The Future of Storage Network Technologies

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Abstract— Storage is a serious issue in today's IT world. Companies depend on information storage systems. It is important that data is available at the right time to any person who needs access to it from any location. This leads to storage-centric architecture which is different from the previous processor-centric architecture. Data in various formats like texts, images, audio and video are used in applications and it is valuable and must be stored securely. Network storage becomes important to store large repositories of data. A network based smart storage system is required and the key factors for deciding the storage solution are availability, scalability, capacity, efficient utilization, flexibility, accessibility, protection and performance. This paper discusses the primary configurations of storage network - SAN, NAS and DAS and the problems related to SAN. It focuses on the recent developments – NVMeoF mainly and the next generation of storage network like SDS, RDMA.

Keywords: NVMe over Fabrics (NVMeoF), Software Defined Storage (SDS), Storage Area Network (SAN), Direct Attached Storage (DAS), Network Attached Storage (NAS)

I. INTRODUCTION

Large amounts of data are being generated every year with the emergence of Internet, Big Data, voice/video/data convergence, data warehousing, rich media streaming and e-Commerce. The survey in [1] predicts the rise and expansion of the digital universe by 300 times from 2006 to 2020 along with the increase in existing data from a few exabytes to trillions of gigabytes. This universe was predicted to multiply twice as much by 2020. A study by IBM shows that enormous amount of data is being produced daily and in the last two years majority of the total data has been created across the globe and these numbers keep rising.

Data is the most valuable asset of any corporate. They face new challenges in effectively storing, protecting, accessing and managing critical data. Traditional technologies like tape media cannot satisfy the need to access and protect data as strategic asset. Tape media has inherent issues which lead to its replacement altogether. Storage architecture is presently based on the network. The most critical factor in day-to-day businesses is downtime and the downtime costs are huge and cause service outrage and customer dis-satisfaction. Stringent requirements for data security and its high availability are created by federal mandates as per compliance standards.

II. STORAGE NETWORK

Storage technology plays an important role in the computer industry recently. The various storage models and interfaces used by the industry from the beginning to the latest storage architectures are analyzed in [4]. It sheds light on the three technologies – Direct Attached Storage (DAS), Network Attached Storage (NAS) and Storage Area Network (SAN). It discusses the improvements, evaluates the performances in terms of data transfer rate of each technology and market availability and also compares with the earlier models.

The 3 configurations which the storage network has evolved into are: Direct Attached Storage (DAS), Network Attached Storage (NAS) and Storage Area Network (SAN)

A. Storage Area Network

A storage area network (SAN) or storage network is a high-performance dedicated network of storage devices, such as disk arrays and tape libraries, that provides access to consolidated, block-level data storage [2]. It enhances the accessibility of shared pool of storage devices (target) from servers (host). It can transfer large data blocks which is extremely useful in imaging, transaction processing, cloud computing, database, virtual environments and other bandwidth-intensive applications. Though it offers reliability and availability, it requires huge investment for design, development and its deployment and is limited to enterprise sector. Fibre Channel (FC) is used for connecting devices such as RAID (Redundant Array of Independent Disks) arrays, DAS or tape libraries to servers in SAN infrastructure. SAN emerged in 1994 but gained popularity later with availability of 1 Gbps FC.

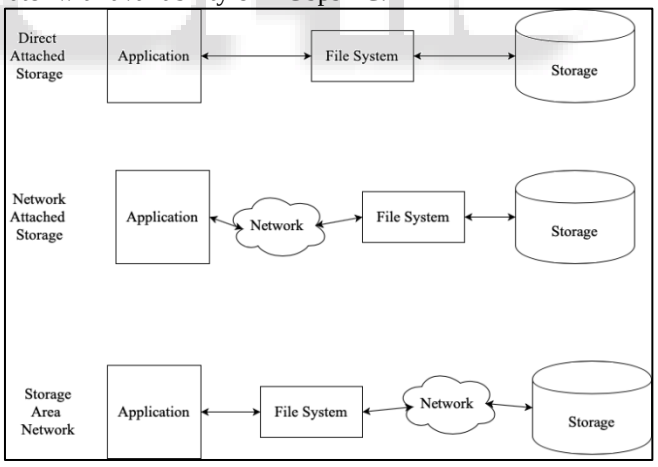

Fig. 1: DAS, NAS, SAN

Unlike DAS, SANs supported shared storage and the utilization of storage was better. The reliability and performance were higher and the management was simplified by usage of a standard set of storage functions available to any or all servers in the data centre. With time the performance improved and the costs decreased to levels enabling wider adoption across enterprise as well as SMB environments. Introduction of new capabilities such as snapshots, remote copy, de-duplication, and compression in SAN increased its outreach against DAS.

B. Direct Attached Storage

The storage device is directly attached to the host (server/computer) in DAS. It is designed such that only a single computer can use it and sharing of resources is not supported. It provides high performance and is easy to setup and configure, and is economical than SAN. It cannot be managed over a network like in SAN.

C. Network Attached Storage

NAS is a special purpose device, comprising of hard disks and management, dedicated to serve files over a network [3]. It allows sharing storage over a network. Various levels of access can be provided and multiple user logins can be created. NAS provides an economical way to gain data access for several clients at file level and is ideal for SMBs to improve its performance and increase the productivity. It is easy to setup and configure compared to SAN, and other advantages include maximum utilization of storage resources, the easy-to-provide RAID redundancy to many users. The protocols used in SAN and NAS are summarized in [6]. Open industry-standard network protocols are used by SAN and NAS to provide storage facility. SAN uses the iSCSI, FCP and FCoE protocols whereas NAS uses the NFS and CIFS protocol. Latency issues exist in NAS due to network issues and are disadvantageous. Table I shows the comparison of DAS, NAS and SAN.

D. Storage Switches

The Director-class switches and Fibre Channel (FC) switches are two kinds of storage switches. SAN switches are compatible with FC switches having FC protocol. FC switch checks the packet header, identifies the origin device and the destination device before forwarding this packet to the specified storage device. Hence by using this switch, a network having high performance, very less latency and transmission of data with zero losses can be achieved. The number of ports in the FC switch is low or medium whereas the port count is high in a director switch. To build larger storage networks, FC switches are networked. The advent and usage of FC started in 1990 and was adopted by global leaders in storage and system manufacturing. FC is available in 2, 4, 8 and 16 gigabit per second (Gb/s) FC solutions. It enables SAN to connect to numerous storage arrays and hosts which is one of its advanced capabilities.

According to [7-8], the SAN switches market can be divided as FC SAN switches and Ethernet SAN switches based on product type. Another classification based on end users/application divides SAN switches market as financial, media, government and telecommunications segments. Concepts such as zoning, Logical Unit Numbering (LUN) masking and protocols used to implement security in SAN are discussed in [11]. IP SAN and FC SAN are compared in [12].

Feature	DAS	NAS	SAN
Interface Technology	SCSI	TCP/IP	FCP, FCIP, FCoE, FICON, iSCSI, HyperSCSI,
File System	FAT, HFS, UDS, UFS, JFS, NTFS	NFS, CIFS or SMB	OS
Capacity	Limited to ports on the local server	Expandable	Expandable
Speed of Accessing storage	Fast	Slow	Very fast
Ease of adding storage	Might require shutting down servers to add storage	Hot-swap	Hot-swap
Redundant connectivity	No	No	Yes
Centralized Management	No	No	YEs
Ease of Expansion	Limited to host's physical ports	Allow modest expansion	Quick and easy
Suited for Databases	Yes	No	Yes
Cost	Inexpensive	Moderately expensive	Moderately expensive
Distance between server and storage	Must be close (<6 feet)	Distance doesn't matter	Distance doesn't matter
Backup	Each volume copied separately from server tape	Each volume copied separately from server tape	Can back up multiple volumes without server interaction

Table 1: Comparison of DAS, NAS, SAN

E. Problems with SAN

The benefits of adopting SAN are storage consolidation, serverless backup, better utilization of storage facilities, scalability, improved fault tolerance and centralized management as analysed in [8]. Some issues in SAN as stated in [7] are compatibility, the capacity limit of SAN, incorrect configuration, storage array problem, HBA configuration, connectivity, booting and hardware failure.

The problems associated with SAN are as follows:

1) Expensive: DAS storage devices were economical compared to SAN storage arrays.
2) Complexity of management: SANs were based on the FC standard and required unique host bus adapters (HBAs), switches and cables and needed understanding of concepts of virtual SAN (VSAN), zoning and masking. The application concepts (VMs) and storage concepts (LUNs) were disconnected, and compute and storage were managed separately. VSAN software provided equivalent sharing capability by pooling together DAS storage across multiple servers and eliminated SANs. For example, Hyperconverged or

HCI systems use clusters of compute servers with DAS storage and provide integrated management of servers and storage using VSAN concepts.

3) Proprietary: SAN storage arrays were proprietary appliances which make use of purpose-built hardware coupled along with proprietary storage array software.
4) Slow**:** SANs are slow when used with Solid-State Drives (SSDs). The total response time for accessing SSDs over SAN is dominated by the network protocol overhead. DAS latency is 2X to 3X better compared to SAN latency.

III. RECENT DEVELOPMENTS

An overview of the present and future networking options within the storage arena is discussed in [5]. It lays emphasis on exploring strategic storage solutions with respect to market influences, transmission evolution, and mediation. It focuses on the key technologies and evolutionary trends in this field, and discusses storage-based issues.

An overview of leading companies, their marketing strategies for success, contribution to the global market and the recent developments is presented in [9]. It further throws light on both global and regional market and provides analysis in depth. In [10], the key factors involved in driving market growth and opportunities along with the challenges and the risks faced by the manufacturers are discussed. Analysis of emerging trends and their impact have also been listed.

A. NVMe over Fabrics (NVMeoF)

Hard disk drives (HDDs) and tape were the primary storage media in 1980s and they used traditional technologies such as SAS and SATA. There was demand for new architecture since SSDs full potential was unutilized. The standard for connecting between a host and storage followed was Small Computer System Interface (SCSI). As an alternative to SCSI, NVMe was designed with lower CPU overhead to be used with faster media like SSDs. Over a computer's PCIe bus, NVMe was used for connecting to local storage and it enabled the use of alternate transports to connect to remote storage. NVMe protocol can be chosen over any low-latency interconnect including high speed Ethernet. NVMe gave high-performance and was a scalable interface suited in current and next generation. In enterprises, flash arrays with NVMe fabric capabilities are developing faster though it may take several years to adopt the same in data centers. It is expected that by the year 2021, solid-state arrays that use external NVMeoF to connect to servers and SANs will generate about 30% of storage revenue, as opined by Gartner [13].

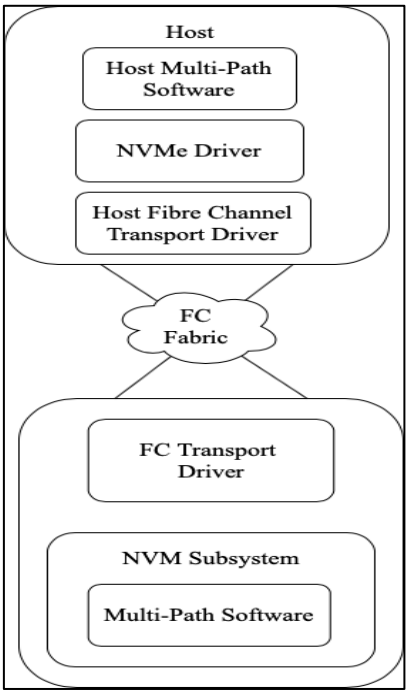

Fig. 2: NVMeoF Architecture

NVMeoF is capable of delivering very high bandwidth with low latency. This potential of NVMeoF makes it a promising storage technology for future. It also has the ability to share flash storage systems among multiple server racks. This would be useful for organisations to deploy large databases. NVMeoF extends direct memory access capabilities over a switched fabric to create shared storage with latency as consistent as PCIe flash in a commodity server, Burgener said.[13] NVMeoF allows sharing of extremely high-performance and costly NVMe storage across many more servers. It will provide storage access to any server connected to the switched fabric unlike PCIe SSDs where only that sever can access efficiently.

NVME fabric development began in 2014, with the goal of extending it to ethernet and fiber channel between other technologies. The challenge lies in establishing connectivity between NVMe-oF host device and the target device. For FC-NVMe and many RDMA protocol technologies, namely RDMA over Converged Ethernet, InfiniBand, Internet Wide-Area RDMA Protocol, the NVMe fabric transports are in development phase. The NVMe products came into market in 2018 by NetApp, Dell EMC and Hewlett Packard Enterprise (HPE). When an NVMe fabric extends from back-end storage to applications directly, it is referred as rack-scale flash systems. End-to-end NVMe arrays belong under the same. But it is used by start-ups. Other enterprises exchanged SAS-connected SSDs and NVMe SSDs. This improved its performance and is considered modernized design. Table II shows the storage architecture of NVMeoF and the corresponding advantages.

Enterprise Arrays	Rows of Servers	Blocks of Storage
High availability	High Performance	Low Latency
Storage services	Lower cost	Low Cost
Vendor supported array	Customized support model	Useful for Single Rack

Table 2: Benefits of NVMEoF Storage Architecture

NVMeoF growth depends on demands of transfer of data between the host and target. SSD rise wasn't visualized by SCSI. The NVMe protocol was developed to have maximum control over flash and replace SATA SSDs. NVMe decreases I/O overhead by bringing data closer and also increases throughput. NVMe is highly scalable since it manages queues well and permits multiple users to query the flash device compared to SAS or SATA SSDs. Separation of compute and storage and their independent scalability is another major advantage of NVMeoF. It permits resources to be efficiently allocated and utilised and plays major role in reducing latency. Latency difference between local storage and remote storage can be eliminated with NVMeoF. It can make up for the difference in performance between DAS and SAN. SCSI is preferred over FC transport in SAN networks. The NVMeoF protocol over RDMA transports will be used in SANs in future.

B. Software-defined Storage (SDS)

Earlier SAN-attached shared block storage controllers were proprietary and built using special motherboards and with special ASICs like in 3Par. Now standard x86 servers are used to build SAN storage controllers which make them competitive in cost, performance and scalability when compared to storage controllers built using proprietary hardware. This is referred to as software-defined storage (SDS). By leveraging standard x86 server hardware, scale-out storage controllers (vendors: Hedvig, Formation data systems) as well as dual controller RAID arrays (vendors: Tegile, Tintri) can be built.

C. Integrated Server and Storage

SAN storage was separated from compute and networking bought as stand-alone. In recent years, integrated systems are used mostly. Converged infrastructure (CI) systems bundle existing server, storage and networking products along with management software and serve it as a single integrated system. Hyperconverged (HCI) systems make use of clusters of compute servers along with DAS storage, and use VSAN software to eliminate SAN needs. Earlier, SAN storage management was storage-centric and non-intuitive. Now, storage supports intuitive, app-centric or VM-centric management.

Using SDS software and standard server hardware, future SAN storage can be built which will allow intuitive application-centric management and will be delivered as converged system or as part of integrated system. The NVMeoF protocol will increase the performance of SAN storage.

D. Remote Direct Memory Access (RDMA)

RDMA improves performance remarkably. It will become more common in enterprise storage. RDMA is present in the storage arena since some years as a cluster interconnect and for High Performance Computing (HPC) storage. Many scale-out storage arrays like InfiniDat, Dell SAN FluidCache,, IBM XIV give high-performance by using DMA for their cluster communications. It gives more throughput, and reduces latency for input output [14]. RDMA allows running multiple virtual machines on CPU and proves to be more efficient. When compared to TCP/IP, it is fast and efficient and deployable.

IV. STORAGE IN NEXT GENERATION

There is a transformation in data centers where the hyper-converged systems, software-defined storage, open source solutions, large cloud-scale storage systems are being used for storage management. Data is expanding to the cloud influences and the world will witness the advancements in the storage arena. The new technologies will have easier interface so that it can be managed by generalists also. Hyper converged infrastructures is one such example which allows the generalist to manage the infrastructure with the new simple tool. This will give more time to storage specialists to concentrate on performance critical storage projects. They need not be in maintenance roles and can add to the business value. The new technologies and trends are being deployed on the traditional architecture.

The changes that can be seen in future in storage networks are that the public cloud will be utilized as a storage admin though there might be risk involved. Hyper-converged systems will be used more and there will be consolidation among vendors. RDMA will emerge and the world will start accepting open source storage software. FC will be used lesser among the new technologies and will get replaced. Automation, data management, scalability, object solutions will gain more focus and importance.

In future, Flash will supersede and will be used with NVMe. Flash with NVMe is capable of sustaining complete line rate and satisfies performance requirements of new applications. Advantages of NVMe can be combined along with centralized storage infrastructure. In data centers, the protocol used in all flash arrays connection is FC as it gives high performance and is available, scalable, plug-and-play system. FC-NVMe brings together the advantages of FC and NVMe to shared storage system and improves scalability, the performance and its flexibility. The key challenges and solutions of flash arrays is listed in Table III.

The SAN storage in future can be based on NVMeoF over RDMA Ethernet and it will be built using SDS on standard x86 servers. NVMeoF will improve access time. x86 server-based controllers will reduce the cost. SAN storage built on standard x86 servers with SDS software is not any longer proprietary. Complexity of management can be removed by use of standard x86 servers for storage controllers, use of virtual networking to replace zoning and masking, and intuitive app-centric storage management. Need for a separate FC fabric can be eliminated by NVMeoF that enables use of high-speed Ethernet with RDMA. Integration of shared storage will ease out the deployment and management for the customer. Hyperconverged systems that are not based on SAN are referred to as superconverged systems.

	Present	Near Future
	Moving towards All Flash arrays from Non-flash arrays	All Flash Array Enterprises
Challenge	Current infrastructure	Complexity of

	not competent enough to carry the high-performance requirements of Flash	troubleshooting and maintenance with growth of SAN infrastructure
Solution	Revamping the SAN infrastructure with MDS 32Giga carefully to give high consistent performance avoiding congestion and latency problems	Integrated analytics and enhanced telemetry to support fabric availability, deep visibility at core and edges of fabric for troubleshooting

Table 3: Key Challenges and Solutions

V. CONCLUSIONS

SAN weaknesses are discussed and these can be overcome in future with new technologies like NVMeoF and software-defined storage. SAN storage will be integrated with servers and Ethernet switches and delivered as a new kind of super converged integrated system in future rather than stand-alone storage. Data is being produced continuously and corporate needs fast networks and processors and fast storage to store and manage the data efficiently and NVMeoF and SDS will serve as a good solution in this digital world.

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