Information Storage and Management

UNIT I - Introduction to Information Storage and Management

- Introduction to Information Storage and Management: Storage System Environment, Information Storage, Evolution of Storage Technology and Architecture, Data Center Infrastructure, Key Challenges in Managing Information, Information Lifecycle Components of Storage System Environment, Disk Drive Components, Disk Drive Performance, Fundamental Laws Governing Disk Performance, Logical Components of the Host, Application Requirements and Disk Performance.

…Briefly described in UNIT III

Components of a Storage System Environment

The three main components in a storage system environment the host, connectivity, and storage are described in this section.

Host

Users store and retrieve data through applications. The computers on which these applications run are referred to as hosts.

Hosts can range from simple laptops to complex clusters of servers.

A host consists of physical components (hardware devices) that communicate with one another using logical components (software and protocols).

Access to data and the overall performance of the storage system environment depend on both the physical and logical components of a host .

Physical Components

- Central processing unit (CPU)
- Storage, such as internal memory and disk devices
- Input/output (I/O) devices

CPU

- Arithmetic Logic Unit (ALU)
- Control Unit
- Register
- Level 1 (L1) cache

Storage

- Random Access Memory (RAM)
- Read-Only Memory (ROM)
- Hard disk (magnetic)
- CD-ROM or DVD-ROM (optical)
- Floppy disk (magnetic)
- Tape drive (magnetic)

I/O Devices

- User to host communications
- Host to host communications
- Host to storage device communications

Connectivity

The discussion here focuses on the connectivity between the host and the storage device.

The components of connectivity in a storage system environment can be classified as **Physical** and **Logical**.

The physical components are the hardware elements that connect the host to storage and the logical components of connectivity are the protocols used for communication between the host and storage.

Physical Components of Connectivity

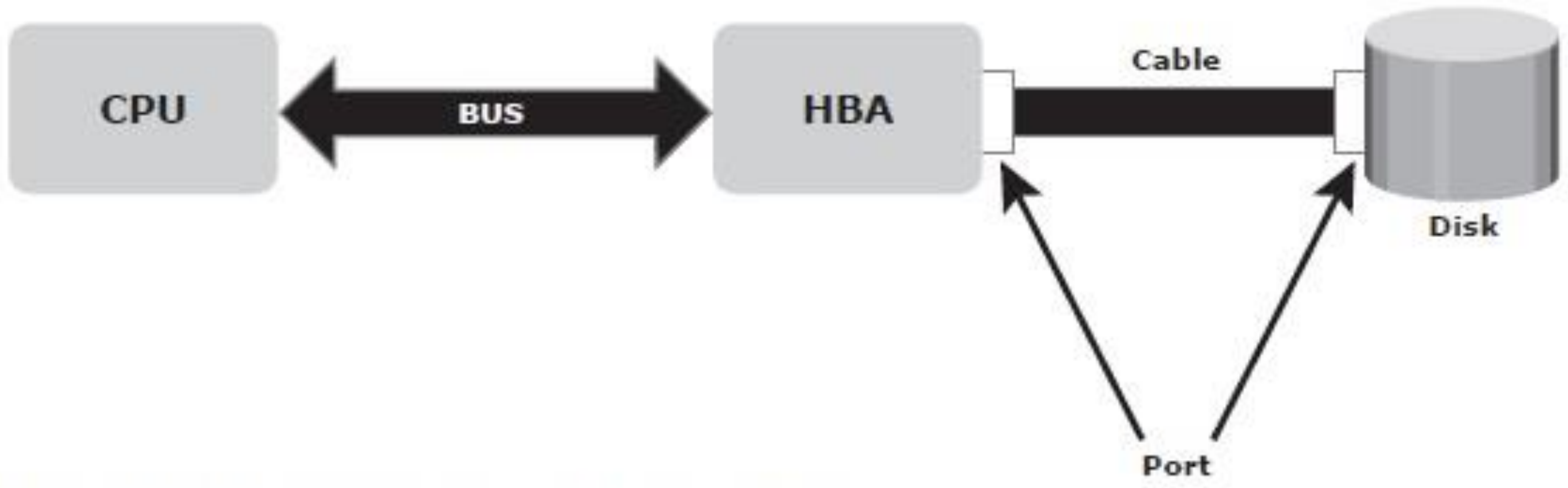


Figure 2-1: Physical components of connectivity

The bus is the collection of paths that facilitates data transmission from one part of a computer to another, such as from the CPU to the memory.

The port is a specialized outlet that enables connectivity between the host and external devices.

Cables connect hosts to internal or external devices using copper or fiber optic media.

Physical components communicate across a bus by sending bits (control, data, and address) of data between devices.

These bits are transmitted through the bus in either of the following ways:

- **Serially**
- **In parallel**

Logical Components of Connectivity

The popular interface protocol used for the local bus to connect to a peripheral device is peripheral component interconnect (PCI). The interface protocols that connect to disk systems are Integrated Device Electronics/Advanced Technology Attachment (IDE/ATA) and Small Computer System Interface (SCSI).

- **PCI**
- **IDE/ATA**
- **SCSI**

Storage

A storage device uses magnetic or solid state media.

Disks, tapes, and diskettes use magnetic media. CD-ROM is an example of a storage device that uses optical media, and removable flash memory card is an example of solid state media.

Tapes are a popular storage media used for backup because of their relatively low cost.

In the past, data centers hosted a large number of tape drives and processed several thousand reels of tape.

However, tape has the following limitations:

- **Data is stored** on the tape linearly along the length of the tape. Search and retrieval of data is done sequentially, invariably taking several seconds to access the data.
- As a result, random data access is slow and time consuming. This limits tapes as a viable option for applications that require real-time, rapid access to data.
- **Data stored** on tape cannot be accessed by multiple applications simultaneously, restricting its use to one application at a time.

- **On a tape drive**, the read/write head touches the tape surface, so the tape degrades or wears out after repeated use.

- **The storage** and retrieval requirements of data from tape and the overhead associated with managing tape media are significant.

Disk Drive Components

A disk drive uses a rapidly moving arm to read and write data across a flat platter coated with magnetic particles.

Data is transferred from the magnetic platter through the R/W head to the computer.

Several platters are assembled together with the R/W head and controller, most commonly referred to as a hard disk drive (HDD).

Data can be recorded and erased on a magnetic disk any number of times.

This section details the different components of the disk, the mechanism for organizing and storing data on disks, and the factors that affect disk performance.

Key components of a disk drive (Figure 2-2):

- **Platter**
- **Spindle**
- **Read/Write Head**
- **Actuator Arm Assembly**
- **Controller**
- **Physical Disk Structure**
- **Zoned Bit Recording**
- **Logical Block Addressing**

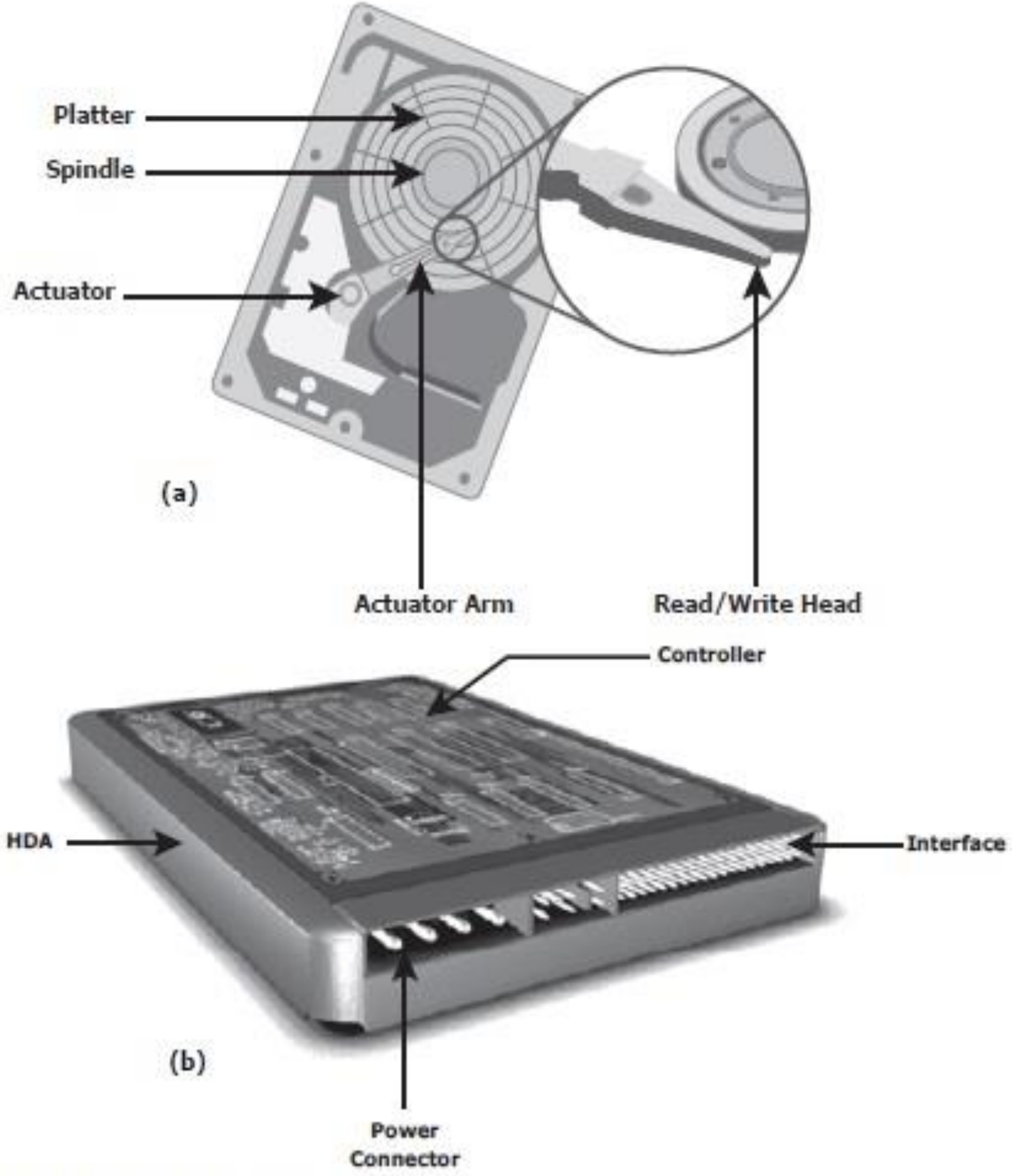


Figure 2-2: Disk Drive Components

Platter

A typical HDD consists of one or more flat circular disks called platters.

The data is recorded on these platters in binary codes (0s and1s).

The set of rotating platters is sealed in a case, called a 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.

Spindle

A spindle connects all the platters, as shown in Figure 2-3, 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).

Disk drives have spindle speeds of 7,200 rpm, 10,000 rpm, or 15,000 rpm.

Disks used on current storage systems have a platter diameter of 3.5” (90 mm).

When the platter spins at 15,000 rpm, the outer edge is moving at around 25 percent of the speed of sound.

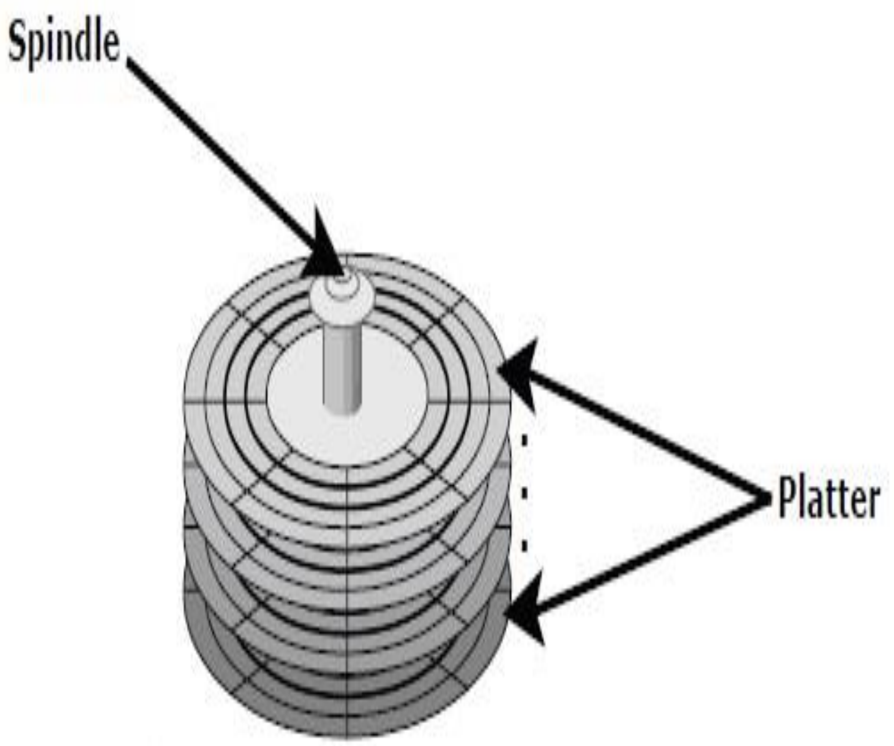


Figure 2-3: Spindle and platter

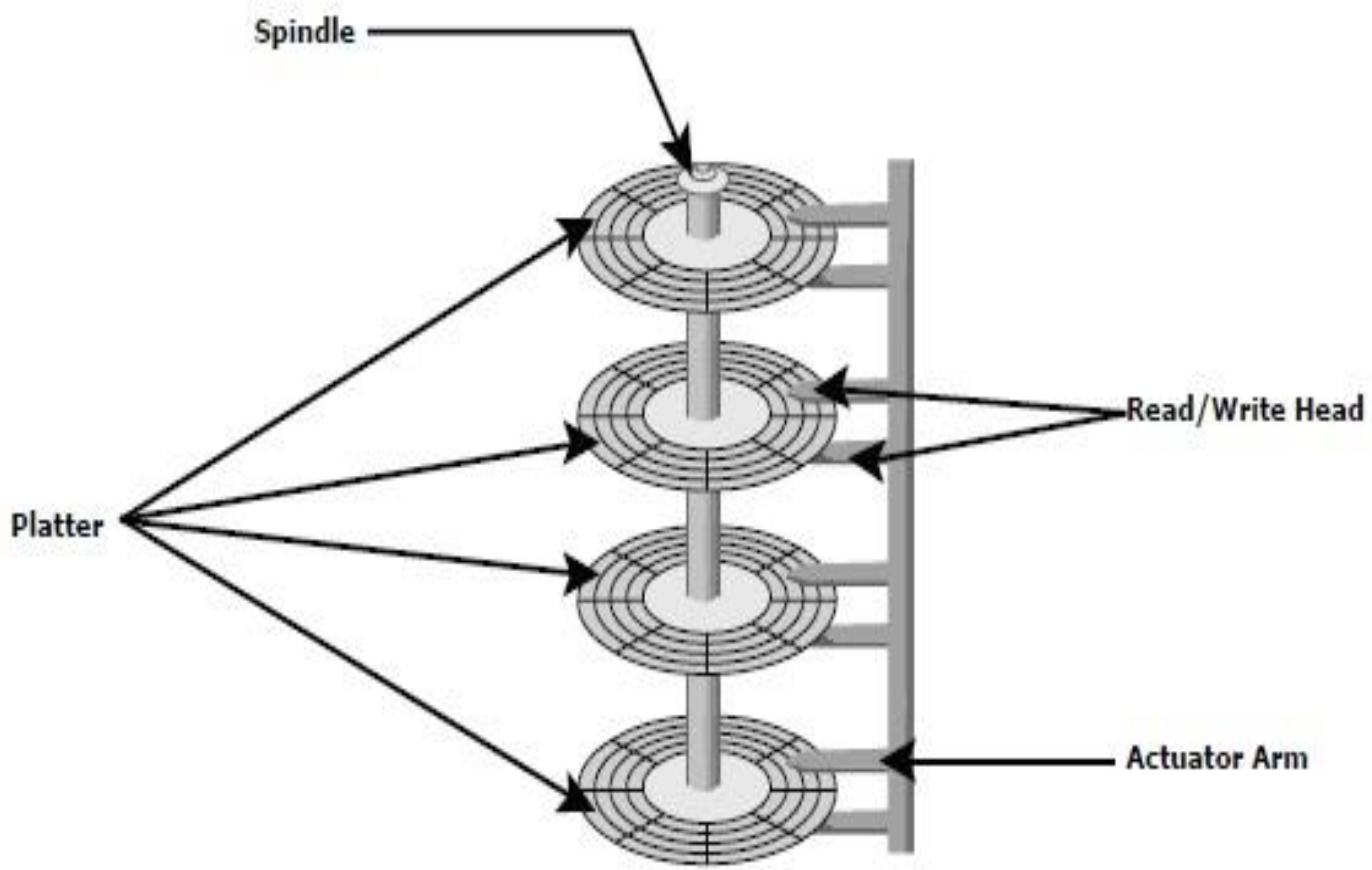


Figure 2-4: Actuator arm assembly

Read/Write Head

Read/Write (R/W) heads, shown in Figure 2-4, read and write data from or to a platter. 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, this head detects 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 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.

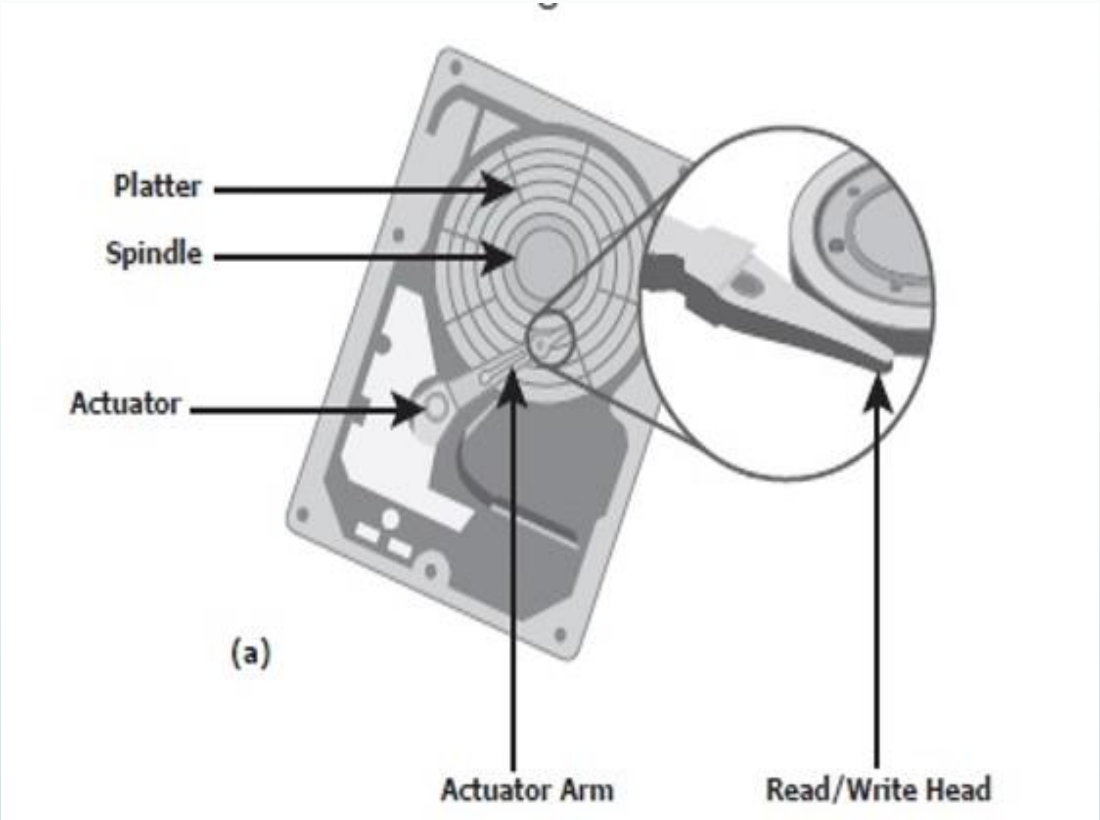
This area is called the landing zone. The landing zone is coated with a lubricant to reduce friction between the head and the platter.

Actuator Arm Assembly

The R/W heads are mounted on the actuator arm assembly (refer to Figure 2-2 [a]), which positions the R/W head at the location on the platter where the data needs to be written or read.

The R/W heads for all platters on a drive are attached to one actuator arm assembly and move across the platters simultaneously.

Note that there are two R/W heads per platter, one for each surface, as shown in Figure 2-4.



Controller

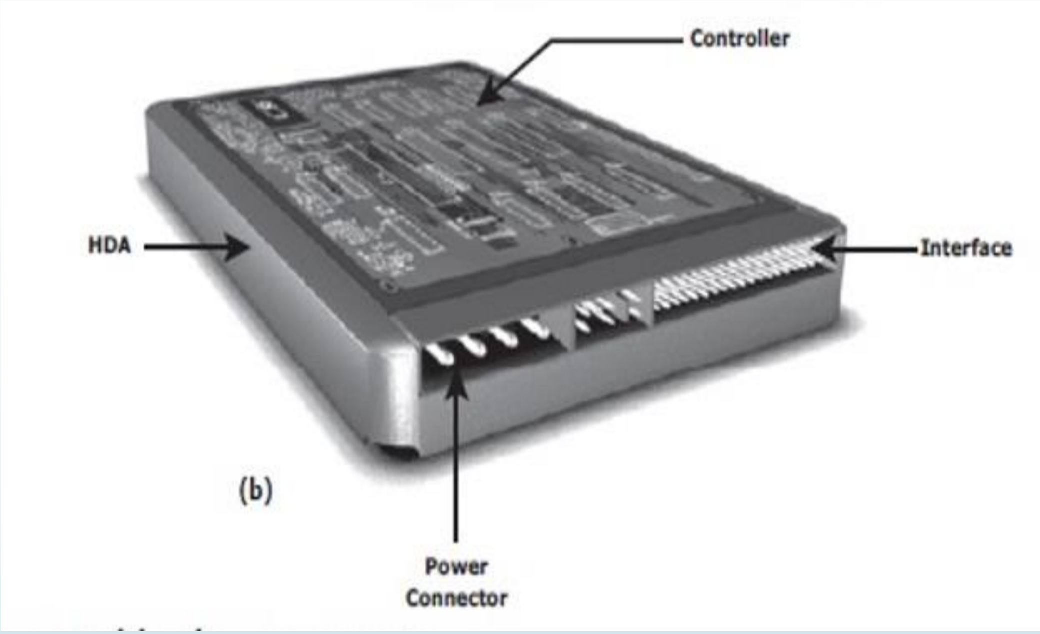
The controller (see Figure 2-2 [b]) is a printed circuit board, mounted at the bottom of a disk drive.

It consists of a microprocessor, internal memory, circuitry, and firmware.

The firmware controls power to the spindle motor and the speed of the motor.

It also manages 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.



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 2-5.

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.

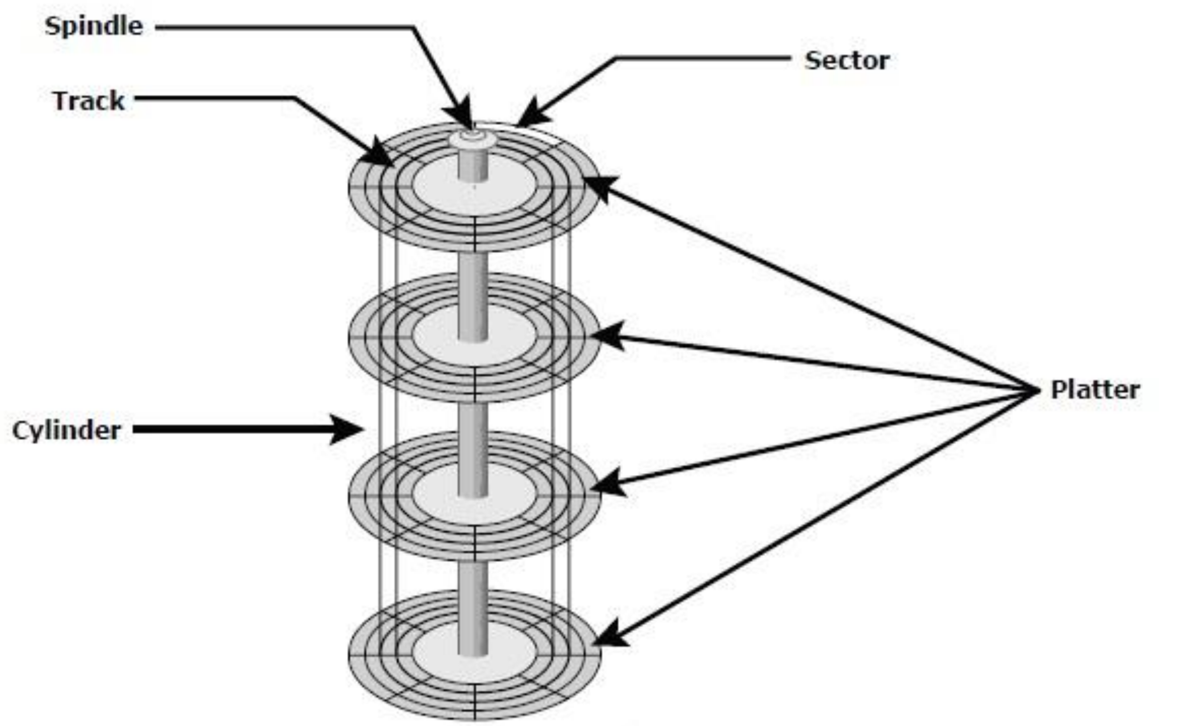


Figure 2-5: Disk structure: sectors, tracks, and cylinders

Zoned Bit Recording

Because the 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, as shown in Figure 2-6 (a).

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 available space. Zone bit recording utilizes the disk efficiently.

As shown in Figure 2-6 (b), this mechanism groups tracks into zones based on their distance from the center of the disk. The zones are numbered, with the outermost zone being zone 0.

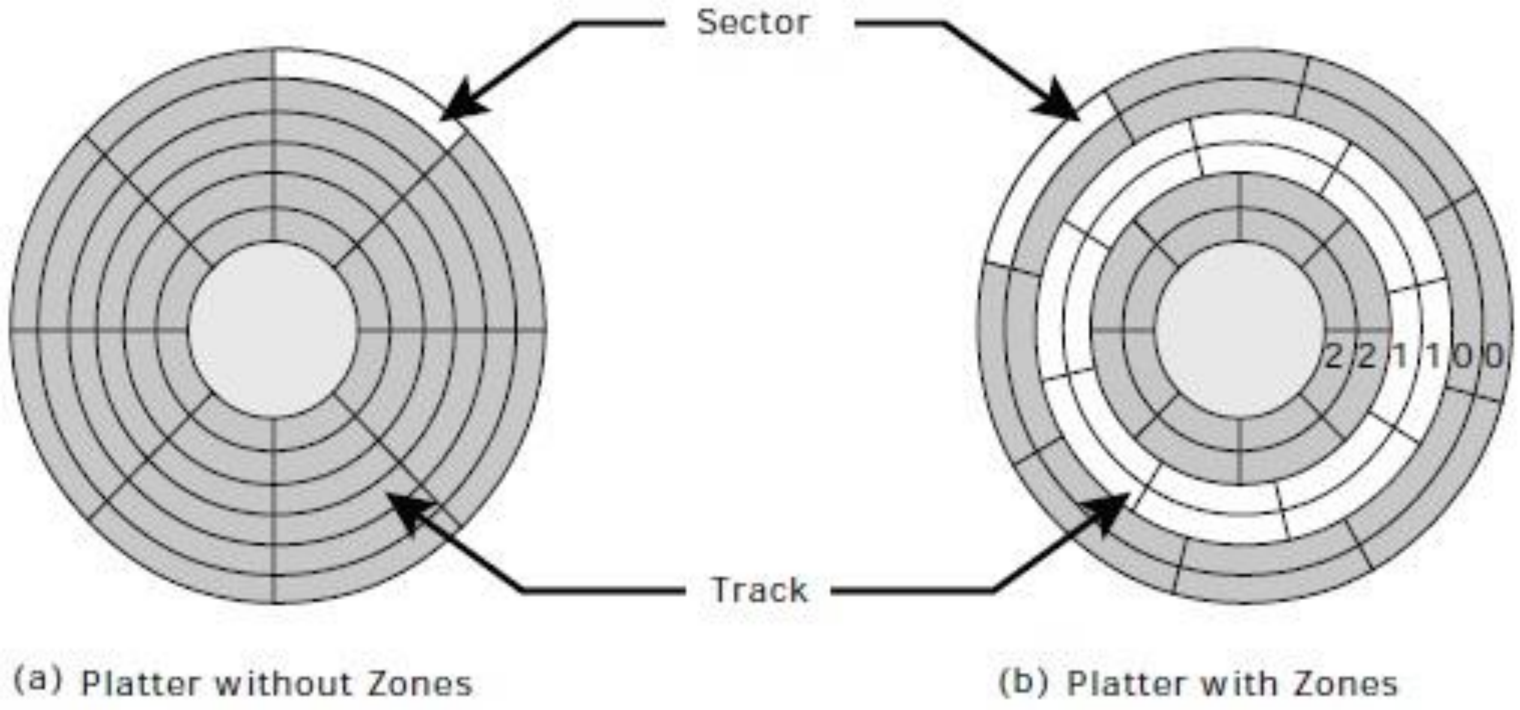


Figure 2-6: Zoned bit recording

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 2-7 (a), and the host operating system had to be aware of the geometry of each disk being used.

Logical block addressing (LBA), shown in Figure 2-7 (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 only needs to know 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.

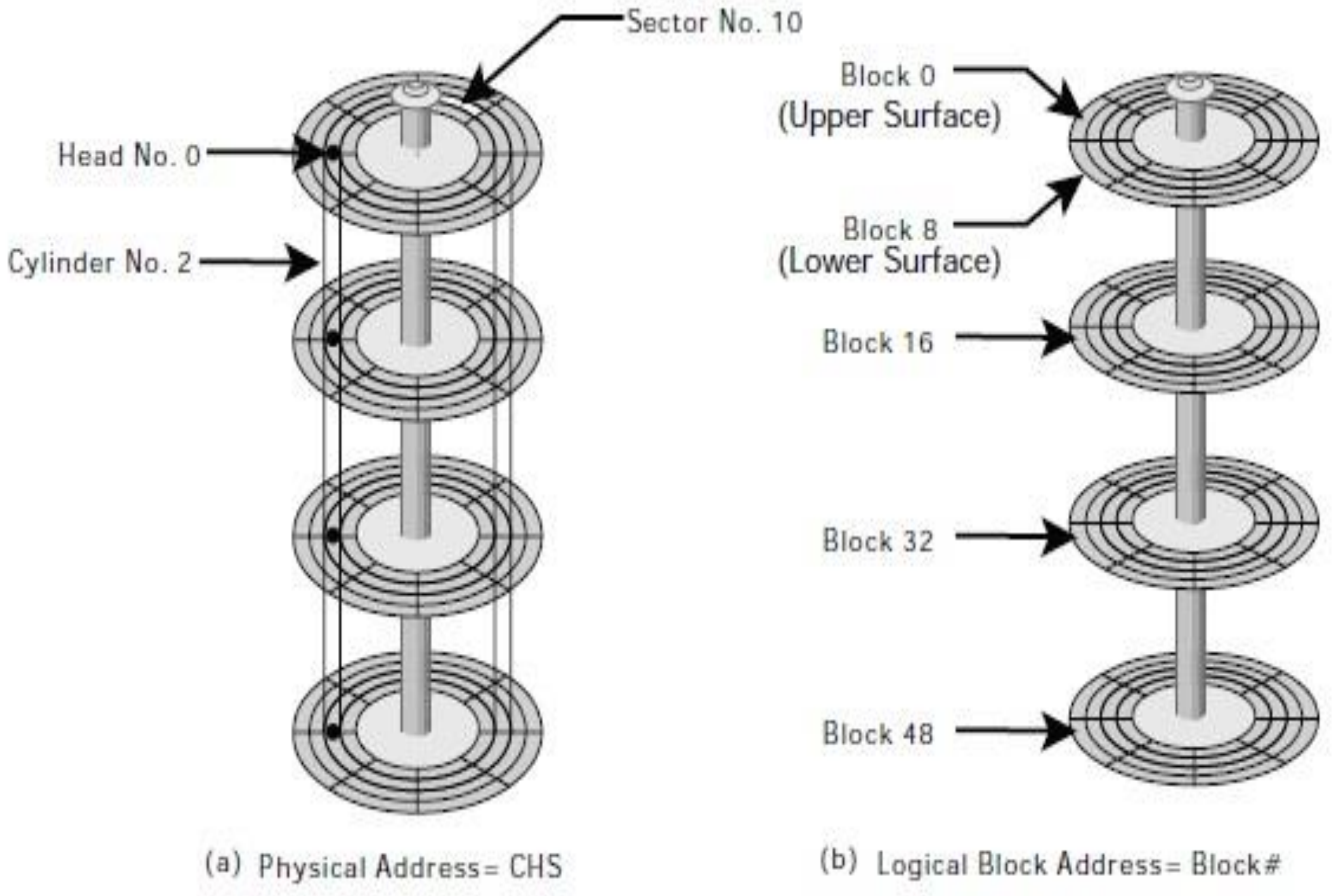


Figure 2-7: Physical address and logical block address

Disk Drive Performance

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

Disk service time is the time taken by a disk to complete an I/O request. Components that contribute to service time on a disk drive are seek time, rotational latency, and data transfer rate.

- **Seek Time**

1) Full Stroke
2) Average
3) Track-to-Track

- **Rotational Latency**
- **Data Transfer Rate**

Fundamental Laws Governing Disk Performance

To understand the laws of disk performance, 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/O s that are waiting in the queue one by one.

As a result, it can be concluded that by reducing the service time (the sum of seek time, latency, and internal transfer rate) or utilization by half, the response time can be reduced drastically (almost six times in the preceding example).

The relationship between utilization and response time is shown in Figure 2-10.

Response time changes are nonlinear as utilization increases.

When the average queue sizes are low, response time remains low.

Response time increases slowly with added load on the queue, and increases exponentially when utilization exceeds 70 percent.

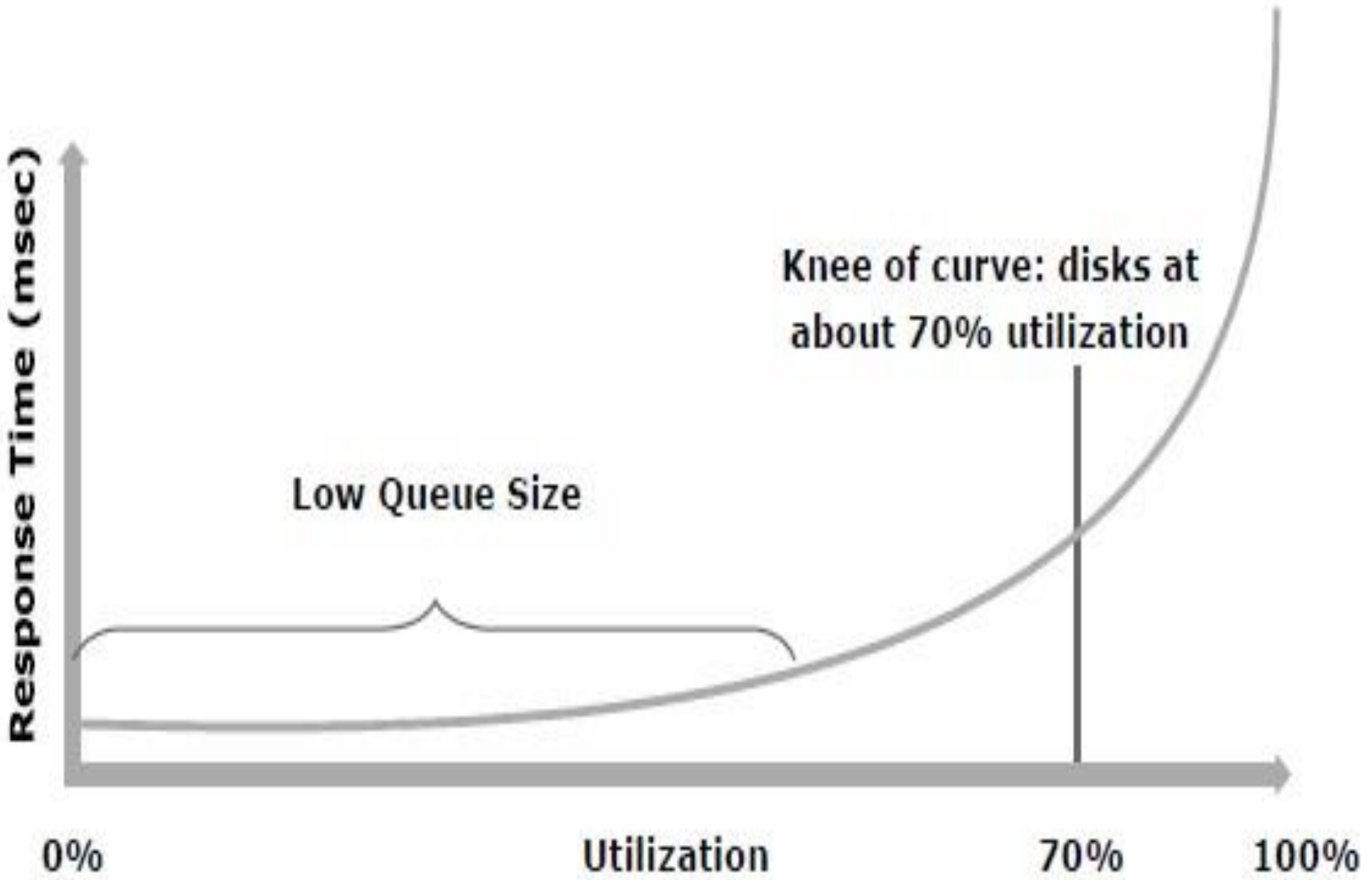


Figure 2-10: Utilization vs. Response time

Logical Components of the Host

The logical components of a host consist of the software applications and protocols that enable data communication with the user as well as the physical components. Following are the logical components of a host:

- **Operating system**
- **Device drivers**
- **Volume manager**
- **File system**
- **Application**

Operating System

An operating system controls all aspects of the computing environment.

It works between the application and physical components of the computer system.

One of the services it provides to the application is data access.

Device Driver

A device driver is special software that permits the operating system to interact with a specific device, such as a printer, a mouse, or a hard drive.

A device driver enables the operating system to recognize the device and to use a standard interface (provided as an application programming interface, or API) to access and control devices.

Device drivers are hardware dependent and operating system specific.

Volume Manager

Disk partitioning was introduced to improve the flexibility and utilization of HDDs. In partitioning, an HDD is divided into logical containers called logical volumes (LVs) (see Figure 2-11).

For example, a large physical drive can be partitioned into multiple LVs to maintain data according to the file system's and applications' requirements.

The partitions are created from groups of contiguous cylinders when the hard disk is initially set up on the host.

The host's file system accesses the partitions without any knowledge of partitioning and the physical structure of the disk.

Concatenation is the process of grouping several smaller physical drives and presenting them to the host as one logical drive (see Figure 2-11).

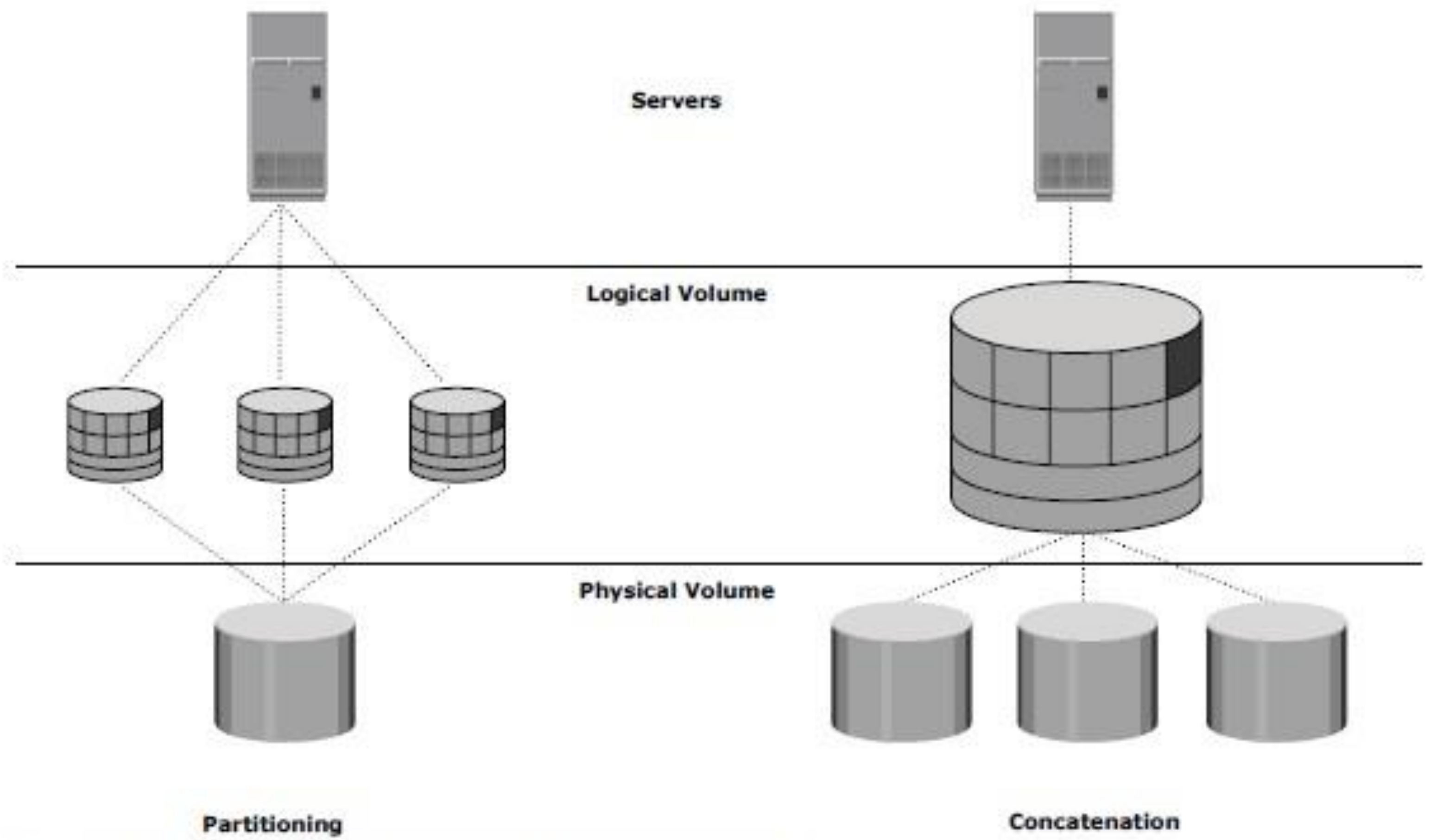


Figure 2-11: Disk partitioning and concatenation

File System

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.

File systems enable easy access to data files residing within a disk drive, a disk partition, or a logical volume.

A file system needs host-based logical structures and software routines that control access to files.

It provides users with the functionality to create, modify, delete, and access files.

Access to the files on the disks is controlled by the permissions given to the file by the owner, which are also maintained by the file system.

- **FAT 32 (File Allocation Table) for Microsoft Windows**
- **NT File System (NTFS) for Microsoft Windows**
- **UNIX File System (UFS) for UNIX**
- **Extended File System (EXT2/3) for Linux**

A file system block is the smallest “container” of physical disk space allocated for data.

Each file system block is a contiguous area on the physical disk.

The block size of a file system is fixed at the time of its creation.

File system size depends on block size and the total number of blocks of data stored.

A file can span multiple file system blocks because most files are larger than the predefined block size of the file system.

File system blocks cease to be contiguous (i.e., become fragmented) when new blocks are added or deleted.

Over time, as files grow larger, the file system becomes increasingly fragmented. Figure 2-12 shows the following process of mapping user files to the disk storage subsystem with an LVM:

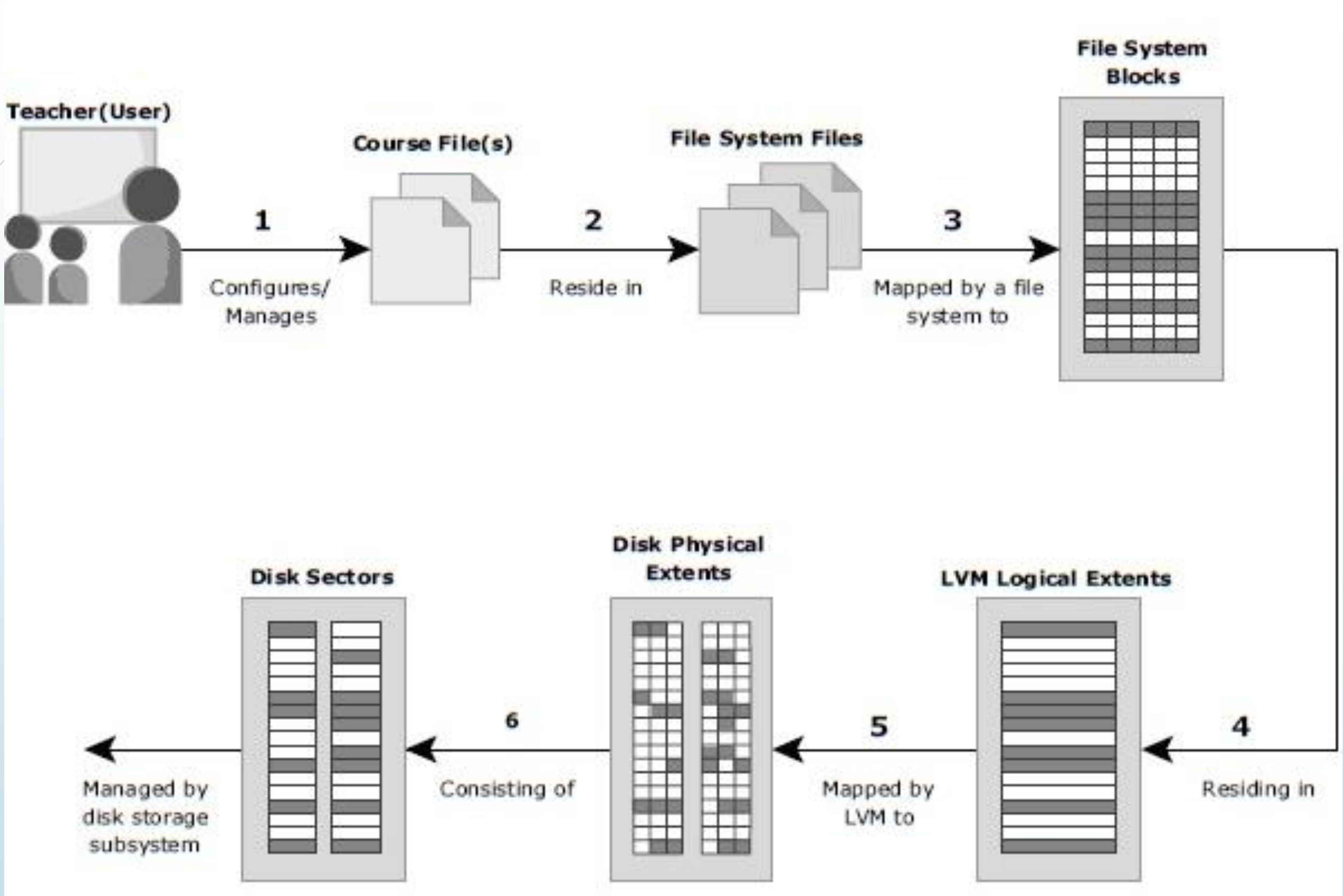
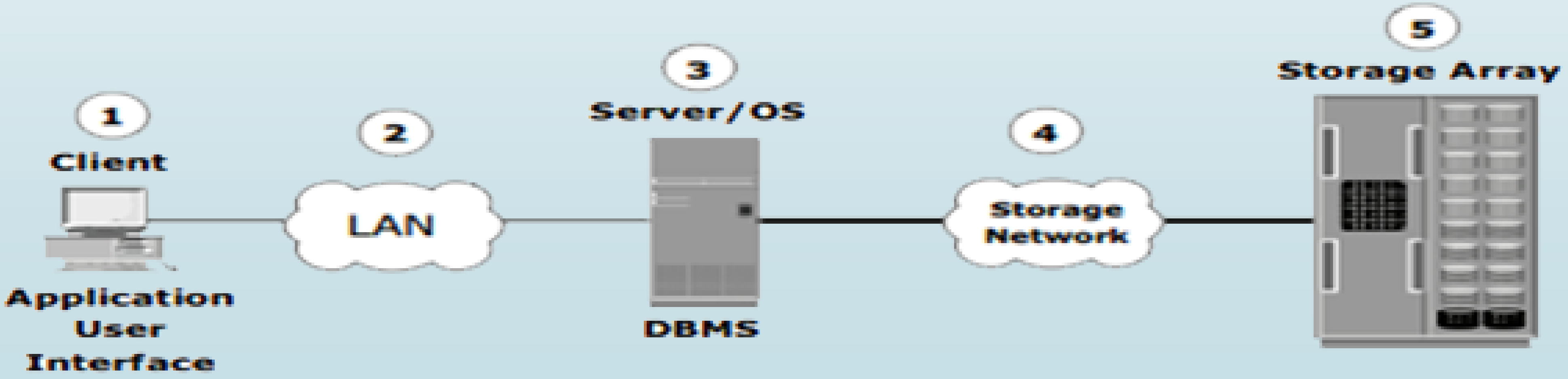


Figure 2-12: Process of mapping user files to disk storage

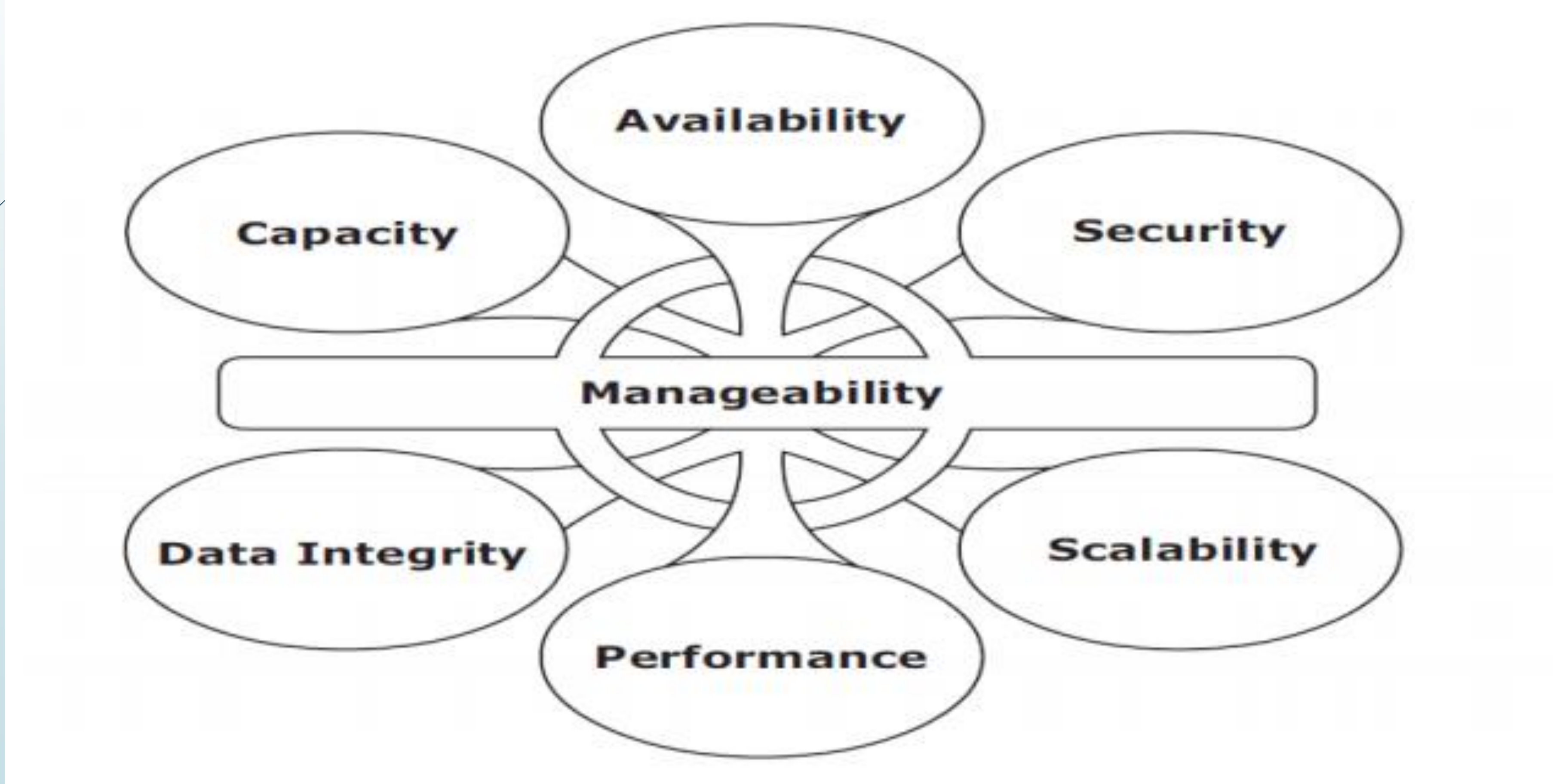
1) Files are created and managed by users and applications.
2) These files reside in the file systems.
3) The file systems are then mapped to units of data, or file system blocks.
4) The file system blocks are mapped to logical extents.
5) These in turn are mapped to disk physical extents either by the operating system or by the LVM.
6) These physical extents are mapped to the disk storage subsystem.

Core elements of a Data center

- **Application**: An application is a computer program that provides the logic for computing operations.
- **Database** : A Database is an organized collection of Data.
- **Server and operating system**: A computing platform that runs applications and databases.
- **Network**: A data path that facilitates communication between clients and servers or between servers and storage.
- **Storage array**: A device that stores data persistently for subsequent use.



Key Requirements for Data Center Elements



Key Requirements for Data Center Elements

- Availability : Accessibility should be insured for a business implementation.
- Security : Polices, procedures, and proper integration of the data center core elements that will prevent unauthorized access to information must be established.
- Scalability : Additional On-Demand services , without interrupting business operations.
- Performance: All the core elements of the data center should be able to provide optimal performance and service all processing requests at high speed.
- Data integrity : Mechanisms such as error correction codes and parity bits which ensure that data is written to disk exactly as it was received.
- Capacity : To increase and decrease core elements capacity on demand.
- 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.

Evolution of Storage Technology and Architecture

- Direct-attached storage (DAS)
- Just a Bunch Of Disk(JBOD)
- Redundant Array of Independent Disks (RAID)
- Network-attached storage (NAS)
- Storage area network (SAN)
- Internet Protocol SAN (IP-SAN)

Information Lifecycle Management(ILM)

Information lifecycle management (ILM) is a proactive strategy that enables an IT organization to effectively manage the data throughout its lifecycle, based on predefined business policies.

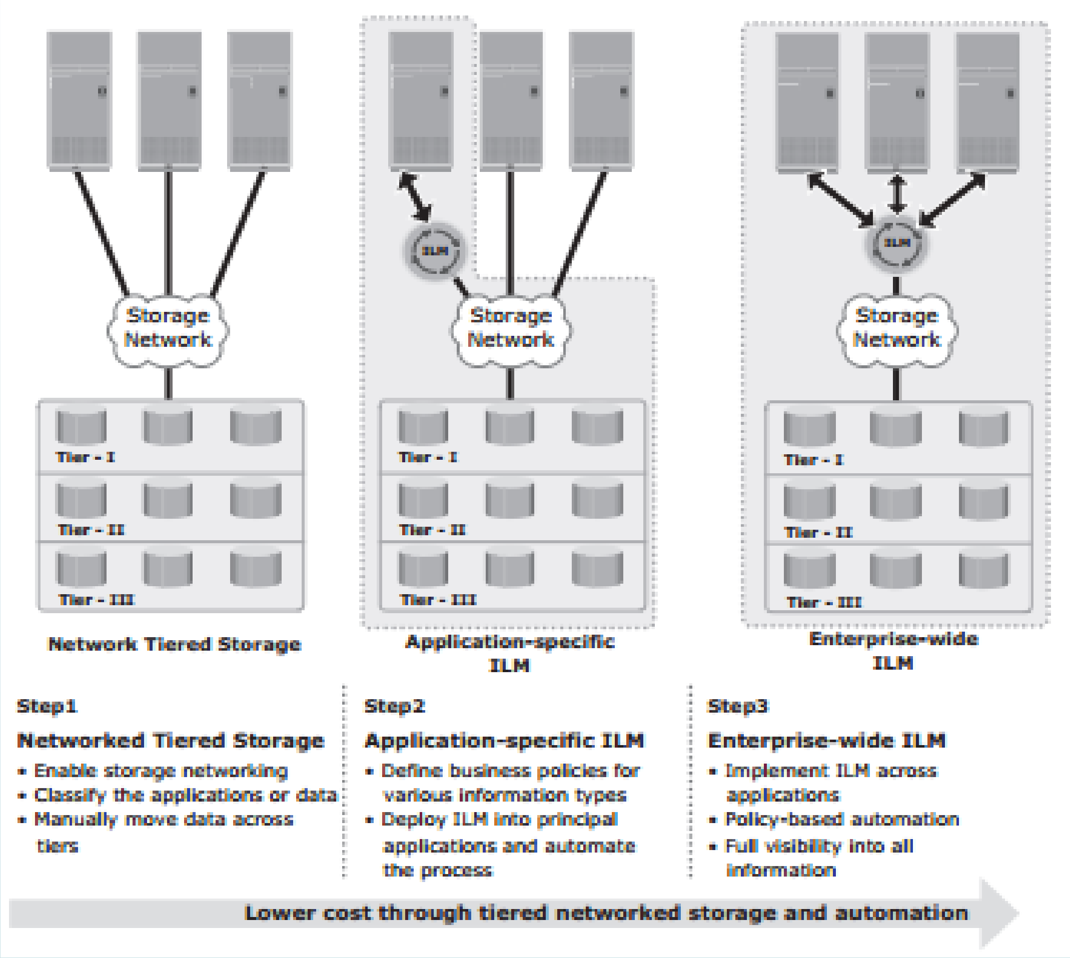
This allows an IT organization to optimize the storage infrastructure for maximum return on investment.

An ILM strategy should include the following characteristics:

- Business-centric: It should be integrated with key processes, applications, and initiatives of the business to meet both current and future growth in information.
- Centrally managed: All the information assets of a business should be under the purview of the ILM strategy.
- Policy-based: The implementation of ILM should not be restricted to a few departments. ILM should be implemented as a policy and encompass all business applications, processes, and resources.
- Heterogeneous: An ILM strategy should take into account all types of storage platforms and operating systems.
- Optimized: Because the value of information varies, an ILM strategy should consider the different storage requirements and allocate storage resources based on the information's value to the business.

ILM Implementation

- Classifying data and applications on the basis of business rules and policies to enable differentiated treatment of information
- Implementing policies by using information management tools, starting from the creation of data and ending with its disposal
- Managing the environment by using integrated tools to reduce operational complexity
- Organizing storage resources in tiers to align the resources with data classes, and storing information in the right type of infrastructure based on the information's current value



ILM Benefits

- Improved utilization by using tiered storage platforms and increased visibility of all enterprise information.
- Simplified management by integrating process steps and interfaces with individual tools and by increasing automation.
- A wider range of options for backup, and recovery to balance the need for business continuity.
- Maintaining compliance by knowing what data needs to be protected for what length of time.
- Lower Total Cost of Ownership (TCO) by aligning the infrastructure and management costs with information value. As a result, resources are not wasted, and complexity is not introduced by managing low-value data at the expense of high-value data.

Key Challenges in Managing Information

- Exploding digital universe: The rate of information growth is increasing exponentially. Duplication of data to ensure high availability and repurposing has also contributed to the multifold increase of information growth.

- Increasing dependency on information: The strategic use of information plays an important role in determining the success of a business and provides competitive advantages in the marketplace.

- Changing value of information: Information that is valuable today may become less important tomorrow. The value of information often changes over time. Framing a policy to meet these challenges involves understanding the value of information over its lifecycle.