NetApp Verified Architecture

Modern SAN cloud-connected flash solution

NetApp, VMware, and Broadcom Verified Architecture Design Edition: With MS Windows Server 2019 and MS SQL Server 2017 Workloads

Modernize and future-proof your enterprise SAN; implement the fastest cloud-ready solution for mission-critical tier-1 enterprise applications and workloads

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Abstract

This NetApp® Verified Architecture has been jointly designed and verified by NetApp, VMware, and Broadcom. It uses the latest Brocade, Emulex, and VMware vSphere technology solutions along with NetApp all-flash storage, which sets a new standard for enterprise SAN storage and data protection that will drive superior business value.

In partnership with

BROADCOM EMULEX | BROCADE FIBRE CHANNEL SOLUTIONS

vmware

Foreword: Thoughts from Broadcom

NetApp and Broadcom's Brocade BU are now in our third decade of partnering together to bring industry leading solutions to our customers. We strive to continuously improve "and validate" how our joint solutions solve our customer's business challenges of today and into the future.

New workloads and data access patterns continuously require much higher storage performance. Real-time big data analytics need an ability to support high degrees of concurrency. Nonvolatile Memory Express (NVMe) emergence has helped support workloads that have high I/O storage requirements while helping to manage TCO investments in infrastructure.

NVMe is now the clear default solution approach customers implement in their deployment strategy. Reasons the industry has seen a quick adoption by customers are simple: Since its inception, NVMe over Fibre Channel (NVMe/FC) has been easy to implement; has improved server CPU utilization and has drastically increased ROI by enabling more application workloads. NVMe/FC's dramatic application performance results have enabled customers to realize performance gains that have far exceeded the promised performance numbers that seemed over-hyped when the NVMe/FC technology was first introduced.

In this document, NetApp, Brocade and VMware will once again prove application performance results that customers can consider when evaluating their technology investments and will also demonstrate how NVMe/FC can seamlessly integrate into existing VMware environments while maintaining the same processes and procedures.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Executive summary

NetApp Verified Architectures describe systems and solutions that are designed, tested, and documented to facilitate and improve customer deployments. These designs incorporate a wide range of technologies and products into a portfolio of solutions that NetApp has developed to help meet the business needs of customers.

This NetApp Verified Architecture provides a solution that modernizes your VMware vSphere SAN storage with a 32Gb NVMe-oF solution based on FC and cloud connectivity options, giving your company the fastest cloud-ready solution for mission-critical virtualized workloads. This report addresses the following:

- The challenge that organizations face today with data assets and infrastructure
- The solution to leverage disruptive future technology nondisruptively for your business today
- Ten good reasons to modernize your traditional SAN infrastructure
- A world-class modern SAN verified reference architecture
- NetApp recommended data protection solutions for this architecture

NVMe/FC support now available from VMware vSphere can be leveraged with your current or new investments in NetApp ONTAP® modern SAN FC-based architectures. NVMe/FC in particular offers a very simple and easy migration path to upgrade applications and workflows to use NVMe/FC instead of SCSI FCP. The rest of this report focuses on requirements, testing, and benefits of adopting the NVMe/FC protocol for your Microsoft SQL Server VM workloads. The information provided can easily be extrapolated to other operating systems and application virtual machines (VMs) as well.

The challenge

The challenge today is how to rapidly and nondisruptively transform, modernize, and streamline critical data and IT services to scale and adapt to continuously evolving customer and business needs. At the same time, these services must be future-proof and cloud-ready so that an organization can maintain a competitive edge. This is particularly important for tier-1 mission-critical enterprise applications and workloads such as Microsoft SQL Server, when deployed in a highly scaled VMware infrastructure.

Background: According to IDC, by 2020, 50% of Forbes Global 2,000 companies will see most of their business depend on their ability to create digitally enhanced products, services, and experiences. Data is the lifeblood of future-thinking companies. The consequence of ever-increasing reliance on data will be a never-ending expansion in the size of the Global DataSphere. IDC forecasts the Global DataSphere to grow to 175ZB by 2025. As businesses contend with the perpetual growth of data, they need to rethink how data is captured, preserved, and processed. Performance, economics, and endurance of data at scale are paramount. It is essential to provide a competitive platform to assist businesses that are dealing with data at scale. However, for many, their current IT infrastructure isn't up to the task. The growing stress on the entire IT infrastructure to manage this overload of data interferes with the ability to quickly capitalize on the inherent value of the data.

The solution

The good news is that just as flash transformed enterprise storage a few years ago, a new emerging technology, Non-Volatile Memory Express (NVMe), is poised to transform enterprise storage again. NVMe is an emergent set of storage access and transport protocols that deliver the fastest response times yet for business-critical enterprise applications.

NVMe is a rich protocol optimized for nonvolatile memory media directly connected to CPU through the PCIe interface. The protocol capitalizes on multiple parallel and low latency data paths to flash devices, similar to the parallelism in CPUs, which reduces I/O overheads and results in higher performance. NVMe also consumes fewer CPU cycles than SCSI- and SATA-based protocols. The NVMe protocol is designed

to transport signals over a PCIe bus and removes the need for an I/O controller between the server CPU and the flash drives.

Ideally, there needs to be a way to extend the benefits of NVMe across the data center to multiple servers and multiple applications—actively and dynamically scaling NVMe to meet demand. This would provide the benefits of high performance NVMe along with the best features of centralized, shared storage we typically associate with SANs, but without the performance compromises we have all had to accept. NVMe-oF is a transformational technology because it affects the data center strategies of today and tomorrow. It consumes significantly less resources than the legacy protocols on both the initiator and the target side allowing better scalability.

NVMe is about to provide a major performance boost for enterprise data storage systems. But this time, the transformative effect could be greater still, because NVMe isn't just a storage specification. The broader NVMe over Fabrics (NVMe-oF) protocol specifies how to encapsulate NVMe inside a variety of network and fabric protocols, such as remote direct memory access (RDMA), Ethernet, TCP, and InfiniBand. These protocols define and enable the use of NVMe across the entire data path, from server to storage system, enabling superior performance and lower latency than traditional technologies can deliver. NVMe/FC replaces the traditional SCSI commands with NVMe commands inside the FC frame—no changes are required for the application to use NVMe. From the applications perspective, NVMe/FC is just another block protocol and can be adopted nondisruptively. Additionally, both NVMe/FC and FC can use exactly the same FC components (HBAs, fiber optic cables, switches, and storage target HBAs) concurrently, which makes the migration from FC to NVMe/FC very simple. It doesn't require a cut-over the way moving from FC to another non-FC protocol such as iSCSI or RoCE would. This makes migrating from FC to NVMe/FC on NetApp the easiest and fastest way to upgrade from SCSI-based to NVMe-based protocols.

NVMe-oF is a quantum leap in the storage technology; it is architected and designed to meet the performance and latency demands of business-critical applications. In order to realize the benefits of faster storage and the associated protocol, VMware supports NVMe/FC starting with vSphere 7.0.

As a result, CxOs now have the opportunity, and the challenge, to harness the power of data through digital transformation and modernization. They can also use these emerging best-in-class technologies from world-class industry leaders NetApp, VMware, and Broadcom's Brocade and Emulex divisions to:

- Rapidly deliver and monetize vital digital data services
- Accelerate the pace of innovation
- Acquire, grow, and retain market share
- Improve customer service and experience
- Maximize return on investment
- Protect and secure customers and critical data
- Increase agility and response to changing business needs

Ten good reasons to modernize your SAN with NetApp, VMware, and Broadcom

This report describes a verified, unified modern SAN solution reference architecture that is designed by the industry leaders NetApp, VMware, and Broadcom, with a first-to-market enterprise NVMe/FC solution. NetApp, VMware, and Broadcom provide an end-to-end NVMe solution, from host to storage controller, that can help you realize the promise and the benefits of NVMe technology right now. With a system that yields the fastest access, management, and utilization of critical data, you can accelerate your time to innovation and leverage the following benefits:

- **Digitally transform critical business applications**. Enable the existing and next generation of your critical applications, ready for analytics, artificial intelligence (AI), and machine learning (ML) capabilities.

- **Harness the power of the hybrid cloud**. Cloud-enable your IT services to get the benefits of on-premises storage with the flexibility of public cloud. The NVMe solution is an ideal choice for hybrid cloud. Hybrid cloud offers the benefits of both public and private clouds and takes advantage of existing architecture in a data center.
- **Get a best-in-class solution for enterprise SAN**. Strengthen your competitive advantage by partnering with the fastest-growing flash, virtualization, SAN, fabric, and host bus adapter (HBA) leaders.
- **Significantly simplify operations**. Improve IT responsiveness through simplification of SAN management while ensuring predictable performance.
- **Modernize and get significant cost savings**. Improve shareholder value by attaining a 30% reduction in database licensing costs, 80% to 90%+ reduction in data center floor space, 50% to 90%+ reduction in power and cooling, and 50% to 80% reduction in labor costs as detailed in NVA-1136-DESIGN: NetApp and Broadcom Modern SAN Cloud-Connected Flash Solution. Additionally, VMs will be more efficient with higher VM densities per server, reducing infrastructure capex, opex costs and simplifying IT
- **Future-proof your SAN environment**. Nondisruptively adopt disruptive performance and technology advancements when you are ready.
- **Rapidly deliver core IT services**. Take advantage of an open platform that supports leading DevOps toolsets to vastly reduce the time to value for development.
- **Don't compromise on availability**. Get 99.9999% availability (backed by several IDC audits, discussed here) and enterprise-grade disaster recovery capabilities.
- **Improve the customer experience**. Best-in-class data protection, the most efficient and scalable storage, and the most flexible IT infrastructure. Accelerate performance, enable instant application cloning, and enable granular data recovery to improve the user experience.
- **Get next-generation enterprise data management**. Bring the value of industry-leading innovation together with enterprise availability to deliver the next generation of your SAN environment.

The architecture

This NetApp, VMware, and Broadcom modern SAN NetApp verified reference architecture for VMware vSphere includes the following key NetApp, VMware, and Broadcom technologies:

- Fibre Channel Protocol (FCP)
- NVMe/FC
- Seventh generation host and fabric technology

The performance benefits accrue as you adopt these technologies. Adopt all of them and get game-changing performance benefits with end-to-end visibility through Fabric Vision technology. In the future, you will be able to add storage-class memory and persistent memory so that you can realize further increased performance.

Solution overview

NetApp, VMware, and Broadcom Modern SAN solution benefits

This solution comprises Brocade Gen 7 Fibre Channel Switches, Emulex Gen 7 FC HBAs, VMware vSphere 7.0, and NetApp AFF storage systems. It is a predesigned, best practice configuration that is built on FC protocol but compares the performance benefits of NVMe over FC versus SCSI FCP (FCP – FC using SCSI command sets) on the latest NetApp, VMware, and Broadcom technologies.

This solution delivers a baseline configuration and can also be sized and optimized to accommodate many different use cases and requirements. It supports tight integration with virtualized and cloud infrastructures and data protection, making it the logical choice for long-term investment.

The solution delivers operational efficiency and consistency with the versatility to meet various SLAs and IT initiatives, including:

- Application rollouts or migrations
- Business continuity
- Cloud delivery models (public, private, and hybrid) and service models (infrastructure as a service [IaaS], platform as a service [PaaS], and software as a service [SaaS])
- Asset consolidation and virtualization
- Data center consolidation and footprint reduction

NetApp, VMware, and Broadcom have thoroughly validated and verified this solution architecture and its many use cases. They have also created a portfolio of detailed documentation, information, presale and post-sale services, and references to assist you in transforming your data center to this shared infrastructure model. This portfolio includes, but is not limited to, the following items:

- Best practice architectural design
- Workload sizing and scaling guidance
- Implementation and deployment instructions
- Technical specifications (rules for what is and what is not a reference architecture)
- Frequently asked questions (FAQs)
- NetApp, VMware, and Broadcom jointly validated designs that focus on various use cases

Target audience

The target audience for this NetApp Verified Architecture document includes the following groups:

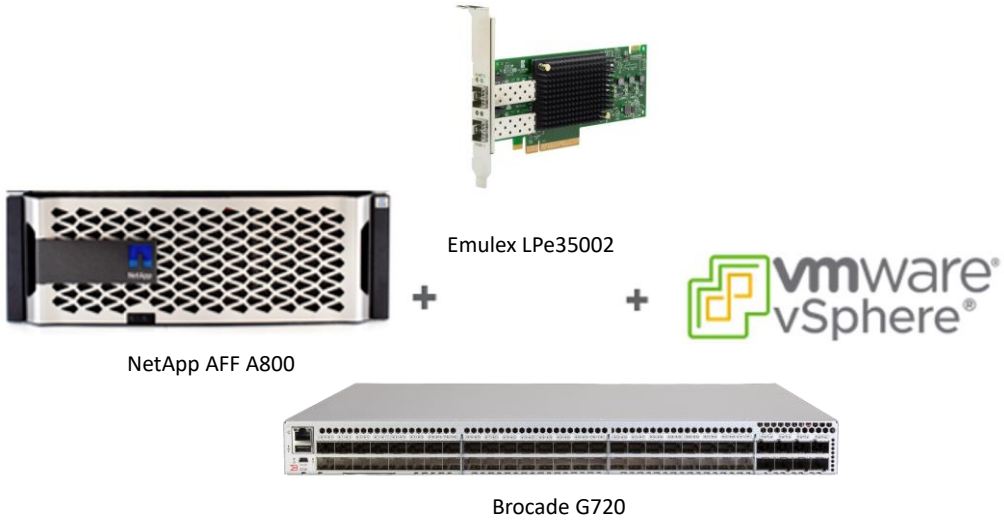
- The CIO, CTO, and CFO, who can benefit from the executive summary, use case examples, ROI and TCO information, and information about future strategies
- Business information officers, who can learn new ways to serve line-of-business owners with benefits from modern technologies
- Architects, administrators, and solutions engineers who are responsible for designing and deploying infrastructure for enterprise mission-critical applications
- Database administrators, who require new data management capabilities and performance to serve evolving data requirements
- Application owners, who need real-time, lower-latency data to feed current and newer generations of applications
- Virtualization architects and administrators who are responsible for designing, deploying, and managing virtualized enterprise mission-critical environments
- Data architects, who require platforms that are designed to enable more real-time analytics and to serve the AI and ML requirements that new workloads need
- Cloud architects, who must harness the power of the hybrid cloud and leverage core and cloud-native solutions
- Backup administrators, who must protect data and leverage new innovations to make data protection seamless and nondisruptive to the business
- Service delivery managers, who must meet SLAs and service-level objectives (SLOs) that require IT infrastructure and solutions that promote consistent and predictable results

Solution technology

In this report, we focus on virtualized workloads. We assume some numbers for typical inefficient utilization rates that we see on legacy storage. We also factor in our 2:1 to 4:1 storage efficiency and workload multitenancy benefits when consolidating multiple traditional SAN storage systems into a NetApp AFF A800 configuration.

Figure 1 shows the component families of the architecture. Implementation of this solution should reduce the footprint, management overhead, maintenance spending, and power and cooling, and it should improve service availability and performance.

Figure 1) Component families of the NetApp, VMware, and Broadcom joint architecture.



Most of today's all-flash arrays are deployed on low-risk, multiqueue-capable, deep-queue-rich, and proven FC-based storage networks, with their robust scalable fabric services and credit-based flow control. Because of their reliability and deterministic performance, FC fabrics serve as the most widely implemented storage network infrastructure for mission-critical applications. Because little change is required in the standards to implement NVMe/FC, the introduction of NVMe/FC along with existing storage is easy, seamless, and noninvasive. And because NVMe/FC can use the same infrastructure components concurrently with other FC traffic, it is easy to migrate workloads at the pace that works for your organization. NVMe/FC also allows the efficient transfer of NVMe commands and structures end to end with no translations.

The world's first end-to-end virtualization enterprise NVMe/FC solution with vSphere 7.0, NetApp All-Flash array, Broadcom's Emulex LPe35002 HBAs, and Brocade Gen 7 Fibre Channel network is purpose-built for tomorrow's mission-critical workloads by leveraging today's infrastructure.

New innovations in storage technology are disrupting the data center industry. The introduction of faster media types and more efficient mechanisms to access those media across well-defined various infrastructures is unlocking unprecedented speeds, lower latencies, and dramatic improvements in system and application efficiency and performance.

The current testing uses available data center solutions, specifically with Broadcom NVMe/FC (and other hardware). You can also use Gen 6 switches and other NetApp controllers, such as the AFF A250, A300, A320, A400, A700, and A700s configurations

NVMe

The NVMe specification is designed to leverage NVMEM in all kinds of compute environments, from mobile phones to web scale service providers. It adds massive I/O path parallelization (65,535 I/O queues, each with a queue depth of up to 64Kb outstanding I/O operations), making communication with storage systems massively parallel. Because of lower protocol overhead and lower-latency connectivity between servers and storage devices, this parallelization provides greater bandwidth.

The massive number of queues and the huge queue depths that each can support enable today's storage and servers to use the increasingly large numbers of cores and memory they have. This capability accelerates processing of I/O threads by spreading the processing across multiple CPU cores. This attribute is critical to bring together traditional enterprise applications with real-time analytics workloads, enabling new digital services for the modern enterprise.

NetApp technology is built for the future. With the industry's only unified data management platform that supports SAN or NAS, all-flash, software-defined, hybrid, and cloud storage, it supports both existing (traditional) and emerging applications (for example, NoSQL databases and AI). These features and capabilities are all part of the data fabric powered by NetApp. NetApp systems support scaling (up and out) dynamically in seconds or minutes, instead of taking hours or days. And you can allocate applications to where they run best across your data fabric delivered by NetApp, whether it's on the premises or in the cloud. And to maximize performance and reduce overall storage cost, NetApp FabricPool enables you to move data automatically between AFF storage solutions and Simple Storage Service (S3) and cloud storage tiers.

Along with the Broadcom's Brocade and Emulex divisions, which are leaders in the SAN fabric space, NetApp is the first to market with an end-to-end enterprise NVMe/FC solution over a 32Gbps FC fabric. With this joint solution, you can enable and accelerate this digital transformation for your enterprise—now.

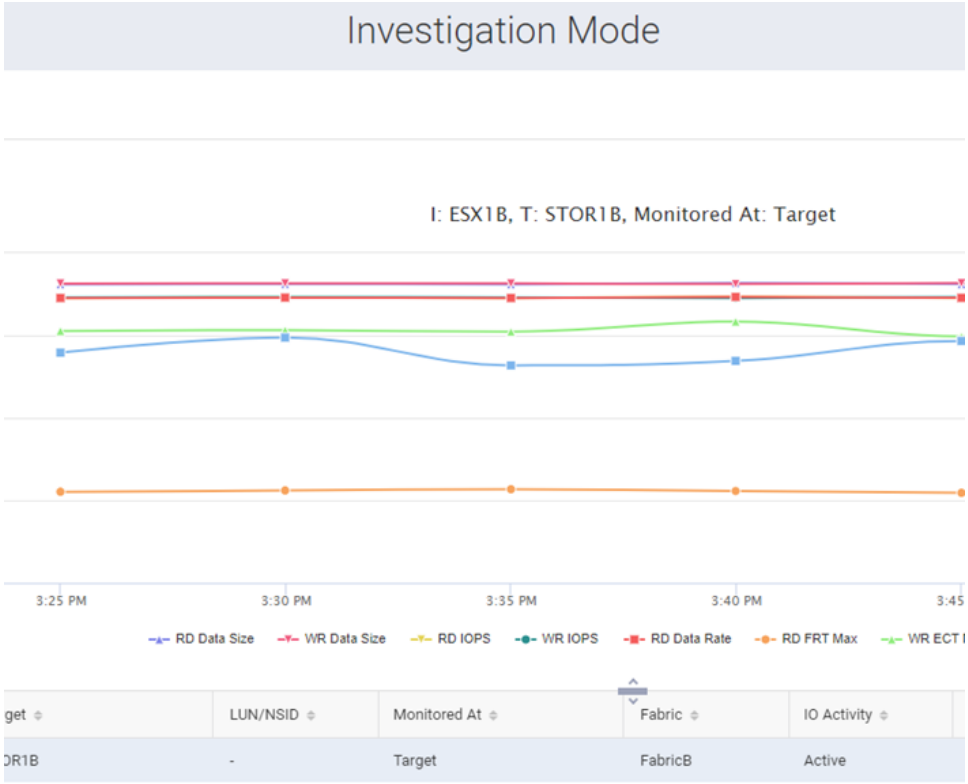
Brocade Gen 7 Fibre Channel platforms

Broadcom's Brocade has been the leading provider of storage networking solutions worldwide for more than 20 years, supporting the mission-critical systems and business-critical applications of most large enterprises. Brocade Gen 7 Fibre Channel is the modern storage network infrastructure for mission-critical storage that combines powerful analytics, advanced automation, and integrated security capabilities to accelerate data access, adapt to evolving requirements, and drive always-on business operations. A Brocade Gen 7 Fibre Channel infrastructure also unleashes the performance of NVMe workloads with reduced latency and increased bandwidth. In addition, this infrastructure lays the foundation for an autonomous SAN by combining powerful analytics and advanced automation capabilities to maximize performance and ensure reliability. With autonomous SAN technology, organizations can realize:

- Self-learning, which gathers and transforms billions of data points into network intelligence, visualizes application and device-based performance and health metrics, detects abnormal traffic behaviors and degraded performance, and eliminates operational steps by automatically learning application flows
- Self-optimizing, which optimizes critical application performance by automatically prioritizing traffic, guarantees application performance by proactively monitoring and actively shaping traffic, eliminates human errors and performance impacts through open DevOps automation technology, and optimizes administrative resources with cloud-like SAN orchestration.
- Self-healing, which instantly notifies end devices of congestion for automatic resolution, ensures data delivery with automatic failover from physical or congestion issues, detects and automatically reconfigures out-of-compliance fabrics, and eliminates performance impacts by automatically taking corrective action on misbehaving devices. Also, Brocade Fabric Vision technology is a suite of

features that leverage comprehensive data collection capabilities with powerful analytics to quickly understand the health and performance of the environment and identify any potential impacts or trending problems. While VM Insight seamlessly monitors virtual machine (VM) performance throughout a storage fabric with standards-based, end-to-end VM tagging to quickly determine the source of VM and application performance anomalies to provision and fine-tune the infrastructure, Brocade products also proactively monitor I/O performance and behavior data points through integrated network sensors to gain deep insight into the environment as shown in Figure 2.

Figure 2) IO Insight metrics displayed in Brocade's SANnav real-time Investigation Mode



Also, to meet the security requirements challenge, Brocade is accelerating the secure digital transformation of data centers. Brocade products support a wide range of authentication, encryption, and management tools to protect fabrics and data from unauthorized access:

- **Authentication**. Authentication protocol support includes CHAP, DH-CHAP, FCAP, IKE, IPsec, RADIUS, TACACS+, and P-EAP/MS-CHAP for RADIUS.
- **Encryption (AES/3-DES**). Brocade provides AES-128 and AES-256 encryption and 168-bit 3-DES encryption for IP links on extension products and management connections. Brocade also supports AES and 3-DES with IPsec. These solutions provide high-performance encryption and compression.
- In-flight encryption over ISLs: Brocade Gen 7 Fibre Channel directors and Brocade G720 switches support in-flight encryption for traffic over ISLs to minimize the risk of unauthorized access to data within the data center and over long-distance links. Data-at-rest and data-in-flight encryption are complementary technologies that serve different purposes, and you might require each to achieve regulatory compliance.
- **Secure Boot**. A switch validates the integrity and authenticity of the FOS boot image to establish a hardware-based root of trust through the manufacturing supply chain.
- Multiple layers of challenge to an attacker to provide the best protection against all types of threats.

The NVMe/FC feature supports both NVMe-oF and SCSI over FC protocols concurrently. Your organization can seamlessly integrate Brocade Gen 7 Fibre Channel networks with the next generation of low-latency flash storage, without a disruptive rip and replace.

VMware

The popularity of NVMe continues to increase, and with good reason. With its low latency and high throughput, NVMe offers the industry additional benefits over traditional storage. VMware is always striving to increase storage performance and efficiency and has been working on NVMe technologies from the start. With the announcement of vSphere 7, VMware has added support for NVMe-oF, enabling customers to connect to external NVMe arrays over the wire. With the initial release, FC and RDMA using RoCEv2 protocols are supported with vSphere 7.

This is an exciting announcement and many of VMware's storage partners have been part of the development of NVMe-oF. Being able to access external NVMe arrays essentially as DAS with the performance and throughput benefits of NVMe solid-state drives (SSDs), gives infrastructures numerous advantages.

Emulex Gen 7 FC HBAs

Emulex FC HBAs by Broadcom are designed to meet the demanding performance, reliability, and management requirements of modern networked storage systems that use high-performance and low-latency SSDs.

The Emulex Gen 7 LPe35000/36000 series FC HBAs with Dynamic Multi-core Architecture delivers unparalleled performance and more efficient port usage than other HBAs by applying all ASIC resources to any port that needs it, providing industry-leading 32Gb FC performance of over 5 million IOPs and over 11 million IOPS for 64Gb FC. The LPe35000/36000 series delivers 12800MBps (two 32Gb FC ports) full duplex, and three times better hardware latency than previous generation adapters. Emulex Gen 7 HBAs running NVMe/FC deliver extreme low latency- up to 55% lower insertion latency for NVMe/FC than SCSI over FC. With the ability to run both NVMe/FC and SCSI FCP concurrently, Emulex provides investment protection by enabling data centers to transition to end-to-end NVMe over FC SANs at their own pace. The secure firmware update feature protects and ensures the authenticity of device firmware.

Emulex works closely with its enterprise customers, developing tools aimed at lowering the cost of management. Emulex SAN Manager is a free, easy-to-use solution that dramatically reduces the operational cost and complexity of running a Fibre Channel SAN via the following:

- Visibility and access to endpoints across an A/B fabric
- Centralized in-band access to managed Emulex HBAs
- A solution to performance issues with direct communication between Emulex HBAs and Brocade fabric switches and directors.

The Emulex SAN Manager tool provides centralized HBA management in-band through the SAN. No Ethernet connection to individual servers is required, no agents are required on hosts, and no dedicated server is required. Emulex SAN Manager is designed for the data center with complete CLI support so that IT administrators can schedule activities and log data.

Contact Emulex support to request your free Emulex SAN Manager license.

VMware vSphere

NetApp offers several standalone software tools that you can use together with ONTAP and vSphere to manage your virtualized environment. The Virtual Storage Console (VSC) is a vCenter plug-in that simplifies storage management and efficiency features, enhances availability, and reduces storage costs and operational overhead, whether using SAN or NAS. VSC uses best practices for provisioning datastores and optimizes ESXi host settings for NFS and block storage environments. For all these

benefits, it is recommended as a best practice when using vSphere with systems running ONTAP software. It includes both a VSC server appliance and UI extensions for vCenter.

Other ONTAP tools not specifically used in this NVA include the NetApp NFS Plug-In for VMware VAAI to use VAAI offload features with NFS storage, the VASA Provider for ONTAP to enable VMware Virtual Volumes (vVols) support, and the Storage Replication Adapter used together with VMware Site Recovery Manager (SRM) to manage data replication between production and disaster recovery sites.

Brocade SAN Health

Your storage architecture is critical for your business agility and success. Brocade's free SAN Health tool delivers clear insights into performance, inventory, and bottlenecks to optimize your SAN infrastructure and to align it with your business needs. This hardware-agnostic and easy-to-run tool generates personalized storage network performance and inventory reports to help you prevent issues, avoid application downtime, reduce troubleshooting time to resolution, and improve capacity planning and productivity. Figure 3 shows the components of the SAN Health tool, and Figure 4 shows how to use it.

Contact your NetApp account team (link) to sign up for a SAN Health check or to get a copy of the NetApp-branded SAN Health tool.

Figure 3) SAN Health report title page and table of contents.

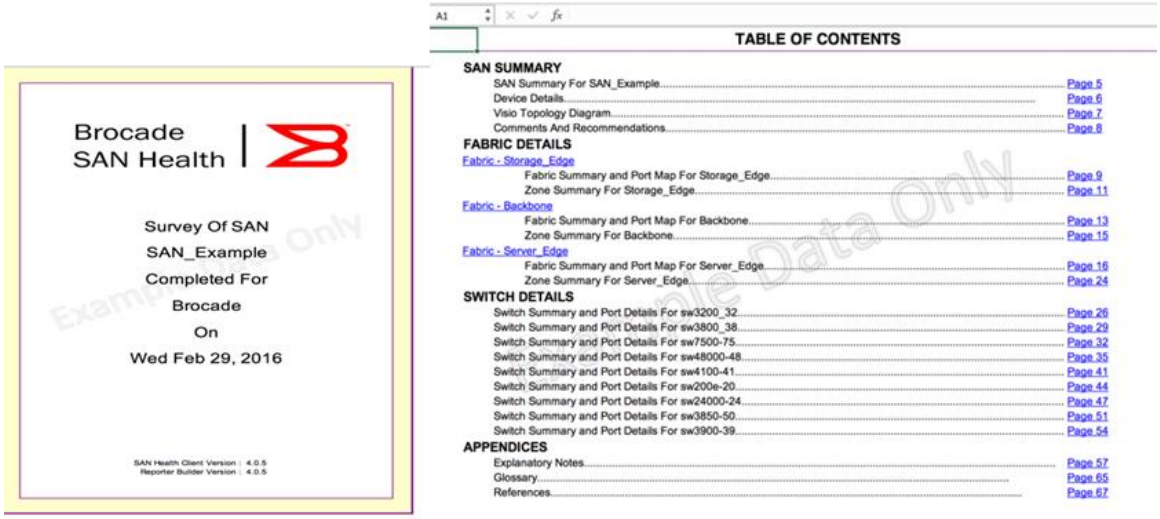
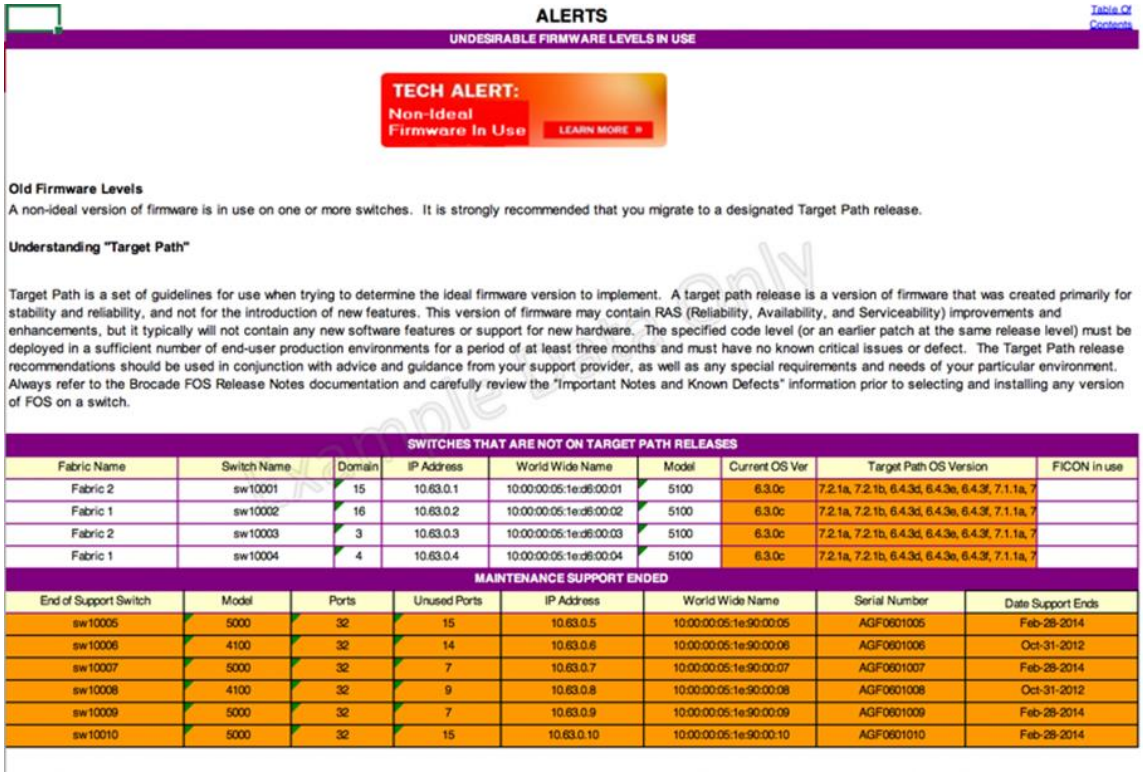


Figure 4) SAN Health color coded alerts and warnings.



ALERTS

Table Of Contents

UNDESIRABLE FIRMWARE LEVELS IN USE

TECH ALERT: Non-Ideal Firmware In Use LEARN MORE »

Old Firmware Levels

A non-ideal version of firmware is in use on one or more switches. It is strongly recommended that you migrate to a designated Target Path release.

Understanding "Target Path"

Target Path is a set of guidelines for use when trying to determine the ideal firmware version to implement. A target path release is a version of firmware that was created primarily for stability and reliability, and not for the introduction of new features. This version of firmware may contain RAS (Reliability, Availability, and Serviceability) improvements and enhancements, but it typically will not contain any new software features or support for new hardware. The specified code level (or an earlier patch at the same release level) must be deployed in a sufficient number of end-user production environments for a period of at least three months and must have no known critical issues or defect. The Target Path release recommendations should be used in conjunction with advice and guidance from your support provider, as well as any special requirements and needs of your particular environment. Always refer to the Brocade FOS Release Notes documentation and carefully review the "Important Notes and Known Defects" information prior to selecting and installing any version of FOS on a switch.

SWITCHES THAT ARE NOT ON TARGET PATH RELEASES

Fabric Name	Switch Name	Domain	IP Address	World Wide Name	Model	Current OS Ver	Target Path OS Version	FICON in use
Fabric 2	sw10001	15	10.63.0.1	10:00:00:05:1e:d6:00:01	5100	6.3.0c	7.2.1a, 7.2.1b, 6.4.3d, 6.4.3e, 6.4.3f, 7.1.1a, 7	
Fabric 1	sw10002	16	10.63.0.2	10:00:00:05:1e:d6:00:02	5100	6.3.0c	7.2.1a, 7.2.1b, 6.4.3d, 6.4.3e, 6.4.3f, 7.1.1a, 7	
Fabric 2	sw10003	3	10.63.0.3	10:00:00:05:1e:d6:00:03	5100	6.3.0c	7.2.1a, 7.2.1b, 6.4.3d, 6.4.3e, 6.4.3f, 7.1.1a, 7	
Fabric 1	sw10004	4	10.63.0.4	10:00:00:05:1e:d6:00:04	5100	6.3.0c	7.2.1a, 7.2.1b, 6.4.3d, 6.4.3e, 6.4.3f, 7.1.1a, 7	

MAINTENANCE SUPPORT ENDED

End of Support Switch	Model	Ports	Unused Ports	IP Address	World Wide Name	Serial Number	Date Support Ends
sw10005	5000	32	15	10.63.0.5	10:00:00:05:1e:90:00:05	AGF0601005	Feb-28-2014
sw10006	4100	32	14	10.63.0.6	10:00:00:05:1e:90:00:06	AGF0601006	Oct-31-2012
sw10007	5000	32	7	10.63.0.7	10:00:00:05:1e:90:00:07	AGF0601007	Feb-28-2014
sw10008	4100	32	9	10.63.0.8	10:00:00:05:1e:90:00:08	AGF0601008	Oct-31-2012
sw10009	5000	32	7	10.63.0.9	10:00:00:05:1e:90:00:09	AGF0601009	Feb-28-2014
sw10010	5000	32	15	10.63.0.10	10:00:00:05:1e:90:00:10	AGF0601010	Feb-28-2014

Using the SAN Health tool eliminates whiteboard-base and gives users clear high-quality reporting that they can use as the basis for SAN documentation and for management reporting. This report, and the Visio topology diagram (Figure 5), accelerate discovery and enable users to proactively fix problems.

Figure 5) SAN Health Visio diagrams accurately illustrates fabric layout and useful object.

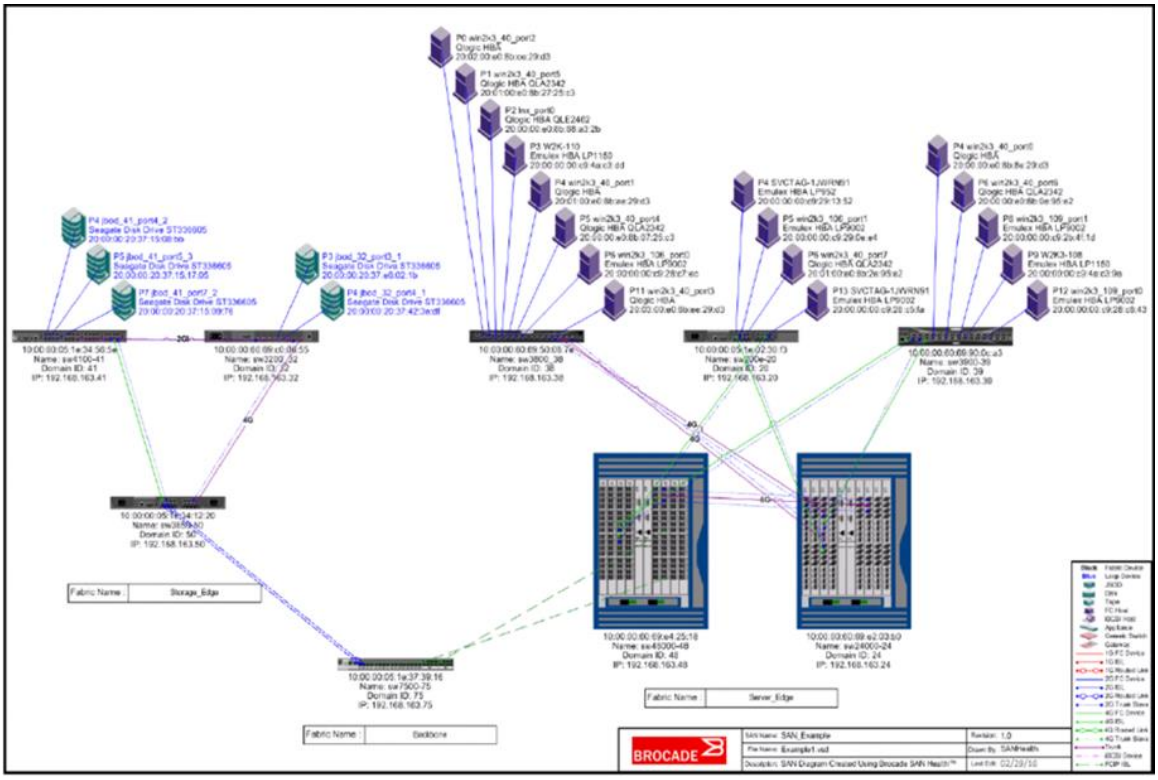
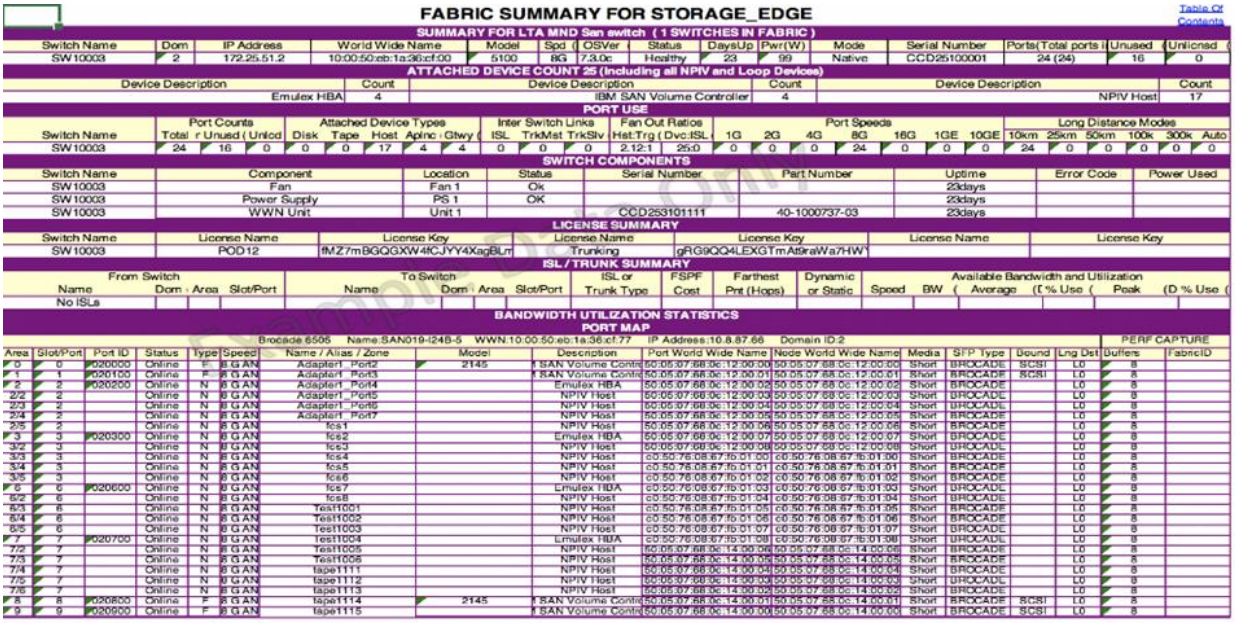


Figure 6 illustrates SAN Summary and how it offers an overview of the audited switches and helps to identify environmental factors where NVMe can enhance workload performance, such as high traffic, producing an insight into balanced traffic.

Figure 6) SAN Health Summary comprehensively details current configuration along with best practice, health and configuration checks.



FABRIC SUMMARY FOR STORAGE_EDGE

Table Of Contents

SUMMARY FOR LTA MND San switch (1 SWITCHES IN FABRIC)

Switch Name	Dom	IP Address	World Wide Name	Model	Spd	OSVer	Status	DaysUp	Pwr(W)	Mode	Serial Number	Ports(Total ports i	Unused	Unlicnsd
SW10003	2	172.25.51.2	10:00:50:eb:1a:36:cf:00	5100	8G	7.3.0c	Healthy	23	99	Native	CCD2510000 1	24 (24)	16	0

ATTACHED DEVICE COUNT 25 (Including all NPIV and Loop Devices)

Device Description	Count	Device Description	Count	Device Description	Count
Emulex HBA	4	IBM SAN Volume Controller	4	NPIV Host	17

PORT USE

Switch Name	Port Counts Total	r Unusd (	Unlcd	Attached Device Types Disk	Tape	Host	Aplnc	Gtwy (	Inter Switch Links ISL	TrkMst	TrkSlv	Fan Out Ratios Hst:Trg (	Dvc:ISL (	Port Speeds 1G	2G	4G	8G	16G	1GE	10GE	Long Distance Modes 10km	25km	50km	100k	300k	Auto
SW10003	24	16	0	0	0	17	4	4	0	0	0	2.12:1	25:0	0	0	0	24	0	0	0	24	0	0	0	0	0

SWITCH COMPONENTS

Switch Name	Component	Location	Status	Serial Number	Part Number	Uptime	Error Code	Power Used
SW10003	Fan	Fan 1	Ok			23days		
SW10003	Power Supply	PS 1	OK			23days		
SW10003	WWN Unit	Unit 1		CCD2531011 11	40-1000737-03	23days		

LICENSE SUMMARY

Switch Name	License Name	License Key	License Name	License Key	License Name	License Key
SW10003	POD12	fMZ7mBGQGXW4fCJYY4XagBLm	Trunking	gRG9QQ4LEXGTmAt9raWa7HWY		

ISL / TRUNK SUMMARY

From Switch Name	Dom	Area	Slot/Port	To Switch Name	Dom	Area	Slot/Port	ISL or Trunk Type	FSPF Cost	Farthest Pnt (Hops)	Dynamic or Static	Available Bandwidth and Utilization Speed	BW (	Average (	% Use (	Peak (	% Use (
No ISLs																	

BANDWIDTH UTILIZATION STATISTICS

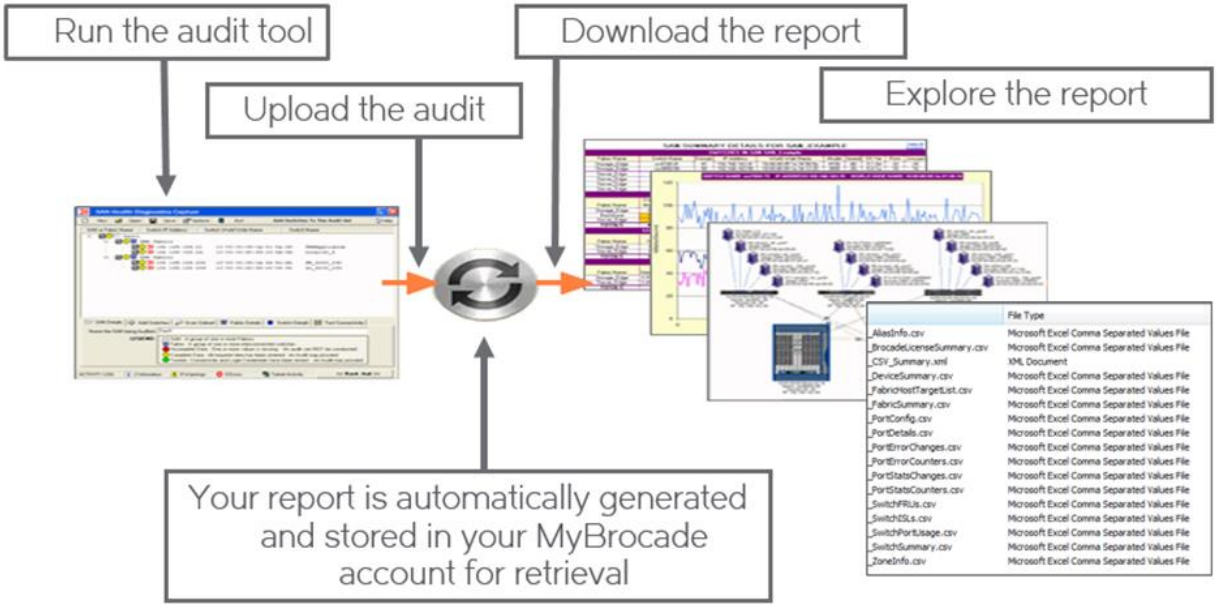
PORT MAP

Brocade 6505 Name:SAN019-I24B-5 WWN:10:00:50:eb:1a:36:cf:77 IP Address:10.8.87.66 Domain ID:2 PERF CAPTURE

Area	Slot/Port	Port ID	Status	Type	Speed	Name / Alias / Zone	Model	Description	Port World Wide Name	Node World Wide Name	Media	SFP Type	Bound	Lng Dst	Buffers	FabricID
0	0	020000	Online	F	8 GAN	Adapter1_Port2	2145	SAN Volume Contro	50:05:07:68:0c:12:00:00	50:05:07:68:0c:12:00:00	Short	BROCADE	SCSI	L0	8	
1	1	020100	Online	F	8 GAN	Adapter1_Port3		SAN Volume Contro	50:05:07:68:0c:12:00:01	50:05:07:68:0c:12:00:01	Short	BROCADE	SCSI	L0	8	
2	2	020200	Online	N	8 GAN	Adapter1_Port4		Emulex HBA	50:05:07:68:0c:12:00:02	50:05:07:68:0c:12:00:02	Short	BROCADE		L0	8	
2/2	2		Online	N	8 GAN	Adapter1_Port5		NPIV Host	50:05:07:68:0c:12:00:03	50:05:07:68:0c:12:00:03	Short	BROCADE		L0	8	
2/3	2		Online	N	8 GAN	Adapter1_Port6		NPIV Host	50:05:07:68:0c:12:00:04	50:05:07:68:0c:12:00:04	Short	BROCADE		L0	8	
2/4	2		Online	N	8 GAN	Adapter1_Port7		NPIV Host	50:05:07:68:0c:12:00:05	50:05:07:68:0c:12:00:05	Short	BROCADE		L0	8	
2/5	2		Online	N	8 GAN	fcs1		NPIV Host	50:05:07:68:0c:12:00:06	50:05:07:68:0c:12:00:06	Short	BROCADE		L0	8	
3	3	020300	Online	N	8 GAN	fcs2		Emulex HBA	50:05:07:68:0c:12:00:07	50:05:07:68:0c:12:00:07	Short	BROCADE		L0	8	
3/2	3		Online	N	8 GAN	fcs3		NPIV Host	50:05:07:68:0c:12:00:08	50:05:07:68:0c:12:00:08	Short	BROCADE		L0	8	
3/3	3		Online	N	8 GAN	fcs4		NPIV Host	c0:50:76:08:67:fb:01:00	c0:50:76:08:67:fb:01:00	Short	BROCADE		L0	8	
3/4	3		Online	N	8 GAN	fcs5		NPIV Host	c0:50:76:08:67:fb:01:01	c0:50:76:08:67:fb:01:01	Short	BROCADE		L0	8	
3/5	3		Online	N	8 GAN	fcs6		NPIV Host	c0:50:76:08:67:fb:01:02	c0:50:76:08:67:fb:01:02	Short	BROCADE		L0	8	
6	6	020600	Online	N	8 GAN	fcs7		Emulex HBA	c0:50:76:08:67:fb:01:03	c0:50:76:08:67:fb:01:03	Short	BROCADE		L0	8	
6/2	6		Online	N	8 GAN	fcs8		NPIV Host	c0:50:76:08:67:fb:01:04	c0:50:76:08:67:fb:01:04	Short	BROCADE		L0	8	
6/3	6		Online	N	8 GAN	Test1001		NPIV Host	c0:50:76:08:67:fb:01:05	c0:50:76:08:67:fb:01:05	Short	BROCADE		L0	8	
6/4	6		Online	N	8 GAN	Test1002		NPIV Host	c0:50:76:08:67:fb:01:06	c0:50:76:08:67:fb:01:06	Short	BROCADE		L0	8	
6/5	6		Online	N	8 GAN	Test1003		NPIV Host	c0:50:76:08:67:fb:01:07	c0:50:76:08:67:fb:01:07	Short	BROCADE		L0	8	
7	7	020700	Online	N	8 GAN	Test1004		Emulex HBA	c0:50:76:08:67:fb:01:08	c0:50:76:08:67:fb:01:08	Short	BROCADE		L0	8	
7/2	7		Online	N	8 GAN	Test1005		NPIV Host	50:05:07:68:0c:14:00:06	50:05:07:68:0c:14:00:06	Short	BROCADE		L0	8	
7/3	7		Online	N	8 GAN	Test1006		NPIV Host	50:05:07:68:0c:14:00:05	50:05:07:68:0c:14:00:05	Short	BROCADE		L0	8	
7/4	7		Online	N	8 GAN	tape1111		NPIV Host	50:05:07:68:0c:14:00:04	50:05:07:68:0c:14:00:04	Short	BROCADE		L0	8	
7/5	7		Online	N	8 GAN	tape1112		NPIV Host	50:05:07:68:0c:14:00:03	50:05:07:68:0c:14:00:03	Short	BROCADE		L0	8	
7/6	7		Online	N	8 GAN	tape1113		NPIV Host	50:05:07:68:0c:14:00:02	50:05:07:68:0c:14:00:02	Short	BROCADE		L0	8	
8	8	020800	Online	F	8 GAN	tape1114	2145	SAN Volume Contro	50:05:07:68:0c:14:00:01	50:05:07:68:0c:14:00:01	Short	BROCADE	SCSI	L0	8	
9	9	020900	Online	F	8 GAN	tape1115		SAN Volume Contro	50:05:07:68:0c:14:00:00	50:05:07:68:0c:14:00:00	Short	BROCADE	SCSI	L0	8	

Also, SAN Health is quick to install and run, as shown in Figure 7.

Figure 7) Steps required to run and to use SAN Health.



VMware vSphere

There are many reasons why more than 50,000 customers have selected ONTAP as their storage solution for vSphere, as a unified storage system supporting both SAN and NAS protocols, robust data protection capabilities by using space-efficient NetApp Snapshot™ copies, and a wealth of tools to help you manage application data. Using a storage system separate from the hypervisor enables you to offload many functions and maximize your investment in vSphere host systems. This approach not only makes sure your host resources are focused on application workloads, but also avoids random performance impacts to applications from storage operations.

Using ONTAP together with vSphere is a great combination that lets you reduce host hardware and VMware software expenses, make sure data is protected at lower cost, and provide consistent high performance. And because virtualized workloads are mobile, you can explore different storage approaches by using Storage vMotion to move VMs across VMware Virtual Machine File System (VMFS), NFS, or vVol datastores, all on the same storage system.

As noted here, vSphere 7.x supports NVMe-oF, enabling connectivity to external NVMe arrays by using FC protocol. As NVMe continues to grow and become the preferred storage, being able to connect to external NVMe arrays through the vSphere infrastructure is critical.

Data protection

Backing up your VMs and quickly recovering them are among the great strengths of ONTAP for vSphere; it is easy to manage this ability inside vCenter with the VSC and NetApp Snapshot technology. Use Snapshot copies to make quick copies of your VM or datastore without affecting performance. This approach minimizes storage space and network bandwidth by only storing changed information.

The power of ONTAP Snapshot technology is extended further with FabricPool. This data fabric technology enables cold Snapshot blocks to automatically move to a separate object storage tier to increase the number of Snapshot copies that can be maintained (to as many as 1,023) while reducing the

cost of storage. This object tier can be in the form of a private cloud (for example, NetApp StorageGRID®) or a public cloud (such as Amazon Web Services (AWS) or Azure). The solution moves cold data to the cloud as the blocks age, yet they are recalled automatically if the Snapshot copy is needed for recovering a VM or entire datastore.

Use case summary

The use case for virtualizing enterprise applications is well known. Not only does virtualization reduce costs through physical consolidation of servers and storage, which increases asset utilization, it also provides business flexibility. You can provision new server instances in moments to address urgent business needs. Furthermore, you can apply automation (the software-defined data center) to enable greater consistency, reducing problems that impact availability and data security.

Yet enterprises today face new imperatives that a modern SAN approach can address simply and quickly. Here are some of the ways NetApp, VMware, and Broadcom customers are adding value with ONTAP:

- **Cloud.** A broad array of hybrid cloud options enabled through the data fabric powered by NetApp supports the goals of most enterprise organizations to use a combination of public and private clouds to add more flexibility and reduce their infrastructure management overhead. Use cloud offerings from Azure, AWS, IBM, Google, and others with integrated ONTAP offerings for data protection, cloud computing, and business continuance while avoiding provider lock in.
- **Data protection.** Integrated data protection by using Snapshot copies and cloning speeds virtual storage provisioning and better protects critical data than relying on external protection systems.
- **Cost efficiency.** Integrated storage efficiency enables ONTAP to significantly reduce storage costs over legacy SAN systems. NetApp AFF systems can run all storage efficiency capabilities in production with no performance impact, something most other SAN arrays cannot do. The broad array of ONTAP storage efficiency features has resulted in customers seeing up to 5:1 savings for virtual server infrastructure and up to 30:1 for virtual desktop infrastructure. NetApp makes it simple to plan for these efficiency benefits with the most effective guarantee available.
- **Security.** ONTAP offers a range of features to meet an organization's security needs. You can enable NetApp Volume Encryption (NVE) quickly on any ONTAP volume and it does not require an external key server. You can also use it to enable digital shredding of data. Or use NetApp Storage Encryption (NSE) with self-encrypting disks for full disk encryption. Snapshot copies are used by many customers to protect against malware and ransomware and can be further strengthened with immutable Snapshot copies by using NetApp SnapLock® software. For more information, see TR-4572: The NetApp Solution for Ransomware.
- **Performance.** As described throughout this document, a modern SAN solution leveraging 32Gb FC SAN or NVMe/FC can meet the ever-faster performance requirements demanded by today's global, always-on enterprise.
- **Flexibility.** Needs change quickly in today's organization, and ONTAP is quick to adapt. Most of these capabilities are included with an ONTAP system at no additional charge or can be enabled with a license key. And while the focus of this NetApp Verified Architecture is SAN, the unified storage capabilities of ONTAP make it simple to add NAS protocols to support other applications and file sharing.

Technology requirements

This section covers the minimal technology requirements for this NetApp, VMware, and Broadcom NVMe/FC verified architecture.

Hardware requirements

Table 1) Hardware requirements for the joint solution.

Hardware	
Storage controllers	NetApp AFF A320/A400/A700/A700s/A800/A900 high-availability (HA) pair with 32Gb FC target ports and at least 24 SAS 960GB or larger SSDs
Switches	G720, X7 Directors, X6 Directors, G630, G620, G610 Switches, 8510 Directors, 6520, 6510 & 6505 Switches
Fibre Channel HBAs	Emulex LPe35002-M2 32Gb FC
x86 servers	Fujitsu Primergy RX2540 M4

Software requirements

Table 2) Software requirements for the joint solution.

Software	Version
NetApp	ONTAP 9.7 or later
Brocade Fabric OS (FOS)	8.1.0a or later
Emulex Firmware	FW:12.6.234.3 DRVR:12.6.228.4 or later
VMware	vSphere 7.0 or later

Technology used during testing

This section covers the technology used in our lab for this NetApp, VMware, and Broadcom NVMe/FC verified architecture.

Table 3) Hardware used for the joint solution.

Hardware	Quantity
Storage NetApp AFF A800 HA pair with four 32Gb FC target ports and 24 SAS 1.9TB SSDs	1
Switches Brocade G720 32Gb FC switches 10Gb Ethernet switches	2 2
Fibre Channel HBAs Emulex LPe35002-M2 32Gb FC	7
x86 servers Fujitsu Primergy RX2540 M4	9 (7 SQL Server servers and 2 for test infrastructure)

Table 4) Software used for the joint solution.

Software	Version
NetApp ONTAP	9.10.1GA
Brocade Fabric OS (FOS)	8.2.1b
Emulex Firmware	12.6.234.3 DVR: 12.6.228.4
Microsoft SQL Server	2017
Microsoft Windows	2019
VMware	ESXi 7.0 U3c Build 19193900

Testbed design

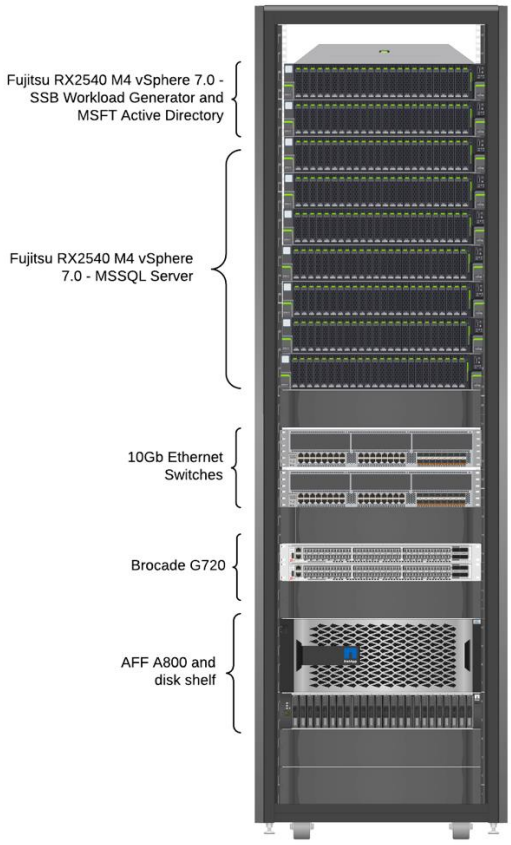
This section provides details for the tested configurations as well as an overview of the hardware that was used for the performance results.

As shown in Figure 8, we deployed seven Fujitsu Primergy RX2540 M4 servers. We installed VMware ESXi 7.0 Update 3c on each server and installed two Microsoft Windows 2019 VMs per server. Each VM contained one MS SQL Server instance with one MS SQL Server database. This resulted in a total of 14 MS SQL Server databases.

We allocated each SQL Server VM with 10 vCPUs and 110GB vRAM. We created an 400GB MS SQL Server 2017 database on each host. For our FCP testing, we distributed each database across six LUNs (five LUNs for data and one LUN for logs). For our NVMe/FC testing, we distributed each database across three namespaces (two namespaces for data and one namespace with both data and logs).

The diagram in Figure 8 shows the rack layout of our solution used to generate the workload.

Figure 8) NetApp, VMware, and Broadcom validated architecture testbed layout.



We configured each ESXi host to have two 32Gb FC ports each connected to a two G720 Brocade switches. The AFF A800 had four 32Gb FC connections on each of two storage nodes, resulting in a total of four 32Gb connections to each G720 switch. We configured zoning on the Brocade director by using single initiator zoning and WWPNs to identify zone members. Port zoning on the G720 switches was configured to allow for each initiator port map to eight target ports (four targets on each AFF A800 node).

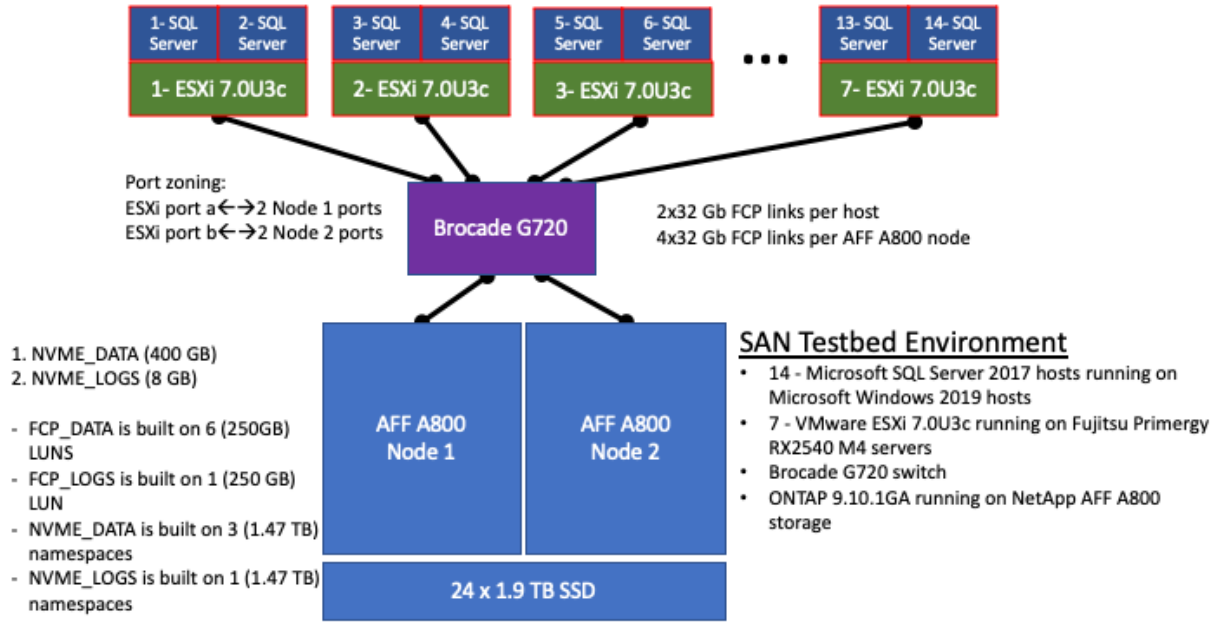
If we instead chose to use switch ports to identify zone membership, we would have lost the granularity required to be able to zone LIFs individually.

Only the VMDKs for the databases and logs were stored on the AFF A800 storage system. We stored the host VMDKs, which included the Windows operating system and SQL Server application, on local ESXi datastores.

Although all links were active during our workload testing, we configured Asynchronous Namespace Access (ANA) in our testbed.

Figure 9 shows a block diagram of the SAN testbed environment.

Figure 9) SAN Testbed block diagram.



In addition to the 14 MS SQL Server VMs, we created one additional VM on a dedicated server to drive the SSB workload application, and another VM on a dedicated server to act as the Active Directory for the Windows environment.

For Ethernet connectivity, each of the hosts had both 1Gb and 10Gb links for management, vMotion, and other provisioning traffic.

Each of the (ESXi Hosts) SQL Server hosts also had two FCP ports that were connected to each G720. Each AFF A800 node had two FCP target ports that were also connected to each switch, for eight total connected target ports.

Workload design

For our testing, we used SQL Storage Benchmark (SSB), an Open Source Benchmark tool written in Python. It is designed to generate a 'real-world' workload that emulates SQL database interaction in such a way to measure the performance of the storage subsystem. SSB can drive massive-scale SQL execution against a SQL Server database to simulate an OLTP workload. We used SSB to generate a workload by making SELECT and UPDATE SQL statement calls directly to the SQL Server database environment installed on our host systems. We configured the SSB workload generator on a dedicated server to ensure that the workload execution did not disrupt our test workload.

For this project, we ran a set of SSB workloads to ramp from 14 to 1,400 SQL Server users, with 10 or 12 intermediate points. Each data point ran a fixed number of users and threads for 15 minutes. This allowed us to gather performance metrics at a range of different load points and determine peak performance. Metrics were collected by SSB. Each set of data points was run three or more times for each workload mix to ensure repeatable results. All sets of workloads were run on the two test configurations: NVMe/FC and FCP.

We ran two suites of load points:

- 100% SELECT statement workload (simulating a 100% random-read workload)

- 80% SELECT and 20% UPDATE statement workload (simulating an ~80% random-read workload).

We used the SSB tool to create a 400GB SQL Server database. We spread the database across five 200GB VMDK files, and one additional 200GB VMDK to handle the database log activity. For the FCP environment, we deployed six 250GB LUNs on each of the 14 SQL Server hosts. We created one LUN per volume and one VMDK per LUN. For the NVMe/FC environment, we created three 1.46TB namespaces per SQL Server host but used two VMDKs per namespace.

The tool allowed each virtual user to randomly access the schemas in the database and randomly choose where to read or update within that schema. This ensured that the working data set used the entire database and wasn't completely resident in memory.

Solution verification

NetApp studied the performance of an AFF A800 storage system. This section describes the test methodology that we used to verify the architecture while we ran a suite of synthetic workloads.

Test methodology

VMware ESXi 7.0 was installed on each of the 14 hosts. The AFF A800 storage system contained two nodes, with a single disk aggregate on each. FCP was configured by using a single ONTAP SVM. The VSC was used to configure host settings to best practices

ONTAP best practices for vSphere are to use a single LUN/namespace for each datastore, with a recommended size of 4TB to 8TB. This size is a good balance point for performance, ease of management, and data protection (using either tape backup or remote replication). For FCP, datastores were provisioned using the VSC using:

- Thin provisioning (NetApp FlexVol volumes, LUNs, and VM files)
- FlexVol volume autosize (VSC default)
- All storage efficiency including inline zero-block deduplication, inline adaptive compression, inline and background (auto) volume and aggregate deduplication, and inline data compaction (AFF default)
- Supported Snapshot copies (not scheduled or reserved)

As ONTAP systems are designed for multiple workloads and tenants, best performance is obtained when at least four FlexVol volumes are used per node. IT teams evaluating ONTAP systems for vSphere should keep this in mind. It might be simpler to configure a single datastore with a single LUN for a proof of concept (POC) evaluation; however, this doesn't represent a normal vSphere storage environment and will not deliver the best performance from an ONTAP system. Likewise, performance is best tested with multiple VMs. Testing storage performance by running a storage benchmark tool in a single VM is not representative of typical virtualization workloads.

Test results

In our tests, we observed that NVMe/FC delivered over 50% higher total IOPS compared with SCSI over FCP by using the same hardware configuration and the SSB workloads, as shown by the 100% select workload at 1ms latency. This result means that you can run many more workloads on the same hardware by simply upgrading your software to NVMe-capable versions in the client operating system, in the fabric firmware, and in the ONTAP version for NetApp storage. Tests also showed a reduction in latency at each corresponding total IOPS measurement. This lower latency means a better response time for client I/O requests, again with only a simple software upgrade.

In addition:

- **NVMe/FC is easy to adopt**. All the performance gains that we observed were made possible by a simple software upgrade.

- **NVMe/FC protects your investment**. The benefits that we observed were with existing hardware that supports 32Gb FC.
- **NVMe/FC promotes data center consolidation**. With increased IOPS density, your system can complete more work in the same hardware footprint. Also, because NVMe/FC often reduces processor and memory loads on initiators, if you adopt NVMe/FC, your organization might be able to reduce the number of servers that you need for your workloads. This reduction translates to fewer servers and lower software licensing, footprint, and power and cooling costs.

IOPS benefits

A more efficient fabric protocol can deliver higher IOPS. In our tests, we observed a greater than 50% increase in total IOPS by simply moving over to the NVMe/FC fabric from the traditional FCP (FC-SCSI) fabric. With NVMe/FC, 530K total IOPS at 1ms latency was achieved during the MS SQL 100% SELECT workload.

With the goal to consistently serve our customers better, NetApp, VMware, and Broadcom are in pursuit of further improving the performance of the NVMe/FC solution. The performance gain with the upcoming version of products will be higher, a good reason to future proof your investment now.

Latency benefits

NVMe/FC has lower latency than traditional FCP (FC-SCSI). Our observations showed a reduction in latency at each corresponding total IOPS measurement.

Better performance with existing hardware

These benefits can be achieved by simply applying a software upgrade for the FC HBAs. By moving to NVMe/FC with the same storage hardware, you can attain dramatic increases in performance.

NVMe/FC Benefits—FC HBAs

NVMe/FC brings native parallelism and efficiency to block storage that FCP (FC-SCSI) cannot. In separate testing over at least the past year, Broadcom (Emulex division) has observed performance improvements of up to two times with NVMe/FC over FC-SCSI.

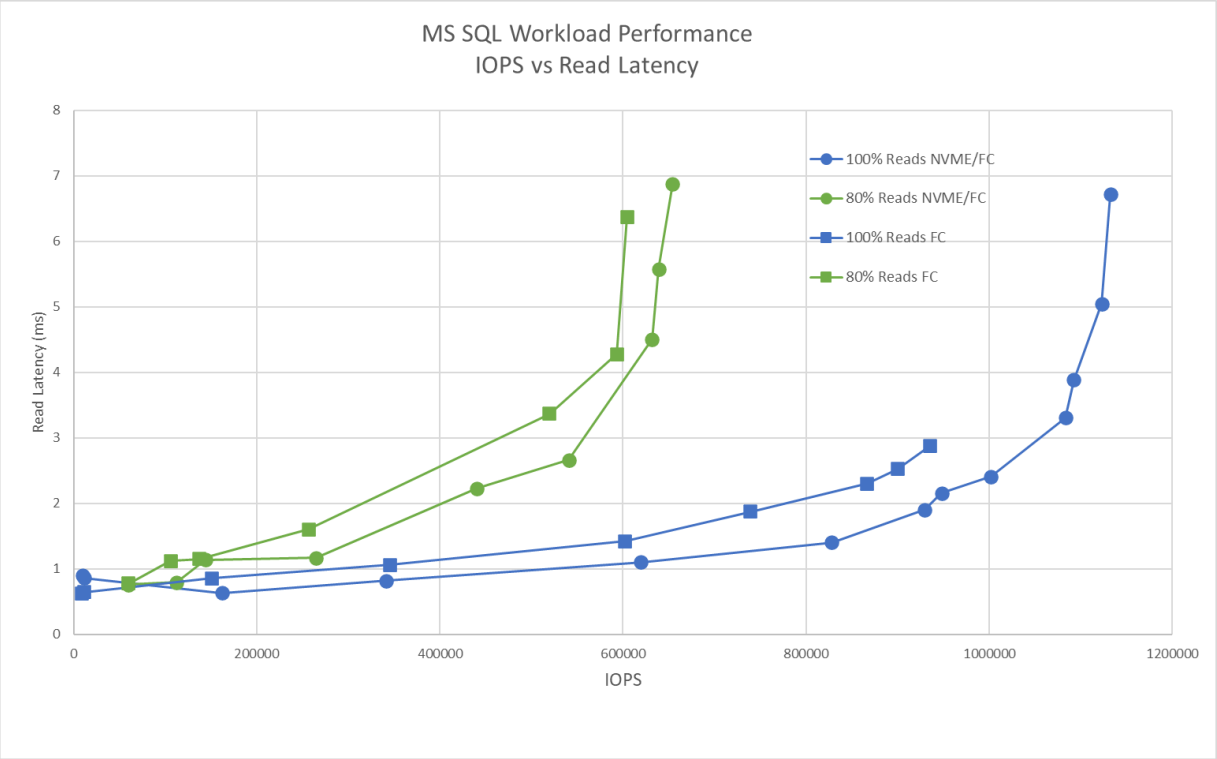
NVMe/FC Benefits—FC Switches

Brocade Gen 7 Fibre Channel fabrics transport both NVMe and FCP (FC-SCSI) traffic concurrently with the same high bandwidth and low latency. Overall, the NVMe performance benefits are in the end nodes—initiators (host servers) and targets (storage), both featuring Emulex HBAs in this architecture. NVMe/FC provides the same proven security that the traditional FCP has provided for many years. FC provides full fabric services for NVMe/FC and FCP (FC-SCSI), such as discovery and zoning. Also, NVMe/FC is the first enterprise NVMe-oF transport that meets the same high bar as SCSI over FC with full-matrix testing as an enabler and as essential for enterprise-level support.

Figure 10 compares the two workloads. Blue represents the 100% SELECT datapoints and green represents the 80% SELECT datapoints. Square markers represent FCP protocol datapoints and circles represent NVMe/FC protocol datapoints. It is easy to see the big improvements in IOPS offered by NVMe/FC on both workloads

During testing, we observed that read data had higher cache hits to disk hits, ~70%/30%. As the load increased, we observed that there was a decrease in cache hits and increase in disk hits at ~20/80.

Figure 10) Total IOPS versus server read latency.



Future disruptive innovation

For the past few years, the IT industry has undergone a rapid chain of innovation that has resulted in substantial disruption to traditional IT delivery models and has rendered many legacy hardware vendors obsolete. Most architectures are unable to evolve with the changes, resulting in successive waves of disruption, re-architecture, fork-lift upgrades, and migration for customers that they can no longer afford from either an inefficiency or financial perspective.

At NetApp, we have pioneered the concept of nondisruptive operations (NDO) migrations and online transitions between generations of technology with heterogeneously scalable IT infrastructure. NetApp has focused on innovation in software and on the ability for you to add infrastructure as you grow, with connections between each generation of technology. The following is just a short list of recent disruptions. NetApp stands ready to take these innovations into our architectures of today and help you integrate them without forklift upgrades or disruptive migrations.

Key technology initiatives that are driving change include:

- HDDs replaced by flash
- Hardware appliances augmented or replaced by software-defined storage (SDS)
- NVMe-based media attached for flash
- NVMe-based host attachment
- Storage-class memory (SCM, also known as PMEM used for caching and MAX Data)
- Cloud-based IT infrastructure
- Hyper converged infrastructure
- AI, deep learning computing

As these initiatives come into the market, NetApp continues to support the evolution and revolution of IT with an agile software-defined approach. We support initiatives such as IoT, DevOps, hybrid cloud, and in-memory database server technologies, beyond what other vendors can comfortably discuss. We recently announced partnerships with three major hyperscalers for the NetApp cloud-connected flash array; our edge-to-core-to-cloud data pipeline; and the ability to mix SDS, hardware, and cloud instances of our data platform. These offerings give us a superior ability to future-proof your architecture.

As we have discussed in this report, with a simple software upgrade to the NVMe/FC protocol, you can easily future-proof your infrastructure and accelerate tier-1 mission-critical enterprise applications and workloads with an investment in NetApp.

Conclusion

In this report, we presented the NetApp, VMware, and Broadcom modern enterprise SAN verified architecture. This solution is the optimal infrastructure approach for you to leverage best-in-class, end-to-end, modern SAN and NVMe technologies to deliver business-critical IT services today while preparing for the future. As we have already seen that future will include serving high-performance database, analytics, AI and machine learning, and IoT requirements.

NetApp, VMware, and Broadcom have created an architecture framework that is both future-ready and usable today and that is easy for you to implement within your current operational processes and procedures. One of our main objectives is to enable organizations like yours to quickly and nondisruptively streamline and modernize their traditional SAN infrastructure and the IT services that rely on it. To meet this objective, these modern platforms must:

- Be high performing to provide more real-time analysis and availability of critical data
- Adopt modern future-facing and disruptive technologies in a nondisruptive manner
- Provide agility, flexibility, and high scalability
- Fit within current operational frameworks
- Align with organizational objectives to consolidate and streamline infrastructure and operations

In this NetApp Verified Architecture, tests on a virtualized environment represent the benefits of a modern SAN architecture that is suited for multiple use cases and for critical SAN-based workloads. These benefits apply to most virtualized environments running VMware vSphere in a SAN environment.

For example, database administrators can meet evolving database performance and data management requirements by virtualizing their RDBMS with VMware and NVMe/FC. Databases and their log file tiers can be moved to virtual disk devices (i.e., VMDKs) in datastores provisioned in an NVMe/FC namespace. This enables the RDBMS to reap the performance benefits of increased IOPS at lower latency to drive better data access to applications, as shown in this NetApp Verified Architecture. Additionally, database administrators benefit from a simplified storage configuration, and can take advantage of advanced host-side features, even if those features do not yet support NVMe/FC!

With the flexibility and scalability of this NetApp Verified Architecture, your organization can start with a framework to modernize and to right-size your infrastructure and can ultimately grow with and adapt to evolving business requirements. With these benefits, your system can serve existing workloads while streamlining infrastructure, reducing operational costs, and preparing for new workloads in the future.

Where to find additional information

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

- Leading the Future of Flash with NVMe
  www.netapp.com/us/info/nvme.aspx
- An Industry First: All-Flash NVMe over Fibre Channel
  https://blog.netapp.com/leading-the-industry-with-nvme-over-fibre-channel
- When You're Implementing NVMe Over Fabrics, the Fabric Really Matters
  https://blog.netapp.com/nvme-over-fabric/
- TR-4684: Implementing and Configuring Modern SANs with NVMe/FC
  https://www.netapp.com/us/media/tr-4684.pdf
- TR-4080: Best Practices for Modern SAN ONTAP 9
  https://www.netapp.com/us/media/tr-4080.pdf
- SAN Solutions
  https://www.netapp.com/us/products/storage-systems/storage-area-network.aspx
- Brocade Fibre Channel Networking Switches
  https://www.broadcom.com/products/fibre-channel-networking/switches/
- Brocade Fibre Channel Networking Directors
  https://www.broadcom.com/products/fibre-channel-networking/directors
- Brocade/NetApp Partner Documents
  https://www.broadcom.com/company/oem-partners/fibre-channel-networking/netapp
- NVMe over Fibre Channel for Dummies
  https://www.netapp.com/us/forms/campaign/nvme-for-dummies-ebook-lp.aspx
- NetApp SAN Health Program
  https://www.netapp.com/us/forms/campaign/amer-us-fy19q3-sss-san-san-health-check-inquiry-form.aspx?ref_source=smc&cid=27476
- MAX Data Public Blog
  https://blog.netapp.com/an-update-on-the-plexistor-acquisition-introducing-netapp-memory-accelerated-data/

Version history

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

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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