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A Study on Network Storage Technologies: DAS, NAS and SAN

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Abstract

Nowadays the storage technology plays a major role in the computer industry. The paper analyzes the various storage models and interfaces used by the industry from the beginning to the newest storage architectures namely direct access storage device technology - direct attached storage and its improvements, network attached storage models and storage area network models along with its performances in terms of data transfer rate of each technology and its availability in the market. Further the comparisons of each technology with the earlier model are also examined.

Keywords: Direct Attached Storage, Network Attached Storage, Storage Area Network, RAID, JBOD.

Introduction

A secondary storage device connected to a network is referred to as network interconnect along with the network access facilities. The main feature of the network interconnect storage is that the device may be shared among the other computers in network. As on now, the available network storage categories [1, 15, 17, 18] are: (1) *Direct Attached Storage (DAS)*, (2) *Network Attached Storage (NAS)* and (3) *Storage Area Network (SAN)*. Direct Attached Storage is a traditional storage category. Network Attached Storage and Storage Area Network are new as well as special types of network storage. Fibre channel devises strengthens the SAN performance. The typical models [17] of these three are shown in figure 1.

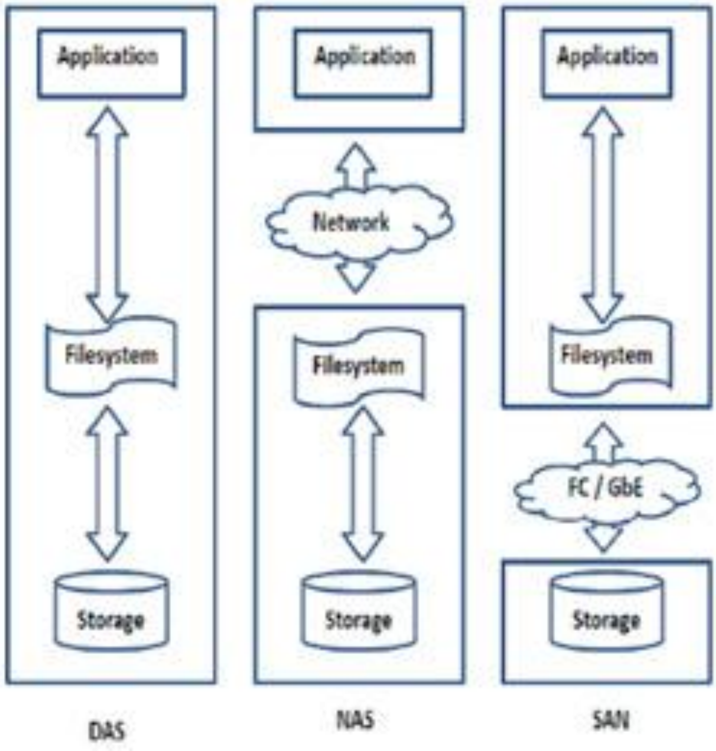


Figure 1: Typical Models of DAS, NAS and SAN

DAS

Direct attached storage is a traditional digital storage system. It is directly connected to desktop/client/server. DAS allows optional network connection and supports both file level and block level accesses [25]. Basically DAS are internal devices [13].

Technologies used in DAS

PATA stands for *Parallel ATA*. It is an interface standard for the connection of storage devices such as hard disks, floppy disks and optical disks. ATA stands for *Advanced Technology Attachment* which follows *ATA Packet Interface – ATAPI* standards. It is best suited for *Integrated Drive Electronics – IDE* interface. It is designed for *Industry Standard Architecture - ISA* bus. A PATA cable can connect only two storage devices at a time but ISA interface can connect maximum six devices. Figure 2 shows the sample PATA cable and table 1 lists the speed.

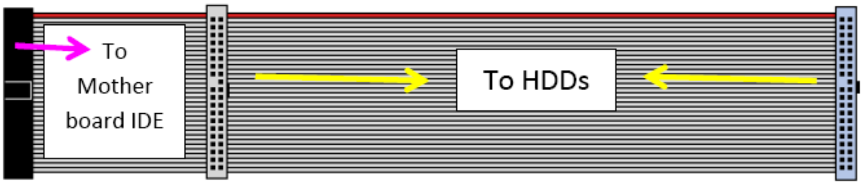


Figure 2: PATA Cable

Table 1:PATA Data Transfer Rates

Type	*Transfer rate*	*Year Released*
PATA (IDE)	3.3 MBytes/s to 25 MBps	1983
PATA 133 (Enhanced IDE)	16.7 MBps to 133 MBps	1994

SATA stands for *Serial ATA* from SATA International Organization. It is a kind of bus interface with *Host Bus Adapters (HBA)*. The SATA replaces PATA by simplified cable and cost with faster data transfer. Only one device can be connected to a single cable. A typical cable is shown in figure 3 with logo and table 2 shows the speed.

Figure 3: SATA Cable and Logo

Table 2:SATA Data Transfer Rates

Type	*Transfer rate*	*Year Released*
SATA 1.0	150 MBps	2002
SATA 2.0	300 MBps	2006
SATA 3.0	600 MBps	2009
SATA Express	8Gbps to 16 Gbps	2011

SCSI stands for *Small Computer System Interface which has* a set of standards with commands and protocols. It is mainly used in servers because it is intelligent, buffered, peer-to-peer interface. A single SCSI bus can able to connect from 8 to 16 devices simultaneously. Another variation of SCSI is *Parallel SCSI* (*SCSI Parallel Interface – SPI*) and *Serial Attached SCSI – SAS*. The figure 4 shows connector, logo and SAS cable and table 3 lists the speed.

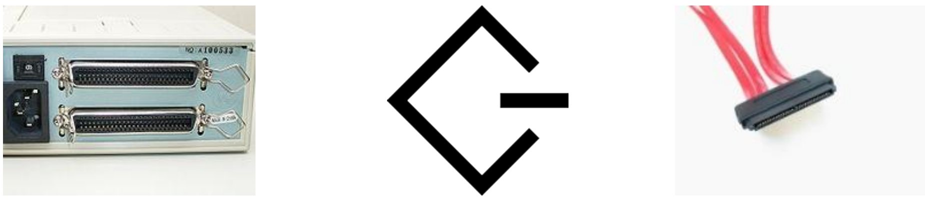


Figure 4:SCSI Connector, Logo and SAS Cable

Table 3:SCSI Data Transfer Rates

Type	*Transfer rate*	*Year Released*
SCSI (Parallel)	5 MBps to 20 MBps	1986
SCSI Ultra models	40 MBps to 160 MBps	2003
SCSI Ultra-320	320 MBps	2003
SCSI Ultra-640	640 MBps	2003
SAS models	300 MBps to 1200 MBps	2008

USB stands for *Universal Serial Bus, a new data transfer technology designed with hardware.* All USB storage devices are external peripherals. USB storage technology is industry standardized. Figure 5 shows a sample and table 4 shows the speed.

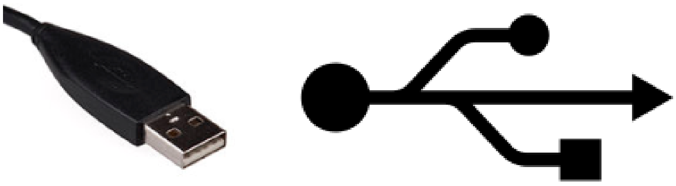


Figure 5: USB Cable and Logo

Table 4: USB Data Transfer Rates

Type	*Transfer rate*	*Year Released*
USB 1.0 (Full Speed)	1.5 Mbps to 12 Mbps	1996
USB 2.0 (Hi-Speed)	480 Mbps	2000
USB 3.0 (Super-Speed)	Up to 5 Gbps	2010

Features of DAS

DAS is optimized [11] for single, isolated processors and low initial cost. The advantages are low cost solution and simple to configure and drawbacks are decentralized storage, no high availability, no storage consolidation and low performance [7, 25].

NAS

Network attached storage is the real network interconnect with file level access, which may work as a server and connect to heterogeneous types of clients. Nowadays NAS devices are very popular in sharing files. It is external an equipment [13, 20]. The benefits of NAS are easier setup, quicker data access, and simple administration. The architecture of NAS [33] is depicted in figure 6 and table 5 lists the speed [14].

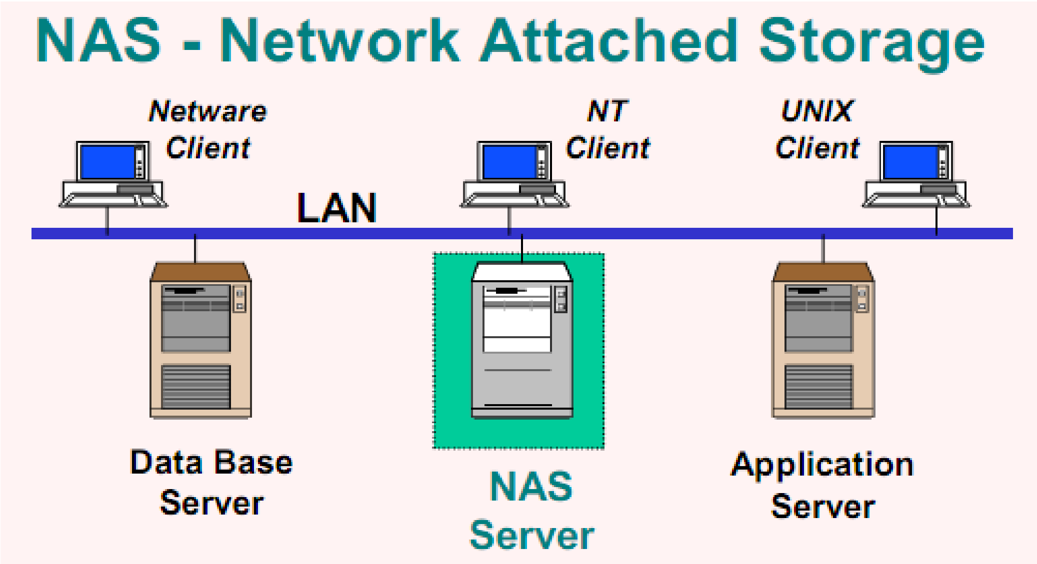


Figure 6: NAS Architecture

Table 5:NAS Data Transfer Rates

Type	*Transfer rate*	*Year Released*
Standard NAS appliance	100 Mbps to 1 Gbps	1997-2001
Ultra ATA based NAS	400 Mbps	1999
SATA based NAS	800 Mbps	2000

Features of NAS

The standard NAS interconnect uses *Network File System (NFS), Parallel NFS (pNFS)* and *Common Internet File System (CIFS)* protocols over TCP/IP [6, 14, 15, 27]. NAS is optimized [11] for ease of management and file sharing using lower cost Ethernet based networks. Storage capacity is automatically assigned to users on demand. The advantages are heterogeneous environment, centralized storage and simplicity of setup and the drawbacks are low performance, network congestion during backups and restores, limited scalability and Ethernet limitations [7, 25]. The NAS applications [10] include file sharing in NFS and CIFS, limited read only data base access and small block data transfer over long distances.

DAS vs NAS

DAS is an extension of existing server with optional networking. NAS is developed as simple and independent solution for sharing files on network. DAS and NAS can potentially increase availability of data. NAS gives better results than DAS with file serving. The cache memory in both models decides the overall performance.

SAN

Storage area network is another variation with block-level access storage model. These kinds are always external types [13] and uses fibre channel storage devices. The architecture [33] is depicted in figure 7 and table 6 lists the speed [2, 3, 4, 5].

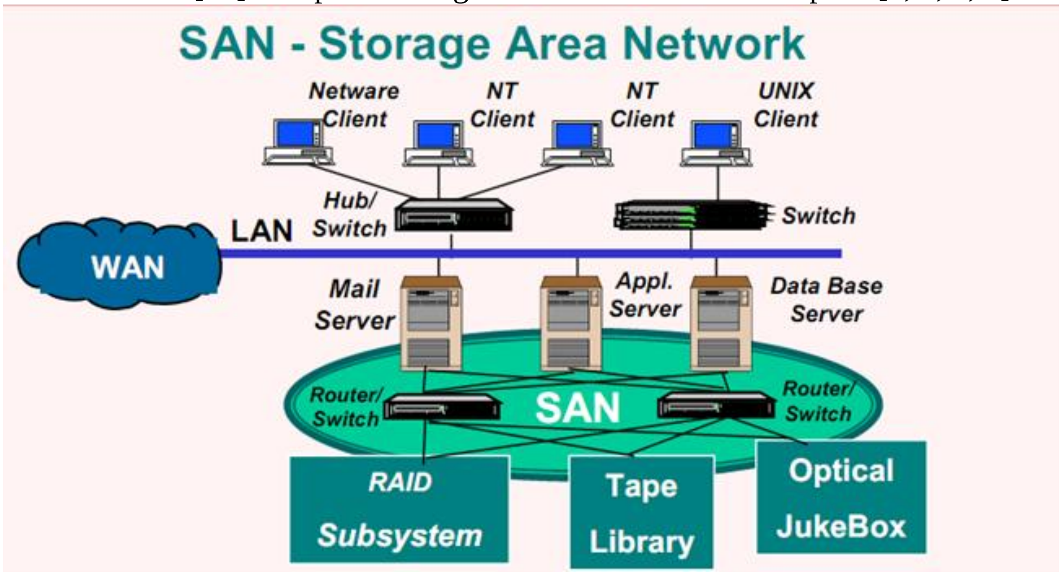


Figure 7: SAN architecture

Table 6:SAN data transfer rates

Type	*Transfer rate*	*Year Released*
1GFC	1 Gbps	1997
2GFC	2 Gbps	2000
4GFC	4 Gbps	2005
8GFC	8 Gbps	2008
10GFC	10 Gbps	2009
16GFC	16 Gbps	2011
32GFC	32 Gbps	2013
10GFCoE	10 Gbps	2010
40GFCoE	40 Gbps	2013
80GFC	80 Gbps	Expected
160GFC	160 Gbps	Expected

Features of SAN

The standard SAN interconnect uses *Internet Small Computer System Interface (iSCSI), Fibre Channel Protocol (FCP), Fibre Channel over Ethernet (FCoE), ATA over Ethernet (AoE) and Hyper SCSI* protocols [6, 12, 15, 34 35]. It is tuned [11] for performance and elasticity. SAN benefits are high speed fibre channel media which is optimized for best storage and controlling of several disks as a shared pool. The advantages are storage consolidation, centralized storage management, fast and efficient backups and restores, high degree of fault tolerance, dynamic scalability and superior results [7]. The bandwidth provisioning in a low-cost setup is the key challenge for future SAN [26]. SAN application [10] includes disaster recovery, transaction-based application processing, centralized data backup and storage consolidation. Table 7 lists the various generations of SAN [13].

Table 7: Generations of SAN

Generation	*# of FC ports*	*Speed*	*Release*
1st	10s	1GFC	1998
2nd	100s	2GFC	2002
3rd	1,000s	4/10GFC, GE	2005
4th	10,000s	8/10 GFC, 10GE	2008
5th	1,00,000s	16/20GFC	2011

(GE – Gigabit Ethernet, GFC – Gigabit/second Fibre Channel)

Technologies Used In SAN

iSCSI stands for *Internet Small Computer System Interface*. It is used to manage storage over long distances along with SCSI commands over Web. It can be applied to transfer data via LANs, WANs, or internet and can allow storage as location independent. SCSI commands are used by clients for its devices on remote servers [27, 28, 29, 30, 31, 32]. This allows companies to merge storage into data center storage arrays while providing hosts with the illusion of locally connected disks. iSCSI can be run for long distances using existing network setup.

Fibre Channel (FC) is a high-speed network technology used to connect all kinds of storage devices. It is standardized in the T11 Technical Committee of the *International Committee for Information Technology Standards (INCITS)*(ANSI accredited standards committee). *Fibre Channel Protocol (FCP)* is a transport protocol that predominantly transports SCSI commands on network. Point-to-point, arbitrated loop and fibre fabric/switch are the standard FC topologies.

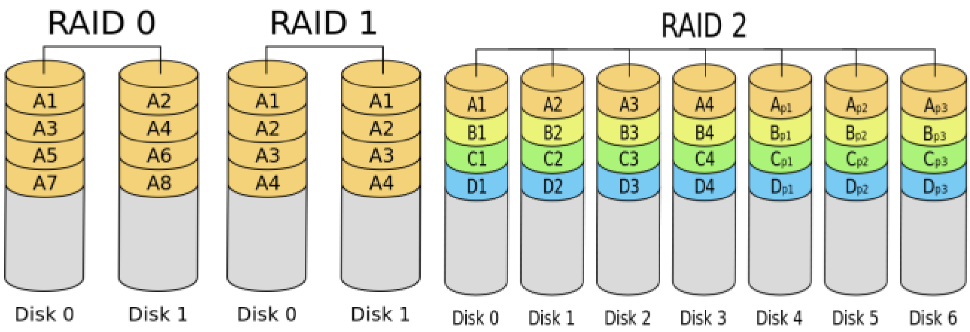
RAID stands for *Redundant Array of Independent/Inexpensive Disks* [24]. In this a logical unit is formed by grouping several disks. Data are stored around disk drives in one of several ways say *RAID levels* which are based on the level of redundancy as well as performance required.. The operating system can access the array as a single drive. The levels are indicated by RAID 0, RAID 1 and so on. The reliability and readiness, performance and size are the key objectives. RAID levels higher than RAID 0 provide security against unrecoverable read faults and disk disaster.

Standard RAID Levels

A number of standard schemes have evolved as *levels*. Primarily, there are five RAID levels [14]. The *Storage Networking Industry Association (SNIA)* approved some models with a common RAID *Disk Drive Format (DDF)* standard.

RAID 0 is a block-level striping without parity or mirroring without redundancy. A problem in a disk drive terminates the setup. In this fault tolerance and performance are enhanced. This is shown in figure 8(a). *Examples:* Windows XP, Apple OS X and Linux.

RAID 1 is mirroring which has no parity or striping. The data are stored parallel in two disk drives, thereby producing a *mirrored set* the read request is serviced by either of the two drives containing the demanded data, whichever has least seek time and rotational latency. This is depicted in figure 8(b). *Examples:* Apple OS X, Linux and Microsoft Server OSs.



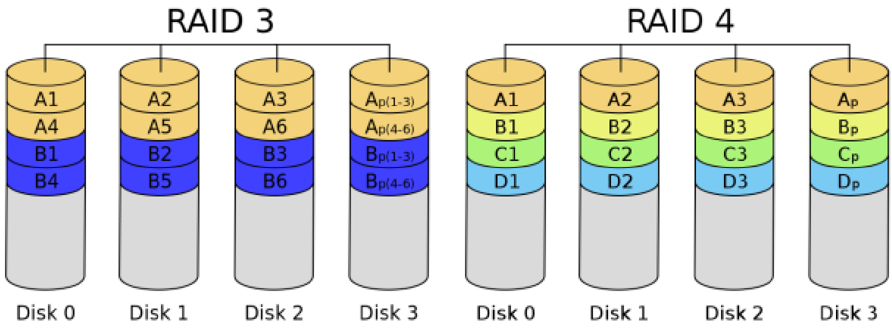
(a) (b)(c)

Figure 8:(a): RAID0, (b) RAID1and (c) RAID2

RAID 2 is bit-level striping with dedicated Hamming code (parity) and all spindles in disk rotation are synchronized. Hamming code is considered crosswise corresponding bits and stored on at least one parity drive. This is shown in figure 8(c).

RAID 3 is byte-level striping with devoted parity and all spindle revolution is coordinated. The data is striped so every sequential byte is on a different disk drive. It is also not generally used in practice. This is depicted in figure 8(d).

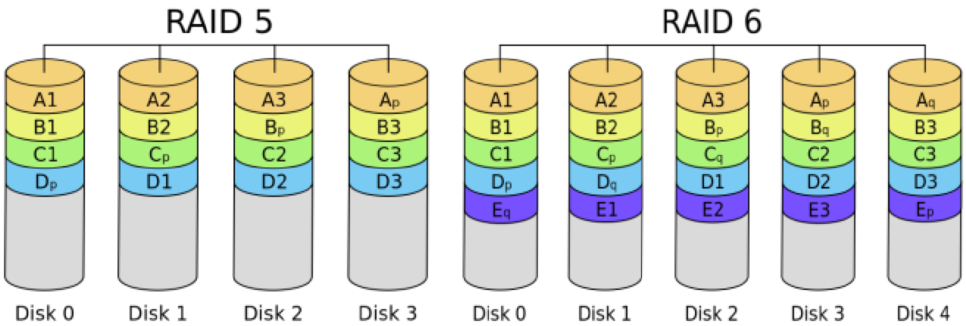
RAID 4 is block-level striping with dedicated parity. It is equivalent to RAID 5 except that all parity data are stored on a single disk drive and files may be spread among numerous disk drives. Every disk drive works autonomously. This is as in figure 8(e). *Example:* Linux.



(d)(e)

Figure 8:(d) RAID3 and(e) RAID4

RAID 5 is block-level striping with distributed parity. On disk drive failure, some consequent reads can be calculated from the parity. This is shown in figure 8(f). *Examples:* Linux and Microsoft server OSs.



(f)(g)

Figure 8: (f) RAID5 and (g) RAID6

RAID 6 is block-level striping with double distributed parity. This develops gradually important as large-capacity drives lengthen the time needed to recover from the failure of a single disk drive. It provides fault tolerance up to two unsuccessful disk drives. Like RAID 5, a single disk drive disaster results in reduced performance of the entire array until the failed drive has been replaced and the associated data rebuilt. This is shown in figure 8(g). *Example:* Linux.

RAID 10is combination of RAID 1 + RAID 0. This means that mirroring and striping. Data is stored in stripes across disks that have been mirrored to the secondary disks.

JBOD stands for *Just a Bunch Of Disks* [19]. It is a non-RAID drives architecture [21] involving several drives either as autonomous hard drives or as a combined single logical volume. The capacity utilization is the major benefit of JBOD. A sample JBOD model is shown in figure 9.

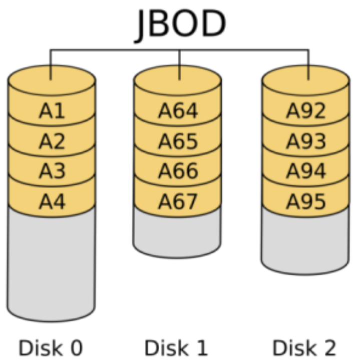


Figure 9: A typical JBOD model

RAID vs JBOD

The individual disks of a JBOD array can each serve as a volume or they can be joined to form one single logical volume. RAID requires all drives of equal capacity, JBOD drives can be of various sizes. A JBOD array fully utilizes all the space on its drives whereas RAID uses only half the capacity of the disks for storage, the other half being used to store the duplicated copy. JBOD is a cost-effective network storage solution. The read/write operations of RAID can be much faster than JBODs. JBOD controllers are less expensive than RAID controllers and we can mix and match disks while using every block for primary storage. Data stream is stored in multiple disks in RAID but JBOD stores a single disk. No duplication of data in JBOD. Data recovery in RAID is limited depending on configurations but JBOD it is unlimited [22].

Advantages of JBOD over RAID

Avoiding Drive Waste: JBOD allows combining different sizes of disks with its full capacity. For example a 10 GB drive, 15 GB drive and 35 GB would combine to make a 60 GB JBOD volume whereas these three different capacity drives cannot be combined in a normal RAID. But RAID 0 allows only 30 GB.

Easier Disaster Recovery: If a disk in a RAID 0 array dies the data on every disk in the array is destroyed because all the files are striped where as if a drive in a JBOD set dies then it may be easier to recover the files on the other drives [23].

NAS vs SAN

The differences between SAN and NAS technologies [7, 8, 16] are: visual differentiation of NAS and SAN is in network architecture. NAS provides both storage and a file system. SAN provides only block-based storage and leaves file system concerns on the "client" side. NAS and SAN may be combined to form a hybrid model. SAN uses fibre channel while NAS uses IP. SAN is reliable but NAS is unreliable. SAN is extremely low CPU overhead while NAS is extremely high. SAN uses large blocks of data but NAS handles large number of small blocks. SAN handles LAN free backup while NAS uses LAN backup. SAN applications are managing own data specifications but NAS applications are driven by universal access to files. The SAN servers manage the file system whereas file system is managed by NAS head unit. In SAN file sharing is operating system dependent whereas a NAS allows greater sharing of information among different operating systems. In SAN backups and mirrors are simply block by block while in a NAS these are on files. SAN addresses the data by logical block numbers but in NAS it is filename.

DAS vs NAS vs SAN

The comparison between DAS, NAS and SAN [9] technologies are listed in table 8.

Table 8: Comparison between DAS, NAS and SAN technologies

DAS (SAS)	*NAS*	*SAN*
Past (1980 onwards)	Present (1997 onwards)	Future
Server centric	File centric	Data centric
Generally part of a server	Dedicated file server	Server/Storage independence
Data access in OS and file system	File sharing between heterogeneous servers	Block sharing between heterogeneous servers
Individual IDE, SCSI with Ethernet	Combines SCSI and Ethernet on a single board	Combines high performance of I/O channel with connectivity of a network
Legacy system all have SAS	Ideal for low cost function servers	Higher cost
Not scalable	Partially scalable	Highly scalable
Hybrid data management	Decentralized data management	Centralized data management
Conflict with network traffic	No conflict with network traffic	No conflict with network traffic
Possibly available	Moderately available	High availability with clustering
Slow response with increased number of users	Medium response with increased number of users	Fast response with increased number of users

Conclusion

Among DAS, NAS and SAN storage technologies, the industry best is SAN because of its standard features like high performance, long distance support and scalability which are needed right now for networks while these are not available in DAS and even in NAS. Further SAN offers several protocols suitable for cost effective industries. The RAID models are already popular in several leading OSs. The future is going to be with SAN based storage devices.

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