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A Study on Evolution of Storage Infrastructure

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Abstract— The amount of data today that needs in every aspect is growing at an explosive rate. The necessity to store this amount of data and access it from different places the systems has caused dramatic changes in the storage infrastructure. Storage infrastructure is the complete set of hardware and software components required to facilitate storage for a system. This study paper revolves around the evolutions associated with the storage infrastructure are explained to overcome the challenges of increasing demands to store more and more information. Also, the different levels of storage infrastructure over last few decades to meet changing customers need are explained in this paper.

Keywords— Infrastructure, Storage Infrastructure, SAN, DAS, NAS, Disks

I. INTRODUCTION

Infrastructure refers to the collection of physical and virtual resources that provides compatibility with all the IT environment such as the server, storage, and network components. Storage infrastructure is also called as a Storage system that is mainly designed by taking potentiality of various storage devices and including the layers of hardware and software to acquire highly reliable, high-performance and easily managed system. To provide the flexibility and stability for the rapidly increasing storage demands the evolutions of storage infrastructure has taken into consideration. There are different levels of Evolution in storage infrastructure- the lowest level of storage infrastructure is hard disks. The hard drive is the non-removable rigid magnetic disk with a large data storage capacity. This paper also focuses different trends of the hard disk. Fibre Channel (FC) is the serial hard disc interface frequently found to endeavour storage environments. FC is famous due to its tremendous speed. Then the hard disks are grouped together into arrays to evolve the RAID technology to provide the data redundancy and performance to the system. As the infrastructure develops further, the new concept clustering emerges. Storage cluster is defined as the groups of storage arrays sharing redundant connections to work collaboratively as a single storage system. The storage systems are attached to evolve DAS, SAN, NAS. DAS storage connects directly to a server (host) or a group of servers in a cluster. The SAN operate behind the servers to provide a common path among storage devices and servers.The primary goal of NAS serving files either by its hardware, software, or configuration. In spite of this, the new configurations are becoming popular including iSCSI.

II. LITERATURE REVIEW

A. Storage infrastructure-

Infrastructures are used to facilitate the use of essential resources. Growing need of the information is satisfied by increasing amount of disks, switches, hubs, disk system and tape system. Big data is growing storage demand and for fulfilling this growing storage demand the term storage infrastructure is taken into consideration. Storage infrastructure provides the following goals: Flexibility- to facilitate the availability of resources and usage of it. And Stability- for reliable and safe domain supported by any business.

B. Evolution of Storage Infrastructure-

Storage capacity demands have grown by leaps and bounds in many real-time applications such as the emergence of the internet, e-mail, e-commerce, data warehousing, voice/video/data convergence, etc. Storage infrastructure is evolved from many years to manage the big data storage. These evolutions are monitored for some parameters such as accessibility, capacity, performance, and security.

1) Accessibility- It is the availability of infrastructure components to perform its desired operations during the specified period. Monitoring the accessibility of hardware components (for example a port, an HBA, or a disk drive) or software component (for example database) includes the checking of their availability status by evaluating the alerts generated from the system.

2) Capacity – It is the amount of storage infrastructure resources available. Capacity monitoring includes the example of examining the free space available on the file system or the number of ports available on a switch. Insufficient capacity leads to the unavailability of services or even degraded the performance. Capacity monitoring offers the availability of uninterrupted data and scalability.

3) Performance – Monitoring the performance, measures and analyses the behaviour regarding the ability to perform at certain predefined level or response time. Performance monitoring evaluates how efficiently different components of storage infrastructure are performing and assist in identifying bottlenecks. The performance also deals with the utilization

of resources. Examples of performance parameter that are monitored are the number of I/O Performance by disk, response time, network utilization and server-CPU utilization.

4) Security- Storage Infrastructure evolutions are the core of any enterprise storage system which is used to provide stability, reliability, performance, speed, flexibility and security at different levels. By all these parameters the levels of storage infrastructure differ from each other.

C. Levels of Evolution of Storage Infrastructure-

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1) Disks -Hard discs are the very lowest level of storage infrastructure. The hard disk is also known as the hard drive, disk drive or hard disk drive that store and relatively provides the fast access to a large amount of data on electromagnetically charged surface or set of a surface.

2) The architecture of HDD - The hard disk is set of stacked disks which are also called as metal plates. Each disk has two heads, as the disk spins these heads read or write the data. The track is the Region of a disk for which a read and write head can read data from any given position. Every track is split into a number of sectors. Each disk records the data electromagnetically in the concentric circle or tracks on the disk. For the particular position of an arm, all the tracks are known as cylinder. The head is used to write or read the information on the tracks. Each read or write operation needs to locate the data this operation is called as seek. First, the cylinder is located to read or write in the disk. Then the particular track is located for reading or writing data. Hard discs performance is heavily influenced by rotational speed which is varying from the 4500 to 7200rpm and most standard in personal computers and secondary storage system. This rotational speed is increased up to 10000 to 15000rpm which transmitted them to the primary storage system and servers.

III. TRENDS IN DISK TECHNOLOGY

In the last two decades hard disk storage has shown a phenomenal increase in capacity from a few MB to a few TB, while the size of the device remained the same. Since the first commercial hard disk was released in 1956, it has undergone persistent evolution. To increase the density of data, reduce the number of grains, the size of grains or both. Following are the trends in Disk Technology-

Perpendicular Magnetic Recording (PMR)- It is the current magnetic recording technique which replaces the Longitudinal Magnetic Recording (LMR) method. PMR technology records the information on a ferromagnetic layer that contains arbitrarily shaped grains about 10 nanometres in size. Each data bit is the magnetically oriented region containing about 60-80 grains. To This PMR technology recording data already at 800 Gigabits per Square inch and it is expected to maximize up to 1 Tb per square inch. To increase the density of data, reduce the number of grains or reduce the size of grains or both. The strength of the signal which is picked up by the read head will reduce by decreasing the number of grains per bit leads to the low signal-to-noise ratio will reduce. Lessen the size of the grain, leads to the eventual data loss which is thermally unstable.

Several new technologies are used to enhance the recording speed up to 1 Terabit per square inch.

Heat Assisted Magnetic Recording (HAMR)- Small grains are thermally unstable. To resist HAMR tendency, the higher magnetic coercivity can be used. But, high magnetic coercivity material requires stronger magnetic fields to magnetize while the smaller write head is required to reduce magnetic bit size. HAMR finds a very creative way out of this dilemma. Magnetic Coercivity decreases considerably when the temperature rises above the critical level which is called as Curie point. Before the magnetic field is applied by the writehead, HAMR adds a pulse of heat to the magnetic bit. Magnetic material is easily magnetized because it is hotter than its Curie point. All this is happening while the platter is moving at 50-100 km per hour. The entire action of heating, magnetization, and cooling of one magnetic bit takes about one nanosecond. This cycle repeats consciously without pause.

Shingled Magnetic Recording- To crowd the magnetic bits closer together Shingled Magnetic Recording takes a radical approach. An HDD has different heads for reading and writing. In the traditional recording, the write head speculates a line of magnetized bits that is broader than the read head on the first track. Overlapping of tracks creates some problem in the recording which is resolved by Shingled Magnetic Recording. This recording technique packs at least 25% more tracks in the same platter by changing just the design of write head. The unit of writable storage is formed by few hundred shingled track which is about in GBs, and after that, there is a gap to the next set of shingled tracks. Some techniques are developed to overcome flash limitations which are applied to the shingled magnetic recording.

Patterned Media - perpendicular magnetic recording uses the ferromagnetic grains which are magnetically isolated from each other which is also called as loose exchange coupling. This loose exchange coupling keeps the adjacent magnetic bits inaccessible from each other, but it also motivates the thermal instability. To maintain the excellent thermal stability Patterned media uses the strong exchange coupling between grains. Isolation among the magnetic bits is acquired by a physical gap in the magnetic material among adjacent bits. In Patterned media a track consist of ferromagnetic grains which are inlaid in the nonmagnetic material. Every ferromagnetic grain is single domain and is a strong stationary magnet. The factor of shrink can be 10x, or more than this leads to increase in the real potential density of 100x or more than this.

Two Dimensional Magnetic Recording - In current technologies such as PMR/LMR the magnetic material is a film which is on the platter, it is made up of arbitrarily shaped magnetic grains of size 10nm. In the shingled magnetic

recording the tracks are crowded together, but it creates the interference on the adjacent tracks of magnetic bits that will limit on the crowded of tracks. To measure and correct this interference the digital signal processing method is used by Two Dimensional Magnetic Recording. In this technique, three read head are considered instead of one which is laying side by side over a track. These three heads are not correctly aligned on the target track. Second head overlays with one adjacent track while the third read head overlays with another adjacent track and the central head is perfectly aligned. To produce the disinfected signal of the target track, the input from the outer head is used to wipe out the noise faced by the central head. All this is obtained by without control of shape or alignment of grains.

Heated Dot Magnetic Recording – All above technologies are not mutually exclusive. Heated Dot Magnetic Recording (HDMR) is the combination of Heat Assisted Magnetic Recording, Patterned Media Magnetic Recording and shingled magnetic recording and two-dimensional magnetic recording.

Helium Filled Disk Drives – No technology increases the areal density directly, this technology is used to enhance the capacity with the same size. To obtain higher capacity disk, more platters are pack together in same height but is must be feasible. The helium has a lower viscosity which is used to solve the barrier to the firmly packed platter.

Solid-state drive (SSD) – It is also called as a solid-state disk or solid-state disk. It is a nonvolatile storage device which is used to store the data permanently. The memory doesn't move in SSD. SSD devices insert the memory chips made up of silicon as storage media for reading and writing data persistently. SSDs are also called as flash cards or flash drive, which are embedded into computer server called as server-side flash storage. Like HDD, SDD doesn't contain any mechanical part. An SDD is an array of semiconductor memory which is well ordered as the disk, by using integrated circuits instead of optical or magnetic storage media. There are different manufacturers of SSD such as Intel, SK Hynixsamsung SanDisk, Toshiba and much more.

Merits and Demerits of SSD vs. HDD – The performance of SSD is much better than the high-performance disks. In SDD, seek time and latency reduced substantially will increase the boot time. SDDs are more resistance than HDDs. Even though HDDs are broadly used that have better stability according to performance, capacity, and reliability. HDD have limitations on data access speed due to their mechanical structure. Although access performance of SDDs is beyond that of HDDs, HDDs are less expensive than SDDs. As the demand for data storage increases with regards to performance and capacity, both HDD and SDD will co-occur by supplementing each other.

RAID- The working life of hard disk is very small or finite. The drive contents are inaccessible due to the media faults, mechanical wear, and electronic failures. Such failures are unacceptable for any organization, so some actions are performed to protect against the failure. One of the widely used tactics for protecting the data is arranging the groups of discs into arrays. Grouping of hard disks leads to the evolution of RAID.RAID is called as the Redundant Array Of Independent (Inexpensive) Disks. Implementation of RAID offers two benefits which are Data redundancy and Enhanced performance. Data redundancy is achieved by making the clone of data to two or more disks. In this case, if a failure occurs at one hard disk the data which is duplicated on another hard disk can be used. In many other cases, the contents of the file are also striped or spanned across multiple disks. The data redundancy improves the performance because various parts of the file can be accessed on multiple disks simultaneously instead of waiting for the complete file to be accessed from single disk.

There are different schemes to implement the RAID – RAID-0 uses the disk striping to enhance the performance, but it doesn't provide the redundancy. RAID-1 offers the disk to disk redundancy by using disk mirroring technique, but it reduces the capacity and enhances the performance marginally.RAID-5 is based on block-level striping with parity. It Improves the read performance by spreading parity information throughout the disk group. RAID-6 includes the multiple parity schemes to enable survival in the case of multiple disk failures in RAID group. There are additional levels of RAID, but these four are most widely used. To obtain more benefits, it is possible to mix the RAID levels for example RAID-50 is the combination of RAID-5 and RAID-0.

There are many ways to arrange the hundreds of disks into storage arrays to evolve storage infrastructure very easily. Hundreds of terabyte(TB), an even petabyte of data, can be stored by the very largest array.

Merits of RAID-In the event of failure RAID offers the backup of data in storage arrays also it provides the redundancy. RAID ensures the reliability of data and increases the I/O performance at lower cost. For any crash in system, RAID provides parity checks. It reads and writes the data simultaneously.

Demerits of RAID-RAID cannot protect the complete data, but it increases the access speed. It does not recover data easily. It is expensive.

JBOD- It is "just a bunch of disks". JBOD is the collection of hard drives which are not configured to act as RAID. For using the RAID level instead of configuring the storage array, the disk within the array is treated as independent disk or disks are connected. The technique called concatenation is used by spanning configuration to merge the capacity of all the disks into a single - large disk. JBOD does not provide any redundancy or performance benefits.

RAID vs. JBOD- After comparing RAID and JBOD, it is observed that the RAID arrays are most reliable and efficient than JBOD arrays. On the other hand, JBOD consists of few hard disks to store large quantities of data.

So to store the massive amount of data JBOD is the best choice. Also, to store the data for a longer period the RAID is used.

Storage arrays classification – Modular and Monolithic storage arrays Modular Storage-It is based on two controllers which are kept apart from each other this ensures that, if the failure occurs at one controller the another controller can be used in such case. These controllers are held on the shelf having the separate power source to the disks. They are connected to disk via cables which are usually copper or optical cables. The advantage of modular storage is that it is inexpensive than the monolithic storage.

Monolithic Storage-It is located on the disks which are fixed into the array frame and connected to various controllers via cache memory. This storage provides the redundancy failure. The plenty of cache memory offers the massive amount storage capacity than the modular storage and makes the storage device faster.

IV. NETWORKS IN STORAGE INFRASTRUCTURE-

IP- It is Internet Protocol networks which are widely used to transport storage traffic with the growth of storage area networks. IP networks offer rising levels of interoperability, manageability, and cost-effectiveness. By connecting storage with the today's IP networks such as LAN/MAN/WAN the advantages are seen throughout storage virtualization, mirroring, backup, consolidation, and management. Storage infrastructure also increases the capacity, expandability, flexibility and scalability by using internet protocol as a network. IP storage network has two new technologies such as Fibre Channel over Ethernet (FCoE) and iSCSI (IP Small Computer System Interface). Both these technologies hold either SCSI commands or Fibre Channel are integrated into IP Datagram. In FCoE technology, Fibre Channel commands are integrated into IP traffic but this needs a Converged Network Adapter (CNA). CNA can explain about encapsulation of both FC and Ethernet.

FC-Fibre Channel (FC)- Local FC is a SAN Interconnection within the data centres. Fibre Channel is the popular serial Hard Disk, which is known for its tremendous speed.FC has the large capability of addressing. It is leading interface for storage networking today.The speed of FC is varying from 2Gbps, and more recently it is 8Gbps to 16 Gbps with data integrity feature. To improve the vast availability of data, it is feasible to generate a fabric of storage devices. FC can be fully engaged offering exceptional redundancy.

Ethernet- Today, 10 GigaBit Ethernet is becoming growing widely as a horizontal application in the storage infrastructure. iSCSI manage over standard Ethernet networks to increase the performance of the system. According to the IEEE 802.3 standard, the distance supported by 10GigaBit Ethernet is used over Fibre cable.

V. PROTOCOLS AND INTERFACES

SCSI- SCSI stands for small computer system interface. This is high data transfer technology that allows connecting the various internal or external devices to server or host. This connection is carried out by using SCSI card that fits inside computer. An example of SCSI is RAID controller that allows a connection to an external storage enclosure with multiple drives. The traditional SCSI is replaced by serial ATA(SATA) which is faster and less expensive than traditional SCSI drives.

iSCSI – This stands for Internet SCSI protocol which encapsulates the SCSI commands into TCP packets and then transmitted them over the Ethernet network to storage devices. iSCSI protocol resolves the traditional SCSI distance limitation by using existing TCP/IP infrastructure. It utilizes existing IP protocol and Ethernet Devices to manage and hold in a SCSI storage Infrastructure. iSCSI is growing the storage infrastructure and SAN connectivity by expanding the advantages of IP networking without limitations of distance.

Clustering- It is new technology related to the storage infrastructure. The group of storage arrays that shares the redundant connections to work collaboratively as a single storage system is known as storage cluster. The storage request is quickly serviced due to the use of multiple arrays which will enhance the performance. Clustering provides the inherent redundancy to ensure the data availability.

VI. STORAGE ON NETWORK

Storage Infrastructure is useless unless network users are accessing it. There are three means of attaching storage systems which are: Direct Attached Storage(DAS), Storage Area Network(SAN), Network Attached Storage (NAS).

Direct Attached Storage (DAS) - It is the computer storage system that is directly connected to the server or host computer instead of directly attached to a network. Direct- attached storage is not limited to only internal storage, but it can also utilize an internal disk enclosure which contains the HDDs, including JBOD enclosures and the RAID enclosures. A typical example of DAS is the dedicated storage array that is attached directly to the server. Multiple computers can use DAS in the case of clustering. DAS uses the primary interfaces and protocols such as SATA/ Serial ATA, Serial Attached SCSI (SAS), external Serial Advanced Technology Attachment (eSATA), and Fibre Channel. This Infrastructure of storage was developed primarily for addressing the shortcomings in drive-bys on the host computer system. Whenever the server needed the extra drive space, then the storage unit was attached. This method also uses the mirroring functionality which allows one server to mirror another. The main substitute for DAS is NAS and SAN.

Applications of DAS-most of DAS devices today use HDDs and SDDs. It is used in hybrid devices especially for applications where performance is vital such as Big Data Analytics.

Storage Area Network (SAN) – This storage infrastructure facilitates block level communication between storage and server by using dedicated, high-performance fibre channel network. SAN is composed of the storage device, interconnection network infrastructure (switches) and servers that are connected to the network. SAN devices provide the fast and continuous access to a large amount of data. SAN is not accessible by other devices through the local area network; it uses the separate network. This infrastructure is managed by Simple Network Management Protocol(SNMP) and other proprietary management protocol. SNMP is TCP/IP based protocol. SAN offers the alert management in the case of system failure. The most common protocols used by SAN are iSCSI, Fibre Channel over Ethernet (FCOE). Also, the capabilities such as disk zoning, disk mapping, LUN masking, and fault management. SAN provides the availability, performance, scalability and cost benefits compared to DAS.

Applications of SAN- SAN uses in horizontal applications such as archiving, data warehousing, backup and disaster protection, vertical applications such as Enterprise Resource Planning, Online Transaction Processing, electronic commerce, etc.

Network-attached storage (NAS)- It is dedicated storage for file serving the application. Unlike SAN, this infrastructure connects to LAN and provides file access to heterogeneous clients. This storage is not directly attached to the host. NAS devices support Ethernet connection and multiple protocols which include common internet file system (CIFS), network attached file systems, Server Message Block (SMB). As the NAS is purposely built for providing storage for filing server application so, it offers higher availability, scalability, cost benefits, performance compared to the general-purpose file servers.

VII. CONCLUSION

Storage Infrastructure is designed to facilitate the storage system. As the demand of storing the big data growing day by day, the different levels of storage infrastructure are evolving. The evolution of storage infrastructure is based on some parameters to enhance the better performance than the previously developed infrastructure. This paper summarizes the different evolution of storage infrastructure based on some parameters such as availability, flexibility, capacity and speed. Each evolution provides the pros and cons for storing the big data and also provides the complete idea behind the use of particular level of storage infrastructure.

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