Fundamentals of Storage and Data Center

Module Number: 02

Module Name: Storage System Environment

Version Code: FSDC1
Released Date:3-July-2018

Storage System Environment

AIM

To equip students with components of storage system environment and present an overview of different storage technologies

Objective of This Module

The Objectives of this module are:

- Make students familiar with components of storage system environment
- To explain the details of hard disk drive technology
- Understand RAID and other Storage Networking Technologies

Storage System Environment

Outcome

At the end of this module, you are expected to:

- Understand the components of Storage System environment
- Knowledge about components of disk drive
- Performance parameters of disk drive
- RAID technology overview
- Get introduced with Storage Networking Technologies (DAS, SAN, NAS)

Storage System Environment

Contents

Components of Storage System Environment

There are three main components in a storage system environment:

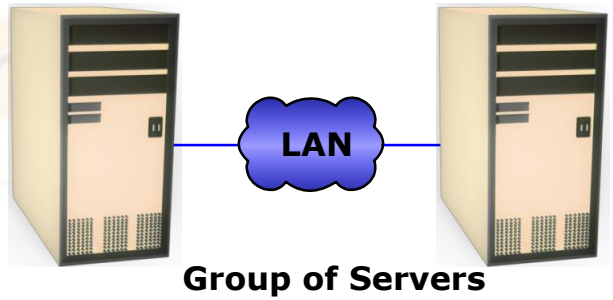
- **Host:** The host system is used for the interaction between the OS and application that has requested the data.
- **Connectivity:** It provides the connection and helps in carrying out the data and the read or write commands between the storage mediums and the host.
- **Storage:** The data gets stored into the storage mediums or devices.

Storage System Environment

Host

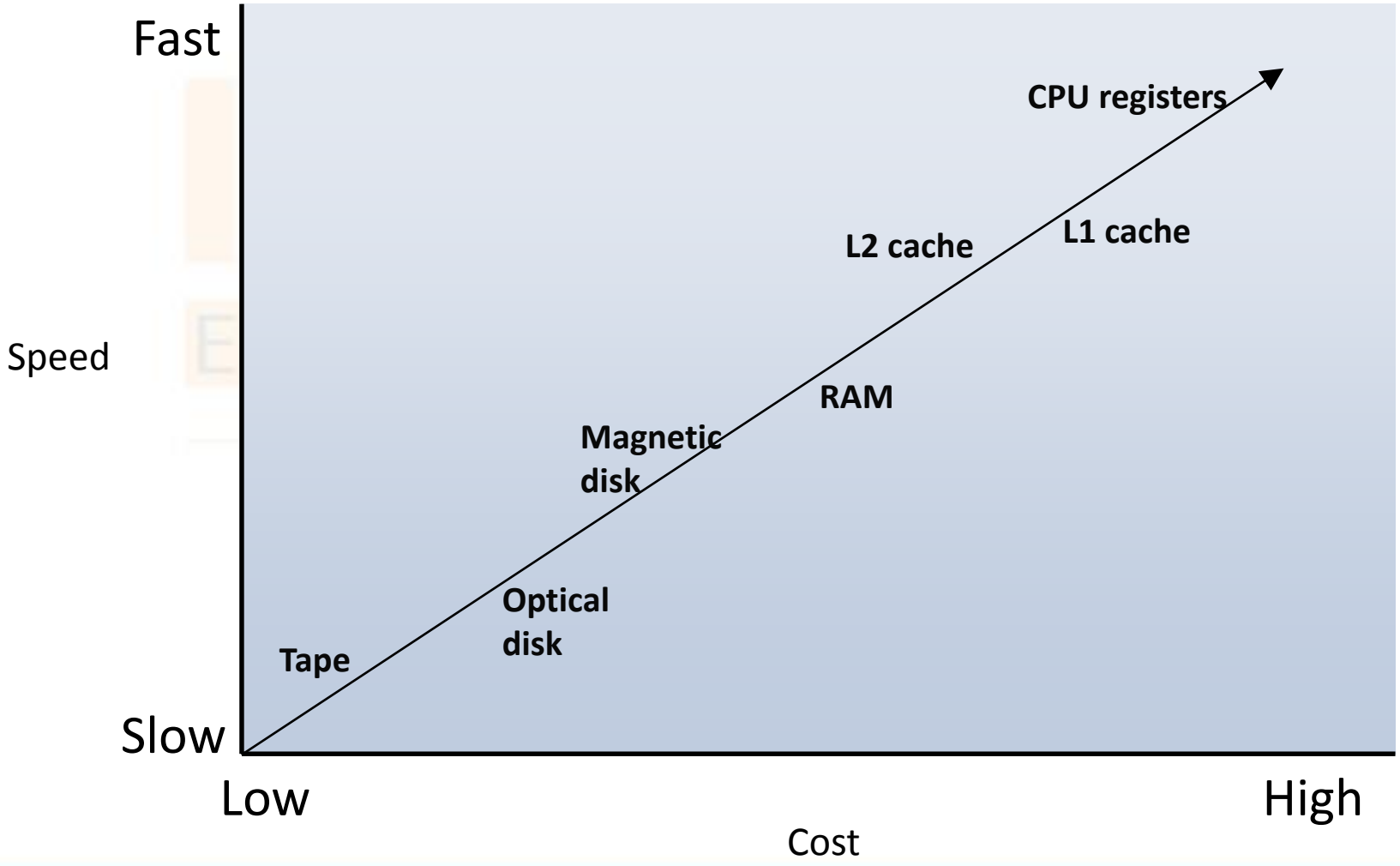
There are three main components in a storage system environment:

- Applications runs on hosts
- Hosts can range from simple laptops to complex server clusters
- Physical components of host:
  1. CPU
  2. Storage
     - Disk device and internal memory
  3. I/O device
     - Host to host communications
       - Network Interface Card (NIC)
     - Host to storage device communications
       - Host Bus Adapter (HBA)



Storage System Environment

Components of Storage



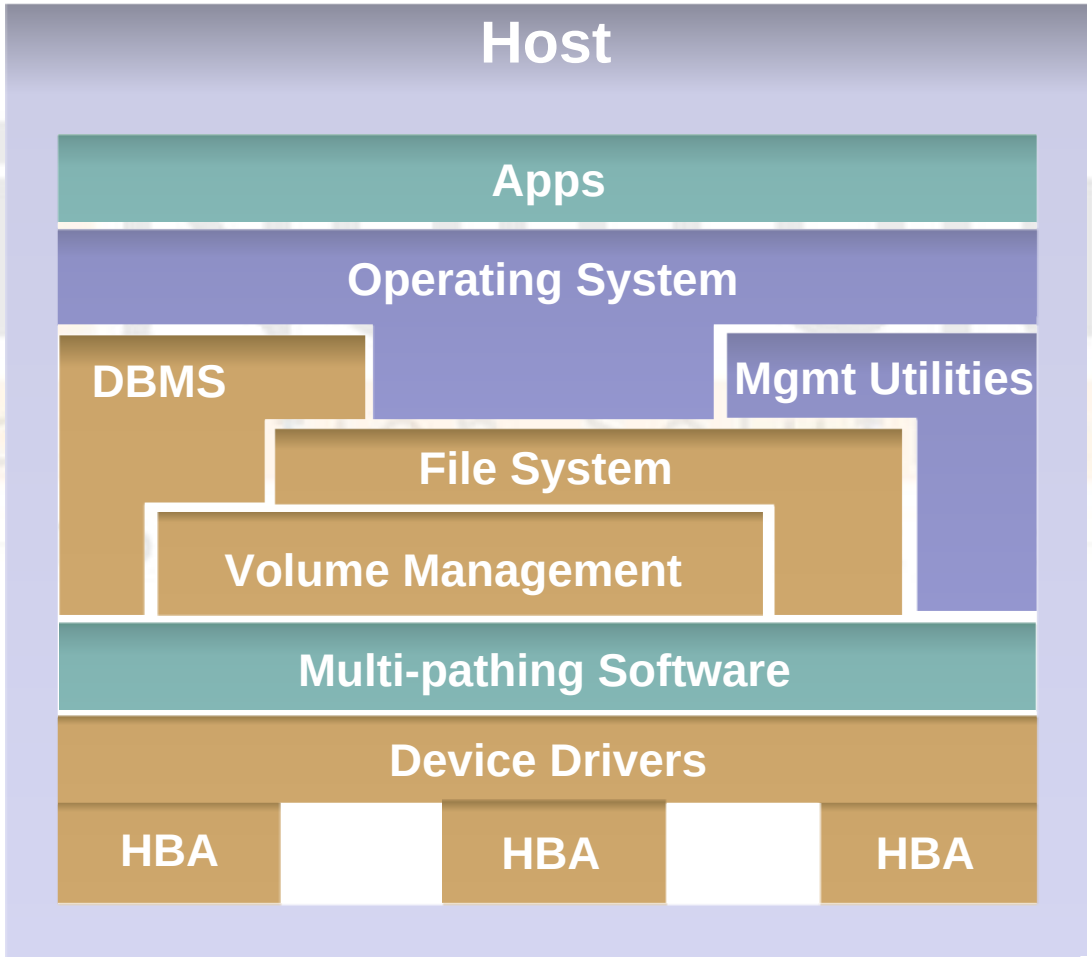
Storage System Environment

I/O Devices

- Human interface
  - Keyboard
  - Mouse
  - Monitor
- Computer-computer interface
  - Network Interface Card (NIC)
- Computer-peripheral interface
  - USB (Universal Serial Bus) port
  - Host Bus Adapter (HBA)

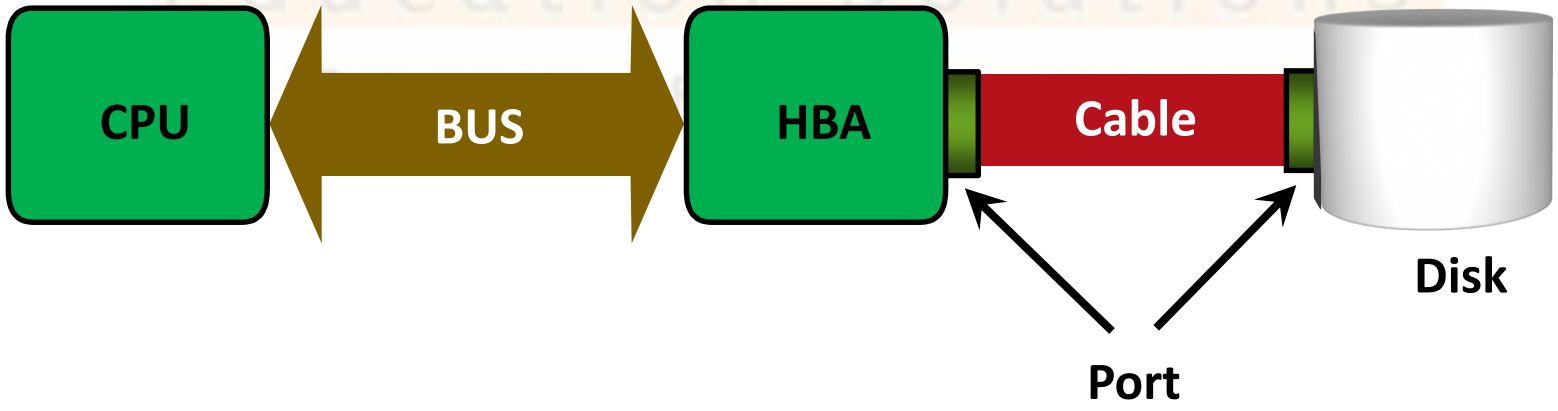
Storage System Environment

Logical Components of Host

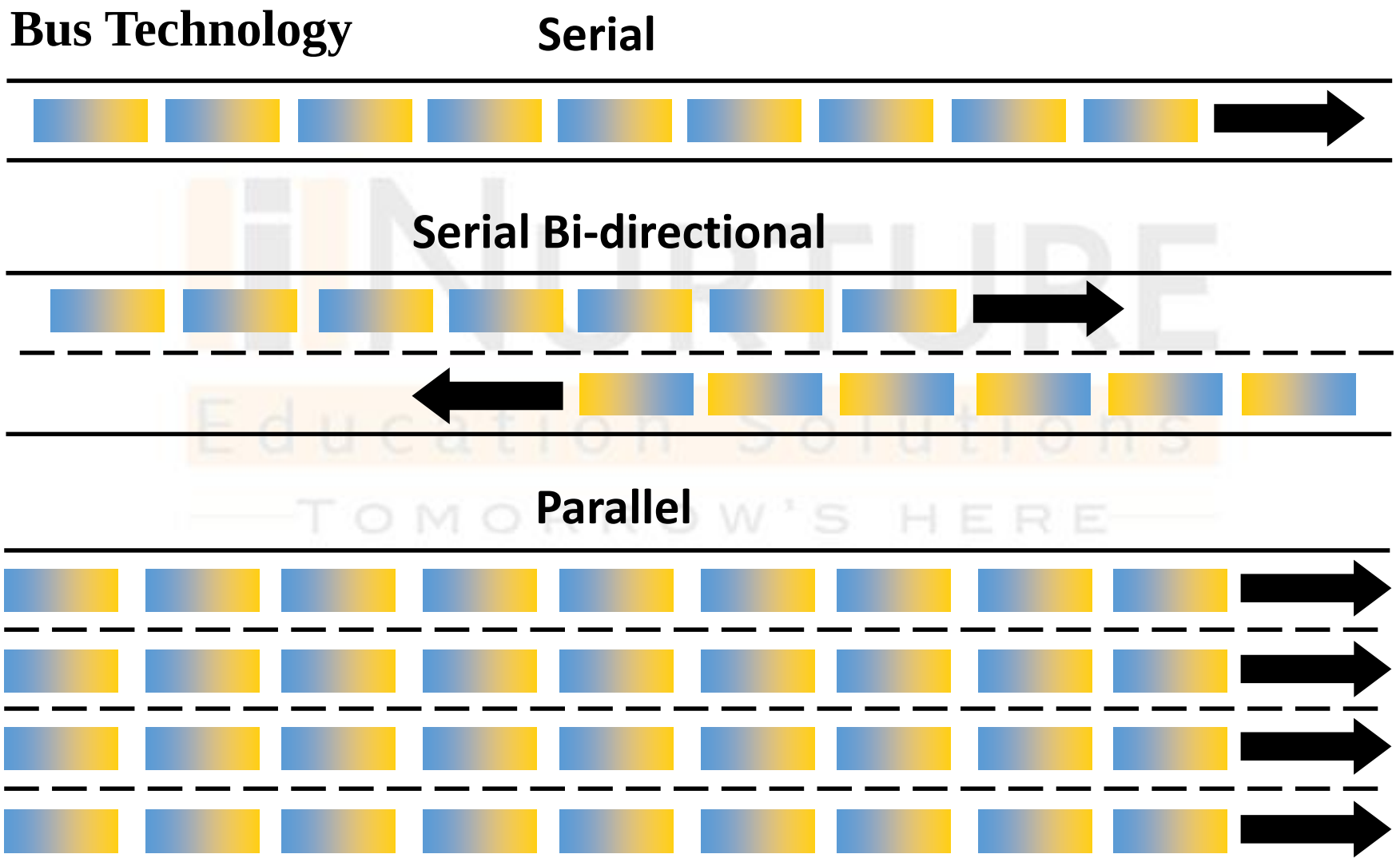


Connectivity

- Provides interconnection between hosts or between a host and any storage devices
- Physical Components of Connectivity are:
  - Bus, Port and Cable



Storage System Environment



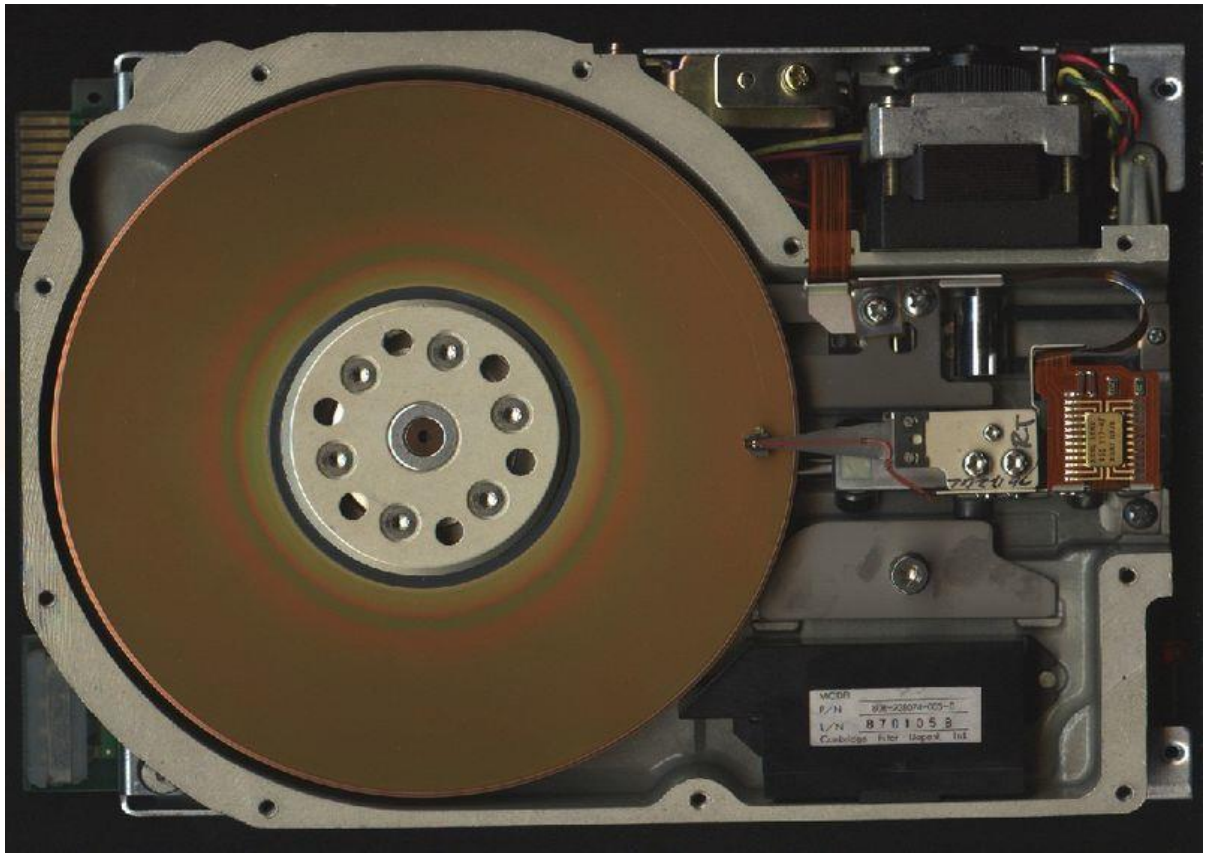
Components of Storage

Magnetic Media

- Magnetic storage is an example of a non-volatile memory, which means when the storage device is not powered, then the data does not get lost and is retained.
- Magnetic storage use various patterns of magnetisation in magnetisable material to store the data.
- Magnetic storages are relatively cheap and are widely used for data storage.
- Examples of devices that use the magnetic media are tapes, disks, and diskettes.

Storage System Environment

Magnetic Disk Drive(Hard disk drive)



Optical Media

- Optical media are the kind of storage media that contain the content in a digital format and the read/write feature can be performed on them using a laser.
- The examples of optical media include CD-ROMs, DVD-ROMs, and all the variations of the two formats, as well as optical jukeboxes.
- Optical media can last up to seven times as long as any traditional storage media.

Storage System Environment

Optical Disk (DVD, CD)

Solid state media

- It is made up of silicon microchips. It is a non-volatile storage and stores data electronically instead of storing it magnetically.
- It contains no mechanical parts, which allows the transfer of data, to and from the storage medium, to take place at a very higher speed.
- Provides data integrity and endurance as any other electronic device.
- An example of a device that uses the solid state media is a removable flash memory.

Storage System Environment

Self Assessment Questions

1. Which of these is not a valid component of a storage system environment?

   a) Host

   b) Connectivity

   c) Storage

   d) Virtual memory

Answer: d)

2. Which of these is not a valid component of a storage system environment?

a) Bus
b) Wire
c) Port
d) Cable

Answer: b)

Document Links

Topics	URL	Notes
Magnetic storage	http://study.com/academy/lesson/magnetic-storage-definition-devices-examples.html	This link explains about magnetic storage technologies with examples
Optical media	http://searchstorage.techtarget.com/definition/optical-media	You will learn in details about optical media with examples and definitions
Solid state storage	http://searchstorage.techtarget.com/definition/solid-state-storage	This link explains about fast solid state storage technology

Video Links

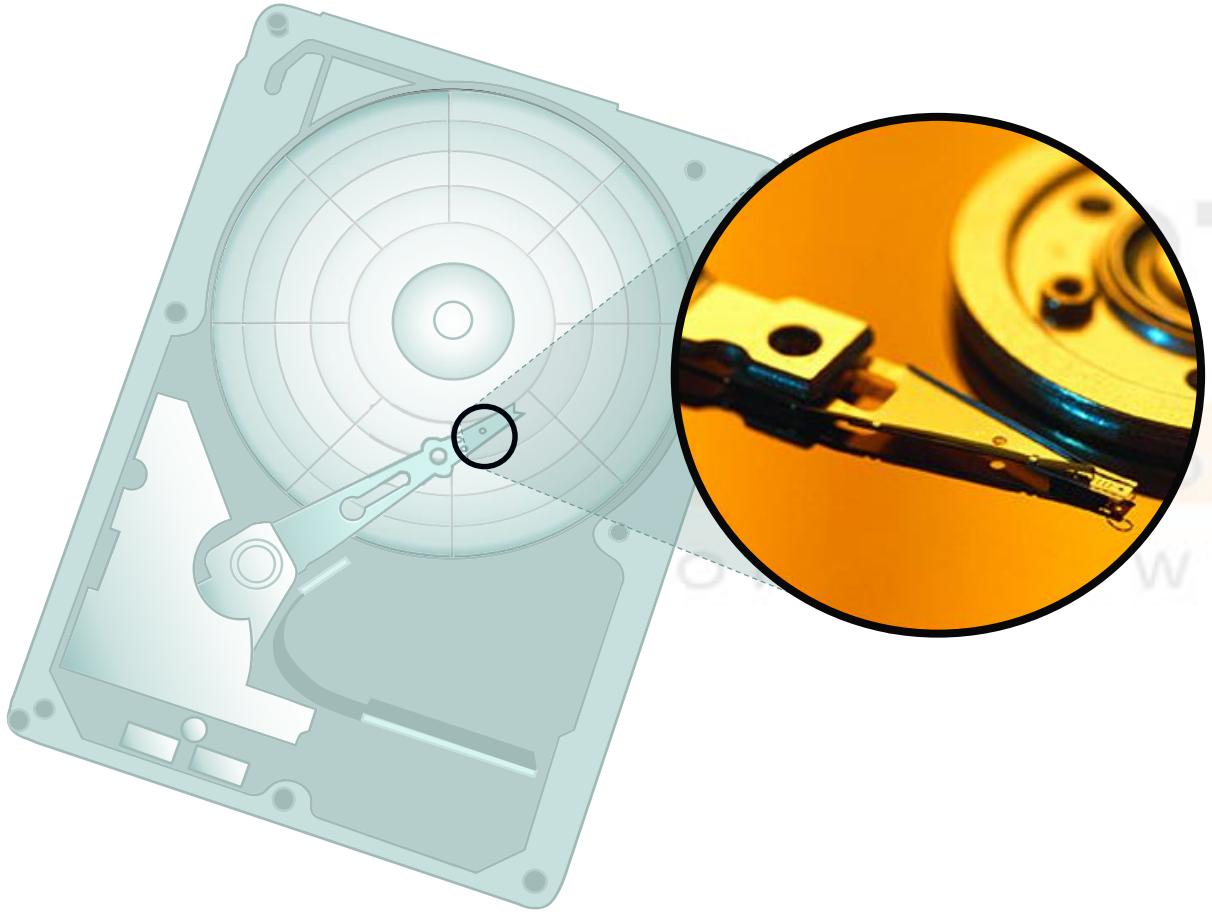
Topics	URL	Notes
Types of storage media	https://www.youtube.com/watch?v=NgVm2kUmrYo	This video explains and compares different types of storage media

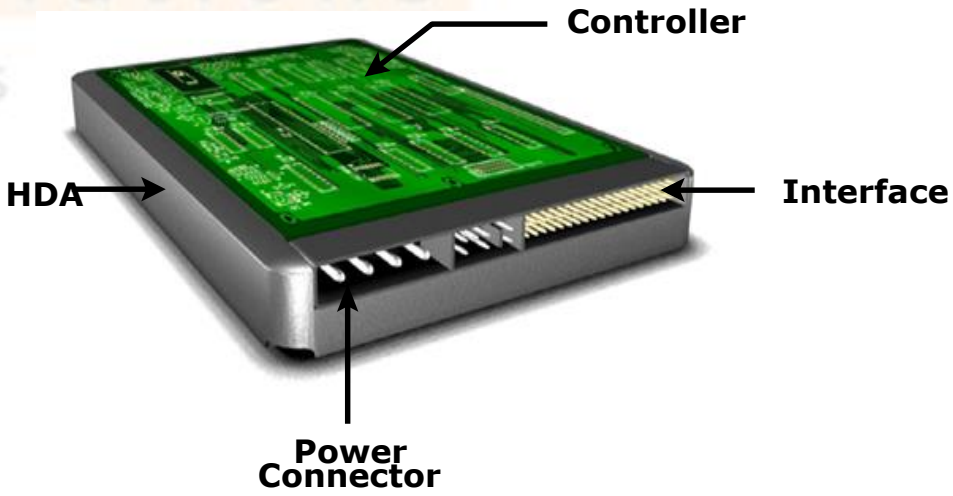
Hard Disk Drive (HDD)

What is a disk drive?

A **disk drive** is one of the most popular, randomly accessible, and rewritable storage medium used in the modern computers. It is a physical drive in a computer which is capable of holding and retrieving information. The disk drives are used for storing and accessing the data for performance-intensive, online application.

Storage System Environment



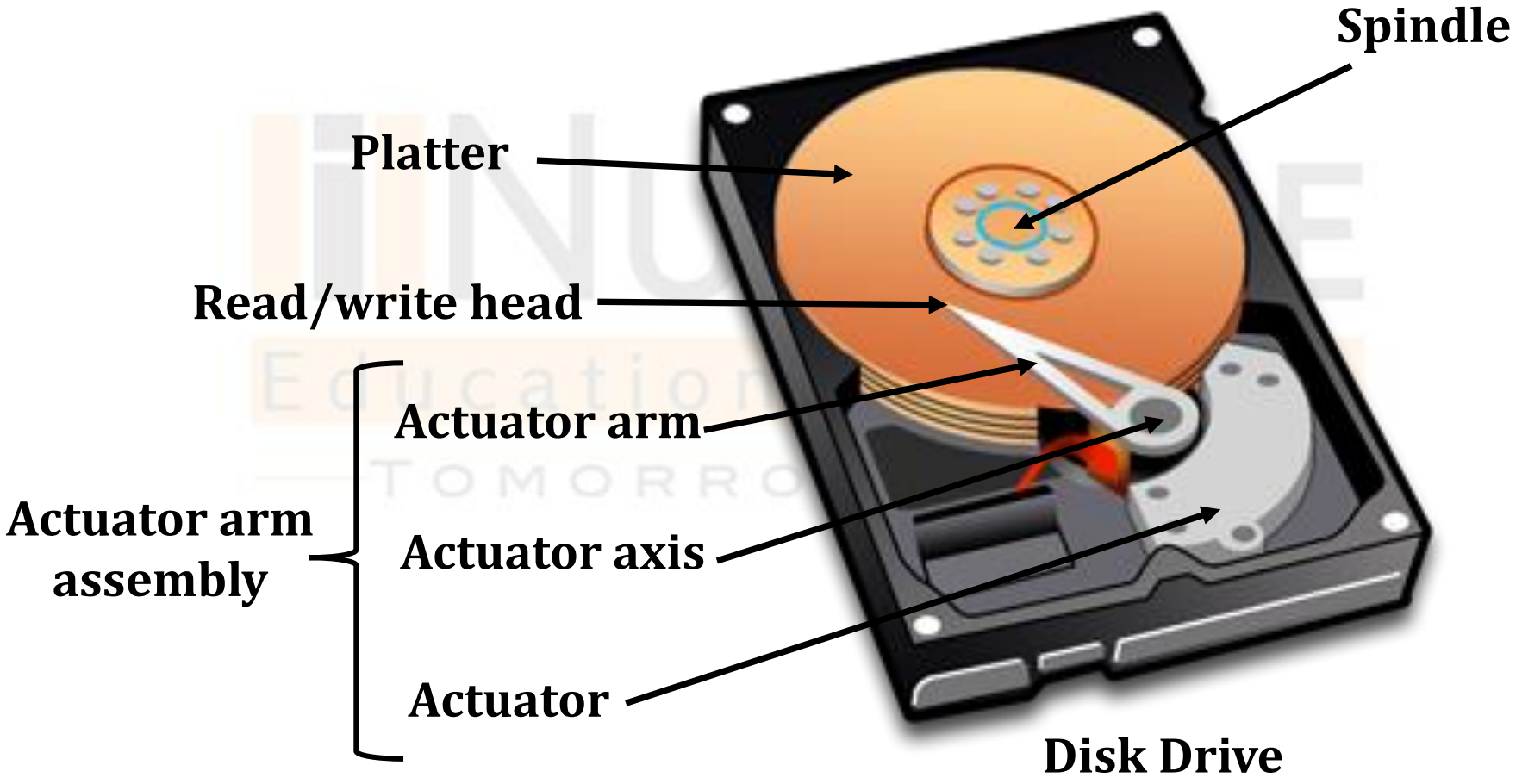


Components of a Disk Drive

The key components of a disk drive are:

- Platter
- Spindle
- Read/write head
- Actuator arm assembly
- Controller

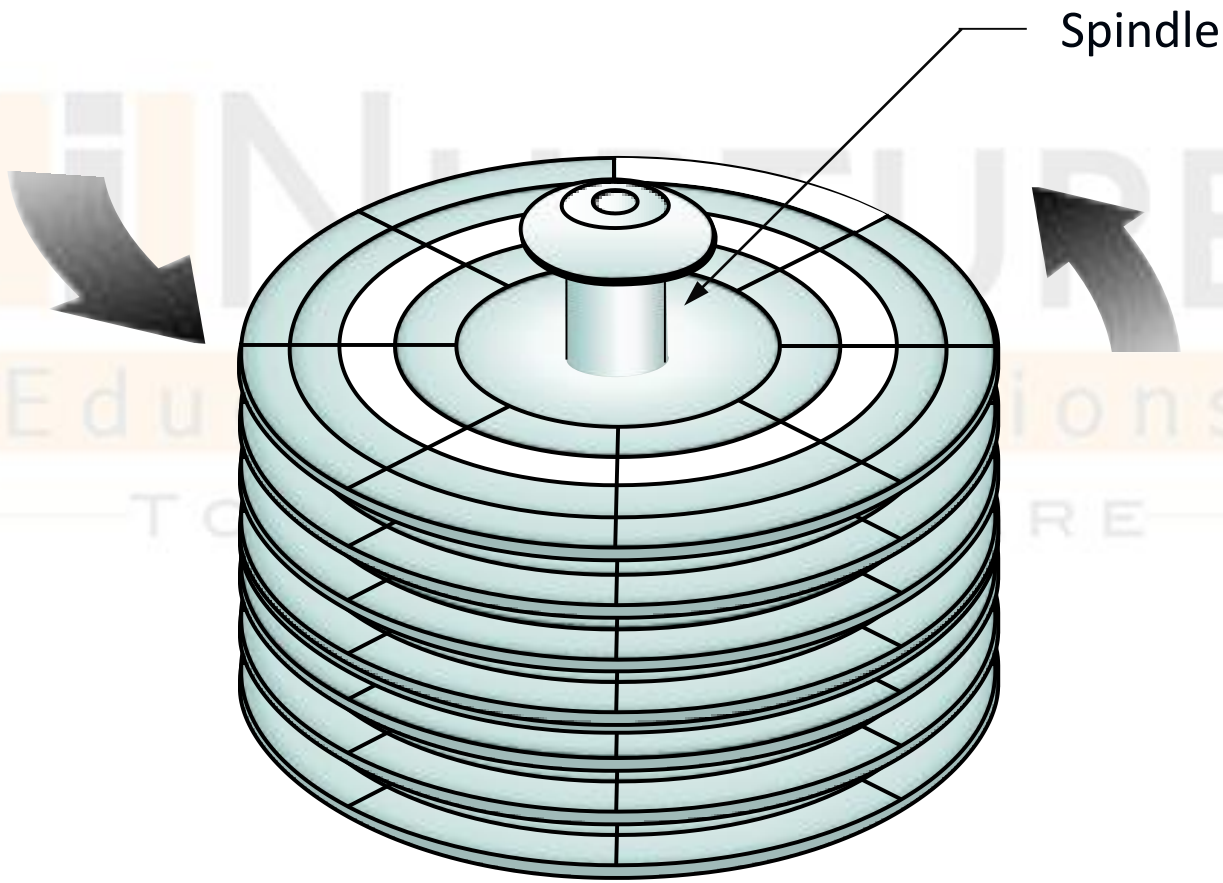
Storage System Environment



Storage System Environment

Platters

Spindle



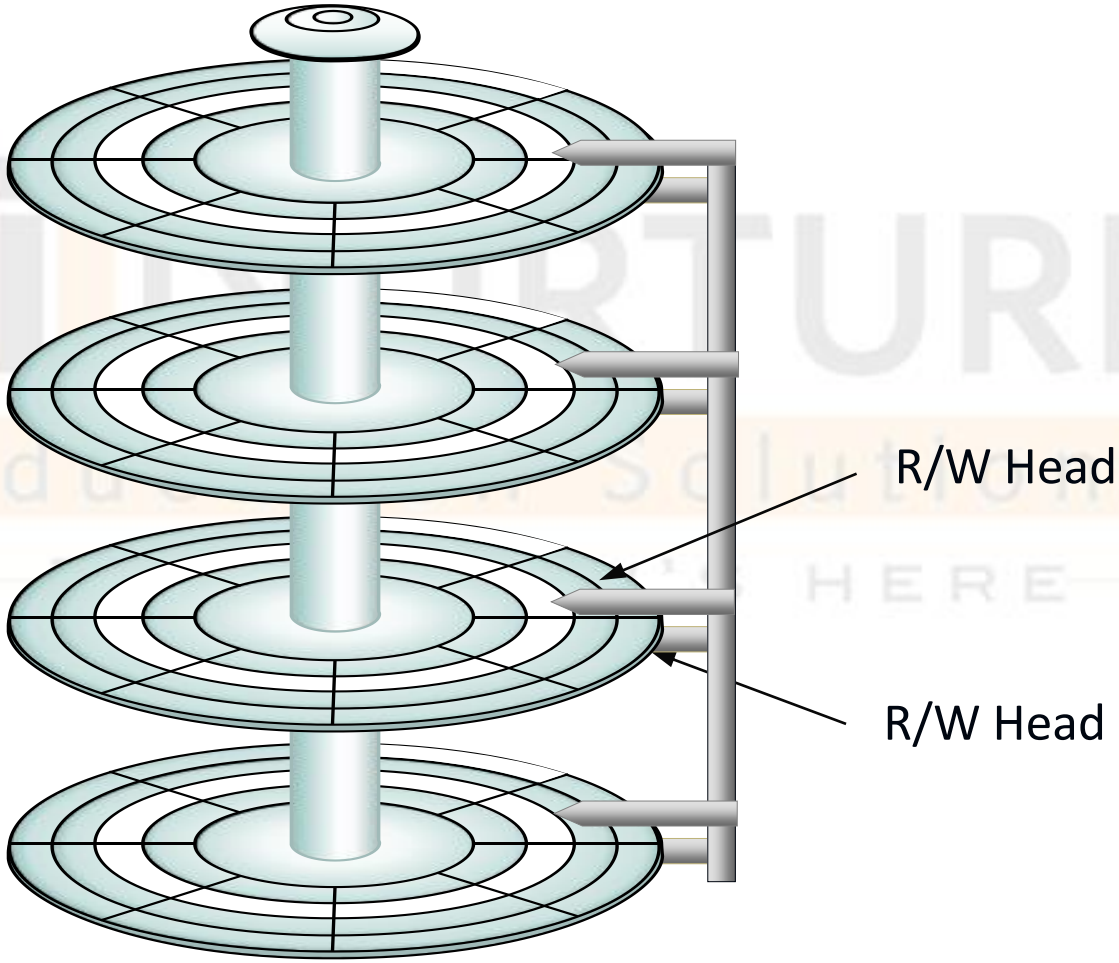
Read/Write Heads

Data is read and written by **read/write heads,** or R/W heads.

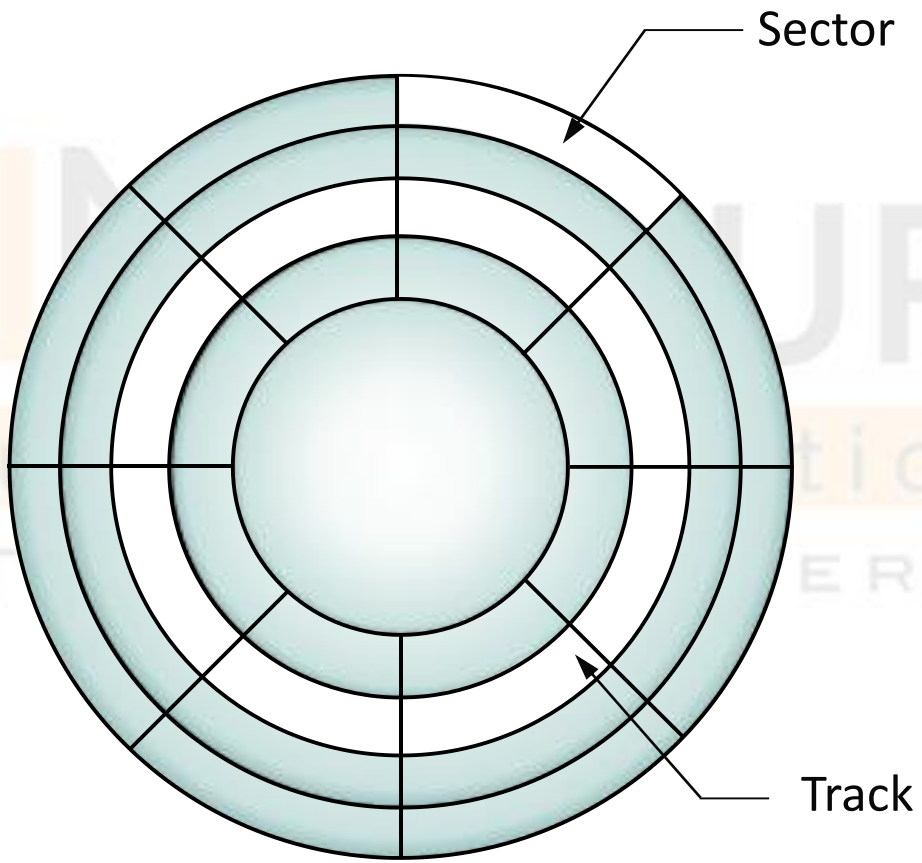
Most drives have two R/W heads per platter, one for each surface of the platter.

- When reading data, they detect magnetic polarization on the platter surface.
- When writing data, they change the magnetic polarization on the platter surface.

Storage System Environment

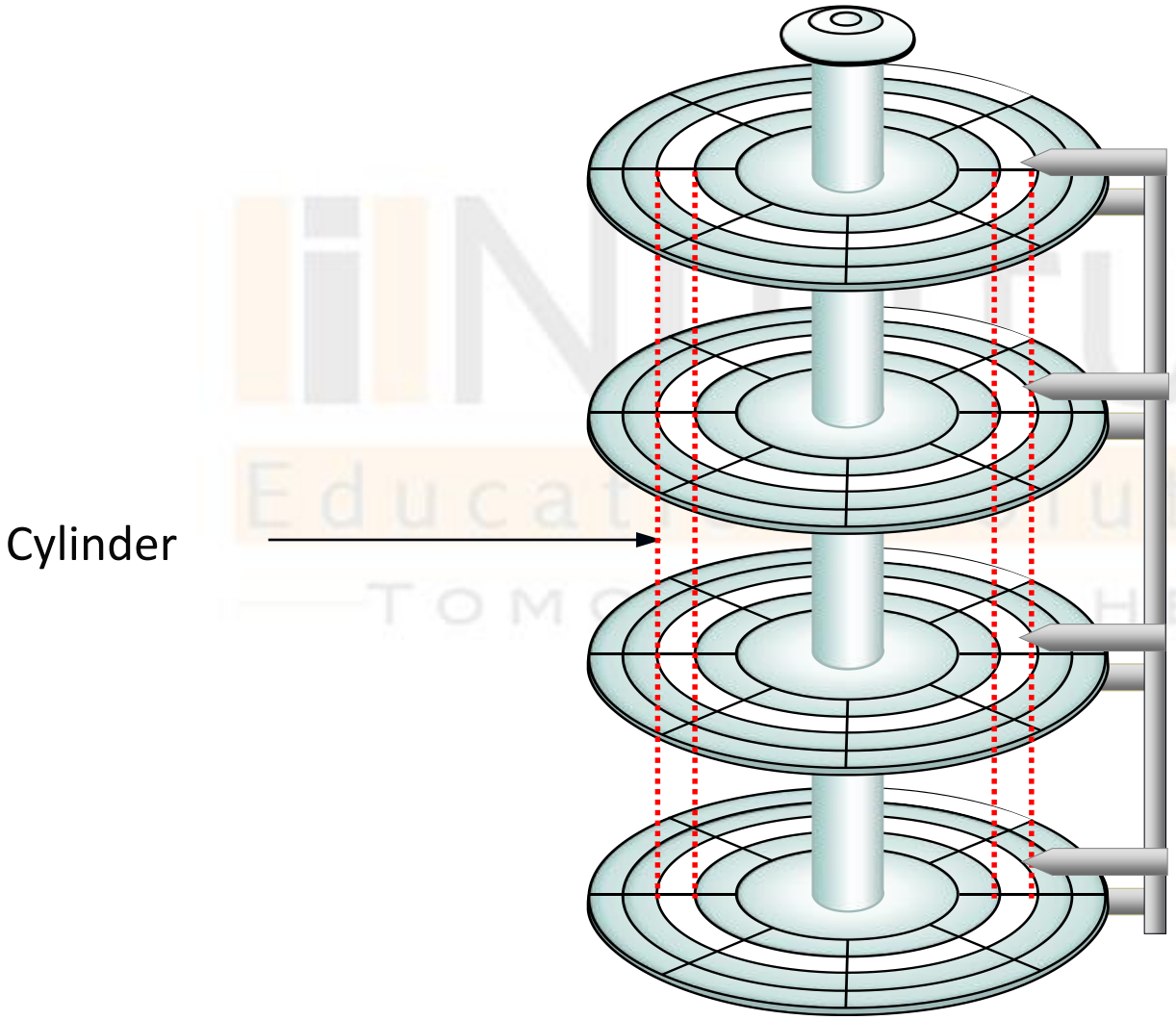


Sectors and Tracks



Platter

Cylinders



Controller

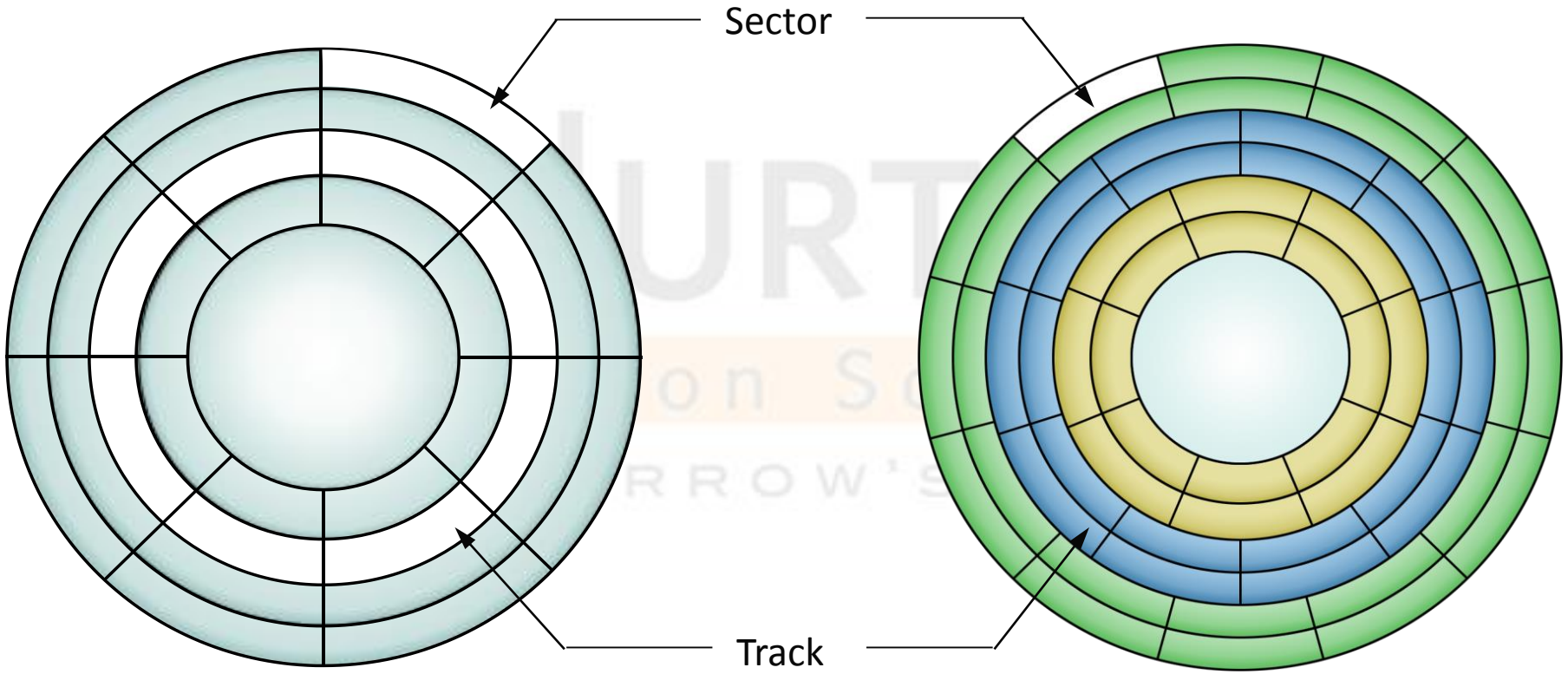
Bottom View of Disk Drive

Zoned-Bit Recording

Since a platter is made up of concentric tracks, the outer tracks can hold more data than the inner ones because they are physically longer than the inner tracks. However, in older disk drives, the outer tracks had the same number of sectors as the inner tracks, which means that the data density was very low on the outer tracks. This was an inefficient use of the available space.

Zoned-bit recording uses the disk more efficiently. It groups tracks into zones that are based upon their distance from the center of the disk.

Storage System Environment



Platter Without Zones

Platter With Zones

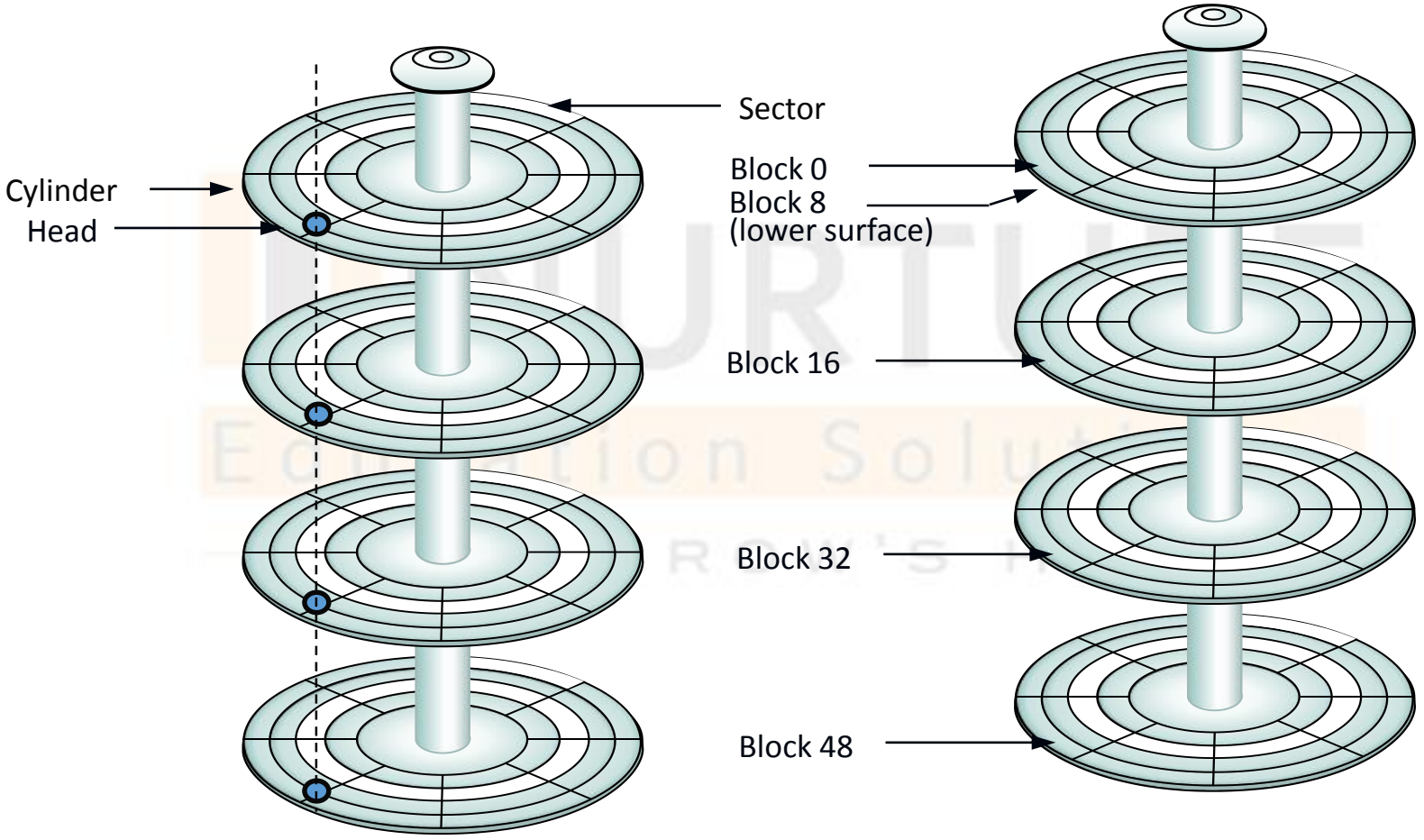
Logical Block Addressing

Earlier, drives used physical addresses made up of the Cylinder, Head, and Sector number (CHS) to refer to specific locations on the disk. This meant that the host had to be aware of the geometry of each disk that was used.

Logical Block Addressing (LBA) simplifies addressing by a using a linear address for accessing physical blocks of data. The disk controller performs the translation process from LBA to CHS address. The host only needs to know the size of the disk drive (how many blocks).

Logical blocks are mapped to physical sectors on a 1:1 basis
Block numbers start at 0 and increment by one until the last block is reached [E.g., 0, 1, 2, 3 … (N-1)]
Block numbering starts at the beginning of a cylinder and continues until the end of that cylinder
This is the traditional method for accessing peripherals on SCSI, Fiber Channel, and newer ATA disks

Storage System Environment



Physical Address = CHS

Logical Block Address = Block #

Self Assessment Questions

3. In Hard drive, the _____ causes the platters to rotate within a sealed case.

a) Tracks

b) Sectors

c) Spindle

d) Read/Write Head

Answer: c)

4. Multiple _____ form a track

a) Sectors
b) Cylinders
c) Zones
d) None of above

Answer: a)

5. Suppose a Disk Drive has 3 platters. The number of recording surfaces is _____

a) Three
b) Four
c) Six
d) Five

Answer: c)

6. Zoned-Bit Recording is a strategy to utilize space

a) True

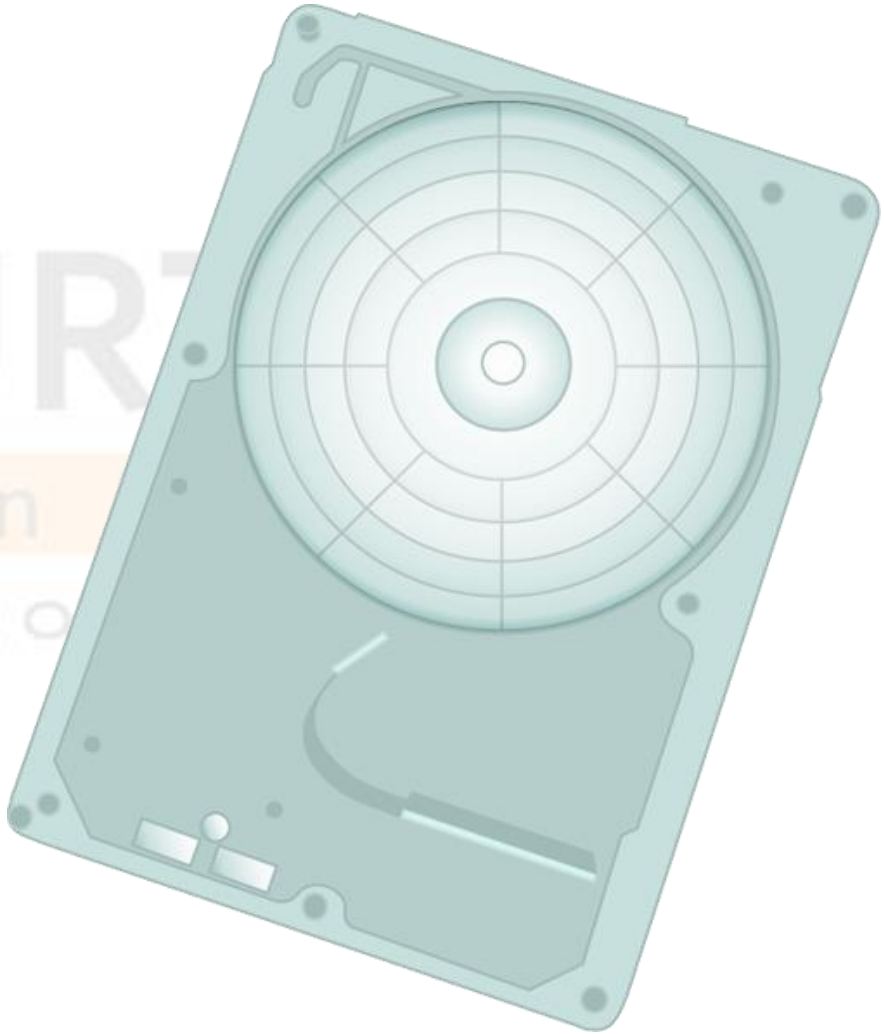
b) False

Answer: a)

PERFORMANCE OF DISK DRIVE

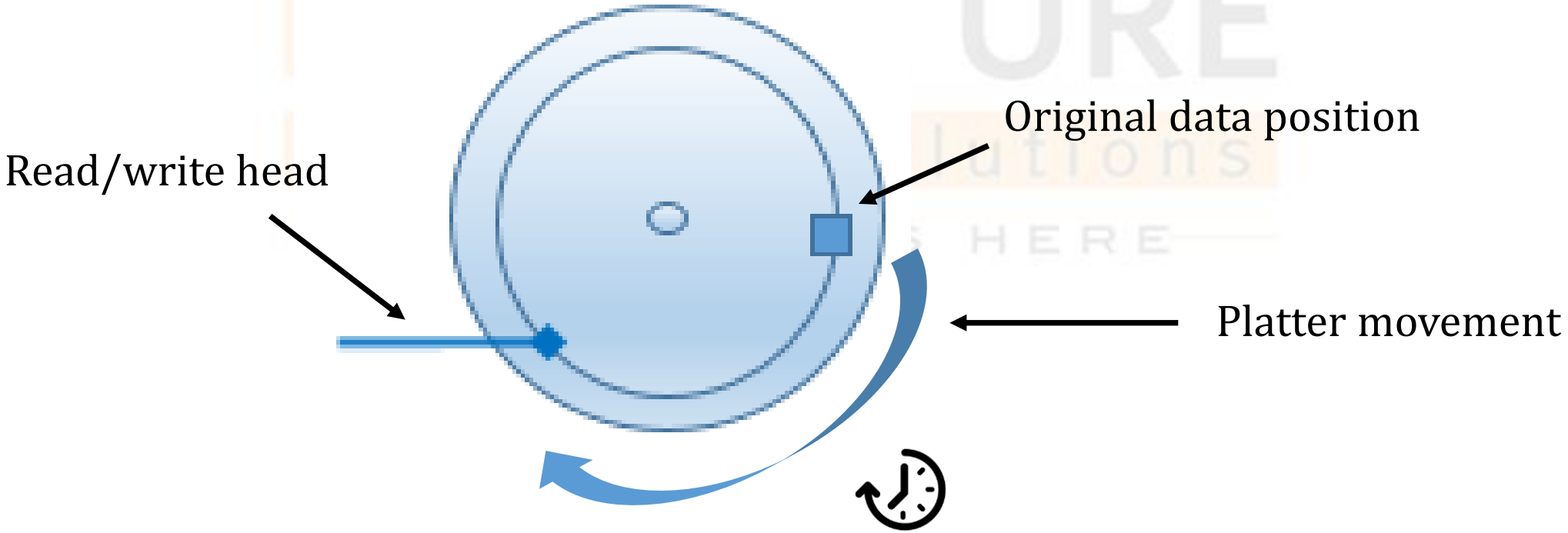
Seek Time

- Seek time is the time for read/write heads to move between tracks
- Seek time specifications include:
  - Full stroke
  - Average seek time
  - Track-to-track

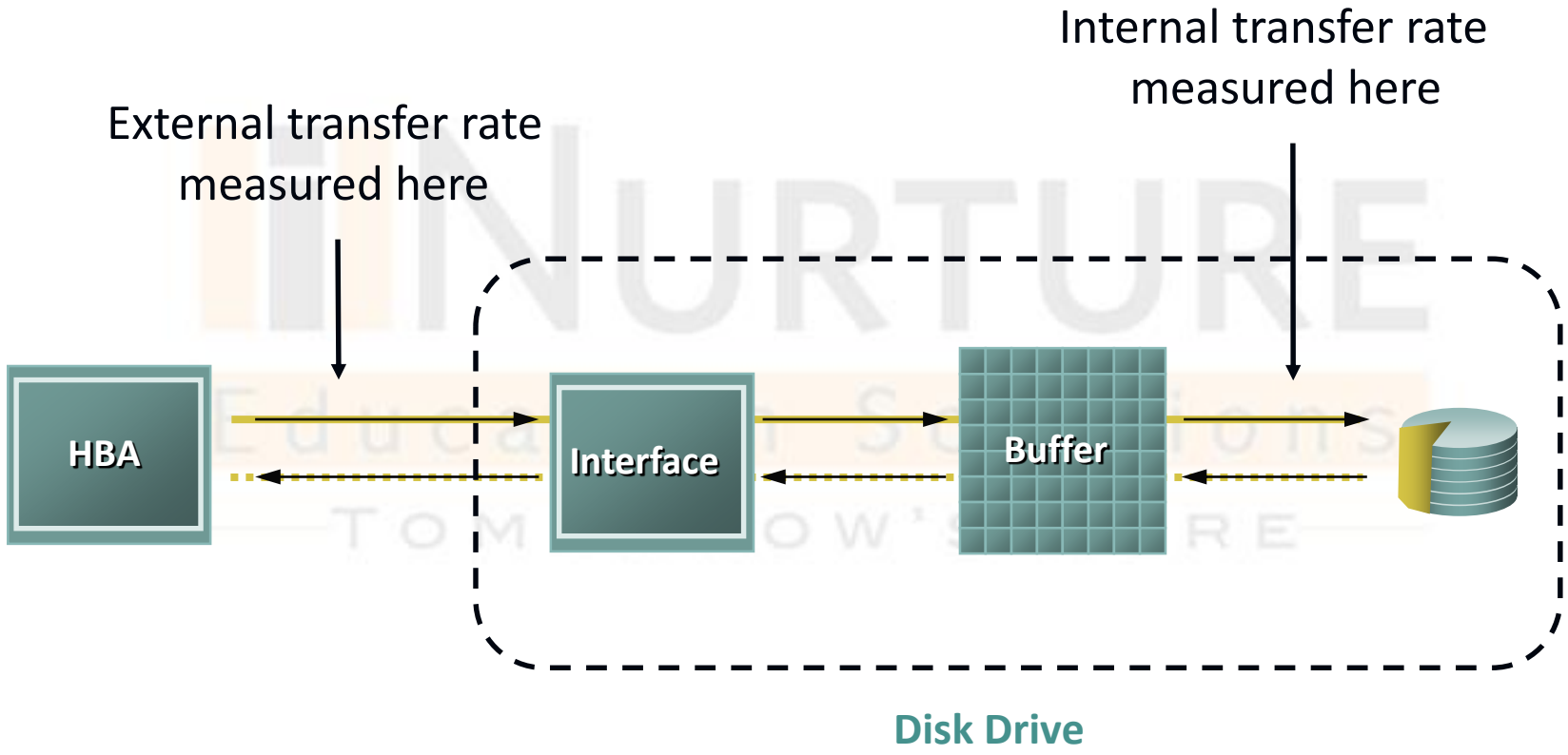


Rotational Latency

It is the time taken to position the data under the read/write head by rotating and repositioning the platter.



Data Transfer Rate



Data transfer rate is also known as transfer rate and it refers to the average amount of data per unit time that can be delivered by the drive to the host bus adapter (HBA).

Data Transfer Rate

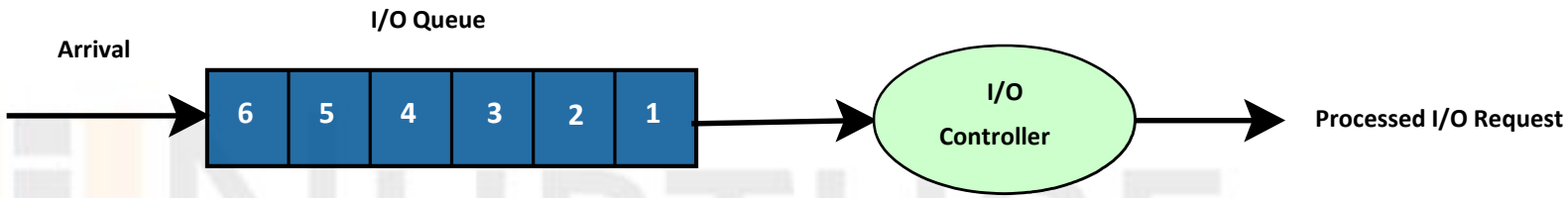
The **Data Transfer Rate** describes the MB/second that the drive can deliver data to the HBA. It can be categorized as:

- **Internal transfer rate -** the speed of moving data from the disk surface to the R/W heads on a single track of one surface of the disk.
- **External transfer rate -** the rate at which data can be moved through the interface to the HBA.

Other Factors affecting Disk Drive Performance

RPM of a disk drive	Size and number of Platter surfaces	Actuator characteristics
Spindle motor speed	Data recording & encoding factors	Disk response time
File system used	CPU speed	Disk Service Time

Fundamental Laws Governing Disk Drive Performance



- Little's Law
  - Describes the relationship between the number of requests in a queue and the response time.
  - **N = a × R**
    - "N" is the total number of requests in the queue system
    - "a" is the arrival rate of I/O requests
    - "R" is the average response time
- Utilization law
  - Defines the I/O controller utilization
  - **U = a × Rs**
    - "U" is the I/O controller utilization
    - "Rs" is the *service time*

Self Assessment Questions

7. For disk performance to be high, seek time should be _____

a) High

b) Low

c) High or Low as per situation

d) None of above

Answer: b)

8. If rotational latency is low, disk performance will be _____

a) High

b) Low

c) High or Low as per situation

d) None of above

Answer: a)

9. _____ is the average time taken by the read/write head to move from one point to another

a) Seek Time

b) Average Seek Time

c) Full stroke

d) Track-to-Track

Answer: b)

Document Links

Topics	URL	Notes
Hard Disk Drive	https://www.explainthatstuff.com/harddrive.html	This link explains about hard disk drive and its components. It presents details about structure of a hard disk drive and its functioning

Video Links

Topics	URL	Notes
Hard Disk Drive in motion	https://www.youtube.com/watch?v=p-JJp-oLx58	This video discusses about the components and working of a hard disk drive. It shows how the components work when the hard disk is in motion

Logical Components of Host

Storage System Environment

Application

- Interface between user and the host
- Three-tiered architecture
  - Application UI, computing logic and underlying databases
- Application data access can be classified as:
  - Block-level access: Data stored and retrieved in blocks, specifying the LBA
  - File-level access: Data stored and retrieved by specifying the name and path of files

Storage System Environment

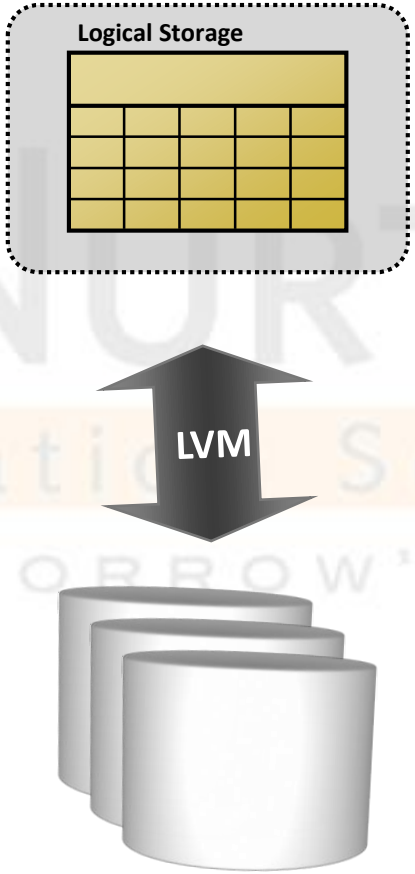
Operating System

- Resides between the applications and the hardware
- Controls the environment

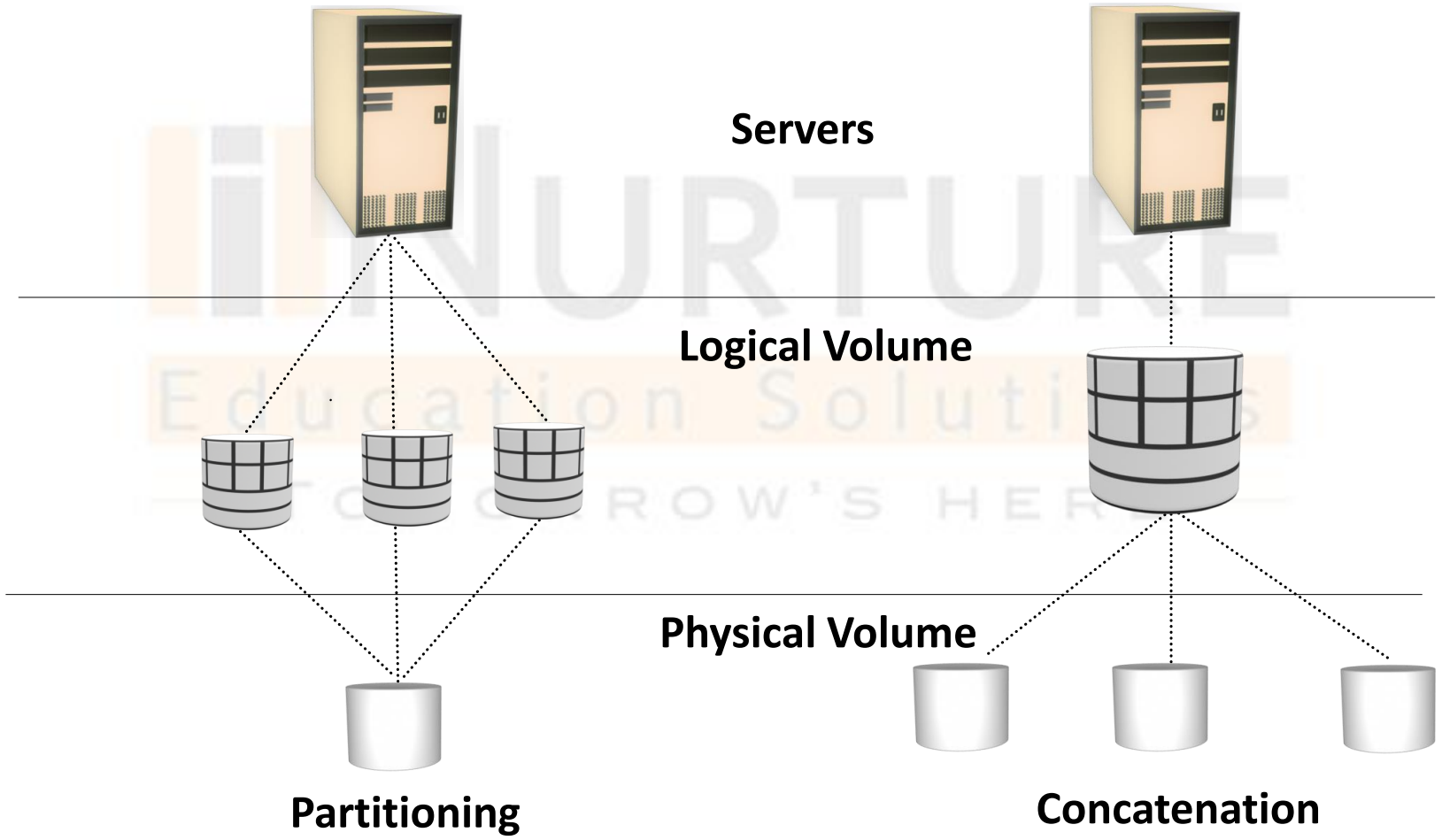
LVM (Logical Volume Manager)

- Responsible for creating and controlling host level logical storage
  - Physical view of storage is converted to a logical view by mapping
  - Logical data blocks are mapped to physical data blocks
- Usually offered as part of the operating system or as third party host software
- LVM Components:
  - Physical Volumes
  - Volume Groups
  - Logical Volumes

Storage System Environment



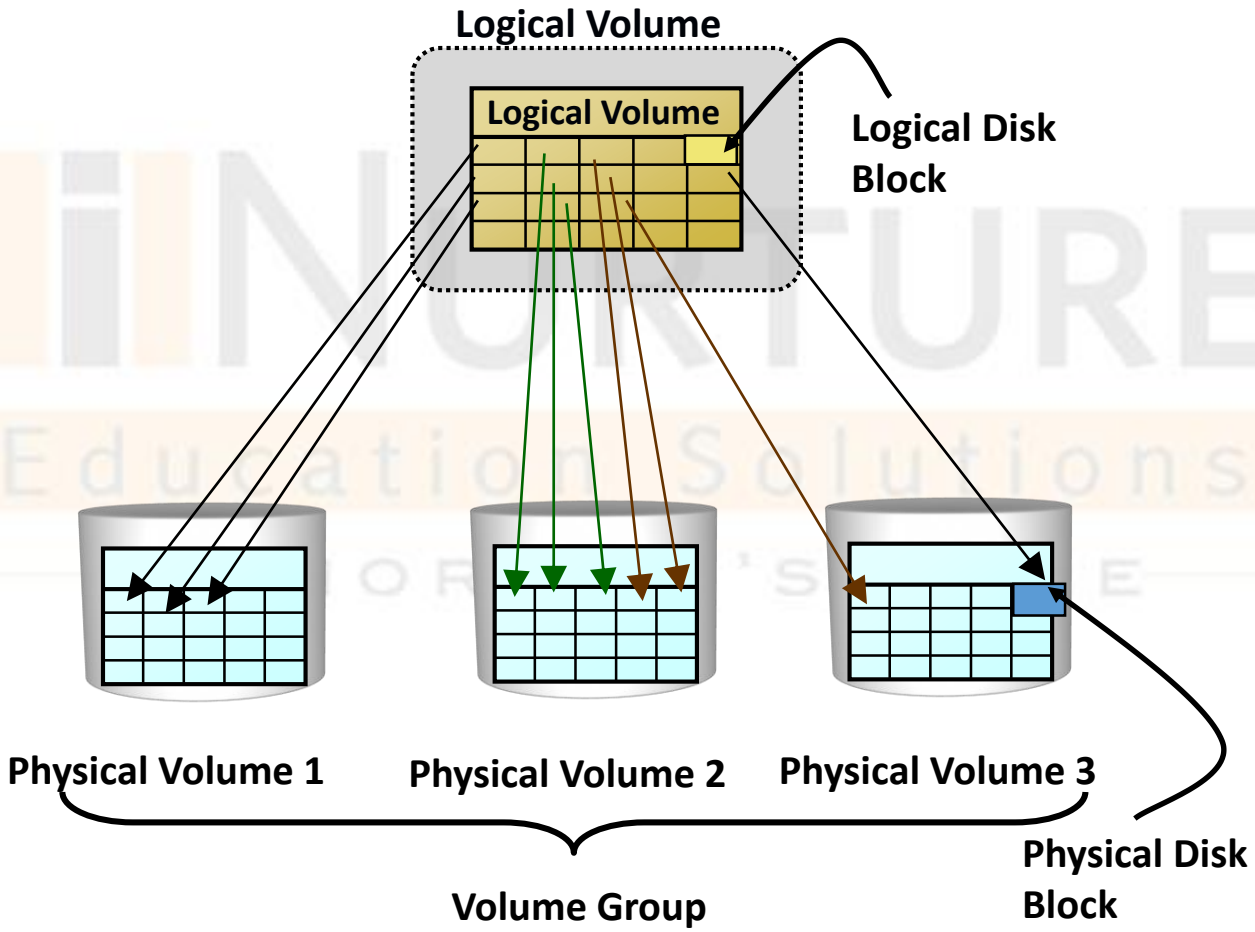
LVM Example


Servers
Logical Volume
Physical Volume
Partitioning
Concatenation

Volume Group

- One or more Physical Volumes form a Volume Group
- LVM manages Volume Groups as a single entity
- Physical Volumes can be added and removed from a Volume Group as necessary
- Physical Volumes are typically divided into contiguous equal-sized disk blocks

Storage System Environment



Storage System Environment

Device Drivers

- Enables operating system to recognize the device
- Provides API to access and control devices
- They are hardware dependent and operating system specific

File System

- File is a collection of related records or data stored as a unit
- File system is the organization of files on disk
  - Examples: FAT 32, NTFS, UNIX FS and EXT2/3

Self Assessment Questions

10. Which of these is not a LVM component?

a) Physical Volumes

b) Logical Volumes

c) Logical Groups

d) Volume Groups

Answer: c)

11. One or more _____ form a Volume Group

a) Logical Volumes
b) Physical Volumes
c) LVM
d) None of the Above

Answer: b)

RAID technology

RAID technology

- RAID stands for Redundant Array of Independent Disks.
- It is a technology that enables greater levels of performance, reliability and/or large volumes when dealing with data.
- High performance is achieved by concurrent use of two or more ‘hard disk drives’.
- Mirroring, Stripping (of data) and Error correction techniques combined with multiple disk arrays gives the desired reliability and performance.

RAID flavors

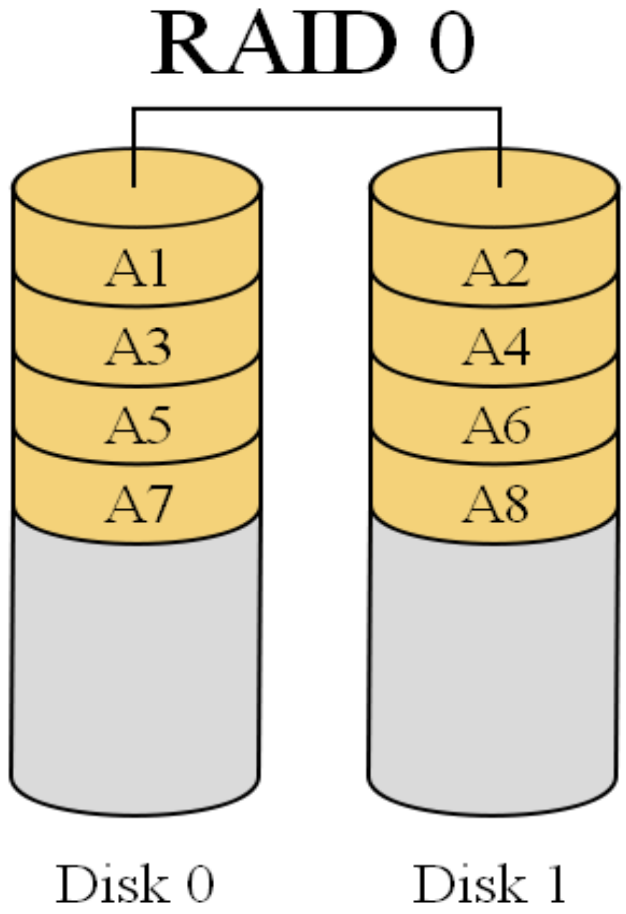
Commonly used ones:

1. RAID 0
2. RAID 1
3. RAID 5
4. RAID 10

Other rarely used types: RAID 2,3,4,6,50……

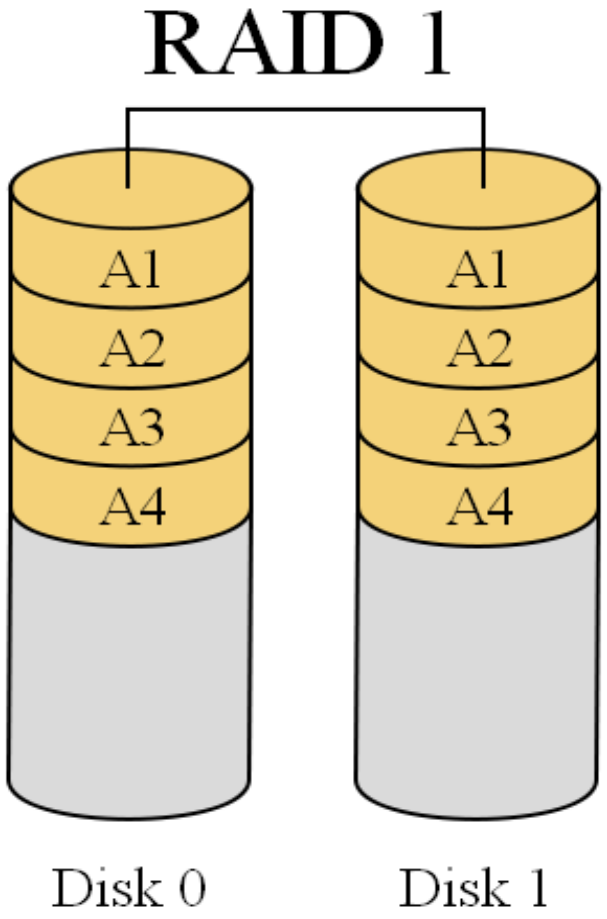
RAID 0

- It splits data among two or more disks.
- Provides good performance.
- Lack of data redundancy means there is no fail over support with this configuration.
- In the diagram to the right, the odd blocks are written to disk 0 and the even blocks to disk 1 such that A1, A2, A3, A4, … would be the order of blocks if read sequentially from the beginning.
- Used in read only NFS systems and gaming systems.



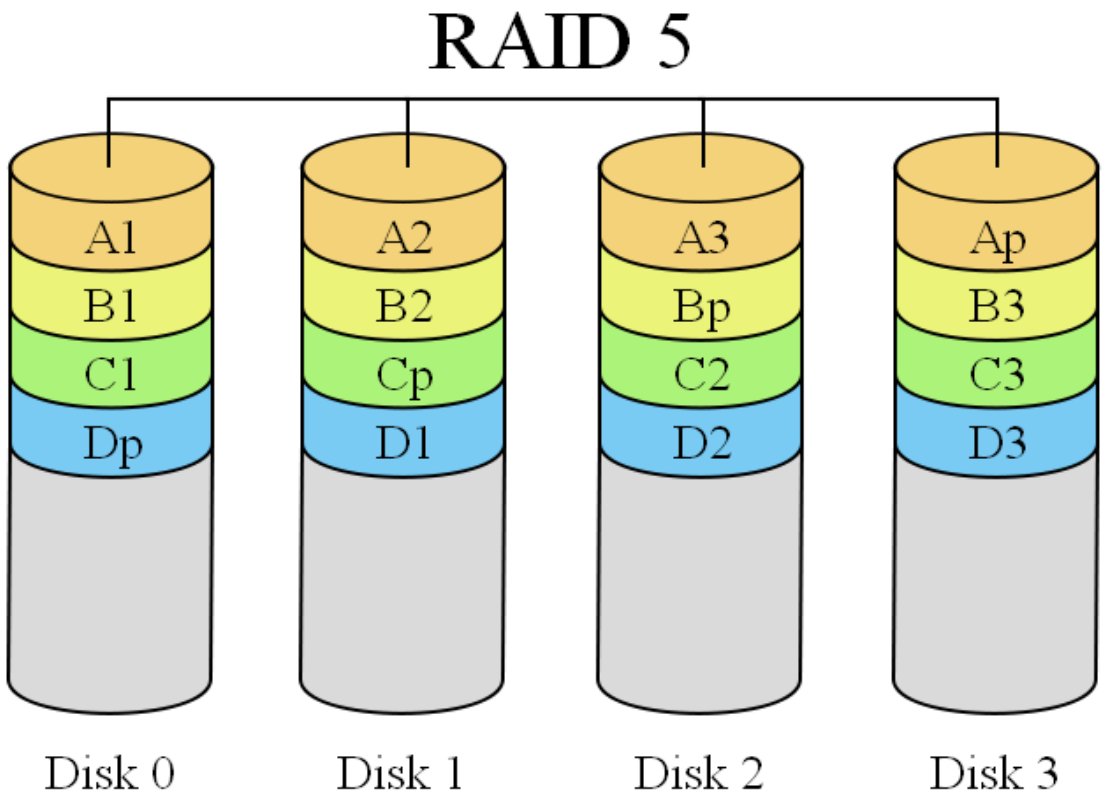
RAID 1

- RAID 1 is ‘data mirroring’.
- Two copies of the data are held on two physical disks, and the data is always identical.
- Twice as many disks are required to store the same data when compared to RAID 0.
- Array continues to operate so long as at least one drive is functioning.



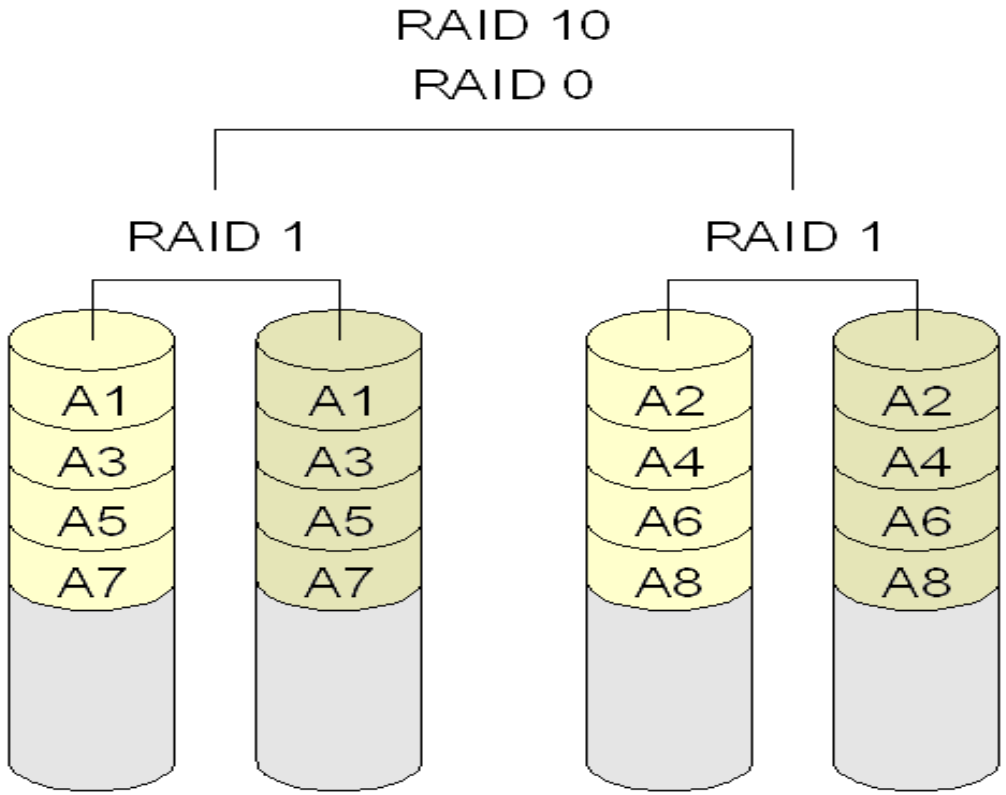
RAID 5

- RAID 5 is an ideal combination of good performance, good fault tolerance and high capacity and storage efficiency.
- An arrangement of parity and CRC to help rebuilding drive data in case of disk failures.
- “Distributed Parity” is the key word here.



RAID 10

- Combines RAID 1 and RAID 0 technology.
- Which means having the pleasure of both good performance and good failover handling.
- Also called ‘Nested RAID’.



Software Based RAID

- Software implementations are provided by many operating systems.
- A software layer sits above the disk device drivers and provides an abstraction layer between the logical drives(RAIDs) and physical drives.
- Server's processor is used to run the RAID software.
- Used for simpler configurations like RAID 0 and RAID 1.

Hardware Based RAID

- A hardware implementation of RAID requires at least a special-purpose RAID controller.
- On a desktop system this may be built into the motherboard.
- Processor is not used for RAID calculations as a separate controller is present.

A PCI-bus-based, IDE/ATA hard disk RAID controller, supporting levels 0, 1 and 10

Self Assessment Questions

12. Data Mirroring is a phenomenon witnessed in which RAID favour?

a) RAID 0
b) RAID 1
c) RAID 5
d) None of above

Answer: b)

13. Hardware based RAID implementation requires no processor use for RAID calculations because _____

a) Does not involve calculations

b) Separate controller is present for calculations

c) Separate program is present for calculations

d) None of the above reasons

Answer: b)

14. Which of these can be achieved through RAID?

a) High performance
b) Reliability
c) Fault tolerance
d) All of these

Answer: d)

Document Links

Topics	URL	Notes
RAID technology	https://www.prepressure.com/library/technology/raid	This link explains about the details of RAID technology with advantages and disadvantages of different RAID flavours

Video Links

Topics	URL	Notes
RAID technology	https://www.youtube.com/watch?v=wTcxRObq738	This video explains about RAID 0, 1, 2, 5, 6, 10
RAID controller	https://www.youtube.com/watch?v=wpZ45890zEk	In this Video, you will learn about RAID controller and its use and need

Storage Networking Technologies

Storage System Environment

Overview

There are 4 basic forms of Network Storage:

- Direct attached storage (DAS)
- Network attached storage (NAS)
- Storage area network (SAN)
- Internet Protocol Storage area network (IP-SAN)

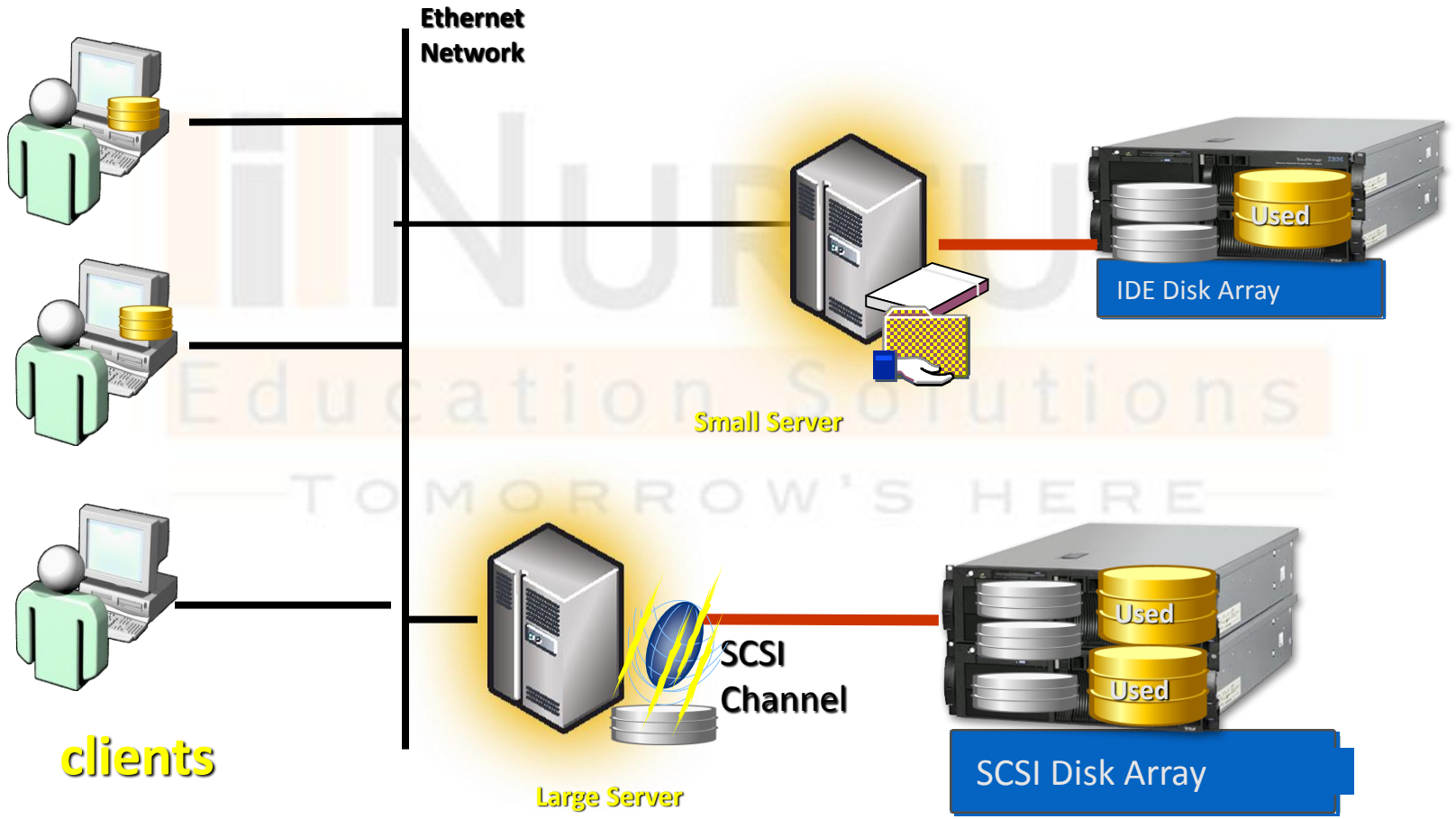
Storage System Environment

Comparison

	DAS	NAS	SAN
Storage Type	sectors	shared files	blocks
Data Transmission	IDE/SCSI	TCP/IP, Ethernet	Fibre Channel
Access Mode	clients or servers	clients or servers	servers
Capacity (bytes)	10^9	10^9 - 10^{12}	10^{12}
Complexity	Easy	Moderate	Difficult
Management Cost (per GB)	High	Moderate	Low

Storage System Environment

DAS Types

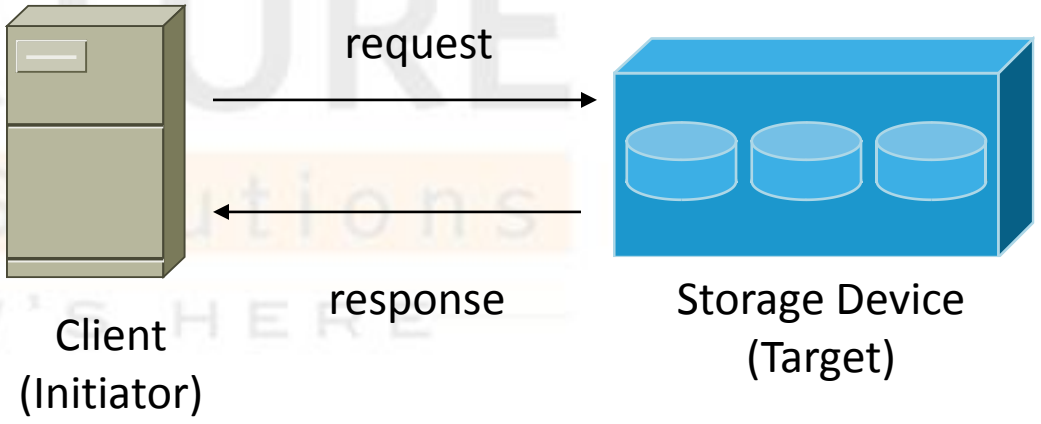


SCSI

- SCSI stands for Small Computer System Interface.
- It is an I/O bus for peripheral device, such as hard drives, tape drives, CD-ROM, scanners, etc.
  - an improvement over IDE
- A single SCSI bus connects multiple elements (max 7 or 15).
- High speed data transfer:
  - 5, 10, 20, 100, 320 MB/sec, …
- Overlapping I/O capability:
  - Multiple read & write commands can be outstanding simultaneously.
  - Different SCSI drives to be processing commands concurrently rather than serially. The data can then be buffered and transferred over the SCSI bus at very high speeds.

SCSI Distribution Architecture

- SCSI is a client/server architecture.
- The client is called the **initiator** and issues request to the server. The client is I/O subsystem under the typical OS control.
- The "server" is called the **target,** which is the SCSI controller inside the storage device. It receives, process, and responds to the requests from the initiator.
- SCSI commands support **block I/O, transferring large amount of data in blocks.**



Storage System Environment

SAN

- A Storage Area Network (SAN) is a specialized, dedicated high speed network joining servers and storage, including disks, disk arrays, tapes, etc.
- Storage (data store) is separated from the processors (and separated processing).
- High capacity, high availability, high scalability, ease of configuration, ease of reconfiguration.
- **Fibre Channel** is the de facto SAN networking architecture, although other network standards could be used.

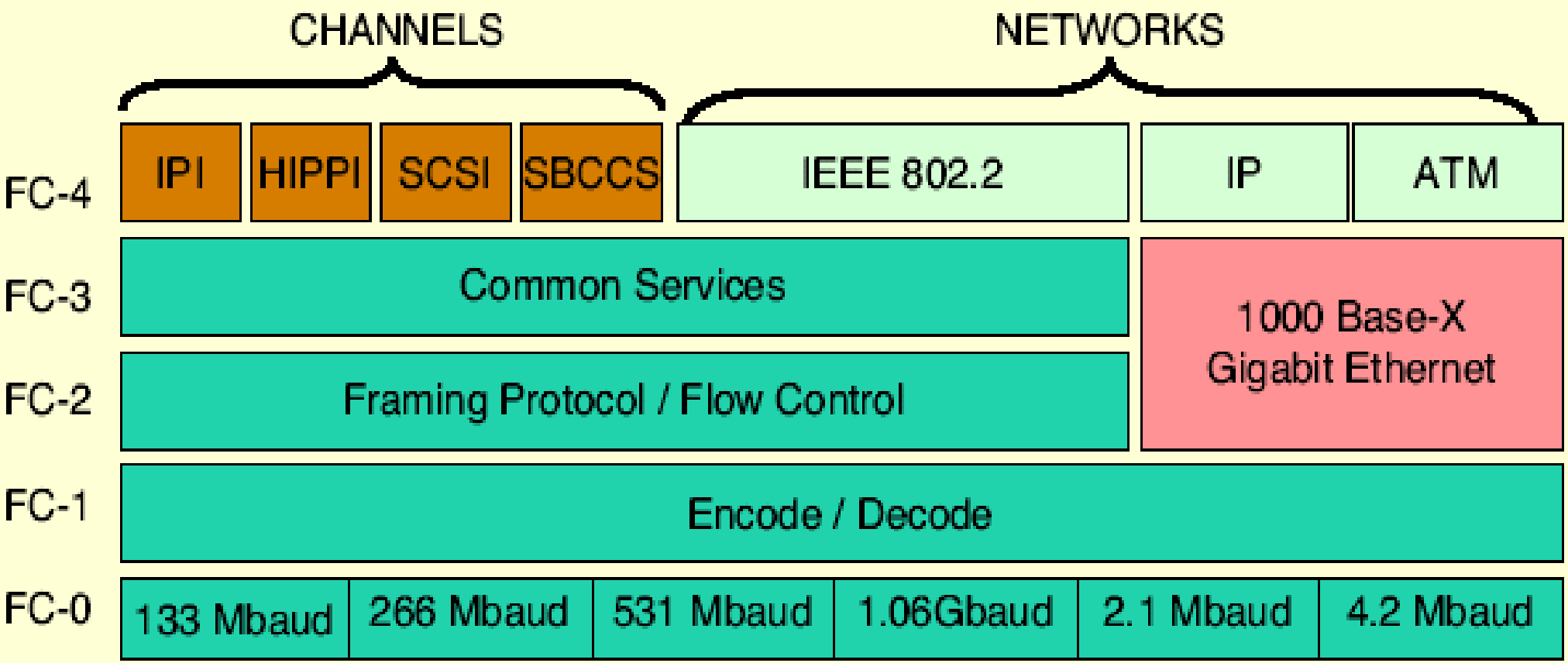
SAN Benefits

- Storage consolidation
- Data sharing
- Non-disruptive scalability for growth
- Improved backup and recovery
- Tape pooling
- LAN-free and server-free data movement
- High performance
- High availability server clustering
- Data integrity
- Disaster tolerance
- Ease of data migration
- Cost-effectiveness (total cost of ownership)

SAN Architecture

- Fibre Channel (FC) is well established in the open systems environment as the underlining architecture of the SAN.
- Fibre Channel is structured with independent layers, as are other networking protocols. There are five layers, where 0 is the lowest layer. The physical layers are 0 to 2. These layers carry the physical attributes of the network and transport the data created by the higher level protocols, such as SCSI, TCP/IP, or FICON.
- ANSI T11 is the technical committee who produced FC Protocol (interface standard) for high-performance and mass storage applications.
- FC Protocol is designed to transport multiple protocols, such as HIPPI, IPI, SCSI, IP, Ethernet, etc.

FC Protocol Layers



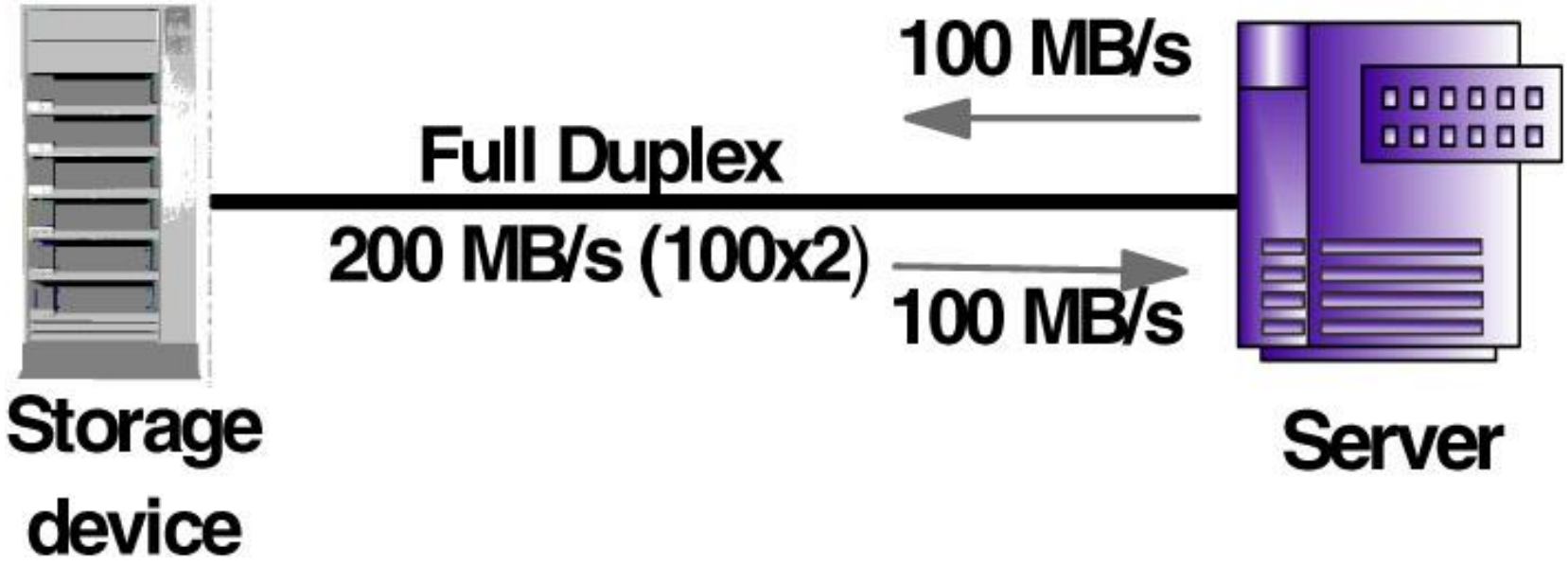
SAN Topologies

Fibre Channel based networks support three types of topologies:

- Point-to-point
- Loop (arbitrated) – shared media
- Switched

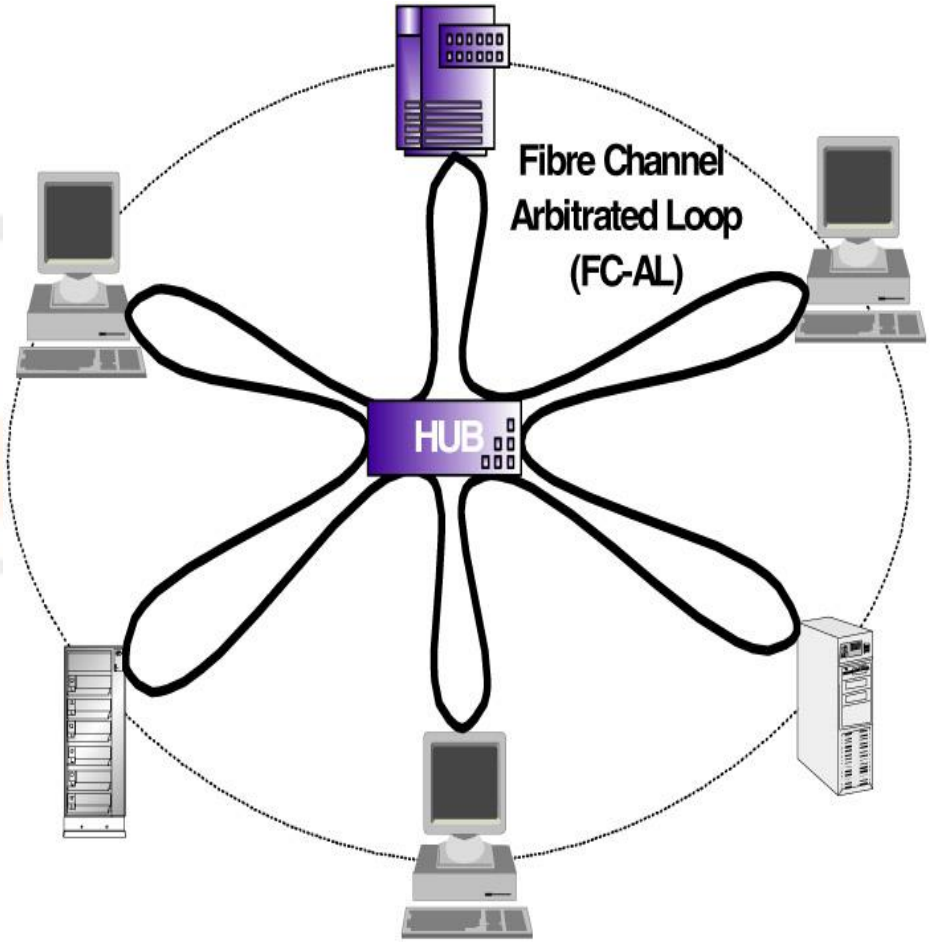
Point-to-Point

- The point-to-point topology is the easiest Fibre Channel configuration to implement, and it is also the easiest to administer.
- The distance between nodes can be up to 10 km.



Arbitrated Loop

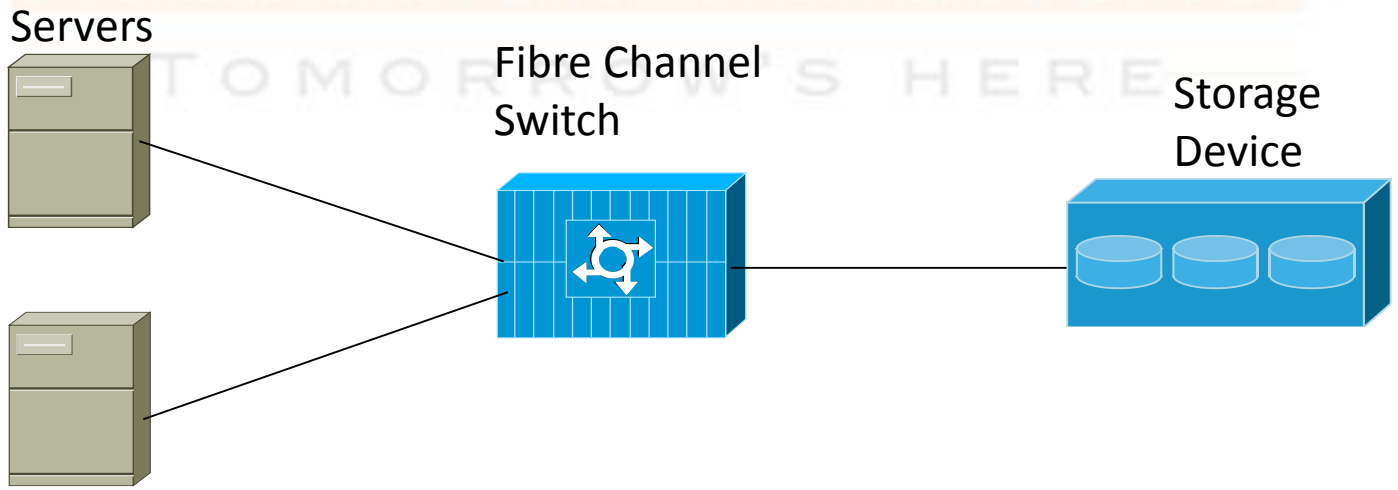
- Shared Media Transport. Similar in concept to shared Ethernet.
- Not common for FC-based SAN.
- Commonly used for JBOD (Just a Bunch of Disks).
- An arbitration protocol determines who can access the media.



Switched FC

- Fibre Channel-switches function in a manner similar to traditional network switches to provide increased bandwidth, scalable performance, an increased number of devices, and, in some cases, increased redundancy. Fibre Channel-switches vary in the number of ports and media types they support.

- Multiple switches can be connected to form a switch fabric capable of supporting a large number of host servers and storage subsystems.

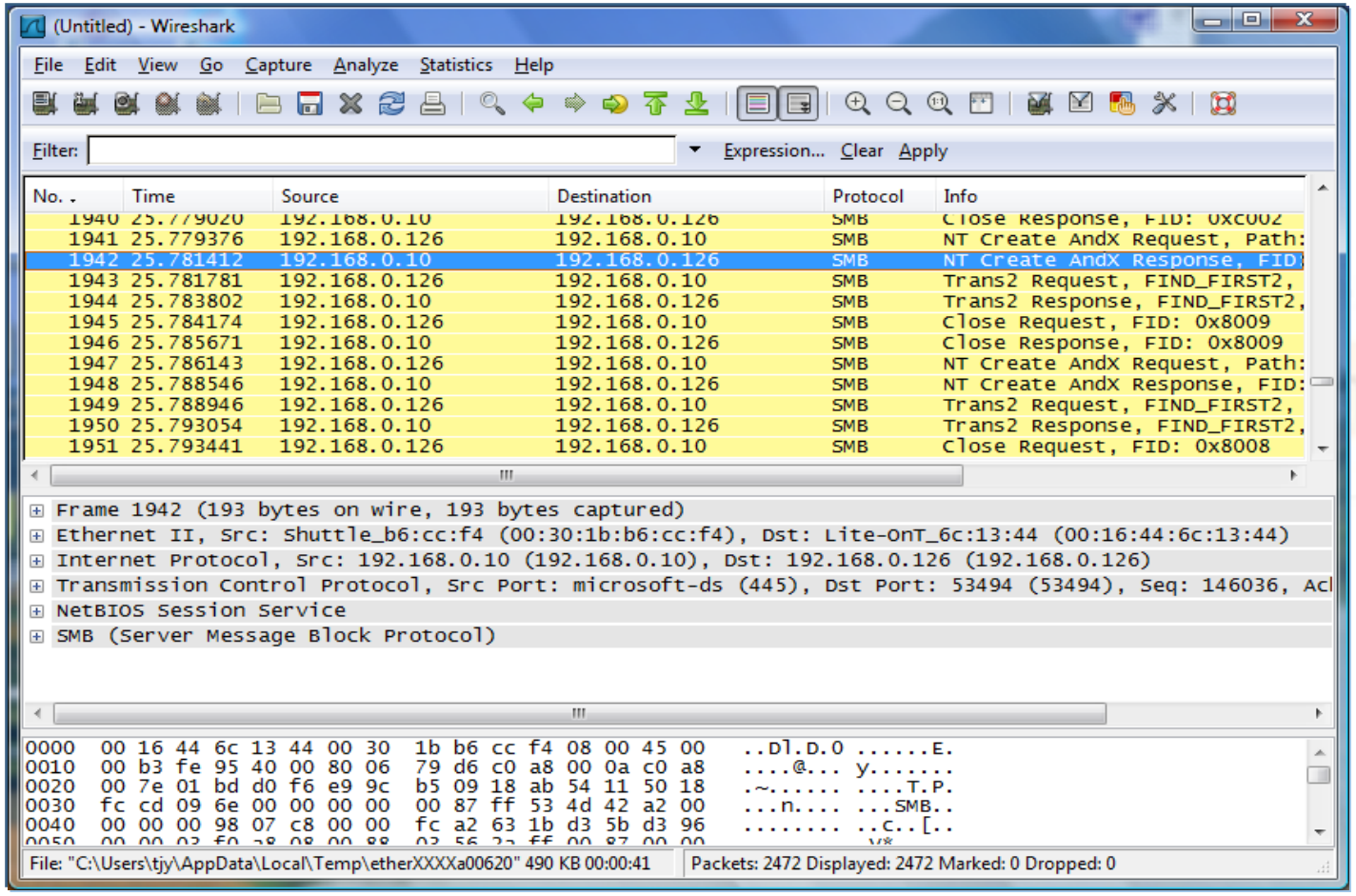


Storage System Environment

NAS

- NAS is a dedicated storage device, and it operates in a client/server mode.
- NAS is connected to the file server via LAN.
- Protocol: NFS (or CIFS) over an IP Network
  - Network File System (NFS) – UNIX/Linux
  - Common Internet File System (CIFS) – Windows Remote file system (drives) mounted on the local system (drives)
    - evolved from Microsoft NetBIOS, NetBIOS over TCP/IP (NBT), and Server Message Block (SMB)
- Advantage: No distance limitation
- Disadvantage: Speed and Latency
- Weakness: Security

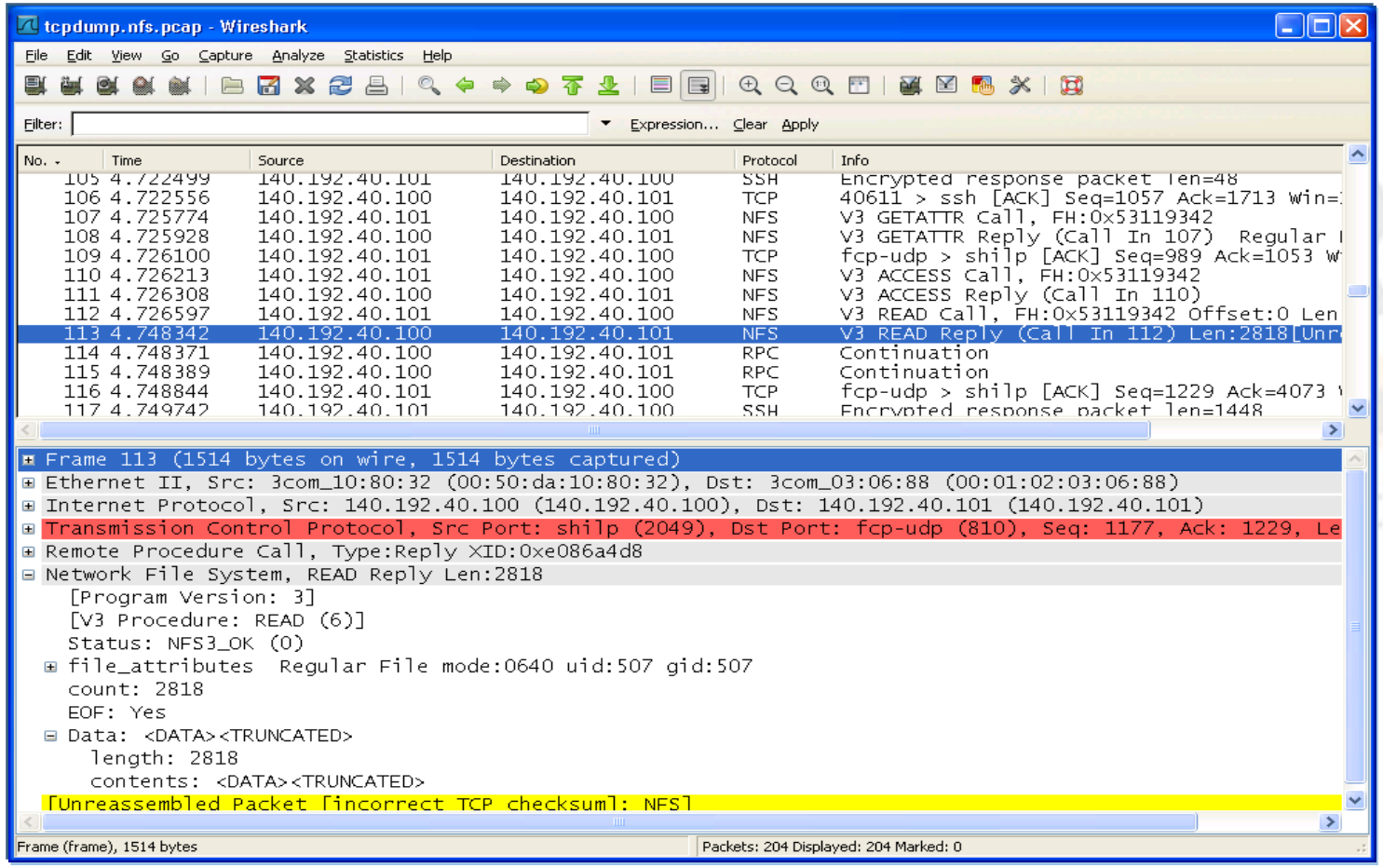
NAS Implementation



SMB
NetBIOS
TCP
IP
802.3

Storage System Environment

NAS Implementation



NFS

TCP

IP

802.3

NAS vs SAN

- Traditionally:
  - NAS is used for low-volume access to a large amount of storage by many users.
  - SAN is the solution for terabytes (1012) of storage and multiple, simultaneous access to files, such as streaming audio/video.
- The lines are becoming blurred between the two technologies now, and while the SAN-versus-NAS debate continues, the fact is that both technologies complement each another.

IP-SAN

- IP storage networking – carrying storage traffic over IP
- Uses TCP, a reliable transport for delivery
- Can be used for local data center and long haul applications
- Two primary IETF protocols/standards:
  - **iSCSI –** Internet SCSI – allows block storage to be accessed over a TCP/IP network as though it were locally attached
  - **FCIP –** Fibre-Channel-over-IP – used to tunnel Fibre Channel frames over TCP/IP connections

Self Assessment Questions

15. Which of these support IDE/SCSI as data transmission mode?

a) DAS

b) NAS

c) SAN

d) None of these

Answer: a)

16. Among these, the one having moderate complexity is _____

a) DAS

b) NAS

c) SAN

d) None of these

Answer: b)

17. Fibre Channel is the networking architecture of _____

a) DAS

b) NAS

c) SAN

d) None of these

Answer: c)

Summary

- A storage system is a group of components providing storage facilities to one or numerous computers.
- The main components of storage system environments are host, connectivity, and storage.
- Components of disk drive are platter, spindle, read/write head, actuator arm assembly, and controller.
- A host is a computer or any other device on which applications run.
- The logical components of host are OS, device driver, volume manager, file system, volume group.
- Zoned bit recording groups tracks into zones based on their distance from the centre of the disk.

Assignment

You need to answer below sets of problem. These sets of questions are meant for testing unit II.

1. Explain the various components of storage system.
2. What is the difference between port and cable?
3. Write a description on various hard disk drive components.
4. Draw a neat diagram of a hard disk drive, showing all its components.
5. Explain various factors affecting hard disk drive performance.
6. Explain the difference between RAID 0 and RAID 1 with examples.
7. Explain various SAN topologies.

Storage System Environment

Document Links

Topics	URL	Notes
Storage System	https://searchstorage.techtarget.com/tip/The-components-that-make-up-a-well-balanced-data-storage-system	The link explains in details all aspects of a balanced data storage system
Magnetic storage	http://study.com/academy/lesson/magnetic-storage-definition-devices-examples.html	This link explains Magnetic Storage: Definition, Devices and Examples
Optical media	http://searchstorage.techtarget.com/definition/optical-media	This link explains about different types of Optical media (CD, DVD)
Solid State Devices	http://searchstorage.techtarget.com/definition/solid-state-storage	This link explains about Solid State Storage Technology
Performance assessment of Disk Drive	https://www.pctechguide.com/hard-disks/hard-disk-hard-drive-performance-transfer-rates-latency-and-seek-times	This link explains various parameters of Drive Performance - transfer rates, latency and seek times
Hard disk drive	https://www.explainthatstuff.com/harddrive.html	This link explains about hard disk drive and its components. It presents details about structure of a hard disk drive and its functioning

Storage System Environment

Video Links

Topics	URL	Notes
Storage Media	https://www.youtube.com/watch?v=NgVm2kUmrYo	This video explains various types of storage media
HDD working	https://www.youtube.com/watch?v=p-JJp-oLx58	This video illustrates various components of hard disk drive and shows their working
Storage Area Network	https://www.youtube.com/watch?v=7et3bmXhr8w	This video explains the building blocks of SAN
Introduction to NAS	https://www.youtube.com/watch?v=KXQUpJWTrlA	This video covers various aspects of NAS in details

E-Book Links

Topics	URL	Page Number
Storage Systems Architecture	http://read.pudn.com/downloads168/ebook/772307/STF2-0SectionIntroduction.pdf	1 to 7
Information Storage and Management	http://web.info.uvt.ro/~hpopa/IM/ISM.pdf	117 to 160