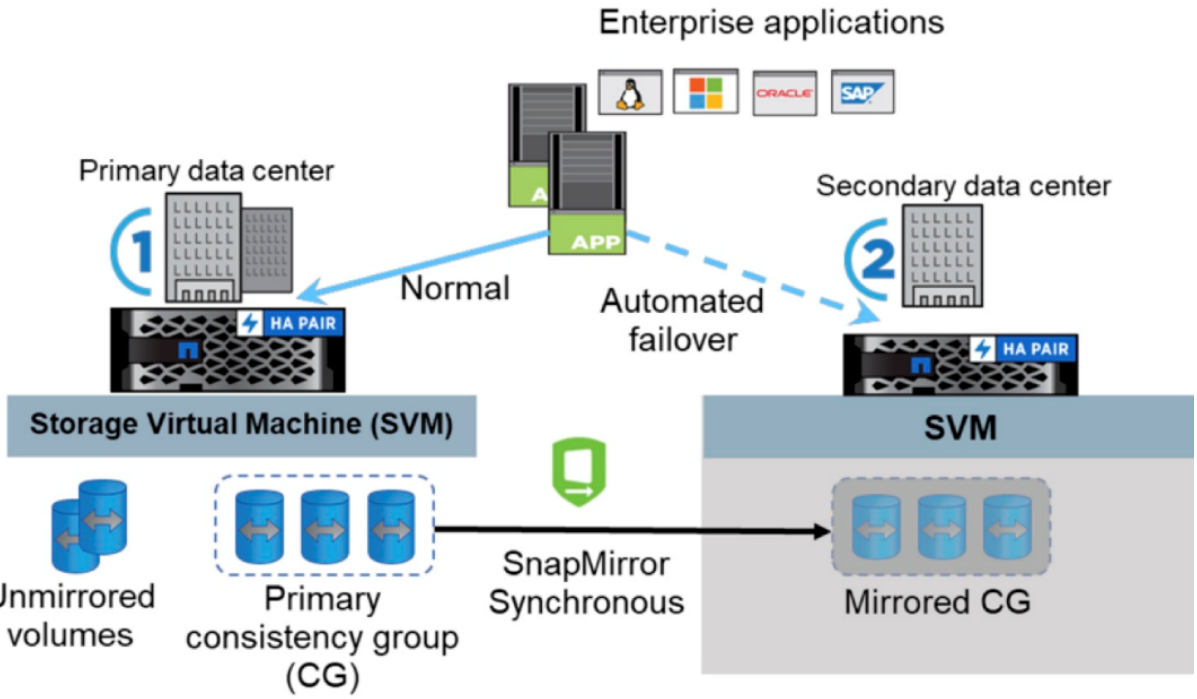

Figure 11) Topology example of NetApp SAN with SnapMirror Business Continuity.

Modern unified SAN and NAS storage: Eliminate siloes with NetApp scale-out

NetApp offers modern unified storage that supports SAN and NAS protocols simultaneously, with solutions ranging from performance-optimized NetApp AFF all-flash arrays to cost-optimized NetApp FAS hybrid arrays. This support allows businesses to use the same ONTAP based platform for the structured, semistructured, and unstructured data of all enterprise databases and applications by using scale-out clustering to mix SSDs and HDDs. As a result, one NetApp cluster can deliver different mixes of high-performance, high-capacity, and high-efficiency (lower-cost) storage for different mixes of block, file, and object workloads.

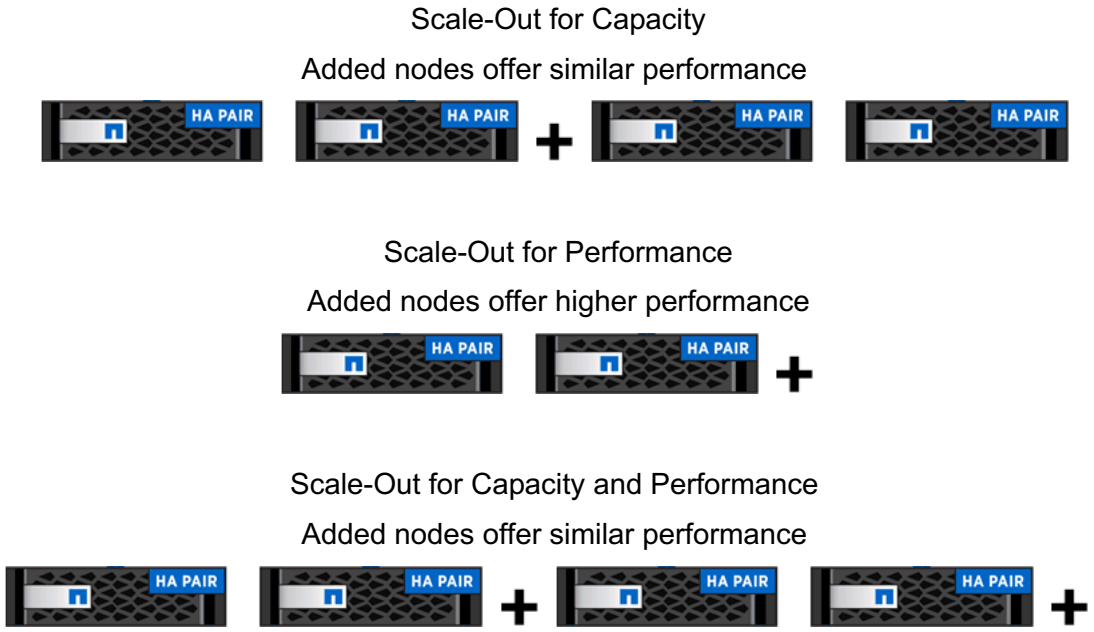

Figure 12) Examples of NetApp AFF and FAS scale-out.

NetApp ONTAP based systems scale out by adding controllers (nodes), as shown in Figure 12. Controllers are paired for high availability (HA), and multiple controller pairs of different types can form a cluster. A NetApp AFF and FAS scale-out network typically consists of a cluster interconnect, a management network for administration, and a data network for clients.

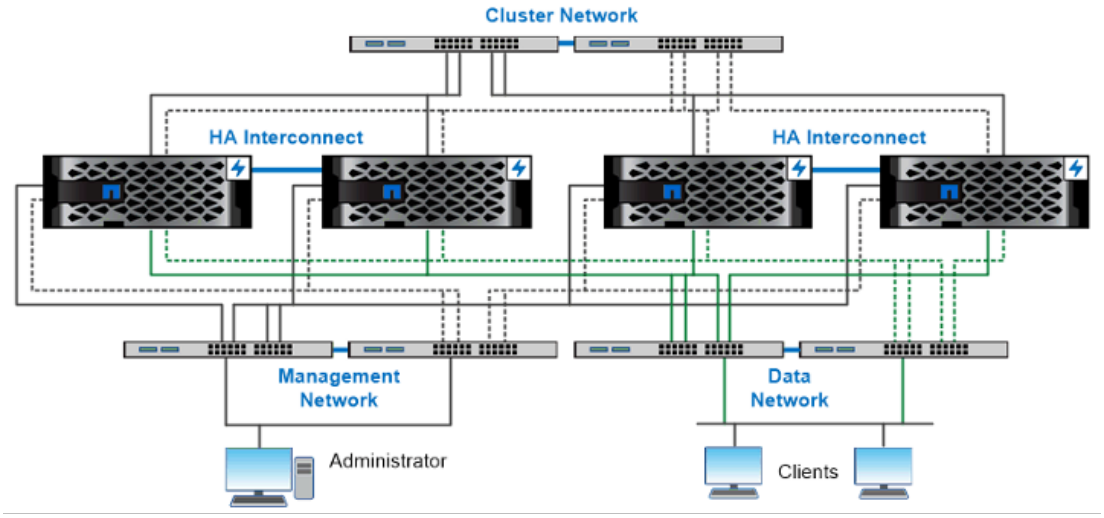

Figure 13) NetApp AFF and FAS scale-out configuration.

Accelerate your databases and applications with end-to-end NVMe

NetApp AFF systems were the industry's first all-flash solution with NVMe inside and out (NVMe end to end) using NVMe over FC, and they are expected to be the first to support NVMe over TCP. A SAN configured for NVMe over Fabrics, including Fibre Channel or Ethernet networks, delivers lower latency, higher IOPS, and more throughput than the same SAN configured for Fibre Channel Protocol using SCSI. The technical reasons for this difference are beyond the scope of this paper, but they generally involve improvements in communication efficiency across the network, including latencies approaching those of direct-attached storage. The use of storage with end-to-end NVMe accelerates enterprise databases and applications to levels beyond what is achievable using storage that supports NVMe drives only.

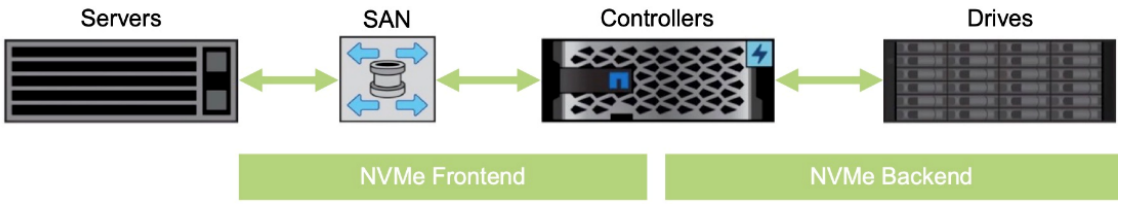

Figure 14) NetApp SAN storage with end-to-end NVMe configuration.

As shown in Figure 14, the use of an NVMe back end (a controller to drive connectivity) improves the efficiency of communications between controllers and drives. This improves the total performance of a storage system but does little to change the performance available to each server that uses SAN FCP protocols. The performance of enterprise database and application servers benefits more from the use of an NVMe front end (server-to-controller connectivity). Optimal storage performance is achieved when using storage like NetApp AFF systems with end-to-end NVMe capabilities.

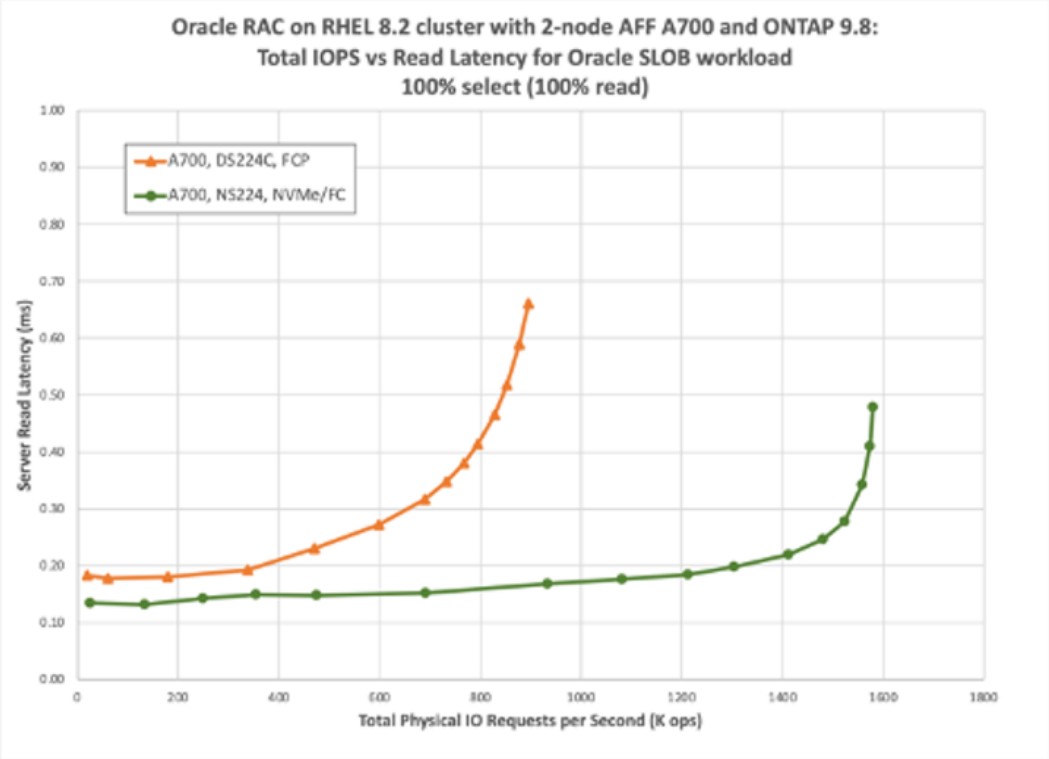

Figure 15) NetApp SAN storage performance for Oracle RAC with end-to-end NVMe configuration.

Benchmarking shows that Oracle Real Application Clusters (RAC) can experience a significant performance increase when using NVMe SAN. As shown in Figure 15, A700 testing using a 100% random read workload generated by Oracle SLOB (an I/O workload-generation toolkit) found that SAN performance improved 85% at 500-microsecond latency when using NVMe instead of FCP over the same Fibre Channel network. Also, the number of total physical I/O requests per second increased by approximately 80% when using NVMe versus FCP. With NetApp AFF systems that support end-to-end NVMe (for example, A800, A700, and A300), switching to NVMe SAN can be as simple as enabling the NVMe options at the adapters, switches, and controllers and mapping traffic from FCP to NVMe paths. The use of NVMe over TCP is expected to deliver performance benefits over FCP also.

Summary

NetApp was the first major storage vendor to deliver end-to-end NVMe storage by using Fibre Channel SAN and is the first to support NVMe over TCP by using Ethernet SAN.

The demands of mission- and business-critical enterprise databases and applications are challenging for storage, so NetApp makes meeting SLOs simple, especially when using NetApp Keystone storage as a service. The ONTAP based storage platform deploys a SAN storage infrastructure with certifications from strategic partners to ensure that solutions are validated for interoperability. Deployment options include FlexPod for converged infrastructure, AFF and FAS for heterogeneous infrastructure, and ONTAP Select for software-defined infrastructure.

With NetApp, businesses can choose the best infrastructure for each requirement. The entire industry ecosystem is open to partnerships and collaborations with NetApp to develop the industry's best storage for enterprise and cloud data centers that complement partner products and services. Long-established NetApp partnerships include Brocade, Cisco, Commvault, Intel, Microsoft, NVIDIA, Oracle, Red Hat, SAP, Splunk, Veeam, Veritas, and others. This differs from companies like Dell Technologies that are focused on selling their storage and compute and network and software to every business while competing with ecosystem technology providers that offer better alternatives.

For example, the newest Dell Technologies PowerStore midrange storage systems still lack many of the enterprise capabilities of the previous storage systems they are intended to replace, such as SC, XtremIO, and Unity XT. This backward step probably means that other Dell midrange storage systems may never gain contemporary capabilities like end-to-end NVMe SAN—in other words, they may forever remain "NVMe-ready." Also, businesses have to wait until PowerStore achieves feature parity with the midrange storage systems they are intended to replace, then perform forklift upgrades to PowerStore. They can only hope that this feature parity occurs before existing storage becomes so old that it must be replaced with the same now-obsolete storage systems.

Dell's midrange storage execution seems intended to force businesses to migrate to high-end PowerMax systems to preserve access to the capabilities commonly available with NetApp storage. An obvious example is the ability to mix SSDs and HDDs as desired to precisely match the needs of every enterprise database and application workload, as is possible when using a storage cluster that uses NetApp AFF and FAS systems.

Dell's storage strategy is purposefully designed to force businesses to purchase multiple storage systems to address their enterprise database and application workload requirements—PowerMax for mission-critical and PowerStore for business-critical structured data workloads, plus PowerScale for unstructured data workloads. NetApp AFF offers storage for mission-critical, business-critical, and other workloads, and their structured and unstructured data support more than 50PB of effective capacity with a single system. With more than 700PB of effective capacity with a single cluster, this is far greater capacity than any PowerMax or PowerStore system.

5. Conclusions

This white paper explores the growing set of capabilities that NetApp brings to the SAN marketplace for virtualized and enterprise application workloads. The success that NetApp has achieved with SAN solutions addresses the SLO needs of enterprise IT organizations that require high performance for all workloads, protection for all data, and high availability for all operations.

SAN is here to stay

SAN is here to stay, with NVMe over Fabrics and flash-based storage arrays fueling a new generation of SAN performance. According to Seamus Crehan, president of Crehan Research Inc., “We are seeing that data center customers continue to choose Fibre Channel to power their mission-critical, highly secure applications. We believe the market will adopt higher-performance 64Gb Fibre Channel to further increase customers’ ROI on all-flash array purchases.”

The Evaluator Group confirms the NetApp advantage

The Evaluator Group’s SAN Storage Evaluation Guide reviews the storage vendor landscape across 10 criteria: Capacity, Price, Performance, Scaling, Security, Data Protection, Business Continuity, Economics, Technology, and Integration. Comparisons of Evaluator Group opinions show that NetApp AFF holds distinct advantages over Dell EMC PowerMax, PowerStore, and Unity XT.

NetApp storage innovation includes a long history of product continuity with nondisruptive upgrades and a long track record of customer successes, with the following advanced SAN interconnect and SAN management capabilities:

- **SAN block storage options** deliver choices with end-to-end NVMe protocol support and modern unified storage support with block, file, and object protocol support.
- **Advanced tiering capabilities** offer storage devices of different performance and cost to address a range of SLOs. Additionally, cold data can be tiered to cloud or object storage, with pools for data protection or storage expansion.
- **Performance QoS to a given workload** with a SAN storage platform that can simultaneously support private and public cloud deployment with container, virtual infrastructure, and bare-metal options.
- **Architectural elasticity** supports traditional on-premises storage coupled with data fabric integration to provide choices of cloud-native storage, software defined storage, and converged infrastructure with storage.
- **SAN deployment flexibility** can run anywhere to support all workloads at the edge, core, and cloud of choice, whether private or public, including Microsoft Azure, AWS, Google Cloud, and IBM Cloud.

SAN strongly supports customers' digital transformation

As businesses become more and more digital, IT operational efficiency achieved with SANs spanning private and public cloud becomes a competitive differentiator. According to the ESG report How Hybrid Cloud Environments Are Changing IT Architecture Priorities, **"**Simplifying application agility across multi-cloud environments reduces the cost and complexity of IT, reduces the burden on IT personnel, accelerates digital initiatives, and reduces the risk of both IT and digital business initiatives." ESG research further indicates that "NetApp's unified architecture and data fabric can offer a valuable, differentiated approach to addressing these needs tied to modern multi-cloud environments."

You're either in or you're out. When it comes to cloud storage, you have a choice. Box yourself in with a Dell data center migration or get more out of your data with NetApp on premises and in the cloud. Visit us at NetApp.com to learn why you should think twice and migrate once.

Appendix: NetApp services and products

NetApp private cloud storage products	
NetApp ASA All SAN Array (ASA) solution equivalent to NetApp AFF, configured to deliver a simplified and dedicated SAN-only experience with support for system scale-up and cluster scale-out.	**NetApp FAS** Fabric-attached storage (FAS) block, file, and object storage solution with HDDs and QLC flash for storage, SSDs for acceleration, and support for system scale-up and cluster scale-out.
NetApp AFF All-Flash FAS (AFF) block, file, and object storage solution with SSDs and support for system scale-up and cluster scale-out.	**FlexPod** Converged infrastructure platform including NetApp storage and Cisco servers and fabrics; available in almost 200 prevalidated designs for enterprise workloads across the edge, core, and cloud.

NetApp public cloud storage services	NetApp public cloud storage products
AWS FSx for NetApp ONTAP Combines the rich -management capabilities of NetApp ONTAP with the agility and scalability of a native AWS service.	**NetApp Cloud Volumes ONTAP** Block and file storage solution that integrates with Microsoft Azure, AWS, and Google Cloud.
Azure NetApp Files File storage solution co-developed by Microsoft and NetApp and directly available from Azure marketplace.	**NetApp ONTAP Select for on premises** Block and file storage solution that integrates with private cloud virtualized servers.
NetApp Cloud Volumes Service File storage solution that is directly available from the AWS and Google Cloud marketplaces.	**NetApp ONTAP Select for IBM Cloud** Block and file storage solution that is directly available from the IBM Cloud marketplace.

NetApp hybrid cloud services

NetApp Cloud Manager
A centralized control plane to manage, monitor, and automate NetApp Cloud Central services, Azure NetApp Files, NetApp Cloud Volumes Service, and NetApp Cloud Volumes ONTAP in hybrid multicloud environments.

NetApp Astra Control
A fully managed application-aware data management service that manages, protects, and moves data-rich Kubernetes workloads in both public clouds and on premises. It enables data protection, disaster recovery, and migration for Kubernetes workloads by leveraging NetApp data management technology for Snapshot copies, backups, replication, and cloning.

NetApp Cloud Insights
Offers visibility into infrastructure and applications with alerting, monitoring, troubleshooting, and optimization of all resources and applications on premises and in the hybrid multicloud. Supports early detection of ransomware events, powerful Kubernetes monitoring, and machine learning.

NetApp Cloud Sync
A cloud-based service for rapidly and securely copying, moving, and synchronizing data across NFS or CIFS file and object storage across private, public, and hybrid cloud locations. Object support includes NetApp StorageGRID®, AWS S3, Azure Blob, and IBM Cloud Object Storage.

NetApp Cloud Data Sense
Provides automated controls for data privacy regulations, such as the GDPR and CCPA, that help businesses to get databases and applications privacy ready, whether their data is on premises or in multiple public clouds.

NetApp Cloud Tiering
Uses NetApp FabricPool technology for policy-based tiering of inactive (cold) data from NetApp storage systems to object storage on premises or in the Microsoft Azure, AWS, and Google Cloud public clouds.

NetApp Global File Cache
Allows distributed enterprises to securely consolidate silos of file servers into one cohesive global storage footprint in the public cloud, which streamlines overall IT management, significantly cuts costs, and boosts business productivity on a global scale.

NetApp Virtual Desktop Service

A global control plane for virtual desktop management that functions as an extension of the cloud. With Virtual Desktop Service, businesses anywhere in the world can deploy a validated solution to address the challenges and inefficiencies that most organizations face when managing legacy virtual desktop solutions.

Spot Cloud Analyzer by NetApp

A cloud infrastructure management solution that uses advanced analytics to provide visibility and insights into your cloud costs, shows you where you can optimize those costs, and lets you implement that optimization using the Spot portfolio of continuous optimization products with just a few clicks.

Spot Eco by NetApp

Eco eliminates risk by identifying and off-loading unused RIs and savings plans. As your needs change, Eco updates your portfolio so you can enjoy the benefits of long-term pricing without financial lock-in.

Spot Ocean by NetApp

Ocean automates cloud infrastructure for containers. It continuously analyzes how containers are using infrastructure. Automatically scales compute resources to maximize utilization and availability by using the optimal blend of spot, reserved, and on-demand compute instances.

NetApp Cloud Backup
An add-on service for NetApp Cloud Volumes and NetApp storage systems that deliver backup and restore capabilities for protection and long-term archiving of data.

Spot PC by NetApp
Spot PC enables on-demand, secure, cost-effective cloud desktops for Azure Virtual Desktop and Windows 365; built and operated by the desktop, infrastructure, and cloud experts at Spot by NetApp.

Spot Elastigroup by NetApp

Elastigroup predictive autoscaling simplifies the process of defining scaling policies, identifying peak times and automatically scaling to ensure the right capacity in advance. Machine learning algorithms predict the future load of the application and proactively scale the cluster to accommodate peak traffic.

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

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