1. What is data? List and explain some of the factors that have contributed to the growth of digital data.

Ans:

- Data is a collection of raw facts from which conclusions may be drawn.
- Eg: a printed book, a family photograph, a movie on videotape, e-mail message, an e-book, a bitmapped image, or a digital movie are all examples of data.
- The data can be generated using a computer and stored in strings of 0s and 1s(as shown in Fig 1.1), is called digital data and is accessible by the user only after it is processed by a computer.
- The following is a list of some of the factors that have contributed to the growth of digital data:
    - Increase in data processing capabilities: Modern-day computers provide a significant increase in processing and storage capabilities. This enables the conversion of various types of content and media from conventional forms to digital formats.
    - Lower cost of digital storage: Technological advances and decrease in the cost of storage devices have provided low-cost solutions and encouraged the development of less expensive data storage devices. This cost benefit has increased the rate at which data is being generated and stored.
    - Affordable and faster communication technology: The rate of sharing digital data is now much faster than traditional approaches. A handwritten letter may take a week to reach its destination, whereas it only takes a few seconds for an e-mail message to reach its recipient.
    - Proliferation of applications and smart devices: Smartphones, tablets, and newer digital devices, along with smart applications, have significantly contributed to the generation of digital content.

2. What is File system? Explain process of mapping user files to disk storage

Ans:

- A file is a collection of related records or data stored as a unit with a name.
- A file system is a hierarchical structure of files.
- A file system enables easy access to data files residing within a disk drive, a disk partition, or a logical volume.
- It provides users with the functionality to create, modify, delete, and access files.
- Access to files on the disks is controlled by the permissions assigned to the file by the owner, which are also maintained by the file system.
- A file system organizes data in a structured hierarchical manner via the use of directories, which are containers for storing pointers to multiple files.
- All file systems maintain a pointer map to the directories, subdirectories, and files that are part of the file system.
- Examples of common file systems are:
    - FAT 32 (File Allocation Table) for Microsoft Windows

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- NT File System (NTFS) for Microsoft Windows
- UNIX File System (UFS) for UNIX
- Extended File System (EXT2/3) for Linux

- The file system also includes a number of other related records, which are collectively called the metadata.
- For example, the metadata in a UNIX environment consists of the superblock, the inodes, and the list of data blocks free and in use.
- A superblock contains important information about the file system, such as the file system type, creation and modification dates, size, and layout.
- An inode is associated with every file and directory and contains information such as the file length, ownership, access privileges, time of last access/modification, number of links, and the address of the data.
- A file system block is the smallest "unit" allocated for storing data.

3. With a neat diagram, explain a Host Access to data.

Ans:

Data is accessed and stored by applications using the underlying infrastructure. The key components of this infrastructure are the operating system (or file system), connectivity, and storage. The storage device can be internal and (or) external to the host. In either case, the host controller card accesses the storage devices using predefined protocols, such as IDE/ATA, SCSI, or Fibre Channel (FC). IDE/ATA and SCSI are popularly used in small and personal computing environments for accessing internal storage. FC and iSCSI protocols are used for accessing data from an external storage device (or subsystems). External storage devices can be connected to the host directly or through the storage network. When the storage is connected directly to the host, it is referred as direct-attached storage (DAS), which is detailed later in this chapter.

Understanding access to data over a network is important because it lays the foundation for storage networking technologies. Data can be accessed over a network in one of the following ways: block level, file level, or object level.

In general, the application requests data from the file system (or operating system) by specifying the file name and location. The file system maps the file attributes to the logical block address of the data and sends the request to the storage device. The storage device converts the logical block address (LBA) to a cylinder-head-sector (CHS) address and fetches the data.

In a block-level access, the file system is created on a host, and data is accessed on a network at the block level, as shown in Figure 2-14
(a). In this case, raw disks or logical volumes are assigned to the host for creating the file system. In a file-level access, the file system is created on a separate file server

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or at the storage side, and the file-level request is sent over a network, as shown in Figure 2-14.
(b). Because data is accessed at the file level, this method has higher overhead, as compared to the data accessed at the block level. Object-level access is an intelligent evolution, whereby data is accessed over a network in terms of self-contained objects with a unique object identifier. Details of storage networking technologies and deployments are covered in Section II of this book, "Storage Networking Technologies."

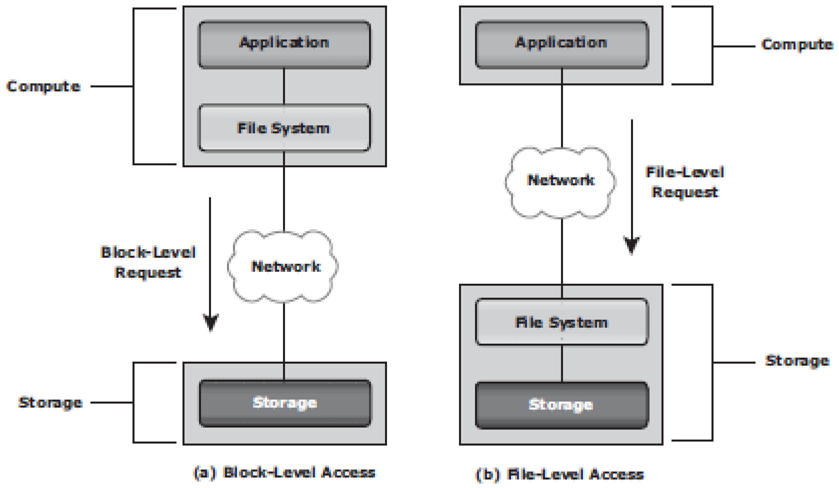

Figure 2-14: Host access to storage

4. Explain with a neat diagram evolution of storage architecture.

Ans:

- Historically, organizations had centralized computers (mainframe) and information storage devices (tape reels and disk packs) in their data center.
- The evolution of open systems and the affordability and ease of deployment that they offer made it possible for business units/departments to have their own servers and storage.
- In earlier implementations of open systems, the storage was typically internal to the server. This approach is referred to as server-centric storage architecture (see Fig 1.4 [a]).
- In this server-centric storage architecture, each server has a limited number of storage devices, and any administrative tasks, such as maintenance of the server or increasing storage capacity, might result in unavailability of information.
- The rapid increase in the number of departmental servers in an enterprise resulted in unprotected, unmanaged, fragmented islands of information and increased capital and operating expenses.
- To overcome these challenges, storage evolved from server-centric to information-centric architecture (see Fig 1.4 [b]).

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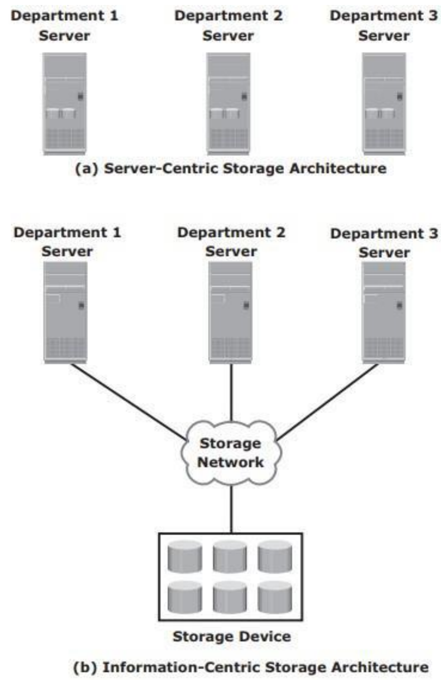

- In information-centric architecture, storage devices are managed centrally and independent of servers.
- These centrally-managed storage devices are shared with multiple servers.
- When a new server is deployed in the environment, storage is assigned from the same shared storage devices to that server.
- The capacity of shared storage can be increased dynamically by adding more storage devices without impacting information availability.
- In this architecture, information management is easier and cost-effective.
- Storage technology and architecture continues to evolve, which enables organizations to consolidate, protect, optimize, and leverage their data to achieve the highest return on information assets.

5. List and explain various key components of Disk drive.

Ans:

The key components of a hard disk drive are platter, spindle, read-write head, actuator arm assembly, and controller board (see Figure 2-5).
I/O operations in an HDD are performed by rapidly moving the arm across the rotating flat platters coated with magnetic particles. Data is transferred between the disk controller and magnetic platters through the read-write (R/W) head which is attached to the arm. Data can be recorded and erased on magnetic platters any number of times. Following sections detail the different components of the disk drive, the mechanism for organizing and storing data on disks, and the factors that affect disk performance.

2.6.1 Platter.

A typical HDD consists of one or more flat circular disks called platters (Figure 2-6). The data is recorded on these platters in binary codes (0s and 1s). The set of rotating platters is sealed in a case, called the Head Disk Assembly (HDA). A platter is a rigid, round disk coated with magnetic material on both surfaces (top and bottom). The data is encoded by polarizing the magnetic area, or domains, of the disk surface. Data can be written to or read from both surfaces of the platter. The number of platters and the storage capacity of each platter determine the total capacity of the drive.

2.6.2 Spindle

A spindle connects all the platters (refer to Figure 2-6) and is connected to a motor. The motor of the spindle rotates with a constant speed.
The disk platter spins at a speed of several thousands of revolutions per minute (rpm). Common spindle speeds are 5,400 rpm, 7,200 rpm, 10,000 rpm, and 15,000 rpm. The speed of the platter is increasing with improvements in technology, although the extent to which it can be improved is limited.

2.6.3 Read/Write Head

Read/Write (R/W) heads, as shown in Figure 2-7, read and write data from or to platters. Drives have two R/W heads per platter, one for each surface of the platter. The R/W head changes the magnetic polarization on the surface of the platter when writing data. While reading data, the head detects the magnetic polarization on the surface of the platter. During reads and writes, the R/W head senses the magnetic polarization and never touches the surface of the platter. When the spindle is rotating, there is a microscopic air gap maintained between the R/W heads and the platters, known as the head flying height. This air gap is removed when the spindle stops rotating and the R/W head rests on a special area on the platter near the spindle. This area is called the landing zone. The landing zone is coated with a lubricant to reduce friction between the head and the platter.
The logic on the disk drive ensures that heads are moved to the landing zone before they touch the surface. If the drive malfunctions and the R/W head accidentally touches the surface of the platter outside the landing zone, a head crash occurs. In a head crash, the magnetic coating on the platter is scratched and may cause damage to the R/W head. A head crash generally results in data loss.

2.6.4 Actuator Arm Assembly

R/W heads are mounted on the actuator arm assembly, which positions the R/W head at the location on the platter where the data needs to be written or read (Refer to Figure 2-7). The R/W heads for all platters on a drive are attached to one actuator arm assembly and move across the platters simultaneously.

2.6.5 Drive Controller Board

The controller (refer to Figure 2-5 [b]) is a printed circuit board, mounted at the bottom of a disk drive. It consists of a microprocessor, internal memory, circuitry, and firmware. The firmware controls the power to the spindle motor and the speed of the motor. It also manages the communication between the drive and the host. In addition, it controls the R/W operations by moving the actuator arm and switching between different R/W heads, and performs the optimization of data access.

2.6.6 Physical Disk Structure

Data on the disk is recorded on tracks, which are concentric rings on the platter around the spindle, as shown in Figure 2-8. The tracks are numbered, starting from zero, from the outer edge of the platter. The number of tracks per inch (TPI) on the platter (or the track density) measures how tightly the tracks are packed on a platter.

Each track is divided into smaller units called sectors. A sector is the smallest, individually addressable unit of storage. The track and sector structure are written on the platter by the drive manufacturer using a low-level formatting operation. The number of sectors per track varies according to the drive type. The first personal computer disks had 17 sectors per track. Recent disks have a much larger number of sectors on a single track. There can be thousands of tracks on a platter, depending on the physical dimensions and recording density of the platter.

Typically, a sector holds 512 bytes of user data, although some disks can be formatted with larger sector sizes. In addition to user data, a sector also stores other information, such as the sector number, head number or platter number, and track number. This information helps the controller to locate the data on the drive.

A cylinder is a set of identical tracks on both surfaces of each drive platter. The location of R/W heads is referred to by the cylinder number, not by the track number.

2.6.7 Zoned

Bit Recording Platters are made of concentric tracks; the outer tracks can hold more data than the inner tracks because the outer tracks are physically longer than the inner tracks. On older disk drives, the outer tracks had the same number of sectors as the inner tracks, so data density was low on the outer tracks. This was an inefficient use of the available space, as shown in Figure 2-9 (a).

Zoned bit recording uses the disk efficiently. As shown in Figure 2-9 (b), this mechanism groups track into zones based on their distance from the center of the disk. The zones are numbered, with the outermost zone being zone 0. An appropriate number of sectors per track are assigned to each zone, so a zone near the center of the platter has fewer sectors per track than a zone on the outer edge. However, tracks within a particular zone have the same number of sectors.

2.6.8 Logical Block Addressing

Earlier drives used physical addresses consisting of the cylinder, head, and sector (CHS) number to refer to specific locations on the disk, as shown in Figure 2-10 (a), and the host operating system had to be aware of the geometry of each disk used. Logical block addressing (LBA), as shown in Figure 2-10 (b), simplifies addressing by using a linear address to access physical blocks of data. The disk controller translates LBA to a CHS address, and the host needs to know only the size of the disk drive in terms of the number of blocks. The logical blocks are mapped to physical sectors on a 1:1 basis.

6. Explain virtualization and cloud computing

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Ans:

Virtualization:

- Virtualization is a technique of abstracting physical resources, such as compute, storage, and network, and making them appear as logical resources.
- Virtualization has existed in the IT industry for several years and in different forms.
- ➢ Common examples of virtualization are virtual memory used on computer systems and partitioning of raw disks.
- Virtualization enables pooling of physical resources and providing an aggregated view of the physical resource capabilities. For example, storage virtualization enables multiple pooled storage devices to appear as a single large storage entity.
- Similarly, by using compute virtualization, the CPU capacity of the pooled physical servers can be viewed as the aggregation of the power of all CPUs (in megahertz).
- Virtualization also enables centralized management of pooled resources.
- Virtual resources can be created and provisioned from the pooled physical resources. For example, a virtual disk of a given capacity can be created from a storage pool or a virtual server with specific CPU power and memory can be configured from a compute pool.
- These virtual resources share pooled physical resources, which improves the utilization of physical IT resources.
- Based on business requirements, capacity can be added to or removed from the virtual resources without any disruption to applications or users.
- With improved utilization of IT assets, organizations save the costs associated management of new physical resources. Moreover, fewer physical resources mean less space and energy, which leads to better economics and green computing.

Cloud Computing:

- Cloud computing enables individuals or businesses to use IT resources as a service over the network.
- It provides highly scalable and flexible computing that enables provisioning of resources on demand.
- Users can scale up or scale down the demand of computing resources, including storage capacity, with minimal management effort or service provider interaction.
- Cloud computing empowers self-service requesting through a fully automated request fulfilment process.
- Cloud computing enables consumption-based metering; therefore, consumers pay only for the resources they use, such as CPU hours used, amount of data transferred, and gigabytes of data stored.
- Cloud infrastructure is usually built upon virtualized data centres, which provide resource pooling and rapid provisioning of resources.

7. Explain operating system and memory virtualization.

Ans:

Operating System

- In a traditional computing environment, an operating system controls all aspects of computing.
- It works between the application and the physical components of a compute system.
- In a virtualized compute environment, the virtualization layer works between the operating system and the hardware resources.

Functions of OS

- data access
- monitors and responds to user actions and the environment
- organizes and controls hardware components
- manages the allocation of hardware resources
- It provides basic security for the access and usage of all managed resources
- performs basic storage management tasks
- manages the file system, volume manager, and device drivers.

Memory Virtualization

- Memory has been, and continues to be, an expensive component of a host.
- It determines both the size and number of applications that can run on a host.
- Memory virtualization is an operating system feature that virtualizes the physical memory (RAM) of a host.
- It creates virtual memory with an address space larger than the physical memory space present in the compute system.
- The operating system utility that manages the virtual memory is known as the virtual memory manager (VMM).
- The space used by the VMM on the disk is known as a swap space.
- A swap space (also known as page file or swap file) is a portion of the disk drive that appears to be physical memory to the operating system.
- In a virtual memory implementation, the memory of a system is divided into contiguous blocks of fixed-size pages.
- A process known as paging moves inactive physical memory pages onto the swap file and brings them back to the physical memory when required.

8. List and explain core element of a data center. Explain the key characteristics of a data.

Ans:

Key Data Center Elements

Five core elements are essential for the basic functionality of a data center:

1) Application: An application is a computer program that provides the logic for computing operations. Eg: order processing system.

2) Database: More commonly, a database management system (DBMS) provides a structured way to store data in logically organized tables that are interrelated. A DBMS optimizes the storage and retrieval of data.
3) Host or compute: A computing platform (hardware, firmware, and software) that runs applications and databases.
4) Network: A data path that facilitates communication among various networked devices.
5) Storage array: A device that stores data persistently for subsequent use.

➢ These core elements are typically viewed and managed as separate entities, but all the
elements must work together to address data processing requirements.
➢ Fig 1.5 shows an example of an order processing system that involves the five core elements of a data center and illustrates their functionality in a business process.
1) A customer places an order through a client machine connected over a LAN/ WAN to a host running an order-processing application.
2) The client accesses the DBMS on the host through the application to provide order related information, such as the customer's name, address, payment method, products ordered, and quantity ordered.
3) The DBMS uses the host operating system to write this data to the database located on physical disks in the storage array.
4) The Storage Network provides the communication link between the host and the storage array and transports the request to read or write commands between them.
5) The storage array, after receiving the read or write request from the host, performs the necessary operations to store the data on physical disks.

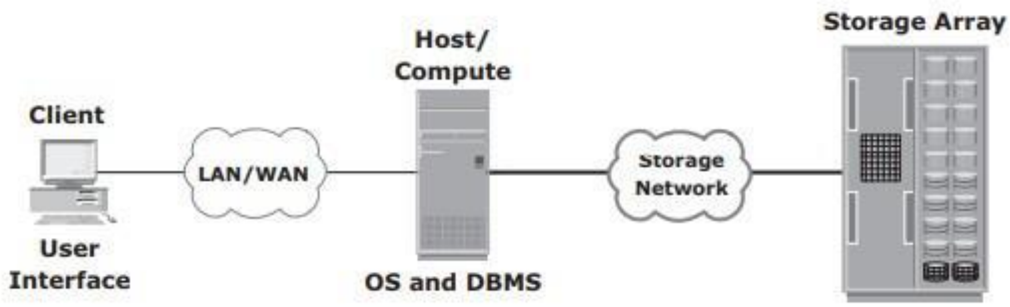

Fig 1.5: Example of an online order transaction system

Key characteristics for Data Center Elements

Key characteristics of data center elements are:
1) Availability: All data center elements should be designed to ensure accessibility. The inability of users to access data can have a significant negative impact on a business.
2) Security: Polices, procedures, and proper integration of the data center core elements that will prevent unauthorized access to information must be established. Specific mechanisms must enable servers to access only their allocated resources on storage arrays.
3) Scalability: Data center operations should be able to allocate additional processing capabilities (eg: servers, new applications, and additional databases) or storage on

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demand, without interrupting business operations. The storage solution should be able to grow with the business.

4) Performance: All the core elements of the data center should be able to provide optimal performance and service all processing requests at high speed. The infrastructure should be able to support performance requirements.

5) Data integrity: Data integrity refers to mechanisms such as error correction codes or parity bits which ensure that data is written to disk exactly as it was received. Any variation in data during its retrieval implies corruption, which may affect the operations of the organization.

6) Capacity: Data center operations require adequate resources to store and process large amounts of data efficiently. When capacity requirements increase, the data center must be able to provide additional capacity without interrupting availability, or, at the very least, with minimal disruption. Capacity may be managed by reallocation of existing resources, rather than by adding new resources.

7) Manageability: A data center should perform all operations and activities in the most efficient manner. Manageability can be achieved through automation and the reduction of human (manual) intervention in common tasks.

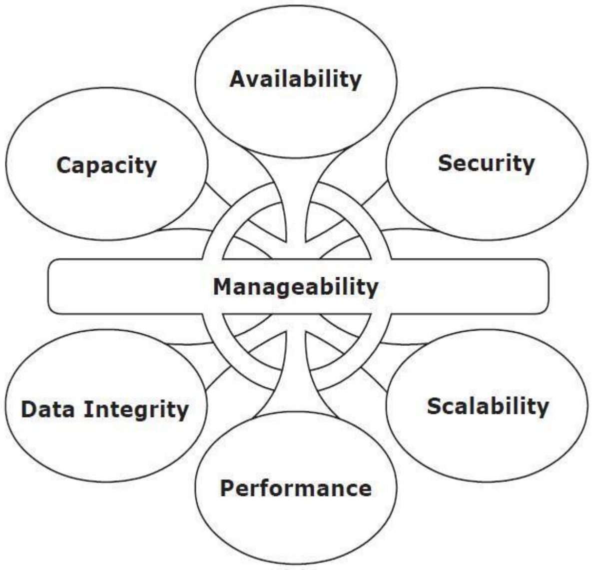

Fig 1.6: Key characteristics of data center elements

9. Explain various factors that affects the performance of disk drives

Ans:

- A disk drive is an electromechanical device that governs the overall performance of the storage system environment. The various factors that affect the performance of disk drives are discussed in this section.
- Disk service time is the time taken by a disk to complete an I/O request. Components that contribute to the service time on a disk drive are seek time, rotational latency, and data transfer rate.

1. Seek Time:

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The seek time (also called access time) describes the time taken to position the R/W heads across the platter with a radial movement (moving along the radius of the platter). In other words, it is the time taken to position and settle the arm and the head over the correct track. Therefore, the lower the seek time, the faster the I/O operation. Disk vendors publish the following seek time specifications:

- Full Stroke: The time taken by the R/W head to move across the entire width of the disk, from the innermost track to the outermost track.
- Average: The average time taken by the R/W head to move from one random track to another, normally listed as the time for one-third of a full stroke.
- Track-to-Track: The time taken by the R/W head to move between adjacent tracks.

Each of these specifications is measured in milliseconds. The seek time of a disk is typically specified by the drive manufacturer. The average seek time on a modern disk is typically in the range of 3 to 15 milliseconds. Seek time has more impact on the read operation of random tracks rather than adjacent tracks. To minimize the seek time, data can be written to only a subset of the available cylinders. This results in lower usable capacity than the actual capacity of the drive. For example, a 500 GB disk drive is set up to use only the first 40 percent of the cylinders and is effectively treated as a 200 GB drive. This is known as short-stroking the drive.

2. Rotational Latency

To access data, the actuator arm moves the R/W head over the platter to a particular track while the platter spins to position the requested sector under the R/W head. The time taken by the platter to rotate and position the data under the R/W head is called rotational latency. This latency depends on the rotation speed of the spindle and is measured in milliseconds. The average rotational latency is one-half of the time taken for a full rotation. Similar to the seek time, rotational latency has more impact on the reading/writing of random sectors on the disk than on the same operations on adjacent sectors.

Average rotational latency is approximately 5.5 ms for a 5,400-rpm drive, and around 2.0 ms for a 15,000-rpm (or 250-rps revolution per second) drive as shown here:

Average rotational latency for 15,000 rpm (or 250 rps)
drive = 0.5/250 = 2 milliseconds.

3. Data Transfer Rate

The data transfer rate (also called transfer rate) refers to the average amount of data per unit time that the drive can deliver to the HBA. It is important to first understand the process of read/write operations to calculate data transfer rates. In a read operation, the data first moves from disk platters to R/W heads; then it moves to the drives internal buffer. Finally, data moves from the buffer through the interface to the host HBA. In a write operation, the data moves from the HBA to the

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internal buffer of the disk drive through the drive’s interface. The data then moves from the buffer to the R/W heads. Finally, it moves from the R/W heads to the platters.

The data transfer rates during the R/W operations are measured in terms of internal and external transfer rates, as shown in Figure 2-11.

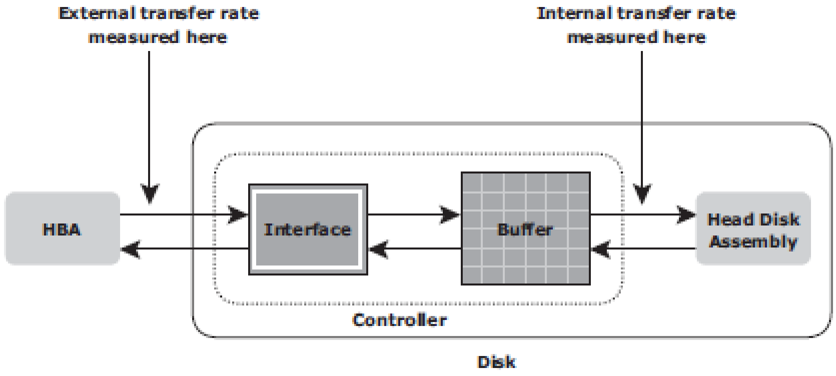

Figure 2-11: Data transfer rate

Internal transfer rate is the speed at which data moves from a platter’s surface to the internal buffer (cache) of the disk. The internal transfer rate takes into account factors such as the seek time and rotational latency. External transfer rate is the rate at which data can move through the interface to the HBA. The external transfer rate is generally the advertised speed of the interface, such as 133 MB/s for ATA. The sustained external transfer rate is lower than the interface speed.

4. Disk I/O Controller Utilization

Utilization of a disk I/O controller has a significant impact on the I/O response time. To understand this impact, consider that a disk can be viewed as a black box consisting of two elements:

- Queue: The location where an I/O request waits before it is processed by the I/O controller
- Disk I/O Controller: Processes I/Os waiting in the queue one by one

The I/O requests arrive at the controller at the rate generated by the application. This rate is also called the arrival rate. These requests are held in the I/O queue, and the I/O controller processes them one by one, as shown in Figure 2-12. The I/O arrival rate, the queue length, and the time taken by the I/O controller to process each request determines the I/O response time. If the controller is busy or heavily utilized, the queue size will be large and the response time will be high.

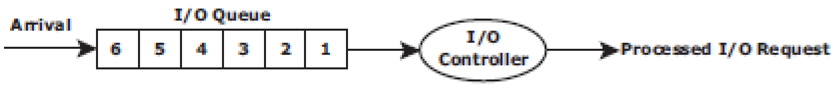

Figure 2-12: I/O processing

Based on the fundamental laws of disk drive performance, the relationship between controller utilization and average response time is given as

Average response time (TR) = Service time (TS) / (1 – Utilization)

where TS is the time taken by the controller to serve an I/O.

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As the utilization reaches 100 percent – that is, as the I/O controller saturates – the response time is closer to infinity. In essence, the saturated component, or the bottleneck, forces the serialization of I/O requests, meaning that each I/O request must wait for the completion of the I/O requests that preceded it. Figure 2-13 shows a graph plotted between utilization and response time.

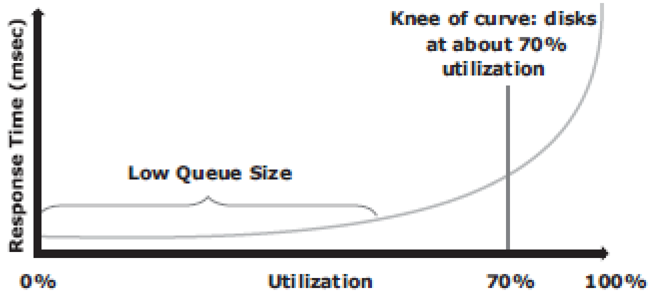

Figure 2-13: Utilization versus response time

The graph indicates that the response time changes are nonlinear as the utilization increases. When the average queue sizes are low, the response time remains low. The response time increases slowly with added load on the queue and increases exponentially when the utilization exceeds 70 percent. Therefore, for performance-sensitive applications, it is common to utilize disks below their 70 percent of I/O serving capability.

10. Explain types of data. Explain big data.

Ans:

Types of Data

- Data can be classified as structured or unstructured (see Fig 1.2) based on how it is stored and managed.
  - Structured data:
    - Structured data is organized in rows and columns in a rigidly defined format so that applications can retrieve and process it efficiently.
    - Structured data is typically stored using a database management system (DBMS).
  - Unstructured data:
    - Data is unstructured if its elements cannot be stored in rows and columns, and is therefore difficult to query and retrieve by business applications.
    - Example: e-mail messages, business cards, or even digital forma files such as .doc, .txt and .pdf.

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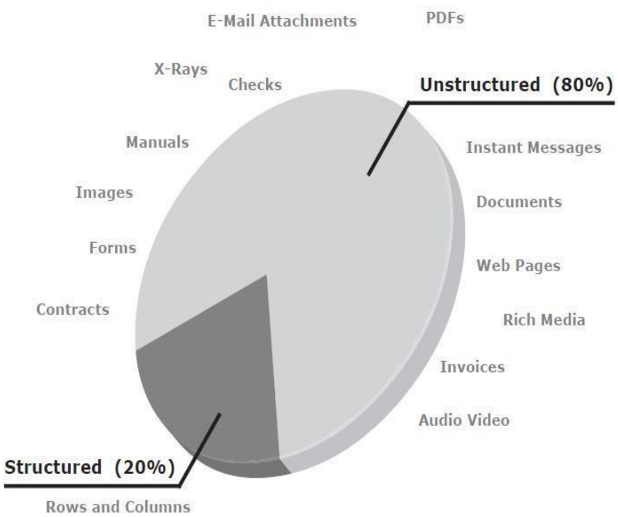

Fig: Types of data

- Big data refers to data sets whose sizes are beyond the capability of commonly used software tools to capture, store, manage, and process within acceptable time limits.
- It includes both structured and unstructured data generated by a variety of sources, including business application transactions, web pages, videos, images, e-mails, social media, and so on.
- The big data ecosystem (see Fig 1.3) consists of the following:
  - Devices that collect data from multiple locations and also generate new data about this data (metadata).
  - Data collectors who gather data from devices and users.
  - Data aggregators that compile the collected data to extract meaningful information.
  - Data users and buyers who benefit from the information collected and aggregated by others in the data value chain.

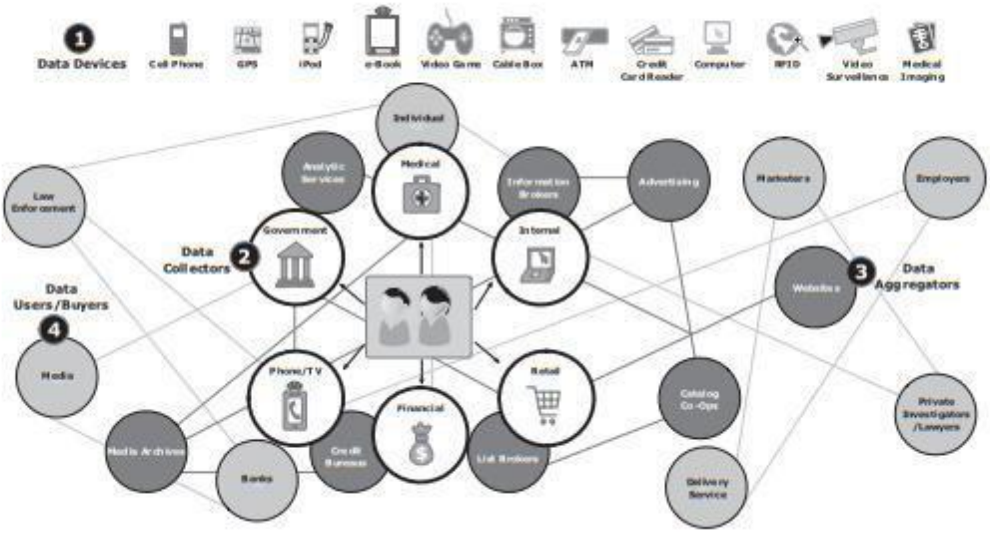

Fig 1.3: Big data Ecosystem

- Big data Analysis in real time requires new techniques, architectures, and tools that provide:
  - high performance,
  - massively parallel processing (MPP) data platforms,

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  - advanced analytics on the data sets.
- Big data Analytics provide an opportunity to translate large volumes of data into right decisions.

11. Explain compute virtualization in details and volume manager in details.

Ans:

Compute Virtualization

- Compute virtualization is a technique for masking or abstracting the physical hardware from the operating system. It enables multiple operating systems to run concurrently on single or clustered physical machines.
- This technique enables creating portable virtual compute systems called virtual machines (VMs) running its own operating system and application instance in an isolated manner.
- Compute virtualization is achieved by a virtualization layer that resides between the hardware and virtual machines called the hypervisor. The hypervisor provides hardware resources, such as CPU, memory, and network to all the virtual machines.
- A virtual machine is a logical entity but appears like a physical host to the operating system, with its own CPU, memory, network controller, and disks. However, all VMs share the same underlying physical hardware in an isolated manner.
- Before Compute virtualization:
  - A physical server often faces resource-conflict issues when two or more applications running on the same server have conflicting requirements. As a result, only one application can be run on a server at a time, as shown in Fig 1.9 (a).
  - Due to this, organizations will need to purchase new physical machines for every application they deploy, resulting in expensive and inflexible infrastructure.
  - Many applications do not fully utilize complete hardware capabilities available to them. Resources such as processors, memory and storage remain underutilized.
  - Compute virtualization enables users to overcome these challenges (see Fig 1.9 (b)).

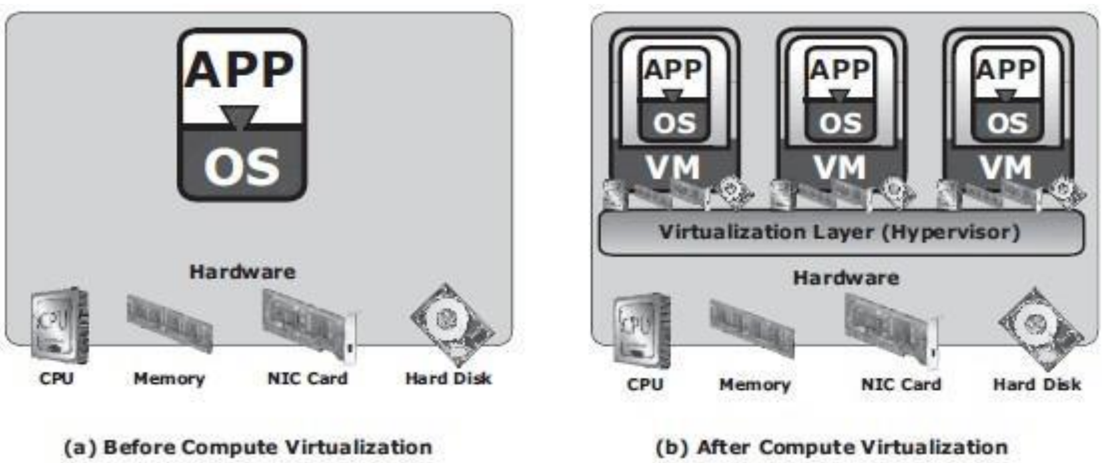

Fig 1.9: Server Virtualization

- After Compute virtualization:

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- This technique significantly improves server utilization and provides server consolidation.
- Server consolidation enables organizations to run their data center with fewer physical servers.
- This, in turn,
    - reduces cost of new server acquisition,
    - reduces operational cost,
    - saves data center floor and rack space.
- Individual VMs can be restarted, upgraded, or even crashed, without affecting the other VMs.
- VMs can be copied or moved from one physical machine to another (non-disruptive migration) without causing application downtime. This is required for maintenance activities.

Volume Manager

- In the early days, disk drives appeared to the operating system as a number of continuous disk blocks. The entire disk drive would be allocated to the file system or other data entity used by the operating system or application.

Disadvantages:

- lack of flexibility.
- When a disk drive ran out of space, there was no easy way to extend the file system's size.
- as the storage capacity of the disk drive increased, allocating the entire disk drive for the file system often resulted in underutilization of storage capacity

Solution: evolution of Logical Volume Managers (LVMs)

- LVM enabled dynamic extension of file system capacity and efficient storage management.
- The LVM is software that runs on the compute system and manages logical and physical storage.
- LVM is an intermediate layer between the file system and the physical disk.
- LVM can partition a larger-capacity disk into virtual, smaller-capacity volumes(called Partitioning) or aggregate several smaller disks to form a larger virtual volume. The process is called concatenation.
- Disk partitioning was introduced to improve the flexibility and utilization of disk drives.
- In partitioning, a disk drive is divided into logical containers called logical volumes (LVs) (see Fig 1.7)

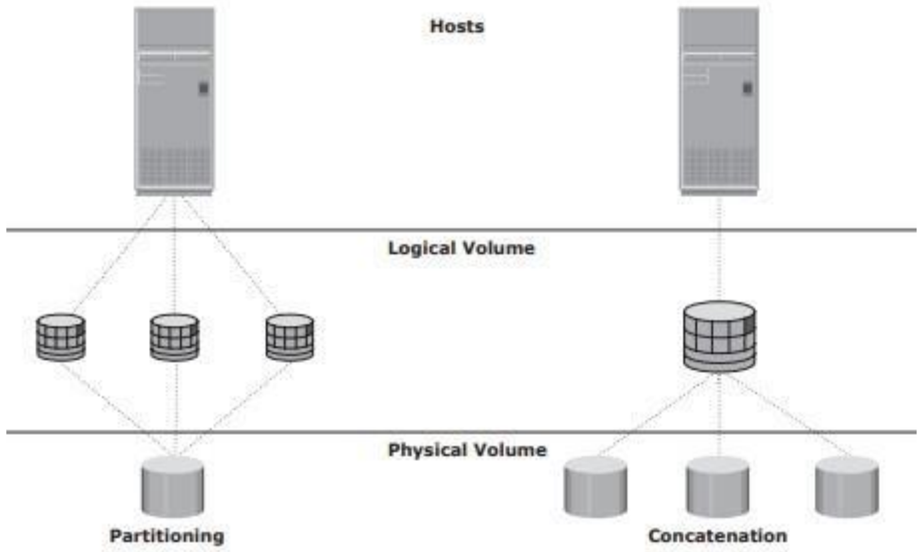

Fig 1.7: Disk Partitioning and concatenation

- Concatenation is the process of grouping several physical drives and presenting them to the host as one big logical volume.
- The basic LVM components are physical volumes, volume groups, and logical volumes.
- Each physical disk connected to the host system is a physical volume (PV).
- A volume group is created by grouping together one or more physical volumes. A unique physical volume identifier (PVID) is assigned to each physical volume when it is initialized for use by the LVM. Each physical volume is partitioned into equal-sized data blocks called physical extents when the volume group is created.
- Logical volumes are created within a given volume group. A logical volume can be thought of as a disk partition, whereas the volume group itself can be thought of as a disk.

12. Explain connectivity Physical components of connectivity and Interface protocols in details.

Ans:

Connectivity

- Connectivity refers to the interconnection between hosts or between a host and peripheral devices, such as printers or storage devices.
- Connectivity and communication between host and storage are enabled using:
  - physical components
  - interface protocols.

❖ **Physical Components of Connectivity**

- The physical components of connectivity are the hardware elements that connect the host to storage.
- Three physical components of connectivity between the host and storage are (refer Fig 1.10):
  - the host interface device
  - port
  - cable.

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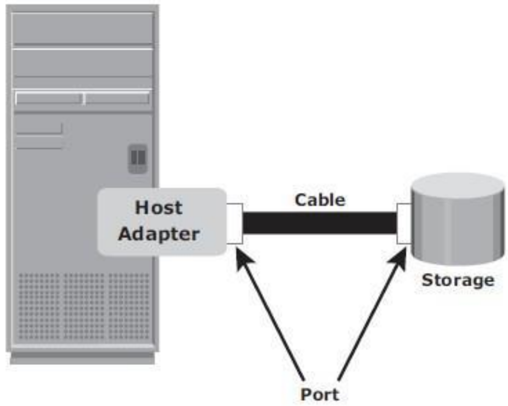

Fig 1.10: Physical components of connectivity

- A host interface device or host adapter connects a host to other hosts and storage devices.
    - Eg: host bus adapter (HBA) and network interface card (NIC).
    - HBA is an application-specific integrated circuit (ASIC) board that performs I/O interface functions between the host and storage, relieving the CPU from additional I/O processing workload.
    - A host typically contains multiple HBAs.
- A port is a specialized outlet that enables connectivity between the host and external devices. An HBA may contain one or more ports to connect the host.
- Cables connect hosts to internal or external devices using copper or fibre optic media.

❖ **Interface Protocols**

- protocol enables communication between the host and storage.
- Protocols are implemented using interface devices (or controllers) at both source and destination.
    - The popular interface protocols used for host to storage communications are:
    - Integrated Device Electronics/Advanced Technology Attachment (IDE/ATA)
    - Small Computer System Interface (SCSI),
    - Fibre Channel (FC)
    - Internet Protocol (IP)

- **IDE/ATA and Serial ATA:**
    - IDE/ATA is a popular interface protocol standard used for connecting storage devices, such as disk drives and CD-ROM drives.
    - This protocol supports parallel transmission and therefore is also known as Parallel ATA (PATA) or simply ATA.
    - IDE/ATA has a variety of standards and names.
    - The Ultra DMA/133 version of ATA supports a throughput of 133 MB per second.
    - In a master-slave configuration, an ATA interface supports two storage devices per connector.
    - If performance of the drive is important, sharing a port between two devices is not recommended.

  - The serial version of this protocol is known as Serial ATA (SATA) and supports single bit serial transmission.
  - High performance and low cost SATA has replaced PATA in newer systems.
  - SATA revision 3.0 provides a data transfer rate up to 6 Gb/s.

- **SCSI and Serial SCSI:**
  - SCSI has emerged as a preferred connectivity protocol in high-end computers.
  - This protocol supports parallel transmission and offers improved performance, scalability, and compatibility compared to ATA.
  - The high cost associated with SCSI limits its popularity among home or personal desktop users.
  - SCSI supports up to 16 devices on a single bus and provides data transfer rates up to 640 MB/s.
  - Serial attached SCSI (SAS) is a point-to-point serial protocol that provides an alternative to parallel SCSI.
  - A newer version of serial SCSI (SAS 2.0) supports a data transfer rate up to 6 Gb/s.

- **Fibre Channel (FC):**
  - Fibre Channel is a widely used protocol for high-speed communication to the storage device.
  - Fibre Channel interface provides gigabit network speed.
  - It provides a serial data transmission that operates over copper wire and optical fiber.
  - The latest version of the FC interface (16FC) allows transmission of data up to 16 Gb/s.

- **Internet Protocol (IP):**
  - IP is a network protocol that has been traditionally used for host-to-host traffic.
  - With the emergence of new technologies, an IP network has become a viable option for host-to-storage communication.
  - IP offers several advantages:
    - cost
    - maturity
    - enables organizations to leverage their existing IP-based network.
  - iSCSI and FCIP protocols are common examples that leverage IP for host-to-storage communication.