CHAPTER 2

THEORETICAL FOUNDATION

2.1 Network Model of Storage Area Network Architecture

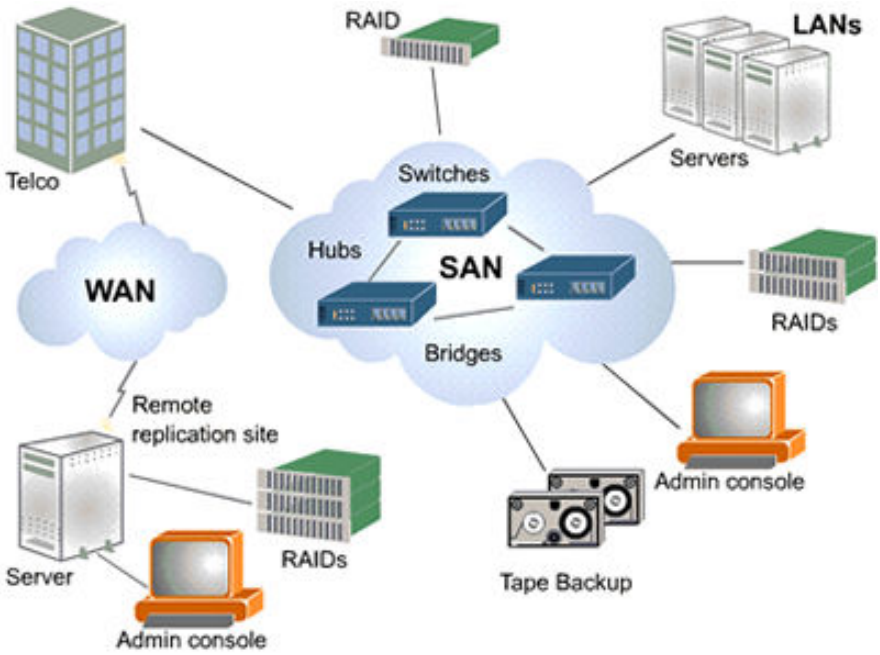

Figure 2.1 Network model of Storage Area Network [1]

Above is the network model illustration on Storage Area Network architecture. It shows how servers, computer users through LAN or WAN, back-up devices, RAIDs, that are located separately, are interconnected to Storage Area Network. They share the same storage resources in Storage Area Network. Inside Storage Area Network itself, the devices are connected with switches, hubs and bridges.

2.2 Computer and Storage Peripherals

2.2.1 Server

A server is generally just a more powerful PC. It uses more powerful processor, large amount of memory and hard disk compared to desktop PC. A server must operate 24 hours a day, 7 seven days a week and very unlikely to be turned off. The main task is to handle communications and activities within the connection or to perform heavy duty that an ordinary PC cannot do.

2.2.2 Disk System

Disk system or disk drive is a box / chassis where several physical storage disks tight together. A central control unit manages all the I/O in a disk system [2].

2.2.3 Tape System

Tape systems or tape drives store data in sequential order and retrieve the data based on that sequential order. It is generally used for back up and restore operations. Tape drive differs with disk drive in its removability, which means it can be transported for safekeeping from disasters or any other threat mechanism. The other difference is tape drives are usually used to write data while disk drives are often used for reading data [3].

Basically, there are three types of tape systems:

Tape Drive – Like disk drive, tape drive is the tape that directly connected to other devices [2].

Tape Autoloader – it is autonomous tape drives that capable of managing tapes automatically. Generally, it is used for performing automatic back-up operations [2].

Tape Library – tape library is a set of independent tape drives or autoloaders that are able to manage multiple tapes simultaneously [2].

2.3 Storage Technology

2.3.1 SATA

Serial Advanced Technology Attachment (SATA) is the development of ATA interface. The main difference is while ATA uses parallel bus connection, SATA use serial connection. ATA is already recognized as a standard interface to connect storage devices [4]. It is also often called Integrated Drive Electronics (IDE).

2.3.2. SCSI

Small Computer System Interface (SCSI) is a collection of ANSI standards for connecting storage devices to hosts through host bus adapters (HBA) [5]. It is known best for transmitting large data blocks.

2.3.3. SAS

Like SCSI, Serial Attached SCSI (SAS) is a data transfer technology used to connect storage devices to host through host bus adapters (HBA). While SCSI uses parallel protocol, SAS uses a point-to-point serial protocol. It uses the standard SCSI command set as well [6].

2.3.4. RAID

Redundant Array of Inexpensive Disk (RAID) is a set of physical disk drives but seen as one unity by the operating system. Data in RAID system are distributed redundantly across the physical drives of an array [7]. In other word, RAID makes *partitioning*. RAID is used to improve performance, data availability and redundancy. Later on, modern computing industry changed the term RAID into Redundant Array of Independent Disk.

2.3.5. JBOD

Just a Bunch Of Disk (JBOD) can be considered as the opposite of *partitioning* or RAID. While RAID divides single drives into smaller logical volume, JBOD combined independent drives into one larger logical volume. The proper official term used to describe JBOD is *spanning* [8]. The term JBOD is now often refers to a cabinet of hard drives where RAID functionality is not present [9].

2.4 Network

2.4.1 Local Area Network (LAN)

Local Area Network (LAN) is a communication network. It interconnects a variety of devices and provides a means of information exchange among those devices. The scope is usually small, e.g. home, office, a single building or a small block of buildings. Generally, it is owned by an organization for their internal usage. In LAN, several computers are connected to one or more servers. The connection distance is short. Within a LAN, many computers can communicate each other, exchange information and share the same resources. Typically, the coverage is less than 5 kilometers.

2.4.2 Wide Area Network (WAN)

Wide Area Network (WAN) has the same functions like LAN but it serves a bigger geographical area than a LAN, e.g. a metropolitan, a regional area, etc.

2.4.3 Ethernet

Ethernet is a popular networking standard for LAN that uses a contention media-access method over a bus topology of coaxial cable. It is referred to the standard specified by IEEE 802.3 [10].

2.5 Network Device

2.5.1 Hub and Switch

Hub is a network device to connect several nodes to establish a bigger network. Switch is like hub but it has more intelligence and better performance. Switch typically has internal bandwidth so it has a constant connection speed while hub uses shared connection speed. Switch can accommodate port at different speed as well.

2.5.2 Router and Bridge

Router is a network device that do routing and forwarding. Router connects two or more network or even the Internet to send data packets among network. Router runs at the third layer of the OSI model (network layer) and using network address as the node's address [11]. Router only works on similar protocol. Some routers also do the task of filtering data packets.

Bridge has the same function as router. The difference is bridge runs at the second layer of the OSI model (data link layer) and it uses MAC address as the address [11].

2.5.3 Gateway

Gateway is the network point that acts as an entrance to another network and vice versa. It almost similar with router or bridges but gateway runs in all seven OSI layers.

Therefore, it is capable of working at different protocol and do necessary translation or conversion among communication networks for both hardware and software [12].

2.5.4 Network Interface Card (NIC)

Network Interface Card (NIC) is the computer peripherals that designed to allow communication between networks. It enables a computer to attach to a network [10]. It is also often called as network card or network adapter.

2.5.5 Host Bus Adapter (HBA)

Host Bus Adapter (HBA) is a card that contains ports for host systems [10]. It connects the host system to other network or storage devices. Nowadays, the term *host bus adapter* is mostly referred to Fibre Channel interface card [13].

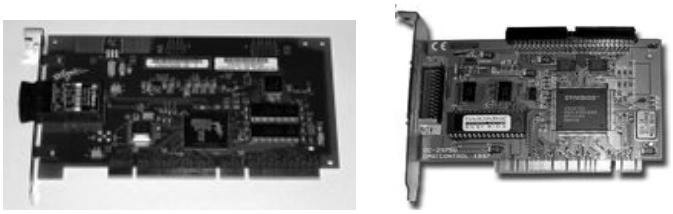

Figure 2.2 Host Bus Adapter:
HBA for Fibre Channel (left), HBA for SCSI (right) [13]

2.6 Fibre Channel

2.6.1 Definition

Fibre Channel is a set of related physical layer networking standard. It is sometimes considered as the main competitor of Ethernet [14]. Fibre Channel supports gigabit-speed network technology and primarily used in storage networking [15].

Fibre Channel is capable of supporting multiple protocols, including access to open system storage (FCP), access to mainframe storage (FICON), SCSI and (TCP/IP). Fibre Channel can support the topology of point to point, arbitrated loop, and switched [16].

Fibre Channel can utilize both copper wiring and fiber-optic cable as the physical medium. Thus, with copper wiring, Fibre Channel can reach only 30 meters in maximum while fiber-optic cables enables the reach up to 10 kilometers [14]. Depends on the physical medium, Fibre Channel can have the speed from 1 Gbps to 10 Gbps [16].

Fiber (with the “er” ending) is always optical connection while fibre (with “re” ending) is a physical connection which may or may not be optical. Nowadays, Fibre Channel is usually associated to Storage Are Network architecture.

2.6.2 History

Fibre Channel started in 1985, with ANSI standard approval in 1995, as a way to simplify the HIPPI system then in use for similar roles. HIPPI (High Performance Parallel Interface) used a massive 50-pair cable with bulky connectors, and had limited cable lengths [14]. It was started primarily for usage in supercomputer field but later on has become a connection that widely used for Storage Area Network in enterprise storage [14].

Fibre Channel was primarily concerned with simplifying the connections and increasing distances as opposed to increasing speed. Later, designers edit the goal of connecting SCSI storage, providing higher speeds and far greater number of connected devices. It also added support for any number of “upper layer” protocols including SCSI, ATM and IP, with SCSI being the predominant usage [14].

Fibre Channel is standardized in the T11 Technical Committee of the International Committee for Information Technology Standards (INCITS), an ANSI accredited standards committee [14].

2.6.3 Characteristic

The main characteristics of Fibre Channel are:

- High speed within a far distance

  Fibre Channel enables data to be transferred in gigabit speed with a low latency through a very far distance. It supports the reach of 10 kilometres with the speed of 10 Gbps.

- Support multiple protocol

  Fibre Channel supports multiple protocols, namely: ATM, FCP, FICON, SCSI, TCP/IP, ATM, etc.

- Support multiple physical medium

  Fibre Channel can work in coaxial cable, ordinary telephone twisted pair and fibre-optic cable [17].

2.6.4 Layer

Fibre Channel consists of 5 layers:

FC0	Physical layer	It is the cables, fiber optics, connectors, pinouts, etc
FC1	Data link layer	Encoding and decoding signals
FC2	Network layer	Consists of the core of Fibre Channel and defines the main protocols
FC3	Common services layer	Functions like encryption or RAID
FC4	Protocol Mapping layer	Encapsulate into information unit for delivery to FC 2

[15]

FC0, FC1 and FC 2 are also known as FC-PH, the physical layers of Fibre Channel. Fibre Channel hubs can operate only on FC0, while switches can run up to FC2. Fibre Channel routers, however, can operate up to FC4 level [15].

2.6.5 Topology

There are 3 topologies of Fibre Channel:

- Point-to-Point (FC-P2P)

  Two devices are directly connected back to back. This is the simplest topology, with limited connectivity. [15].

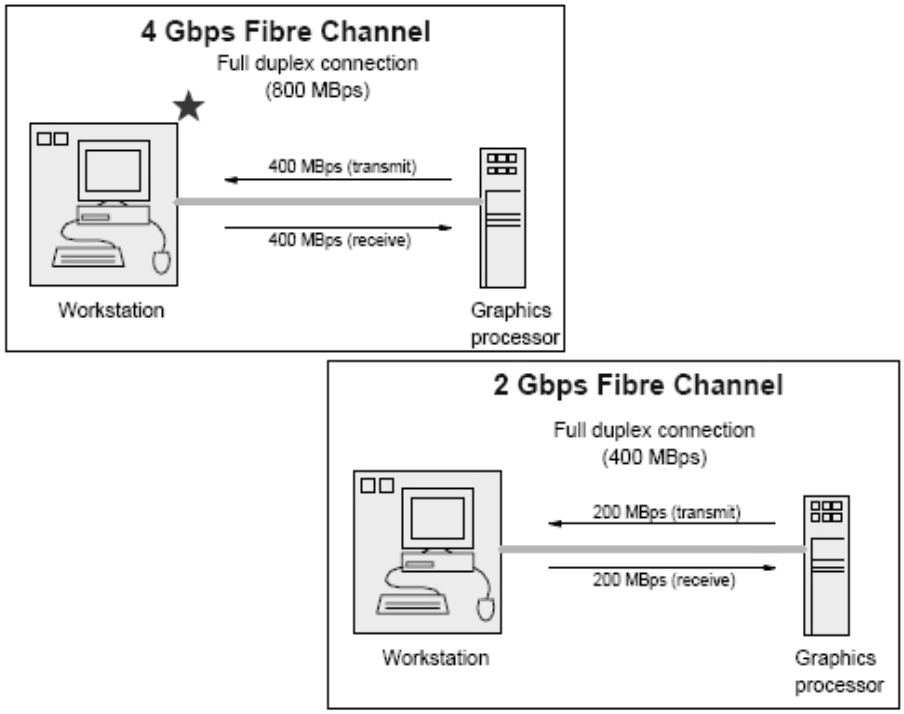

Figure 2.3 Fibre Channel Point-to-Point topology [2]

- Fibre Channel Arbitrated Loop (FC-AL)

  In FC-AL topology, all devices are in a loop or ring, similar to token ring networking [15]. It can have the loop up to 126 nodes that is managed as a shared bus [2]. Any action happened on the loop (i.e. adding or removing device) will cause all activity on the loop to be interrupted. The failure of one device will break the ring [15]. All devices within the topology will communicate in the same bandwidth. The available bandwidth is determined by the traffic in the loop [2].

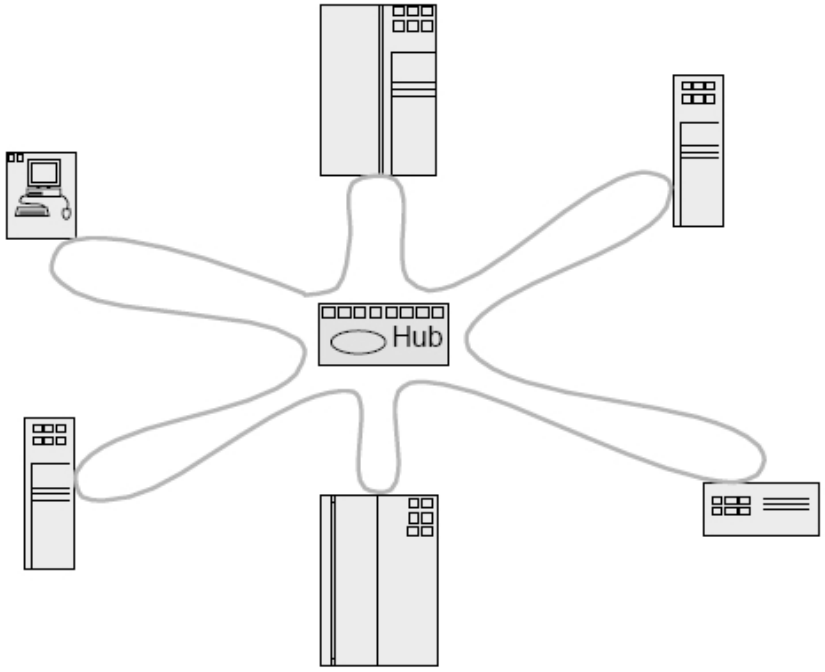

Figure 2.4 Fibre Channel Arbitrated Loop topology [2]

- Switched Fabric (FC-SW)

  All devices or loops of devices are connected to Fibre Channel switches. It is similar with the Ethernet concept. The switches manage the state of the fabric, providing optimized interconnections [15]. FC-SW gives the best connectivity among other topology. In FC-SW, total bandwidth is in linear growth with the amount of port.

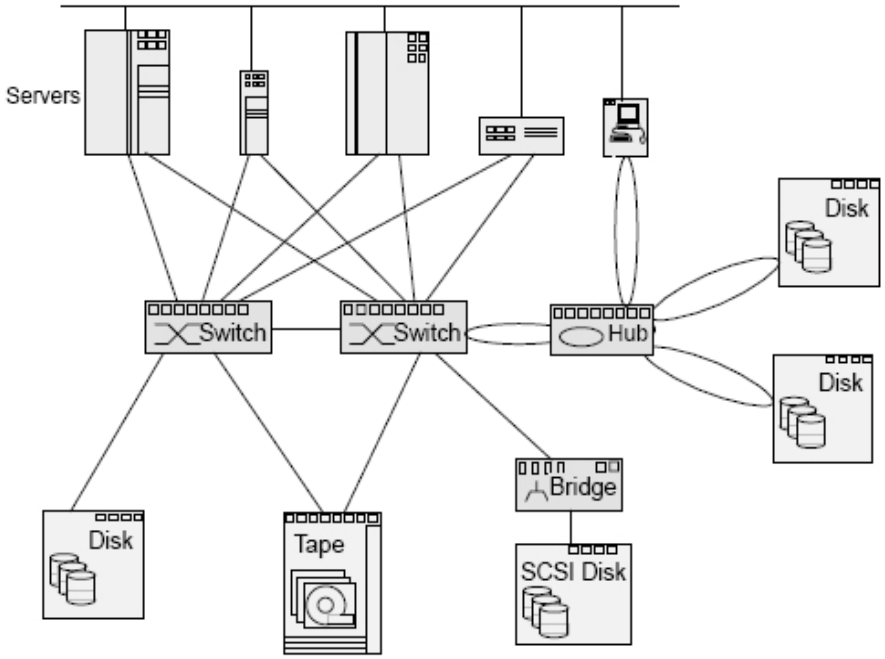

Figure 2.5 Fibre Channel Switched Fabric topology [2]

2.7 Storage System

2.7.1 Direct Attached Storage

In Direct Attached Storage (DAS), all of the storage resources reside with the host computer. In other word, the storage is directly attached to the server, PC or workstation. DAS is a non-networked storage [18].

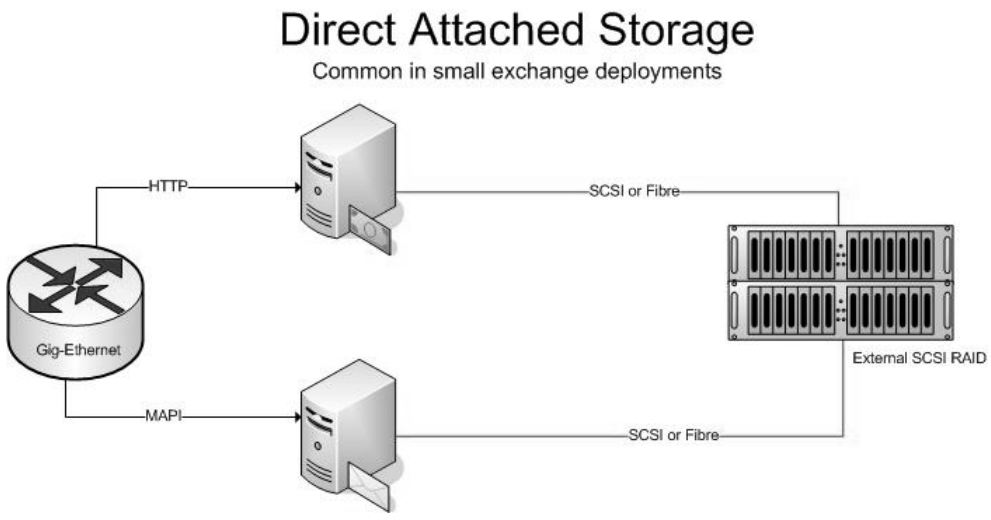

Figure 2.6 Direct Attached Storage model [18]

Typically, a DAS system is established by connecting the server or workstation to one or more enclosure holding storage devices such as hard disk drive and tape drive. The main protocols for DAS are SCSI, SAS and Fibre Channel [18].

2.7.2 Network Attached Storage

In Network Attached Storage (NAS), the process of storing and retrieving the data is done by transferring the data over the LAN. So, the storage-related resource and the application server share the same network resource.

It was first introduced in 1983 in the early file sharing Novell NetWare server OS and NCP protocol. Later on in 1984, Sun Microsystems launched NFS for UNIX. This allowed network servers to share the storage resource among the users/clients [19].

Typically, in NAS system, there is a device that is intended doing only managing and supplying the data for the client and not carrying the general computing tasks at all. However, it still uses the same network and therefore shares the same network resources with other devices. NAS provides both storage and file sytem. It uses file-based protocols such as NFS or SMB [19].

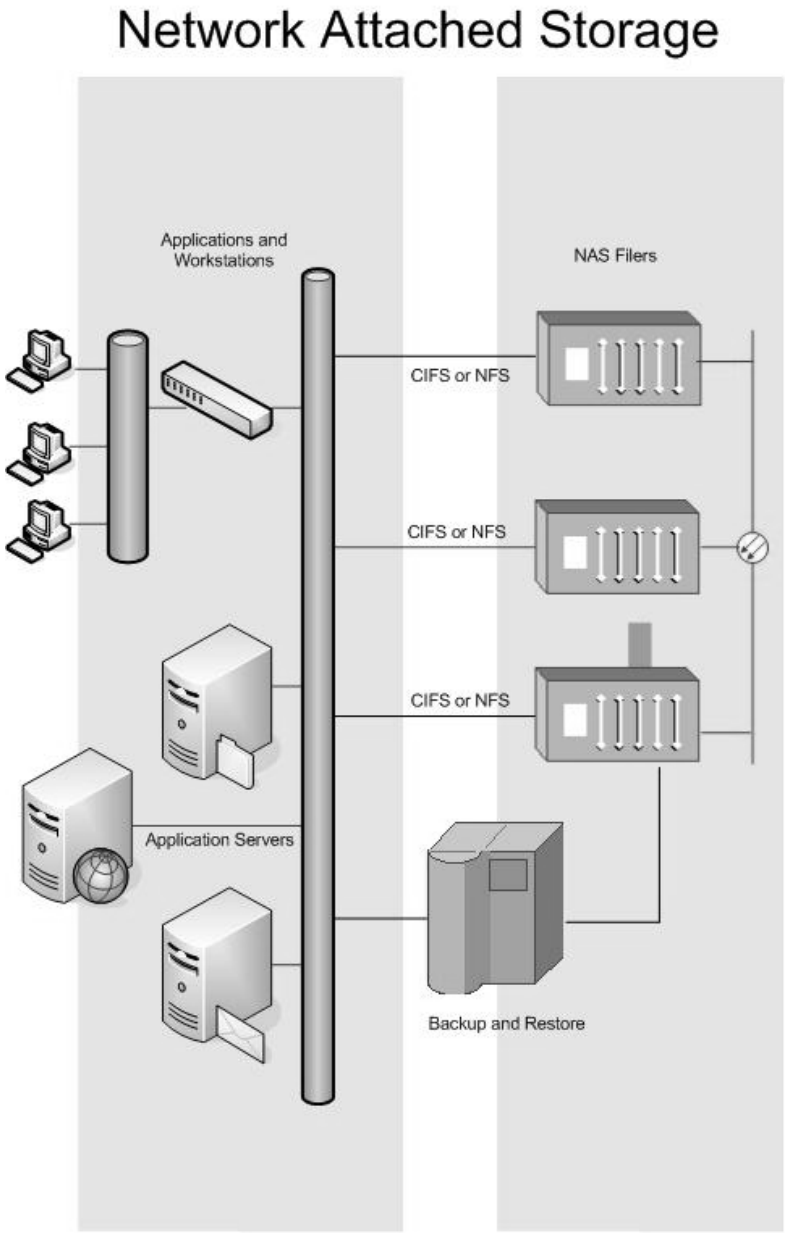

Figure 2.7 Network Attached Storage model [19]

2.7.3 File Area Network

File Area Network is sometimes considered the same as NAS. The term File Area Network (FAN) actually refers to the methods of sharing files over the network [20]. It works at the file level.

2.8 Storage Area Network

2.8.1 Definition

Storage Area Network (SAN) is a dedicated network whose main purpose is to enable data transfer with a high speed between storage devices and computer systems and among storage devices. [2],[5],[21]. Although SAN is located in a separate network, the operating system views the storage devices in SAN as locally attached.

The network of SAN architecture consists of many storage devices and creates a large pool of data. This dedicated storage network and the server network is connected each other in many-to-many basis [2].

While NAS is file-based and works in file-level protocols such as NFS or SMB/CIFS, SAN uses lower level network protocols, i.e. block-level protocols [22]. SAN is generally associated with Fibre Channel in order for it to have a high bandwidth speed.

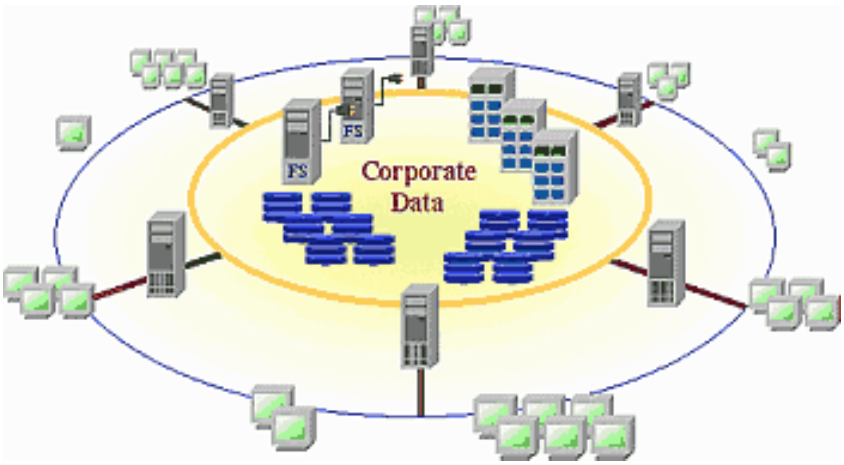

Figure 2.8 Storage Area Network model [23]

2.8.2 History

In 1994, Network Attached Storage technology has been known. However, due to its low throughput, it is not suitable for many applications. At that time, Sun Microsystems launched a storage product that was listed in their SPARC product directory as the SPARC storage array. This product provided industry standard and can give faster throughput due to the usage of fiber optic. It was a Fibre-Channel connected storage. When it is introduced, this product enabled campus wide consolidation of high throughput storage [24].

The product soon gained popularity in the mid 1990s, especially in the pre-press industry where large image files were moved around from workstations to other types of specialized printing equipment. The product is the pioneer of what we called now as Storage Area Network. The terminology “Storage Area Network” itself starts to be used in 1999 [24].

2.8.3 Characteristic

Storage Area Network is generally characterized as:

- Dedicated network

  SAN is a network that is separated from other network. This dedicated network only does the function of storing and retrieving data.

- High interconnection data rates (Gigabits/sec)

  SAN has high interconnection data rates between its members. The speed is usually in the Gigabit/sec level.

- Virtual local attached

  SAN works in such a way that operating system views the storage devices as locally attached though it is actually located in other venue.

- Platform independent

  SAN is platform independent, making it able to work in any kind of platform.

- Using Fibre Channel

  Although not a must, SAN is usually using Fibre Channel. This is because Fibre Channel is considered as the most suitable partner in order to make SAN achieve the gigabit interconnection speed.

2.8.4 Network Connection

Storage Area Network is used to bypass the traditional network bottlenecks. It can be used to facilitate direct, high-speed data flow between the server and storage device [2]. The interaction schemes of the SAN are [2]:

- **Server to storage** – this is the traditional model of server and storage interaction [2]. The server only does the computing process while the storage device stores the data.
- **Server to server** – SAN architecture can also be used for communication between server and server. It enables high-speed and high-volume communications between servers [2].
- **Storage to storage** – this is the data movement without server intervention. Therefore, it frees up the server power for other activities [2]. The easiest example of this interaction is doing back-up to tape device. The back-up process is done in the internal network of SAN without the application server need to get involved in it or *serverless backup*.

2.8.5 Components

SAN components can generally divide into 4 layers: client layer, server layer, fabric layer and the storage layer. Thus, the one that really considered as the SAN are the fabric layer and the storage layer.

Client layer is the users that use the data that is stored in the SAN via the server. Server layer is the line of servers that access the storage resource in the SAN.

The fabric layer is the one that creates connectivity in SAN. The components of the fabric layer are [25]:

Cables and connectors – it provides the physical connection between all the components in SAN.

Adapters – it is the devices that connect to a network, server or storage device and control the electrical protocol for communications [25].

Hub and switch – they connect the nodes in the SAN.

Routers, bridges and gateways – they will extend the SAN over long distances and enable integration of multi-protocol technologies. Thus, storage routers differ from network router. Storage router uses storage protocols like FCP, etc instead of messaging protocols such as TCP/IP [25].

Storage layer is the layer that stores and manages the data in the SAN architecture. They consist of:

Storage device – all devices that store data i.e. disk system or tape system.

Storage server – it is the server that handles the management and control of data in the storage device. It is also the host of the SAN management software.

SAN management software – it is the applicatin that manages the operation of SAN. The software resides in the storage server.

The amount and usage of those components in the SAN is varies, depend on the size of the SAN itself. Bigger data indeed will create a bigger SAN architecture and uses more cables, more adapters, more switches, more routers and of course more storage devices.