# What is DATA ?

It is a collection of raw facts.

The different form of data is given below: -

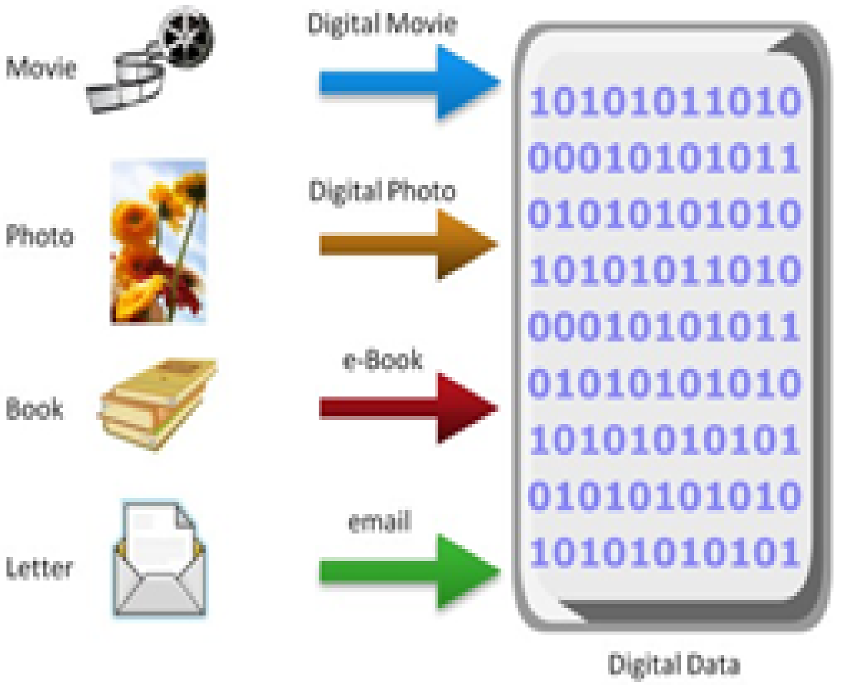
1. In Computing (23091988)
2. In Computer Components
3. In Telecommunications (Voice Call)
4. In DBMS

# What is Data?

**Data**

It is a collection of raw facts from which conclusions may be drawn.

- Data is converted into more convenient form – digital data
- Factors for digital data growth are:
  - Increase in data-processing capabilities
  - Lower cost of digital storage
  - Affordable and faster communication technology
  - Proliferation of applications and smart devices



# *Reason for growth of digital data*

- With the advancement of computer and communication technologies, the rate of data generation and sharing has increased exponentially. 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 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 the decrease in the cost of storage devices have provided low-cost storage solutions. This cost benefit has increased the rate at which digital data is generated and stored.
- **Affordable and faster communication technology:** The rate of sharing digital data is now much faster than traditional approaches. A handwritten letter might take a week to reach its destination, whereas it typically takes only 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.

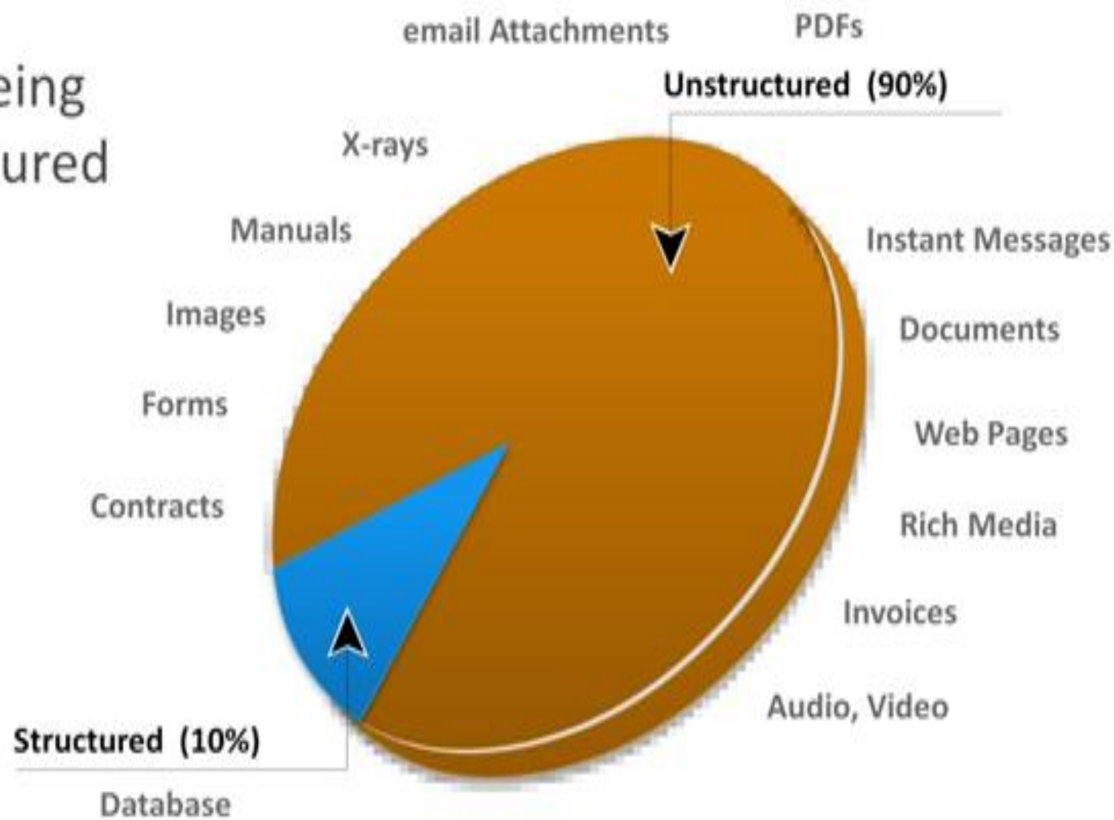
# Key Notes Regarding DATA

Research & Business Data

1. **Seismology:-** Involves collecting data related to various sources and parameters of earthquakes, and other relevant data that needs to be processed to derive meaningful information.
2. **Product Data:** - Involves inventory, description, pricing , availability and sales.
3. **Customer Data:** - A combination of data related to a company's customers, such as order details, shipping addresses, and purchase history.
4. **Medical Data:** - Involves patient history, radiological images, details of medication and other treatment and insurance

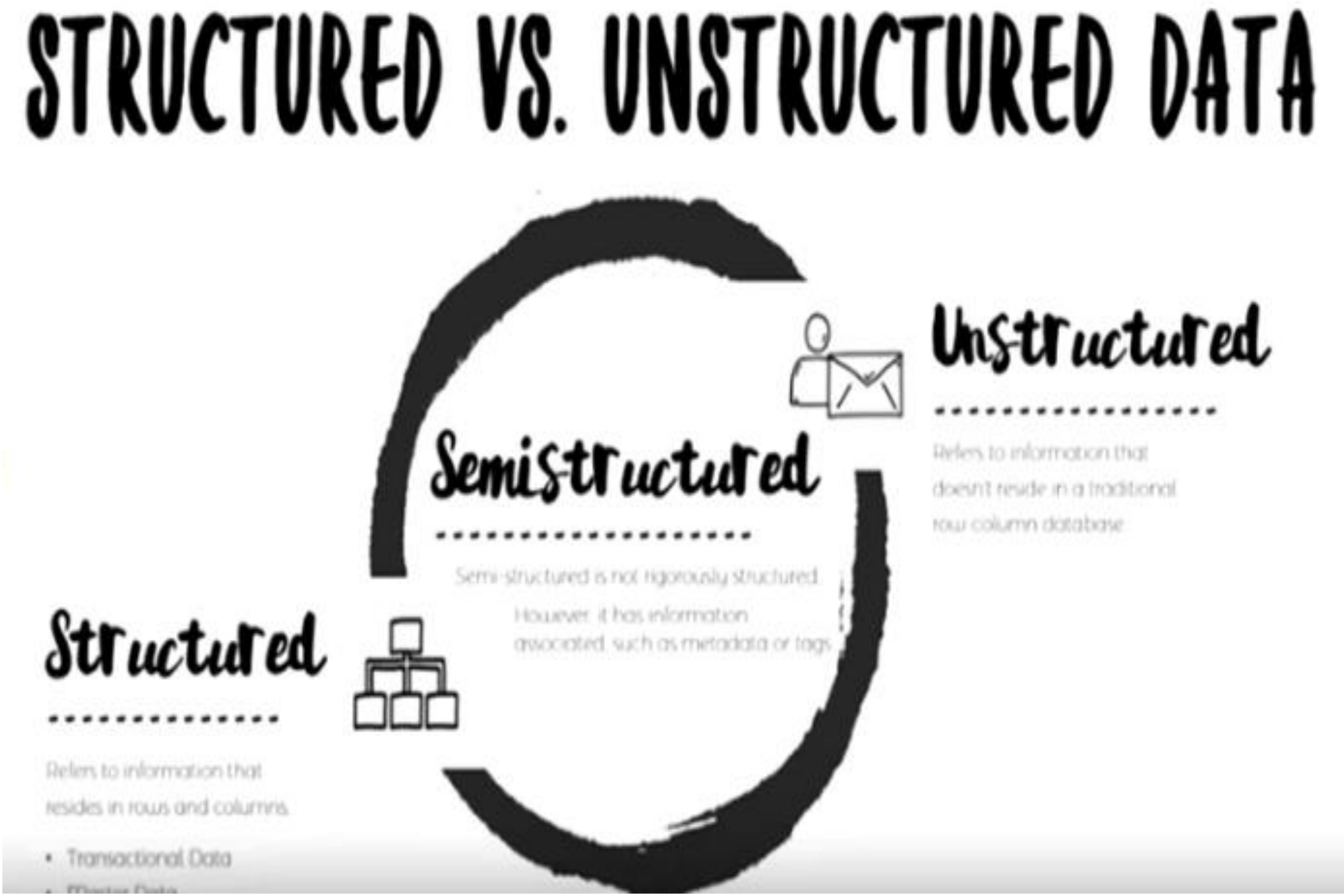
# Types of Data

- Data can be classified as:
  - Structured
  - Unstructured
- Majority of data being created is unstructured



# Types of Data

- Data can be classified **as structured or unstructured** based on how it is stored and managed. 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).
- Data is unstructured if its elements cannot be stored **in rows and columns, which makes it difficult to query and retrieve by applications.** For example, customer contacts that are stored in various forms such as sticky notes, e-mail messages, business cards, or even digital format files, such as .doc, .txt, and .pdf. Due to its unstructured nature, it is difficult to retrieve this data using a traditional customer relationship management application. A vast majority of new data being created today is unstructured. The industry is challenged with new architectures, technologies, techniques, and skills to store, manage, analyze, and derive value from unstructured data from numerous sources.


STRUCTURED VS. UNSTRUCTURED DATA
Unstructured
Refers to information that doesn't reside in a traditional row column database
Semistructured
Semi-structured is not rigorously structured.
However, it has information associated, such as metadata or tags
Structured
Refers to information that resides in rows and columns.
• Transactional Data

# Relational Database

| Client ID | First | Last |
|---|---|---|
| 351569 | John | Doe |
| 351570 | Mary | |
| 351571 | Susan | |
| 351572 | Bill | |

| Client ID | Time | Transaction | Amount |
|---|---|---|---|
| 351569 | 5:06 PM | Withdrawal | $60 |
| 707620 | 5:06 PM | Deposit | $31.57 |
| 884786 | 5:08 PM | Withdrawal | $100 |
| 505681 | 5:09 PM | Transfer | $500 |

# History of SQL

- SEQUEL developed at IBM
- Name changed to SQL
- Launched by Oracle in 1979

# Unstructured Data

- Data not in fixed fields
- Text, presentations, images, etc
- The majority of business data
- Convert the use text-mining programs
- Difficult and time consuming

# Semi-Structured Data

- Fields are marked
- Data are identifiable
- XML (Extensible Markup Language)
- JSON (JavaScript Object Notation)

<xml />

# NoSQL Databases

- Use a semi-structured format
- MongoDB uses JSON
- Flexible structure and often faster
- 16% vs 79% for relational databases
- No standardized query language

| | Structured Data | Unstructured Data |
|---|---|---|
| **Characteristics** | • Pre-defined data models<br>• Usually text only<br>• Easy to search | • No pre-defined data model<br>• May be text, images, sound, video or other formats<br>• Difficult to search |
| **Resides in** | • Relational databases<br>• Data warehouses | • Applications<br>• NoSQL databases<br>• Data warehouses<br>• Data lakes |
| **Generated by** | Humans or machines | Humans or machines |
| **Typical applications** | • Airline reservation systems<br>• Inventory control<br>• CRM systems<br>• ERP systems | • Word processing<br>• Presentation software<br>• Email clients<br>• Tools for viewing or editing media |
| **Examples** | • Dates<br>• Phone numbers<br>• Social security numbers | • Text files<br>• Reports<br>• Email messages |

# Big Data

**Big Data**

It refers to data sets whose sizes are beyond the ability of commonly used software tools to capture, store, manage, and process within acceptable time limits.

- Includes both structured and unstructured data generated by variety of sources
- Big data analysis in real time requires new techniques and tools that provide:
  - High performance
  - Massively parallel processing (MPP) data platforms
  - Advanced analytics
- Big data analytics provide an opportunity to translate large volumes of data into right decisions

# What is Data

- Data is collection of raw facts and figures is called data Data is collected from different sources, it is collected for different purposes.
- Data may consist of numbers, characters, symbols or pictures etc.

# What is information

- The processed data is called information. Information is an organized and processed form of data. It is more meaningful than data and is used for decision making.

# INFORMATION

1. The term "**INFORMATION**" comes from a singular Latin word "**Informer**" which refers to "**the act of informing**".
2. INFORMATION is a processed data and the INFORMATION described as that form of data which is processed, organized and structured.
3. INFORMATION must carry a logical meaning.
4. When the data is transformed into INFORMATION, and it is free form unnecessary details.
5. The INFORMATION is "**what we get**" is totally depend on the "**Input Data**".
6. INFORMATION is the output of the data.

# Difference between data and information

| Data | Information |
|---|---|
| Data consists of Unprocessed raw facts. | Information is the Processed form of data. |
| Data is used as input in computer | Information is the output of computer |
| Data is not meaningful. | Information is meaningful |
| Data is normally huge in its volume | Information is normally Short in volume. |

| | |
|---|---|
| • Data is the asset of an organization and not available for sale | • Information is normally available to people for sale |
| • Data is difficult or even impossible to reproduce. | • Information is easier to reproduce If lost. |
| • Data is used rarely. | • Information ia used frequently. |
| • Data is an independent entity. | • Information depend on data. |
| | • Information is very important for decision making. |

# What do you Think ?

- What is your contribution to the digital Universe ( how many Mb's have you generated till date ?? )

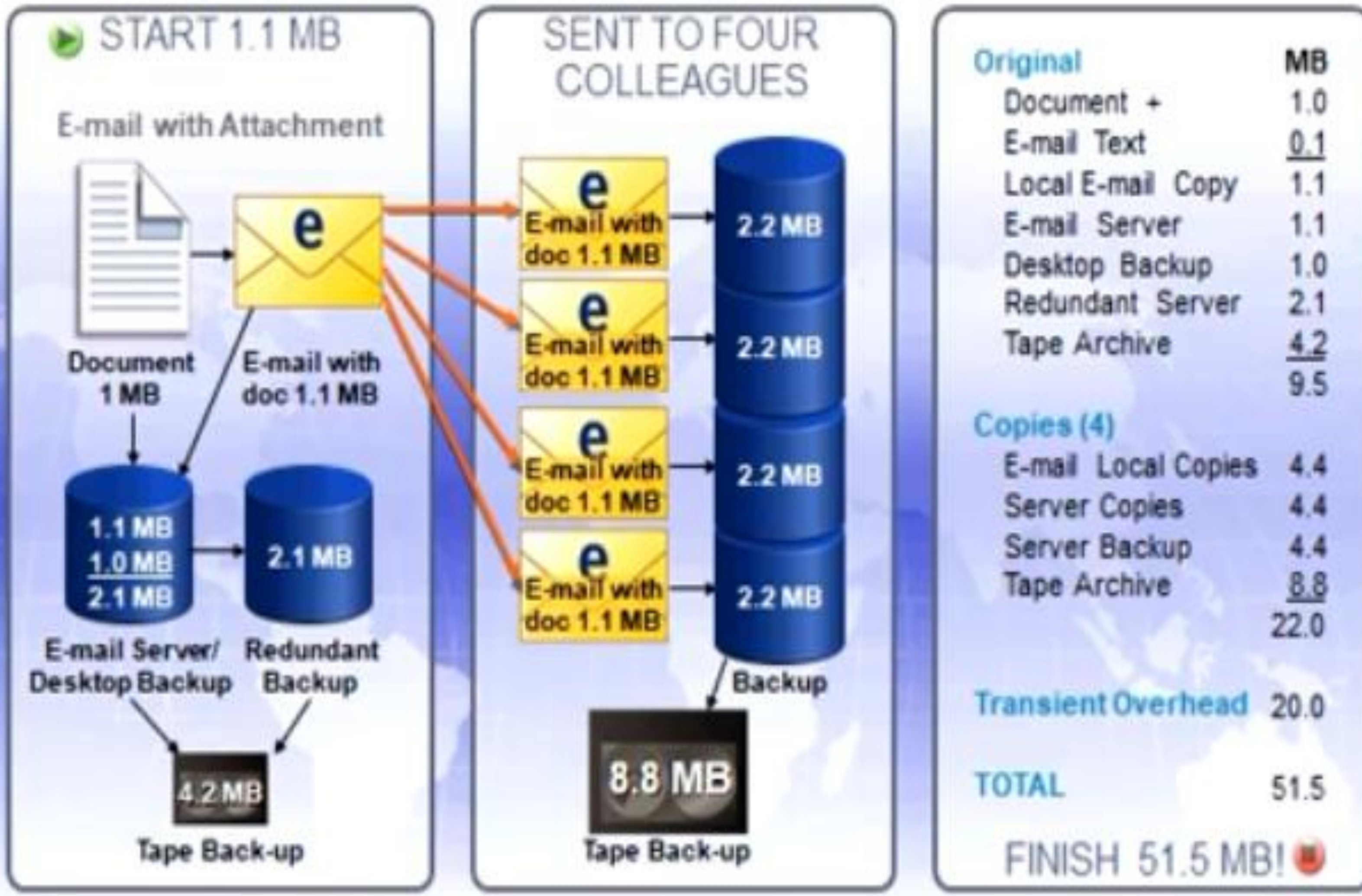
a) <100 GB

b) 100 GB - 500 GB

c) 500 GB – 1 TB

d) > 1 TB

# How Much Data do YOU Create?



# Storage

- Stores data created by individuals and organizations
  - Provides access to data for further processing
- Examples of storage devices are:
  - Media card in a cell phone or digital camera
  - DVDs, CD-ROMs
  - Disk drives
  - Disk arrays
  - Tapes

# Data Center

**Data Center**

It is a facility that contains storage, compute, network, and other IT resources to provide centralized data-processing capabilities.

- Core elements of a data center
  - Application
  - Database management system (DBMS)
  - Host or Compute
  - Network
  - Storage
- These core elements work together to address data-processing requirements

# Storage

- Data created by individuals or businesses must be stored so that it is easily accessible for further processing.
- In a computing environment, devices designed for storing data are termed storage devices or simply storage.
- The type of storage used varies based on the type of data and the rate at which it is created and used. Devices, such as a media card in a cell phone or digital camera, DVDs, CD-ROMs, and disk drives in personal computers are examples of storage devices.
- Businesses have several options available for storing data, including internal hard disks, external disk arrays, and tapes.

# Storage

- Historically, organizations had centralized computers (mainframes) and **information storage devices (tape reels and disk packs) in their data center.**

- The evolution of open systems, their affordability, and ease of deployment 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. **These storage devices could not be shared with any other servers. This approach is referred to server-centric storage architecture.**

- In this 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 proliferation of departmental servers in an enterprise resulted in unprotected, unmanaged, fragmented islands of information and increased capital and operating expenses.**

# Storage

- To overcome these challenges, storage evolved from server-centric to information-centric architecture**. In this 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.**

# CHALLENGES IN DATA STORAGE AND DATA MANAGEMENT, SOLUTIONS AVAILABLE FOR DATA STORAGE

# Challenges In Data Storage And Data Management

- Historically, Organizations had centralized computers (mainframe) and information storage devices (tape reels and disk packs) in their data center.
- Open Systems

Due to 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 , the storage was typically internal to the server.

- Issues

  The proliferation of departmental servers in an enterprise resulted in unprotected, unmanaged, fragmented islands of information and increased operating cost.

  There were very limited policies and processes for managing these servers and the data created.

- Solution

  Storage technology evolved from non-intelligent internal storage to intelligent networked storage(see Figure 1-4)

# Solutions Available For Data Storage

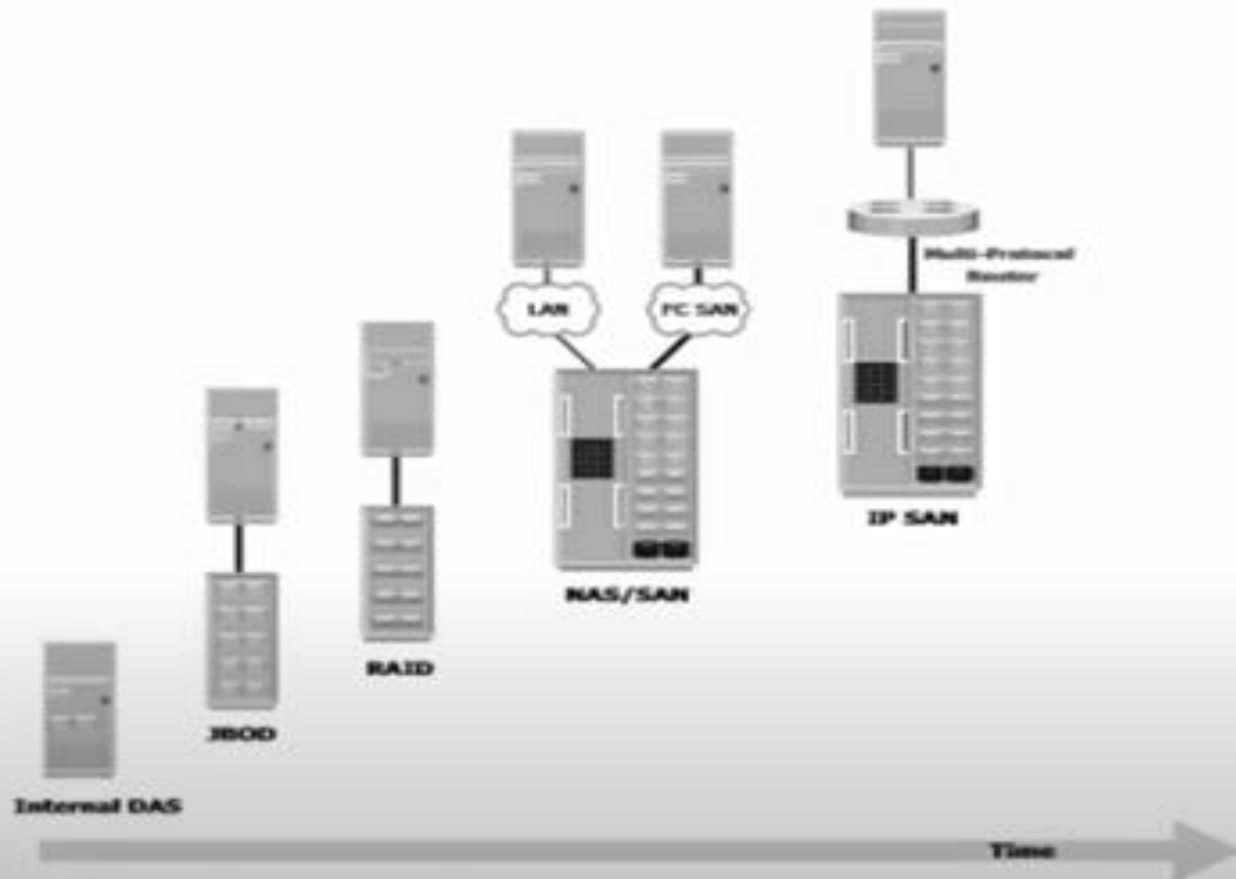


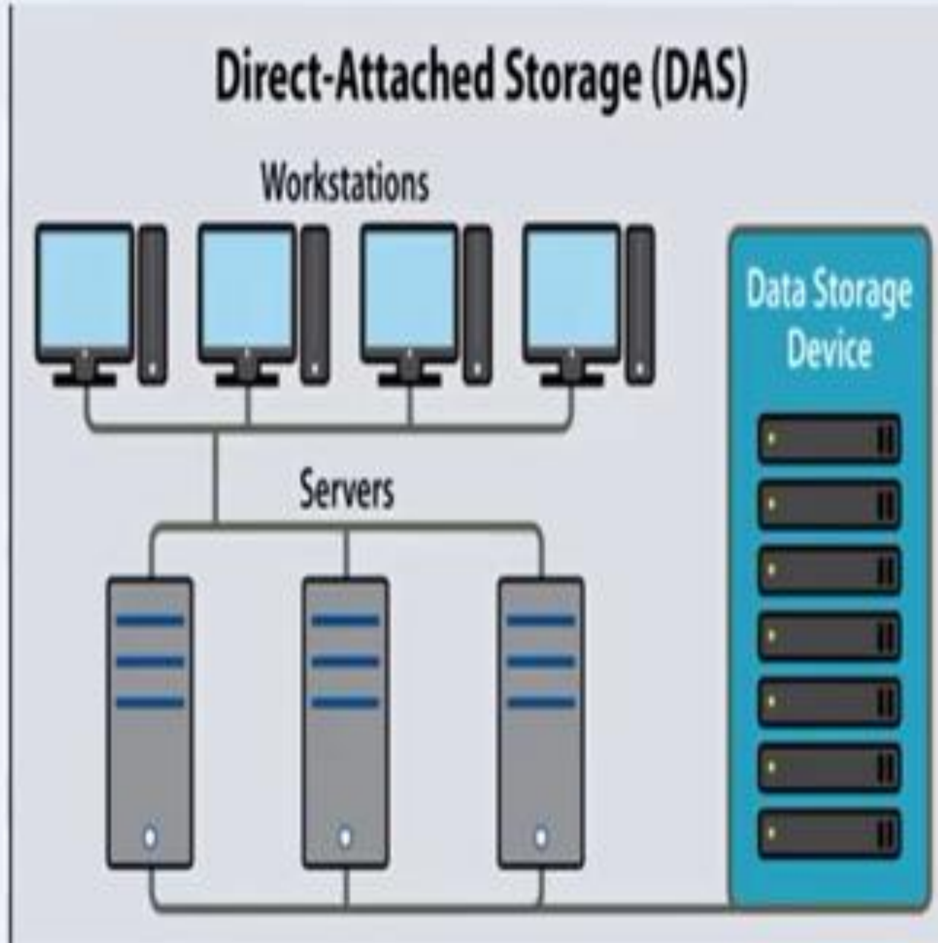

**Figure 1-4:** Evolution of storage architectures

# Redundant Array of Independent Disks (RAID)

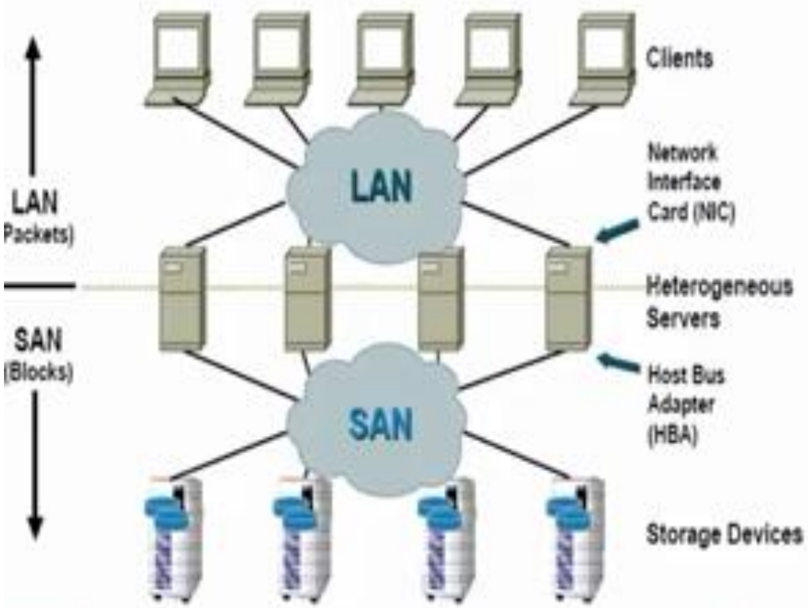
- This technology was developed to address the cost, performance, and availability requirements of data.
- It continues to evolve today and is used in all storage architectures such as DAS, SAN, and so on.

# Direct-attached storage (DAS):

- This type of storage connects directly to a server (host) or a group of servers in a cluster.
- Storage can be either internal or external to the server.
- External DAS alleviated the challenges of limited internal storage capacity.



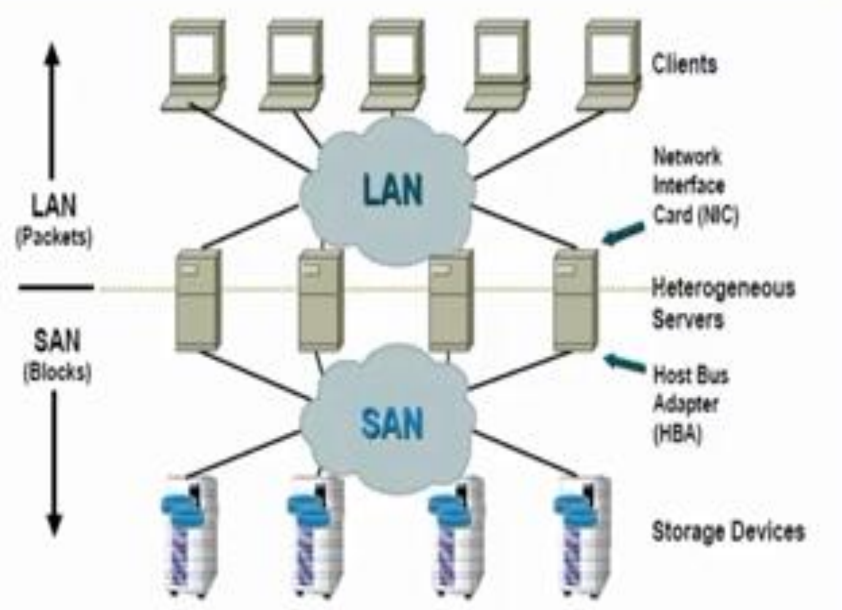
# Storage area network (SAN):




N Is a Dedicated Network for Attaching Servers to Storage Devices

- This is a dedicated, high-performance Fibre channel network to facilitate block-level communication between servers and storage.
- Storage is partitioned and assigned to a server for accessing its data.
- Offers scalability, availability, performance, and cost benefits

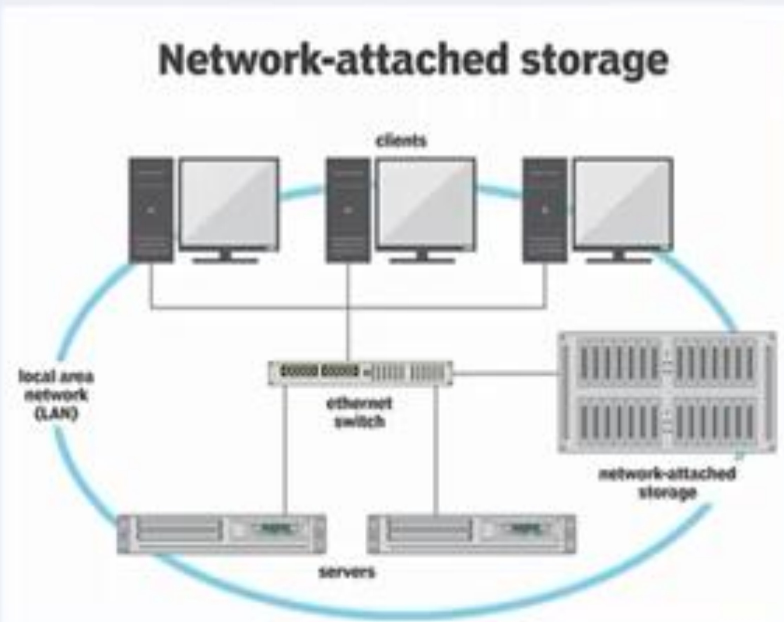
# Storage area network (SAN):



SAN Is a Dedicated Network for Attaching Servers to Storage Devices

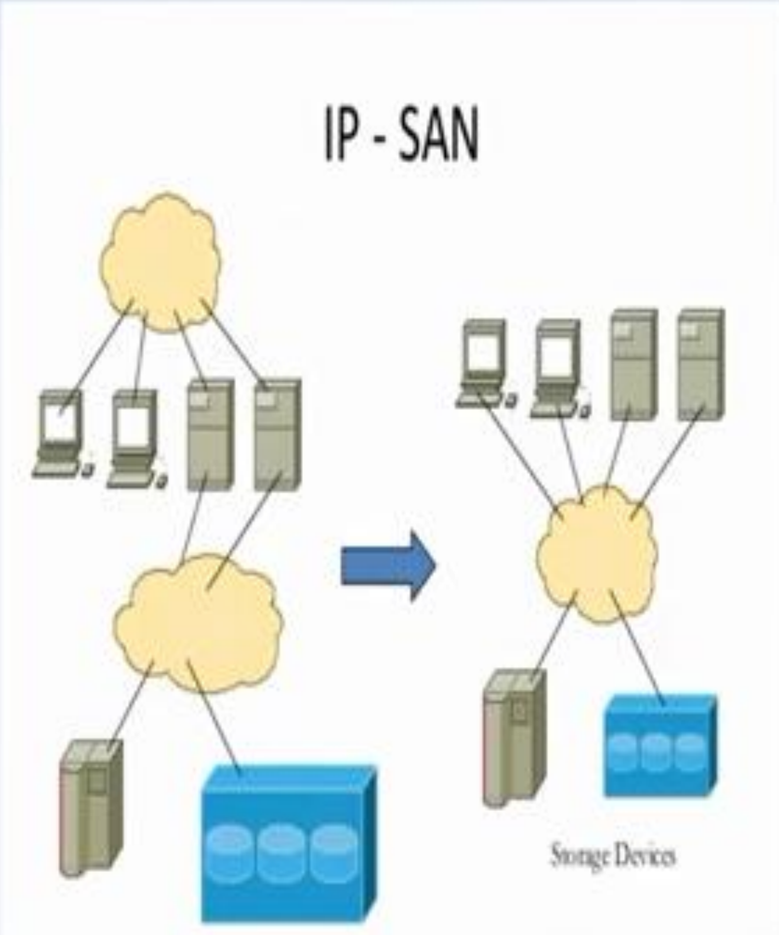
- This is a dedicated, high-performance Fibre channel network to facilitate block-level communication between servers and storage.
- Storage is partitioned and assigned to a server for accessing its data.
- Offers scalability, availability, performance, and cost benefits

# Network-attached storage (NAS):

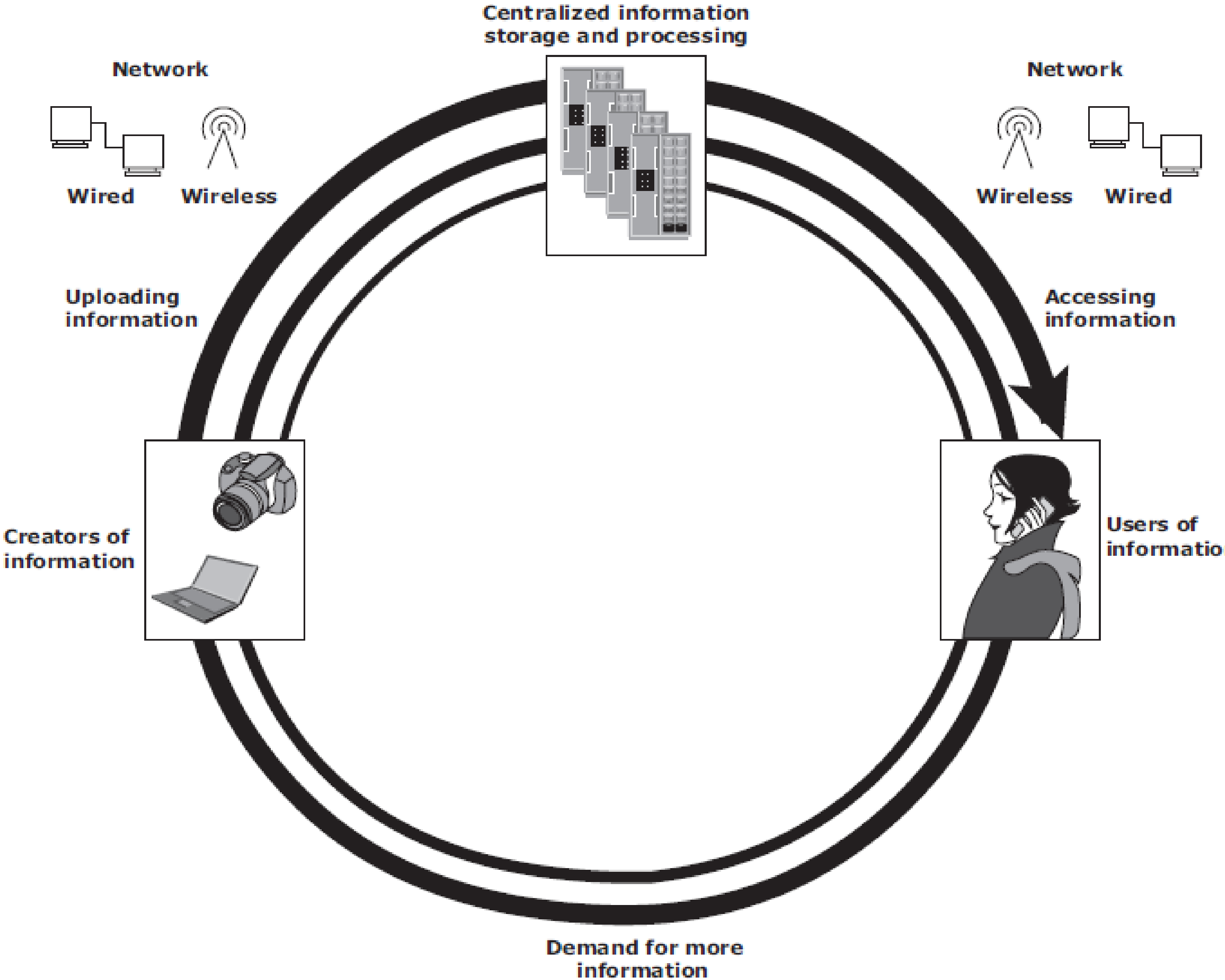



- Dedicated storage for file serving applications.
- Connects to an existing communication network (LAN) and provides file access to heterogeneous clients.
- Offers higher scalability, availability, performance, and cost benefits compared to general purpose file servers.

# Internet Protocol SAN (IP-SAN):




- IP-SAN is a convergence of technologies used in SAN and NAS.
- IP-SAN provides block-level communication across a local or wide area network (LAN or WAN), resulting in greater consolidation and availability of data.


Centralized information storage and processing
Network
Wired
Wireless
Network
Wireless
Wired
Uploading information
Accessing information
Creators of information
Users of information
Demand for more information

# TOPICS

Review data creation and the amount of data being created and understand the value of data to a business, challenges in data storage and data management, Solutions available for data storage, Core elements of a data center infrastructure, role of each element in supporting business activities

# Data Center Infrastructure

- Provide centralized data processing capabilities across the enterprise.
- Store and manage large amounts of mission-critical data.
- Includes computers, storage systems, network devices, dedicated power backups, and environmental controls (such as air conditioning and fire suppression).
- Large organizations often maintain more than one data center to distribute data processing workloads and provide backups in the event of a disaster.

The storage requirements are met by a combination of storage architectures.

# Data Center

**Data Center**

It is a facility that contains storage, compute, network, and other IT resources to provide centralized data-processing capabilities.

- Core elements of a data center
  - Application
  - Database management system (DBMS)
  - Host or Compute
  - Network
  - Storage
- These core elements work together to address data-processing requirements

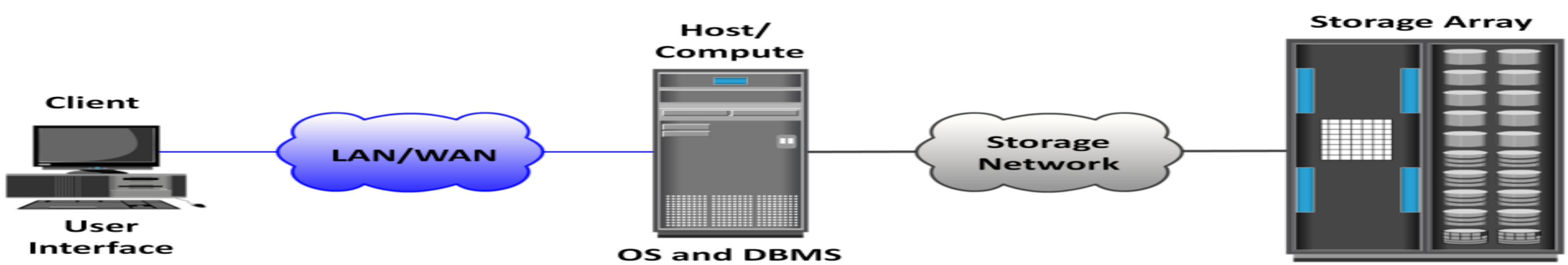
# Data center

- Organizations maintain data centers to provide centralized data-processing capabilities across the enterprise.
- Data centers house and manage large amounts of data. The data center infrastructure includes hardware components, such as computers, storage systems, network devices, and power backups; and software components, such as applications, operating systems, and management software.
- It also includes environmental controls, such as air conditioning, fire suppression, and ventilation.
- Large organizations often maintain more than one data center to distribute data processing workloads and provide backup if a disaster occurs.

# Application:

- An application is a computer program that provides the logic for computing operations. Applications, such as an order processing system, can be layered on a database, which in turn uses operating system services to perform read/write operations to storage devices.

Data Center: Online Order Transaction System Example



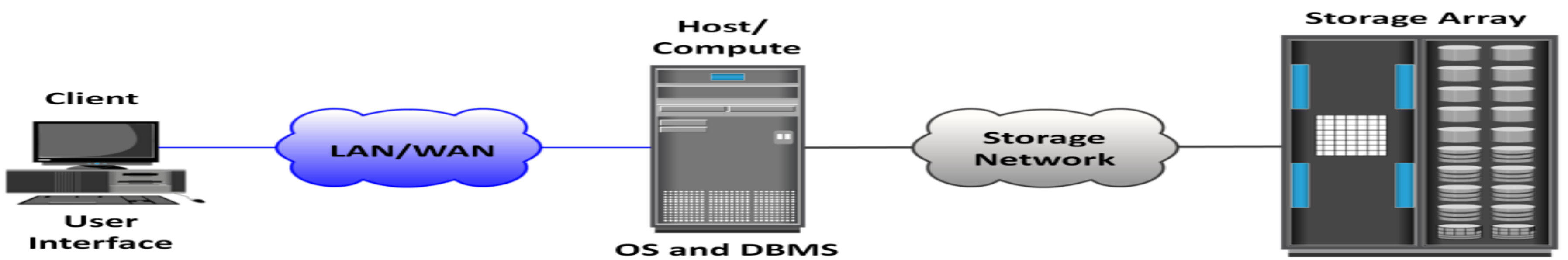
# Application

- A software program that provides logic for computing operatic
- Commonly deployed applications in a data center
  - Business applications – email, enterprise resource planning (ERP
    decision support system (DSS)
  - Management applications – resource management, performanc
    tuning, virtualization
  - Data protection applications – backup, replication
  - Security applications – authentication, antivirus
- Key I/O characteristics of an application
  - Read intensive vs. write intensive
  - Sequential vs. random
  - I/O size

# 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.

Data Center: Online Order Transaction System Example



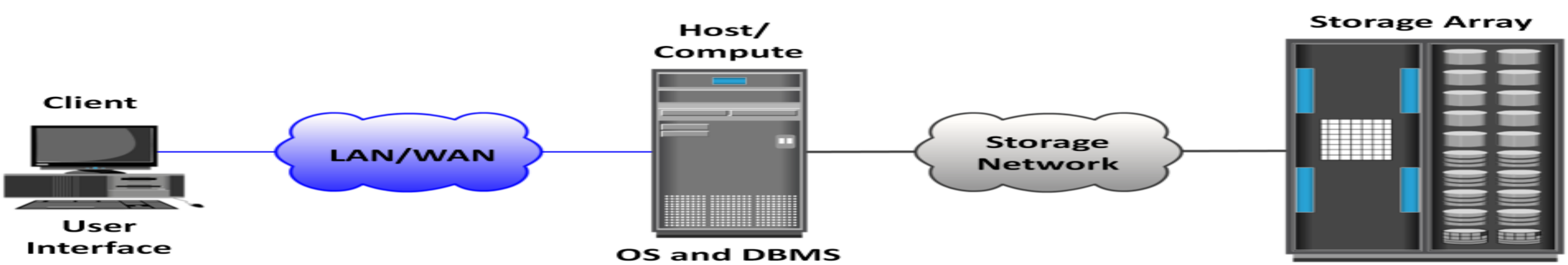
# Database Management System (DBMS)

- Database is a structured way to store data in logically organized tables that are interrelated
  - Helps to optimize the storage and retrieval of data
- DBMS controls the creation, maintenance, and use of databases
  - Processes an application's request for data
  - Instructs the OS to retrieve the appropriate data from storage
- Popular DBMS examples are MySQL, Oracle RDBMS, SQL Server, etc.

# Server and operating system:

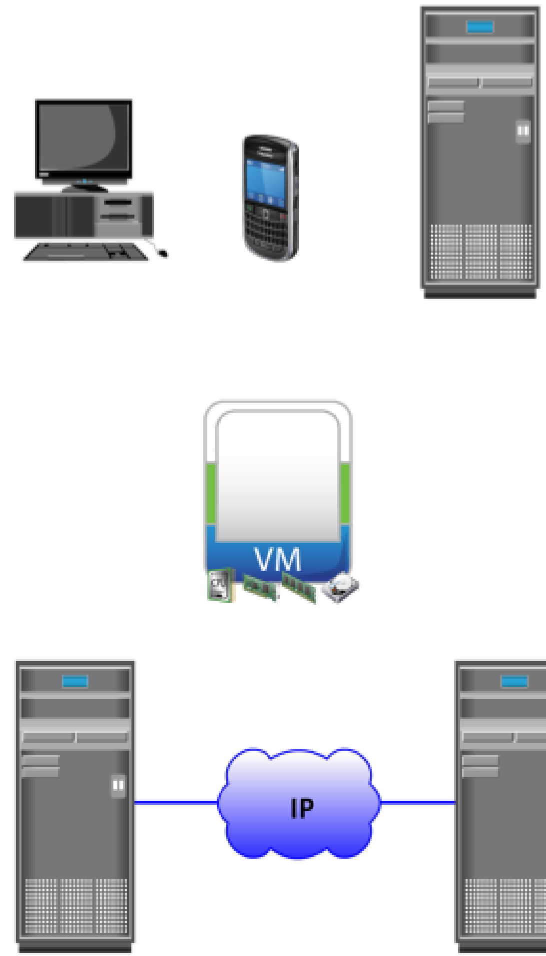
- A computing platform that runs applications and databases.

Data Center: Online Order Transaction System Example



# Host (Compute)

- Resource that runs applications with the help of underlying computing components
  - Example: Servers, mainframes, laptop, desktops, tablets, server clusters, etc.
- Consists of hardware and software components
- Hardware components
  - Include CPU, memory, and input/output (I/O) devices
- Software components
  - Include OS, device driver, file system, volume manager, and so on



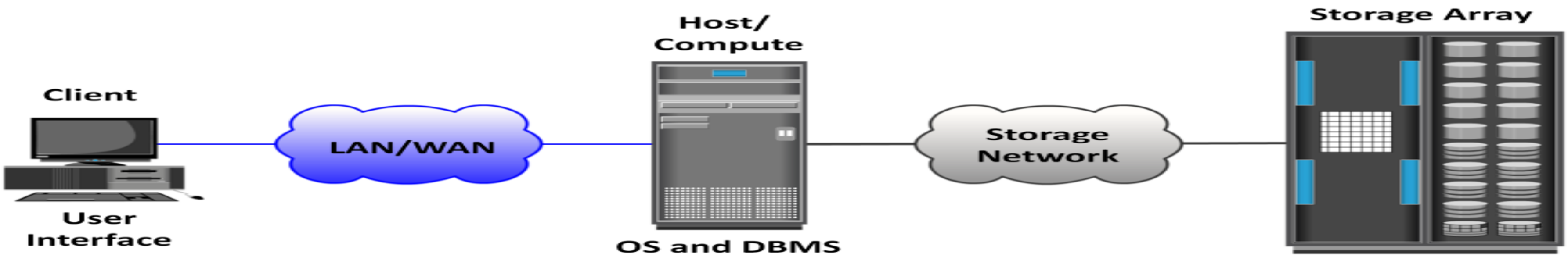
# Operating Systems and Device Driver

- In a traditional environment OS resides between the applications and the hardware
  - Responsible for controlling the environment
- In a virtualized environment virtualization layer works between OS and hardware
  - Virtualization layer controls the environment
  - OS works as a guest and only controls the application environment
  - In some implementation OS is modified to communicate with virtualization layer
- Device driver is a software that enables the OS to recognize the specific device

# Network:

- A data path that facilitates communication between clients and servers or between servers and storage.

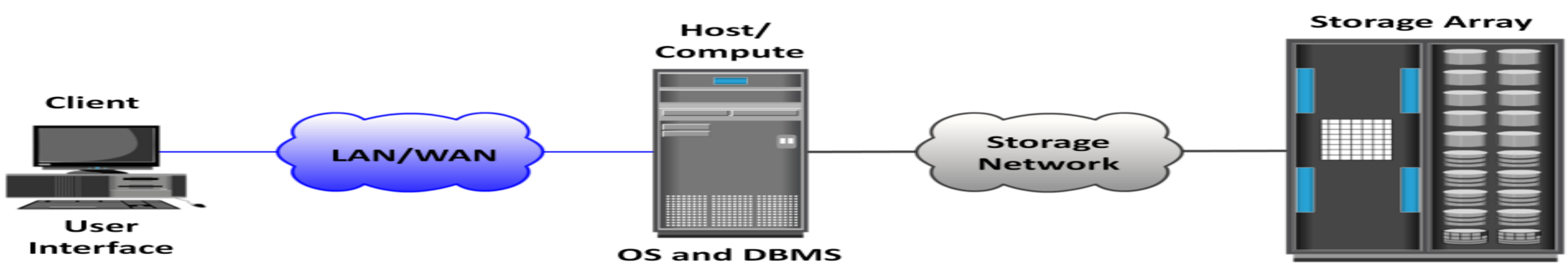
Data Center: Online Order Transaction System Example



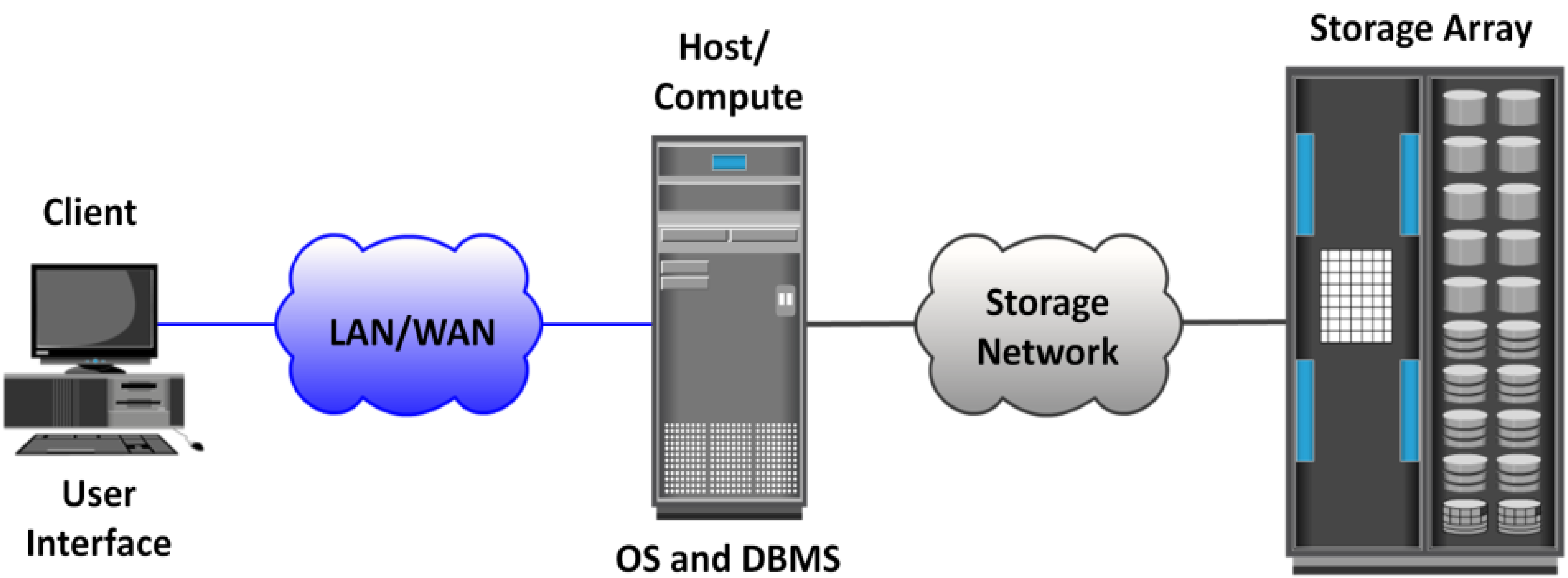
# Storage array:

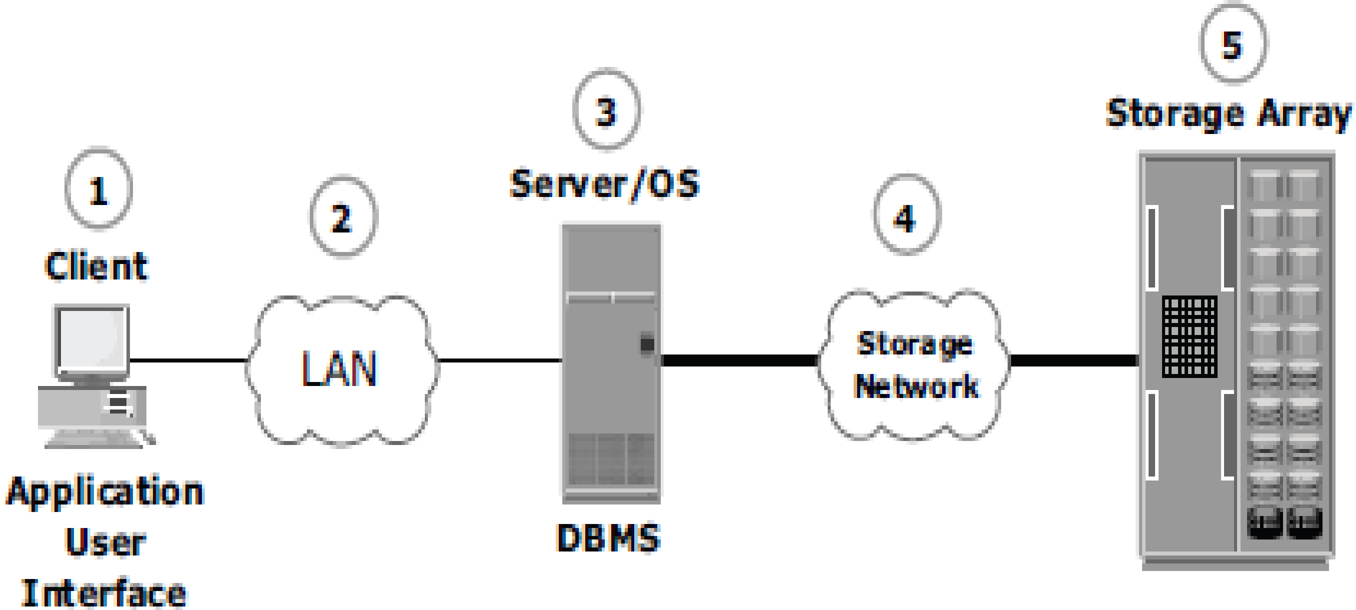
- A device that stores data persistently for subsequent use. These core elements are typically viewed and managed as separate entities, but all the elements must work together to address data processing requirements.

Data Center: Online Order Transaction System Example



# Data Center: Online Order Transaction System Example






1 A customer places an order through the AUI of the order processing application software located on the client computer.

2 The client connects to the server over the LAN and accesses the DBMS located on the server to update the relevant information such as the customer name, address, payment method, products ordered, and quantity ordered.

3 The DBMS uses the server operating system to read and write this data to the database located on physical disks in the storage array.

4 The Storage Network provides the communication link between the server and the storage array and transports the read or write commands between them.

5 The storage array, after receiving the read or write commands from the server, performs the necessary operations to store the data on physical disks.

# Example

- A customer places an order through a client machine connected over a LAN/WAN to a host running an order-processing application.
- The client accesses the DBMS on the host through the application to provide order-related information, such as the customer name, address, payment method, products ordered, and quantity ordered.
- The DBMS uses the host operating system to write this data to the physical disks in the storage array. The storage networks provide the communication link between the host and the storage array and transports the request to read or write data between them.
- The storage array, after receiving the read or write request from the host, performs the necessary operations to store the data on physical disks.

# Key Characteristics of a Data Center

# Key Requirements for Data Center Elements

- **Uninterrupted operation of data centers is critical to the survival and success of a business.** Although the characteristics shown in the slide are applicable to all elements of the data center infrastructure, the focus here is on storage systems.
- **Availability:** A data center should ensure the availability of information when required. Unavailability of information could cost millions of dollars per hour to businesses, such as financial services, telecommunications, and e-commerce.
- **Security:** Data centers must establish policies, procedures, and core element integration to prevent unauthorized access to information.

# Key Requirements for Data Center Elements

- **Scalability:** Business growth often requires deploying more servers, new applications, and additional databases. Data center resources should scale based on requirements, without interrupting business operations.
- **Performance:** All the elements of the data center should provide optimal performance based on the required service levels.
- **Data integrity:** Data integrity refers to mechanisms, such as error correction codes or parity bits, which ensure that data is stored and retrieved exactly as it was received.

# Key Requirements for Data Center Elements

- **Capacity:** Data center operations require adequate resources to store and process large amounts of data, efficiently. When capacity requirements increase, the data center must provide additional capacity without interrupting availability or with minimal disruption. Capacity may be managed by reallocating the existing resources or by adding new resources.
- **Manageability:** A data center should provide easy and integrated management of all its elements. Manageability can be achieved through automation and reduction of human (manual) intervention in common tasks.

# Managing data center

- Managing a data center involves many tasks. The key management activities include the following:

- **Monitoring:** It is a continuous process of gathering information on various elements and services running in a data center. The aspects of a data center that are monitored include security, performance, availability, and capacity.

- **Reporting:** It is done periodically on resource performance, capacity, and utilization. Reporting tasks help to establish business justifications and chargeback of costs associated with data center operations.

- **Provisioning:** It is a process of providing the hardware, software, and other resources required to run a data center. Provisioning activities primarily include resources management to meet capacity, availability, performance, and security requirements.

# Managing Data Center

- Key management activities include
  - Monitoring
    - Continuous process of gathering information on various elements and services running in a data center
  - Reporting
    - Details on resource performance, capacity, and utilization
  - Provisioning
    - Configuration and allocation of resources to meet the capacity, availability, performance, and security requirements
- Virtualization and cloud computing have changed the way data center infrastructure resources are provisioned and managed

# Virtualization and cloud computing

- Virtualization and cloud computing have dramatically changed the way data center infrastructure resources are provisioned and managed. Organizations are rapidly deploying virtualization on various elements of data centers to optimize their utilization. Further, continuous cost pressure on IT and on-demand data processing requirements have resulted in the adoption of cloud computing.

# Virtualization

- Virtualization is a technique of abstracting physical resources, such as compute, storage, and network, and making them appear as logical resources. Virtualization existed in the IT industry for several years and in different forms. Common examples of virtualization are virtual memory used on compute 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 aggregation of the power of all CPUs (in megahertz). Virtualization also enables centralized management of pooled resources

# Virtualization

- 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 with procurement and management of new physical resources. Moreover, fewer physical resources means less space and energy, which leads to better economics and green computing

# Virtualization: An Overview

- Virtualization is a technique of abstracting physical resources and making them appear as logical resources
  - For example partitioning of raw disks
- Pools physical resources and provides an aggregated view of physical resource capabilities
- Virtual resources can be created from pooled physical resources
  - Improves utilization of physical IT resources

# Lesson 1: RAID Overview

During this lesson the following topics are covered:

- RAID Implementation methods
- RAID array components
- RAID techniques

# Why RAID?

**RAID**

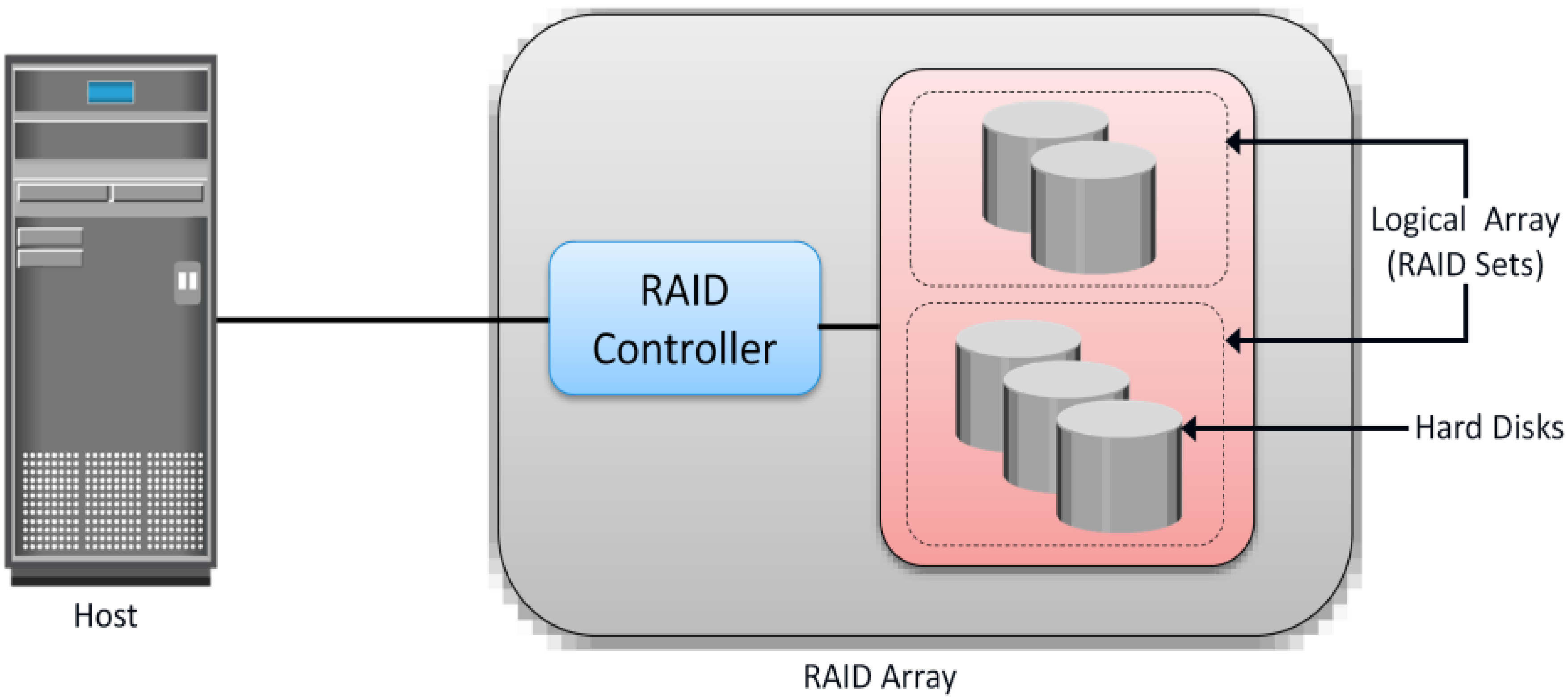
It is a technique that combines multiple disk drives into a logical unit (RAID set) and provides protection, performance, or both.

- Due to mechanical components in a disk drive it offers limited performance
- An individual drive has a certain life expectancy and is measured in MTBF:
  - For example: If the MTBF of a drive is 750,000 hours, and there are 1000 drives in the array, then the MTBF of the array is 750 hours (750,000/1000)
- RAID was introduced to mitigate these problems

# RAID Implementation Methods

- Software RAID implementation
  - Uses host-based software to provide RAID functionality
  - Limitations
    - Use host CPU cycles to perform RAID calculations, hence impact overall system performance
    - Support limited RAID levels
    - RAID software and OS can be upgraded only if they are compatible
- Hardware RAID Implementation
  - Uses a specialized hardware controller installed either on a host or on an array

# RAID Array Components

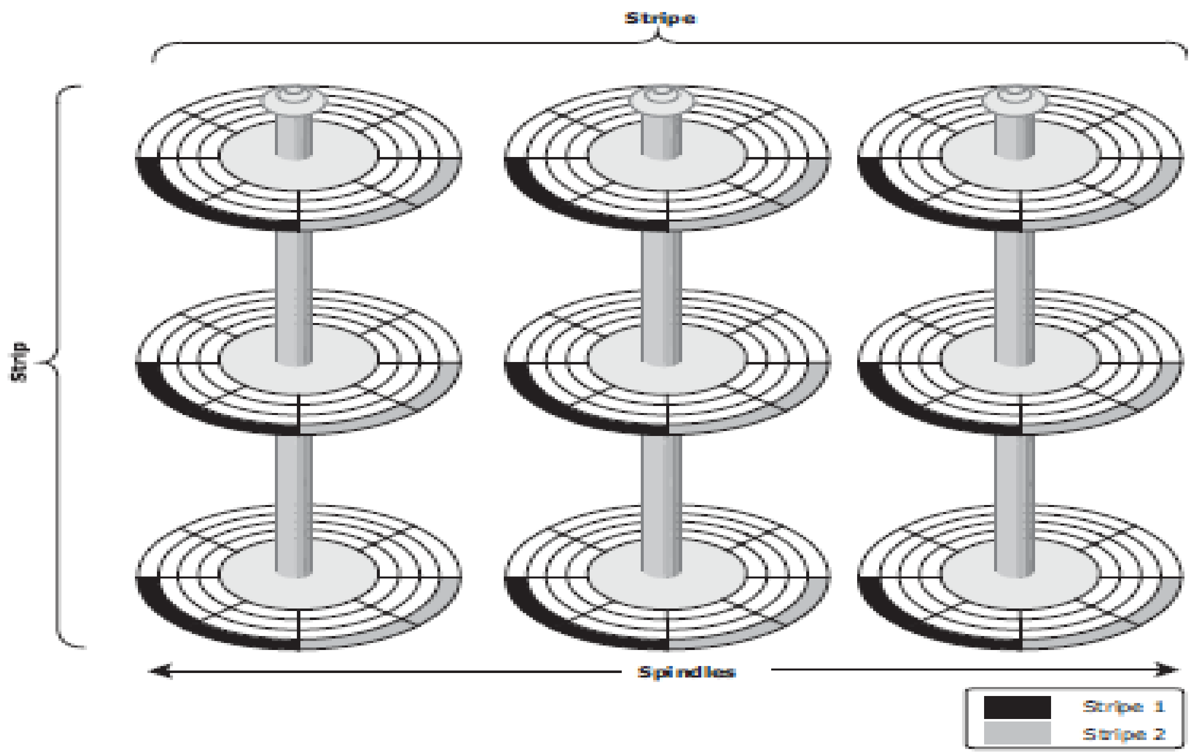


# RAID Techniques

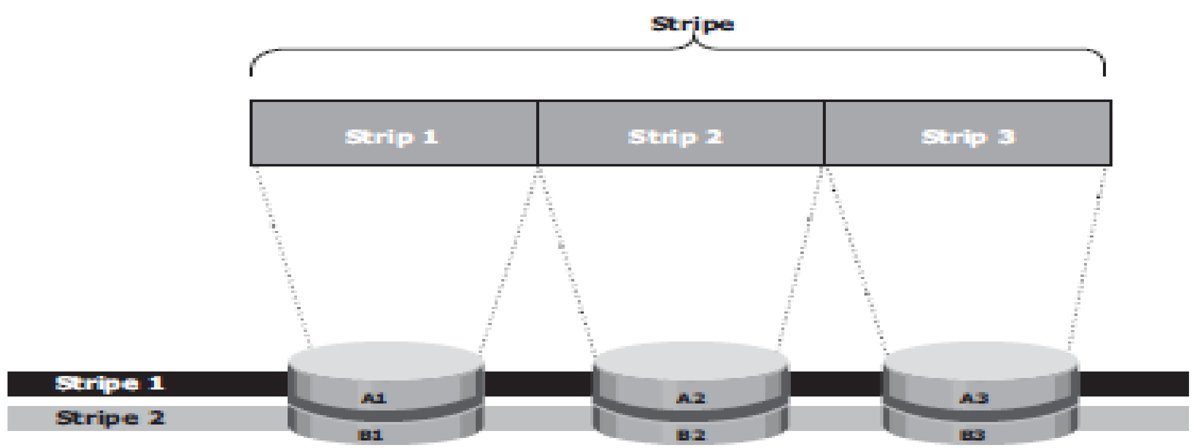
- Three key techniques used for RAID are:
  - Striping
  - Mirroring
  - Parity

# Striping

- A RAID set is a group of disks.
- Within each disk, a predefined number of contiguously addressable disk blocks are defined as *strips*.
- The set of aligned strips that spans across all the disks within the RAID set is called a *stripe*.



Stripe
Strip
Spindles
Stripe 1
Stripe 2

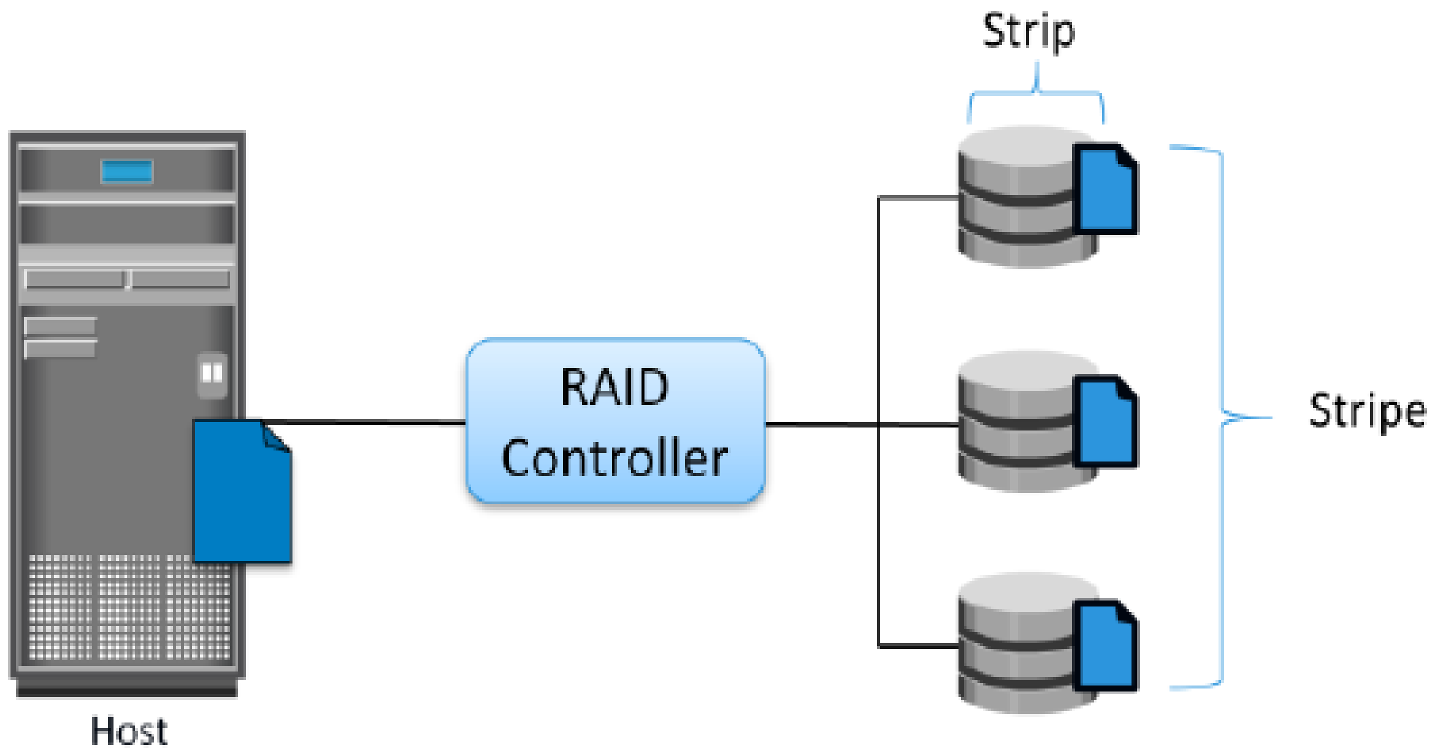
Stripe
Strip 1
Strip 2
Strip 3
Stripe 1
Stripe 2
A1
A2
A3
B1
B2
B3

# Striping

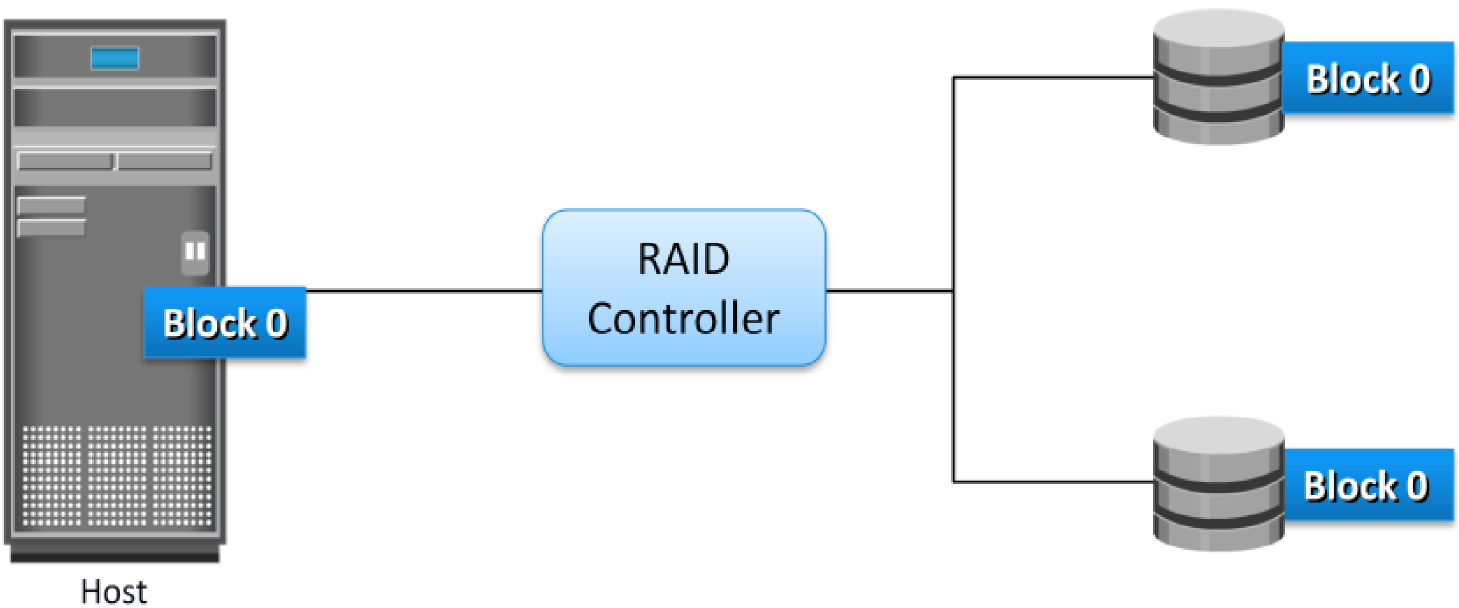
– *Strip size* (also called *stripe depth*) describes the number of blocks in a *strip*, and is the maximum amount of data that can be written to or read from a single HDD in the set before the next HDD is accessed, assuming that the accessed data starts at the beginning of the strip. Note that all strips in a stripe have the same number of blocks, and decreasing strip size means that data is broken into smaller pieces when spread across the disks.

– Stripe size is a multiple of strip size by the number of HDDs in the RAID set.
– *Stripe width* refers to the number of data strips in a stripe.
– Striped RAID does not protect data unless parity or mirroring is used.
– However, striping may significantly improve I/O performance.
– Depending on the type of RAID implementation, the RAID controller can be configured to access data across multiple HDDs simultaneously.

# RAID Technique – Striping

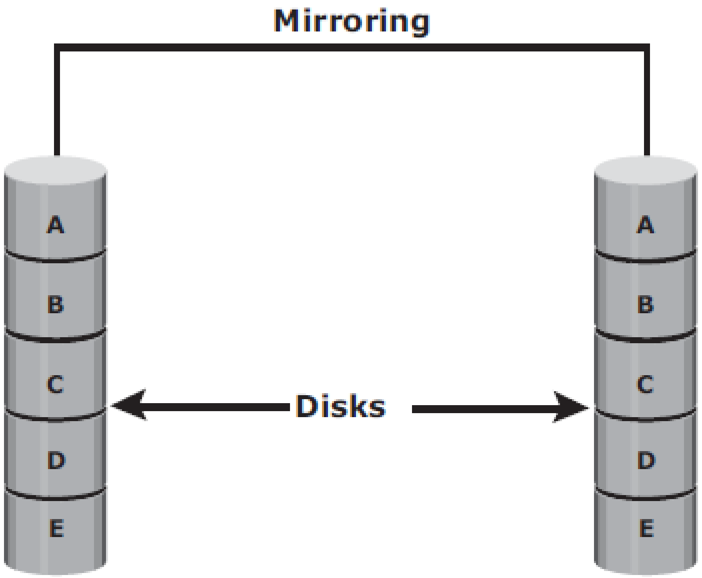


# RAID Technique – Mirroring



# Mirroring

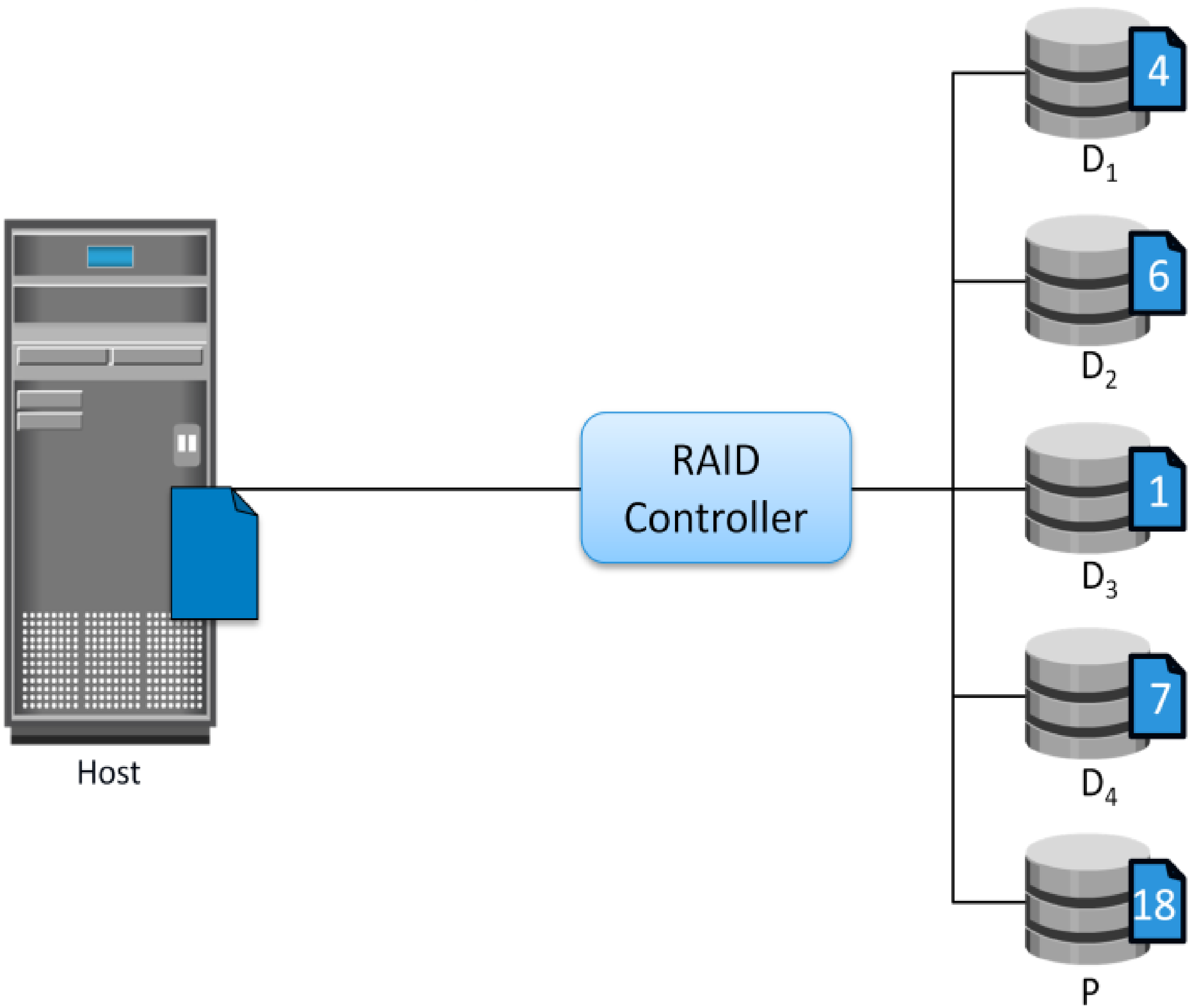
- *Mirroring* is a technique whereby data is stored on two different HDDs, yielding two copies of data.
- In the event of one HDD failure, the data is intact on the surviving HDD and the controller continues to service the host’s data requests from the surviving disk of a mirrored pair.



# Mirroring

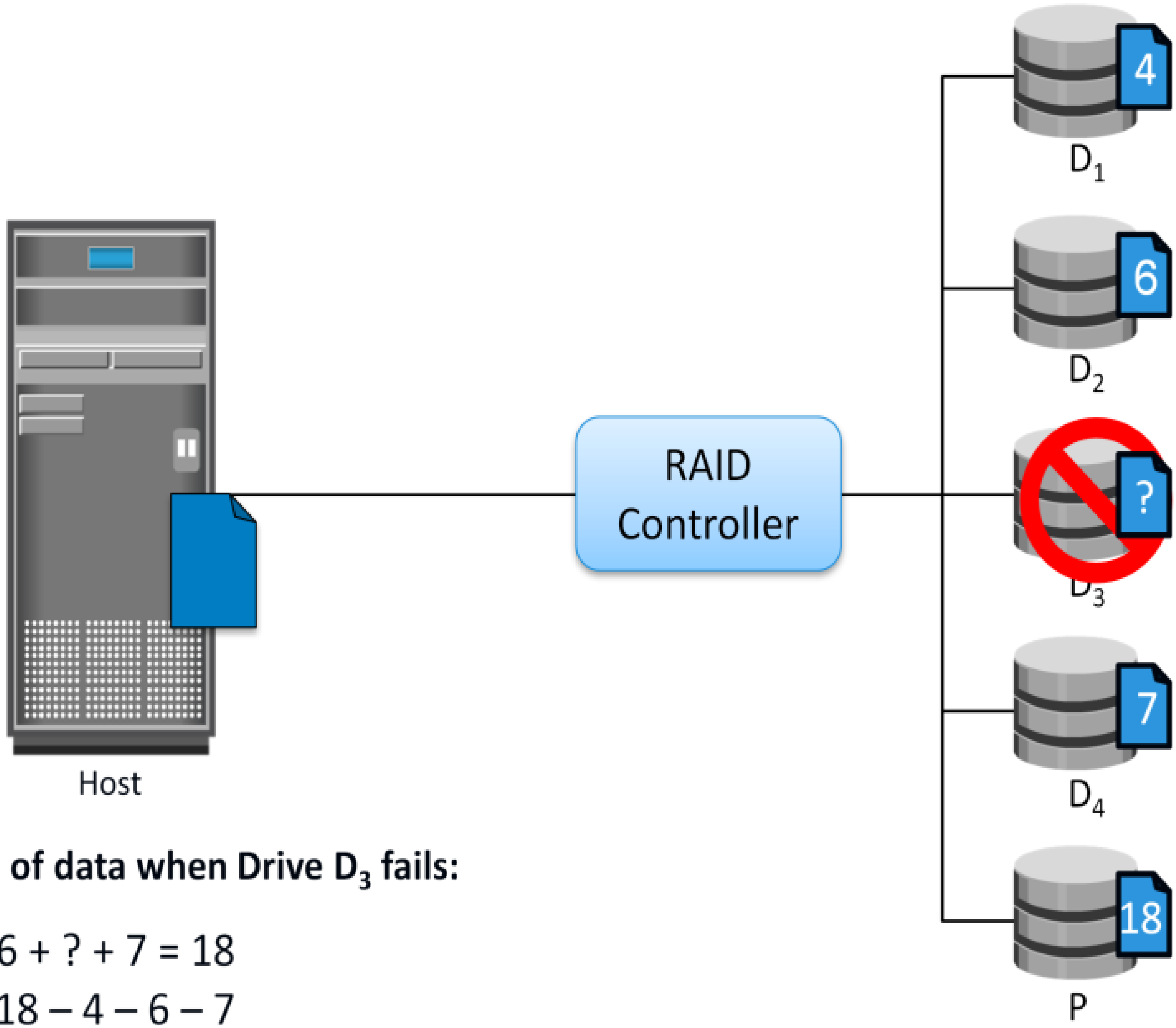
- When the failed disk is replaced with a new disk, the controller copies the data from the surviving disk of the mirrored pair.
- This activity is transparent to the host.
- In addition to providing complete data redundancy, mirroring enables faster recovery from disk failure.
- However, disk mirroring provides only data protection and is not a substitute for data backup. Mirroring constantly captures changes in the data, whereas a backup captures point-in-time images of data.
- Mirroring involves duplication of data — the amount of storage capacity needed is twice the amount of data being stored.
- Therefore, mirroring is considered expensive and is preferred for mission-critical applications that cannot afford data loss.
- Mirroring improves read performance because read requests can be serviced by both disks. However, write performance deteriorates, as each write request manifests as two writes on the HDDs.
- In other words, mirroring does not deliver the same levels of write performance as a striped RAID.

# RAID Technique – Parity




*Actual parity calculation is a bitwise XOR operation*

# Data Recovery in Parity Technique




**Regeneration of data when Drive $D_3$ fails:**

$4 + 6 + ? + 7 = 18$

$? = 18 – 4 – 6 – 7$

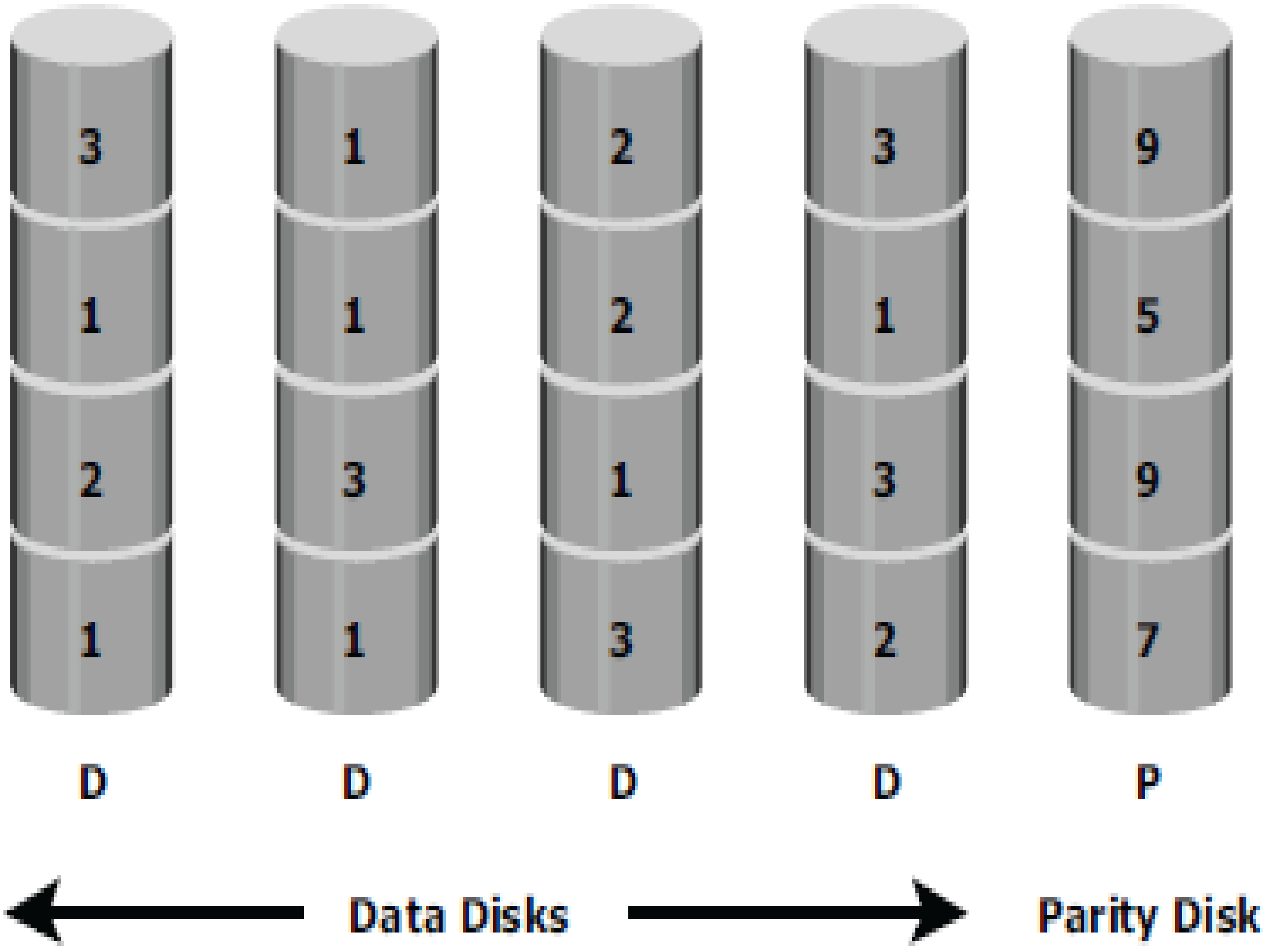
$? = 1$

# Parity

- *Parity* is a method of protecting striped data from HDD failure without the cost of mirroring.
- An additional HDD is added to the stripe width to hold parity, a mathematical construct that allows re-creation of the missing data.

# *Parity*

- Parity is a redundancy check that ensures full protection of data without maintaining a full set of duplicate data.
- Parity information can be stored on separate, dedicated HDDs or distributed across all the drives in a RAID set.
- The first four disks, labeled *D,* contain the data.
- The fifth disk, labeled *P*, stores the parity information, which in this case is the sum of the elements in each row.
- Now, if one of the *D*s fails, the missing value can be calculated by subtracting the sum of the rest of the elements from the parity value.



3
1
2
3
9
1
1
2
1
5
2
3
1
3
9
1
1
3
2
7
D
D
D
D
P
Data Disks
Parity Disk

# *Parity*

- Parity calculation is a *bitwise XOR* operation.
- Calculation of parity is a function of the RAID controller.
- Compared to mirroring, parity implementation considerably reduces the cost associated with data protection.
- Consider a RAID configuration with five disks.
- Four of these disks hold data, and the fifth holds parity information.
- Parity requires 25 percent extra disk space compared to mirroring, which requires 100 percent extra disk space.
- However, there are some disadvantages of using parity. Parity information is generated from data on the data disk. Therefore, parity is recalculated every time there is a change in data. This recalculation is time-consuming and affects the performance of the RAID controller.

# RAID Levels

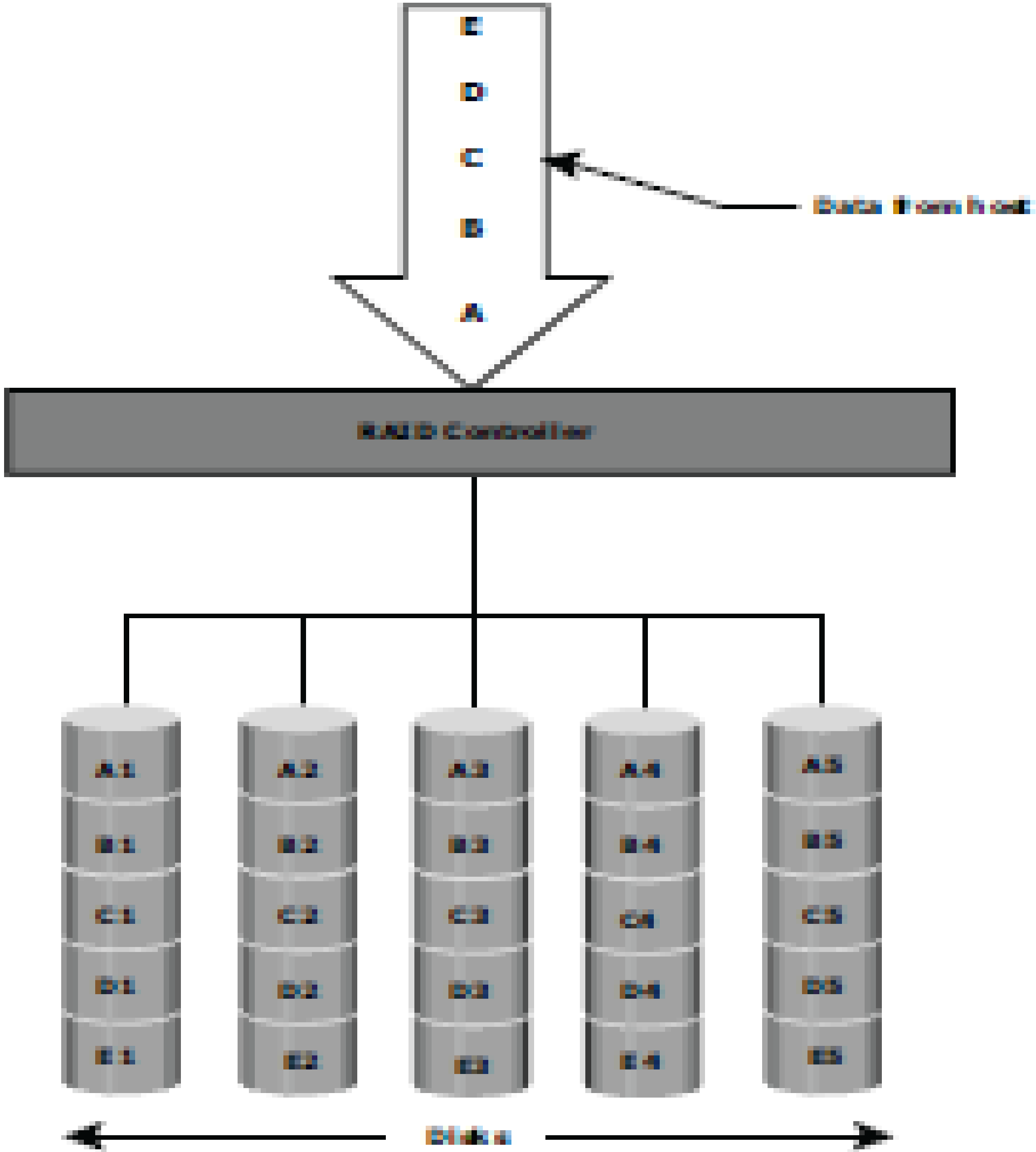
- Commonly used RAID levels are:
  - RAID 0 – Striped set with no fault tolerance
  - RAID 1 – Disk mirroring
  - RAID 1 + 0 – Nested RAID
  - RAID 3 – Striped set with parallel access and dedicated parity disk
  - RAID 5 – Striped set with independent disk access and a distributed parity
  - RAID 6 – Striped set with independent disk access and dual distributed parity

# RAIDᅟ0

– In a RAID 0 configuration, data is striped across the HDDs in a RAID set.
– It utilizes the full storage capacity by distributing strips of data over multiple HDDs in a RAID set.
– To read data, all the strips are put back together by the controller.
– The stripe size is specified at a host level for software RAID and is vendor specific for hardware RAID.

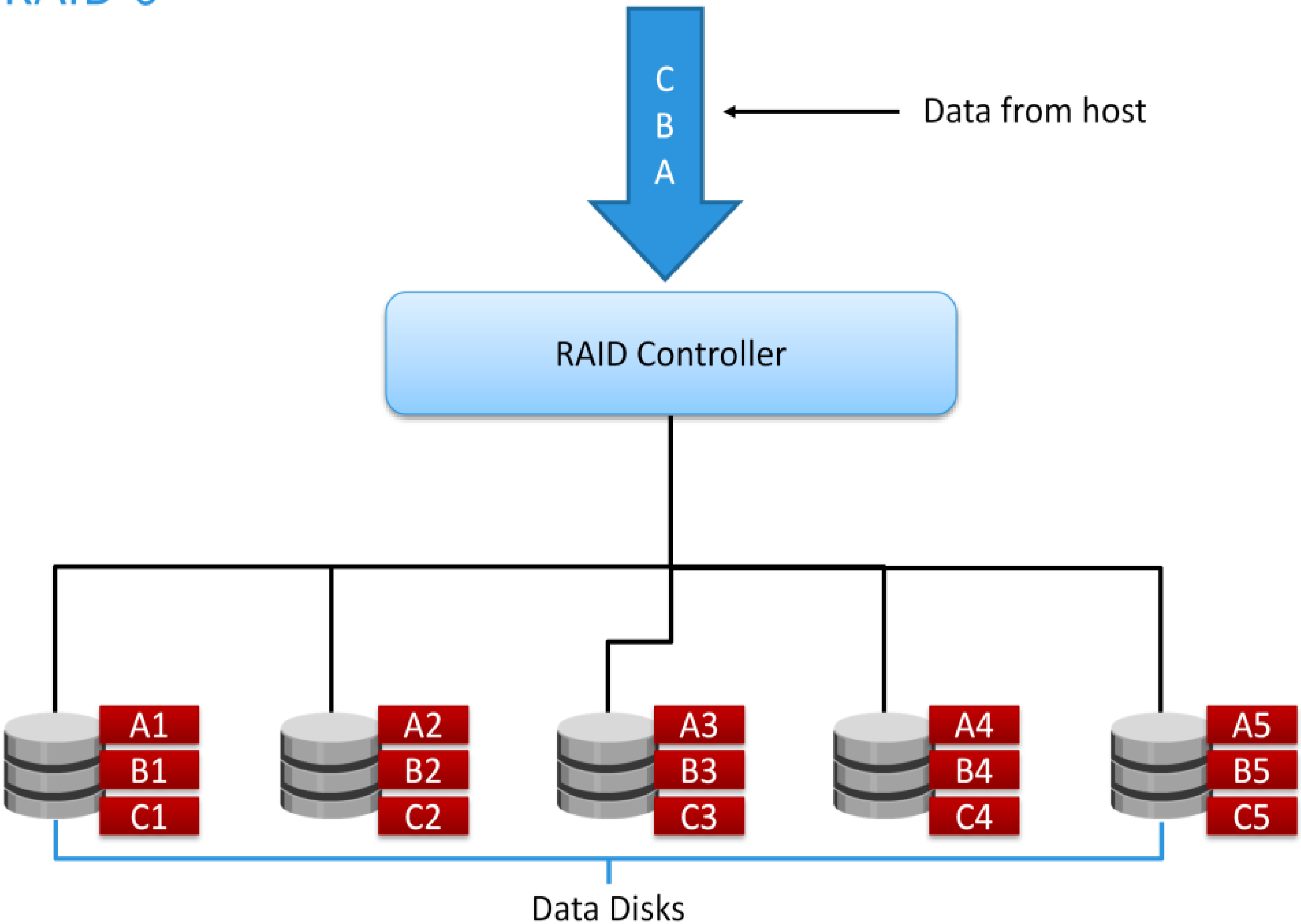
# *RAID 0*

- RAID 0 on a storage array in which data is striped across 5 disks. When the number of drives in the array increases, performance improves because more data can be read or written simultaneously.
- RAID 0 is used in applications that need high I/O throughput.
- However, if these applications require high availability, RAID 0 does not provide data protection and availability in the event of drive failures.



E
D
C
B
A
Data from host
RAID Controller
A1
A2
A3
A4
A5
B1
B2
B3
B4
B5
C1
C2
C3
C4
C5
D1
D2
D3
D4
D5
E1
E2
E3
E4
E5
Disks

# RAID 0



C
B
A
Data from host
RAID Controller
A1
B1
C1
A2
B2
C2
A3
B3
C3
A4
B4
C4
A5
B5
C5
Data Disks

# RAID 1

- In a RAID 1 configuration, data is mirrored to improve fault tolerance.
- A RAID 1 group consists of at least two HDDs. As explained in mirroring, every write is written to both disks, which is transparent to the host in a hardware RAID implementation.
- In the event of disk failure, the impact on data recovery is the least among all RAID implementations.
- This is because the RAID controller uses the mirror drive for data recovery and continuous operation. RAID 1 is suitable for applications that require high availability.

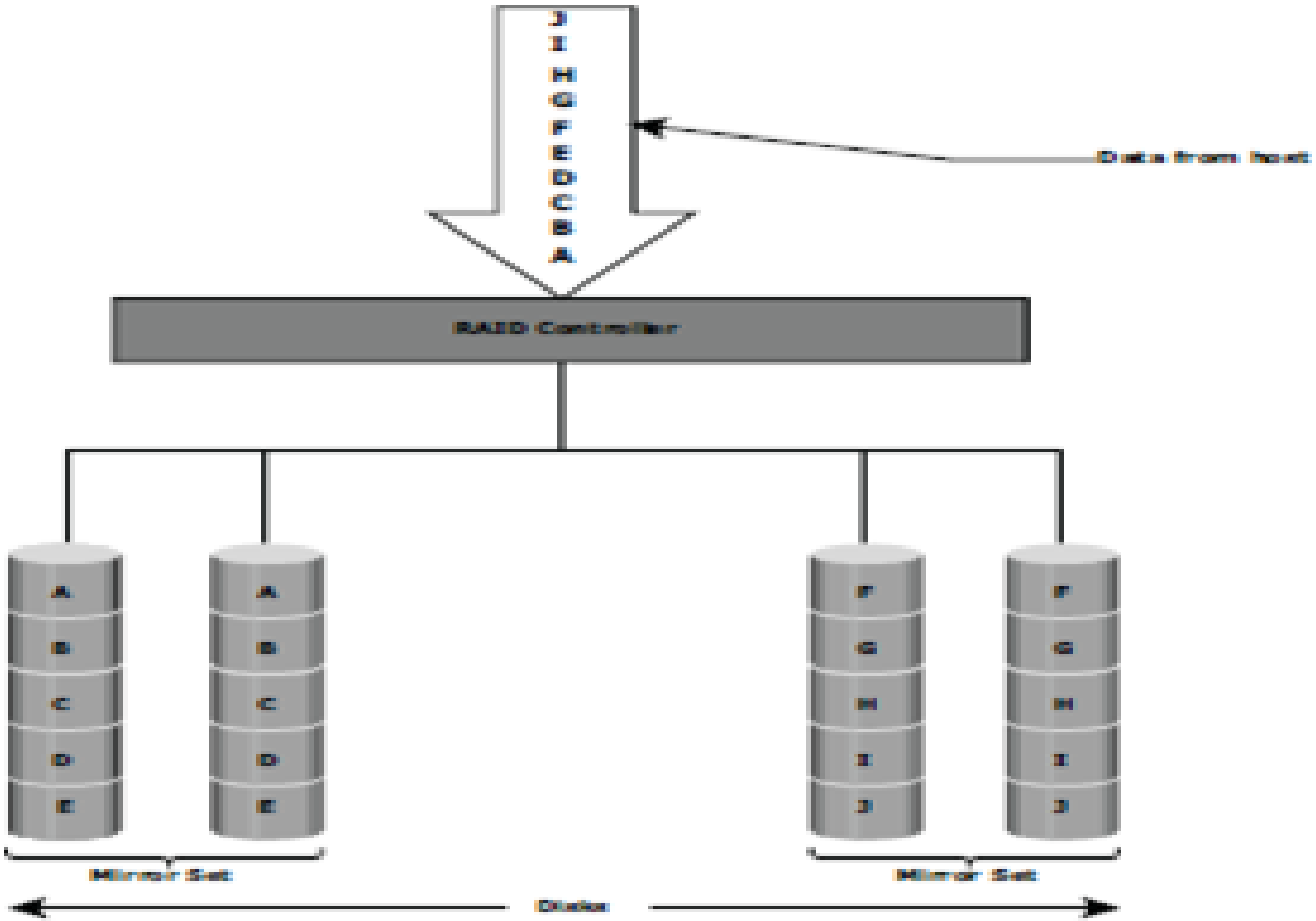
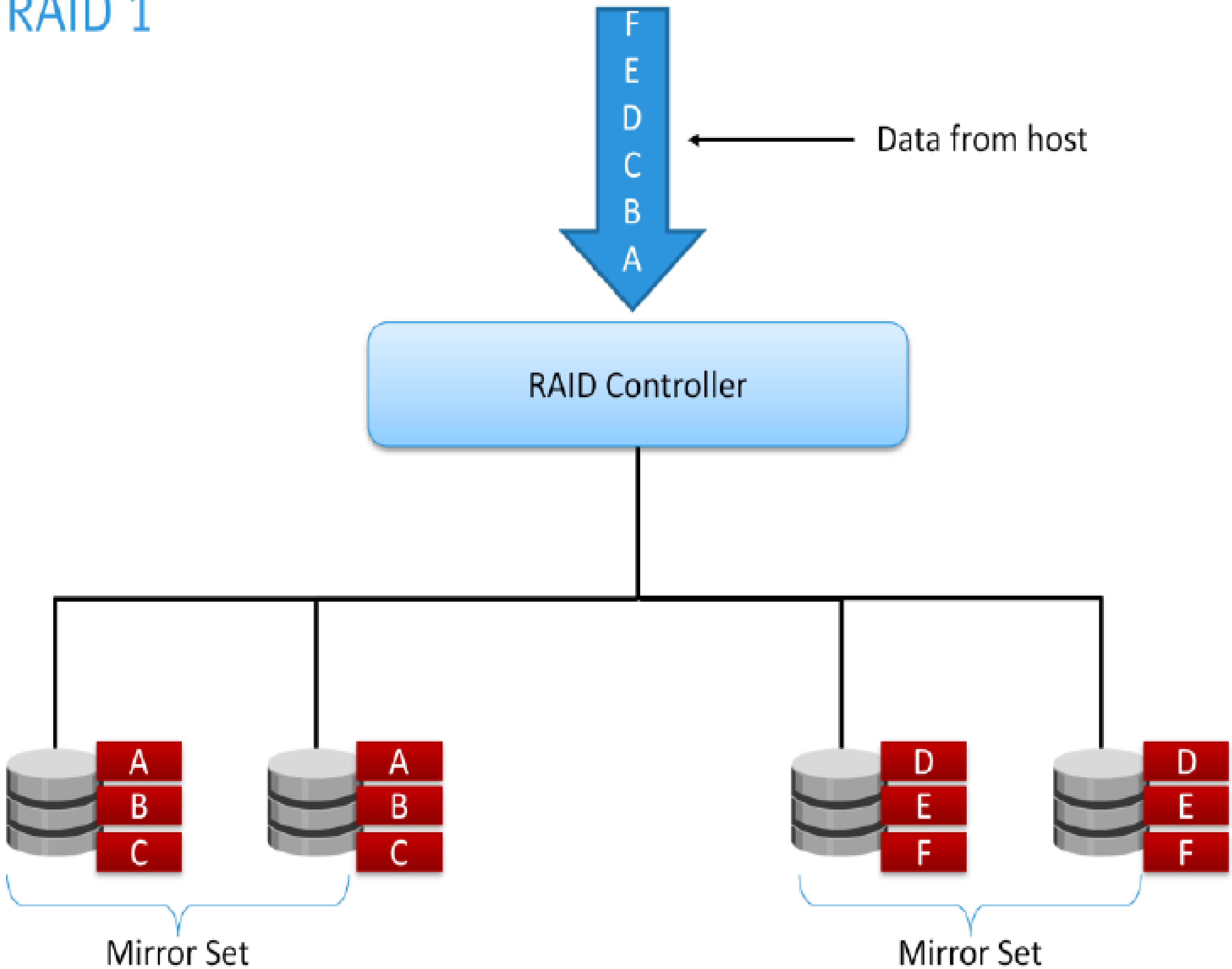



Figure: RAID 1

# RAID 1



F
E
D
C
B
A
Data from host
RAID Controller
A
B
C
A
B
C
D
E
F
D
E
F
Mirror Set
Mirror Set

# Nested RAID

– Most data centers require data redundancy and performance from their RAID arrays.
– RAID 0+1 and RAID 1+0 combine the performance benefits of RAID 0 with the redundancy benefits of RAID 1.
– They use striping and mirroring techniques and combine their benefits. These types of RAID require an even number of disks, the minimum being.
– RAID 1+0 is also known as RAID 10 (Ten) or RAID 1/0.

# Nested RAID

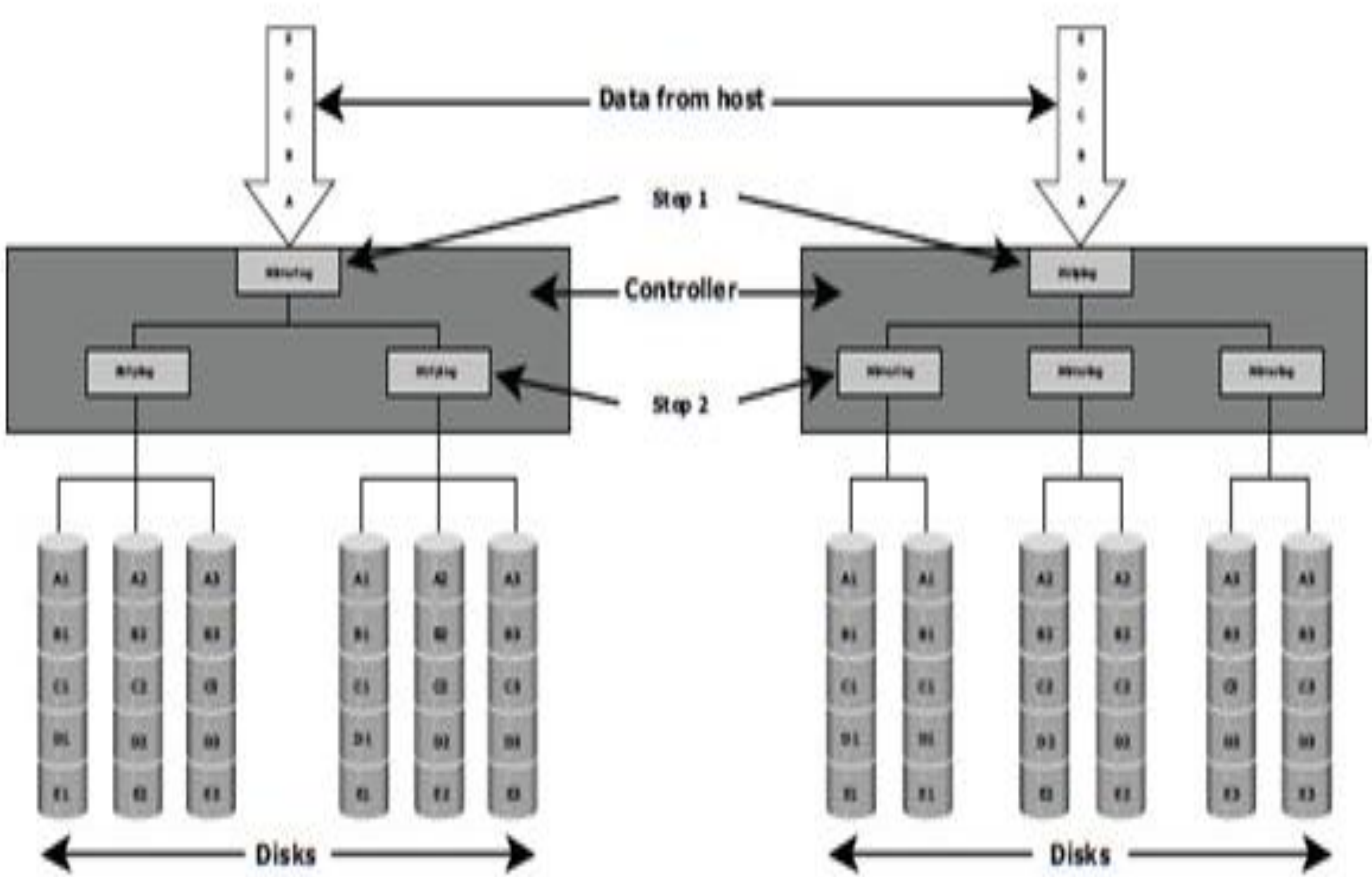
- Similarly, RAID 0+1 is also known as RAID 01 or RAID 0/1. RAID 1+0 performs well for workloads that use small, random, write-intensive I/O.
- Some applications that benefit from RAID 1+0 include the following:
  - High transaction rate Online Transaction Processing (OLTP)
  - Large messaging installations
  - Database applications that require high I/O rate, random access, and high availability
- A common misconception is that RAID 1+0 and RAID 0+1 are the same.
- Under normal conditions, RAID levels 1+0 and 0+1 offer identical benefits.

# Nested RAID

- **However, rebuild operations in the case of disk failure differ between the two.**
- **RAID 1+0 is also called *striped mirror*.**
- **When replacing a failed drive, only the mirror is rebuilt. In other words, the disk array controller uses the surviving drive in the mirrored pair for data recovery and continuous operation.**
- **Data from the surviving disk is copied to the replacement disk.**
- **RAID 0+1 is also called *mirrored stripe*.**
- **The basic element of RAID 0+1 is a stripe. This means that the process of striping data across HDDs is performed initially and then the entire stripe is mirrored.**

# Nested RAID

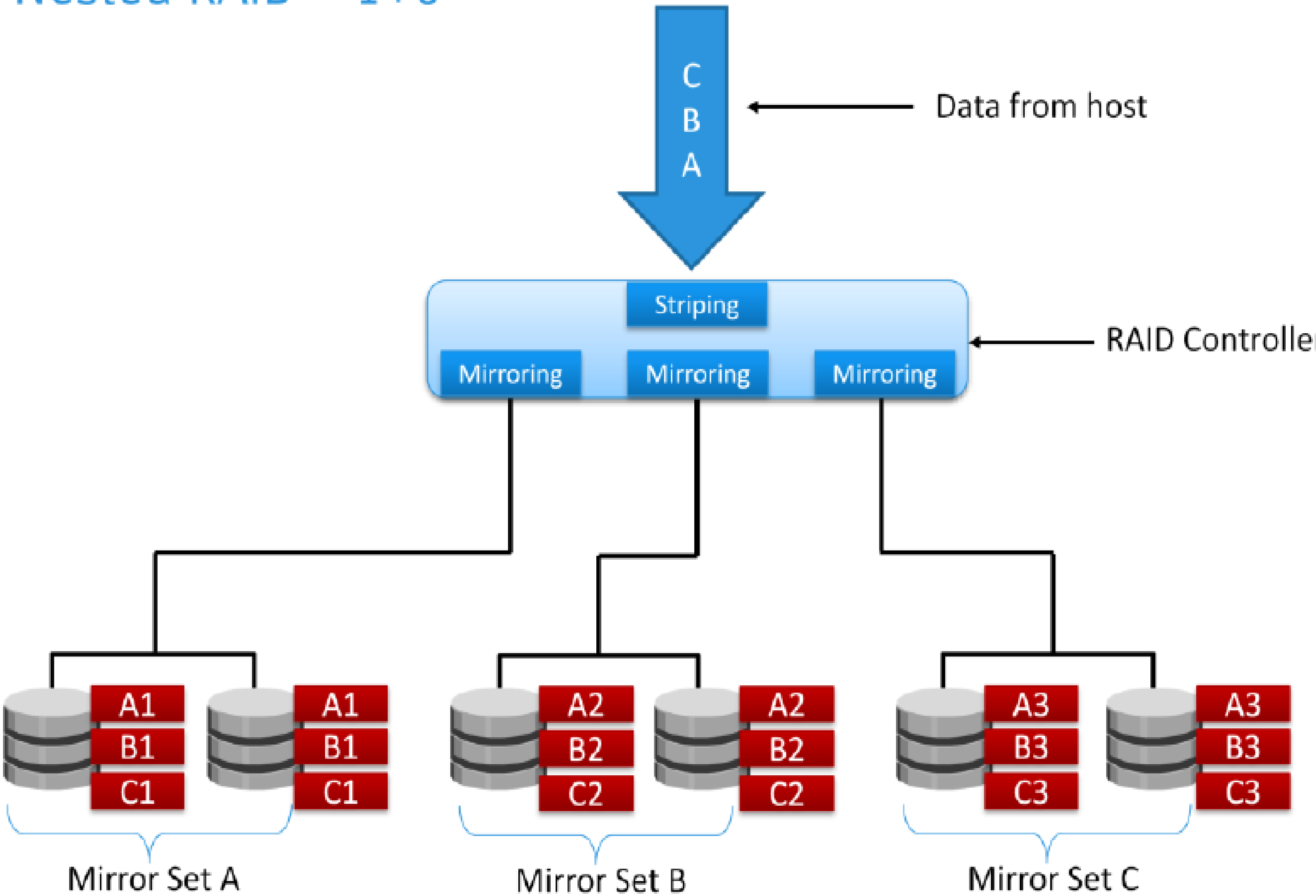
- If one drive fails, then the entire stripe is faulted.
- A rebuild operation copies the entire stripe, copying data from each disk in the healthy stripe to an equivalent disk in the failed stripe.
- This causes increased and unnecessary I/O load on the surviving disks and makes the RAID set more vulnerable to a second disk failure.



(a) RAID 1+0

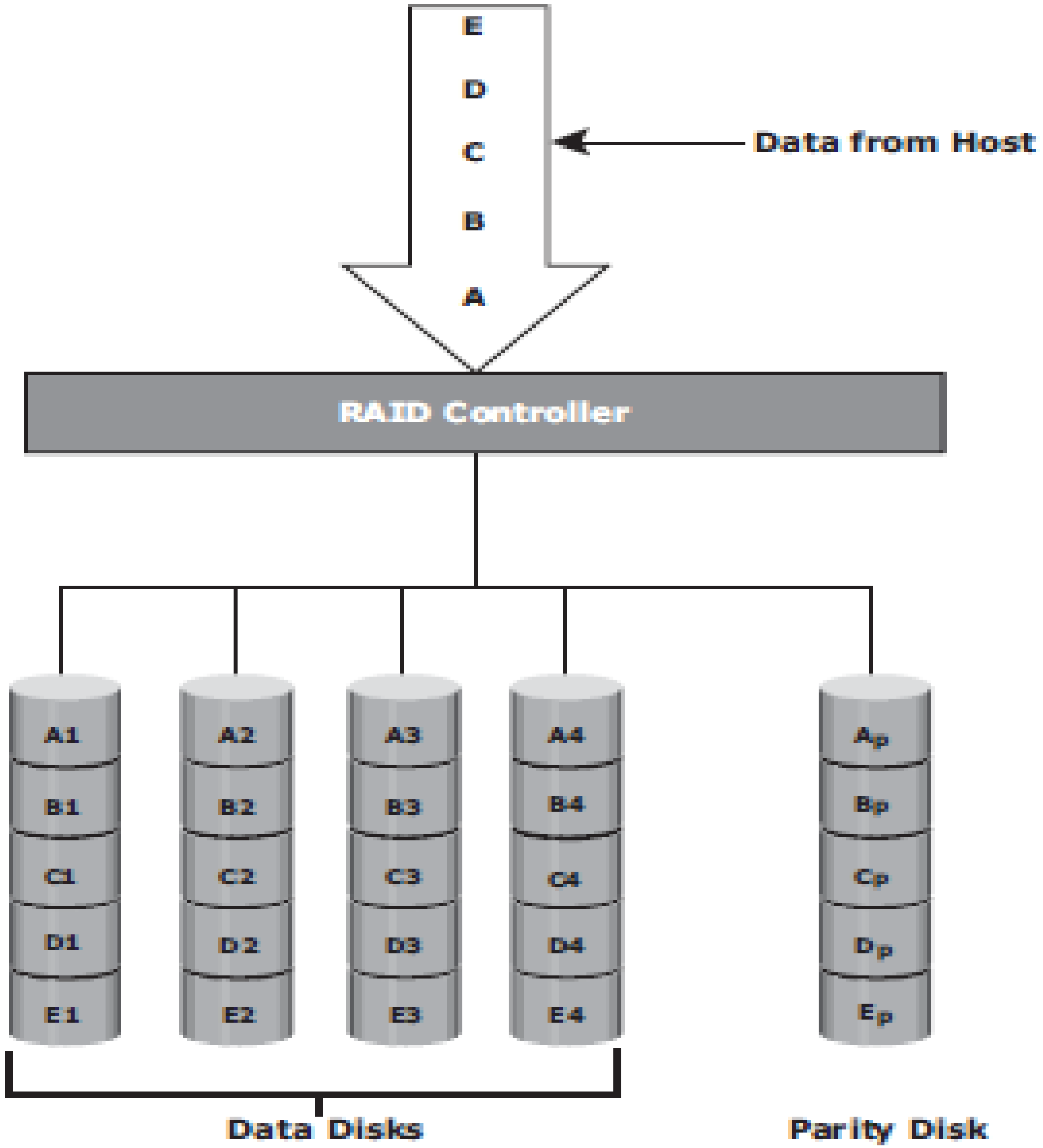
(b) RAID 0+1

# Nested RAID – 1+0



# RAID 3

- RAID 3 stripes data for high performance and uses **parity** for improved fault tolerance.
- Parity information is stored on a dedicated drive so that data can be reconstructed if a drive fails. For example, of five disks, four are used for data and one is used for parity.
- Therefore, the total disk space required is 1.25 times the size of the data disks.
- RAID 3 **always** reads and writes complete stripes of data across all disks, as the drives operate in parallel.
- There are no partial writes that update one out of many strips in a stripe.
- RAID 3 is used in applications that involve large sequential data access, such as video streaming.

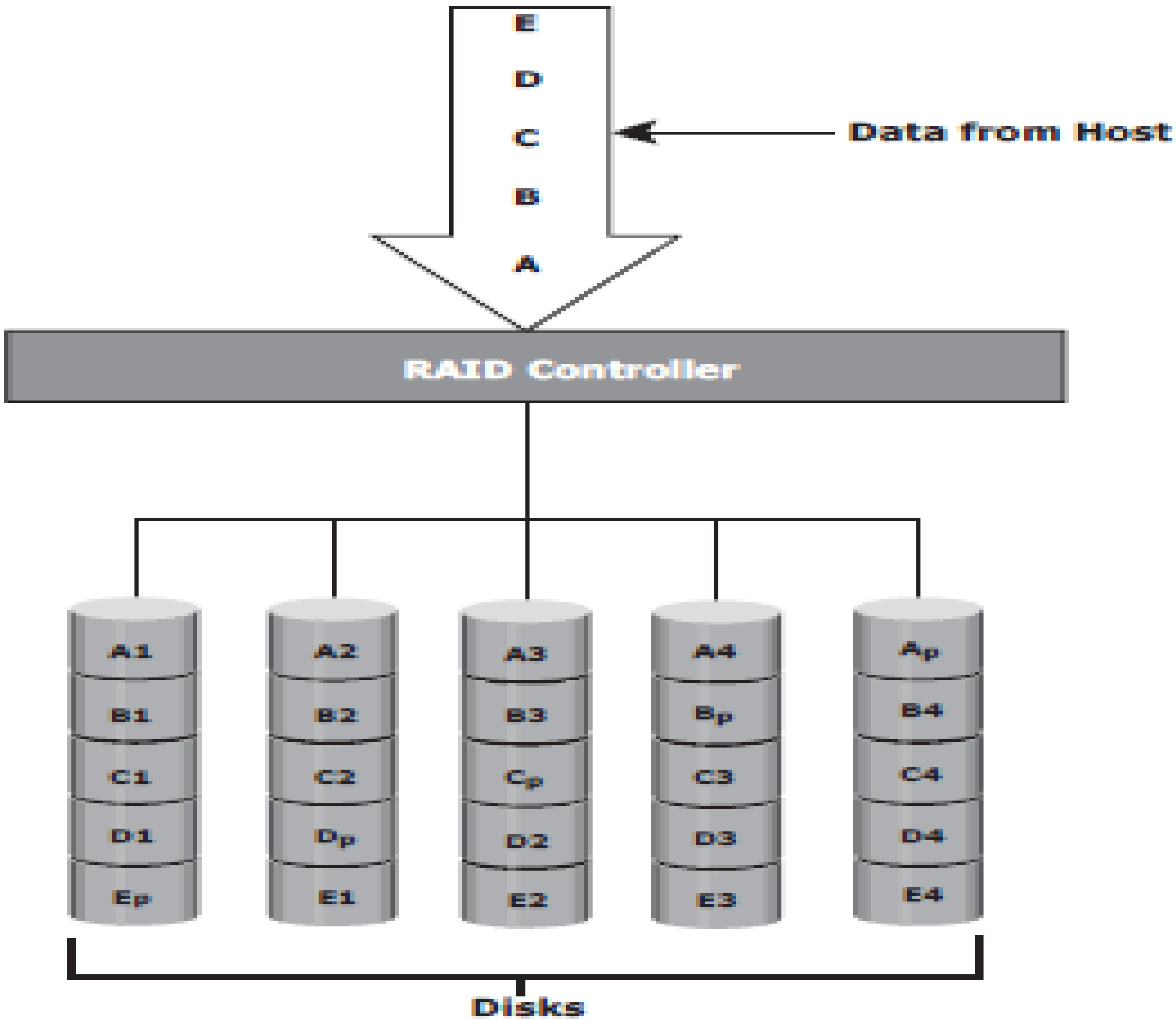

E
D
C
B
A
Data from Host
RAID Controller
A1
B1
C1
D1
E1
A2
B2
C2
D2
E2
A3
B3
C3
D3
E3
A4
B4
C4
D4
E4
Ap
Bp
Cp
Dp
Ep
Data Disks
Parity Disk

# RAID 4

- RAID 4 stripes data for high performance and uses parity for improved fault tolerance.
- Data is striped across all disks except the parity disk in the array.
- Parity information is stored on a dedicated disk so that the data can be rebuilt if a drive fails. Striping is done at the block level.
- Unlike RAID 3, data disks in RAID 4 can be accessed independently so that specific data elements can be read or written on single disk without read or write of an entire stripe.
- RAID 4 provides good read throughput and reasonable write throughput.

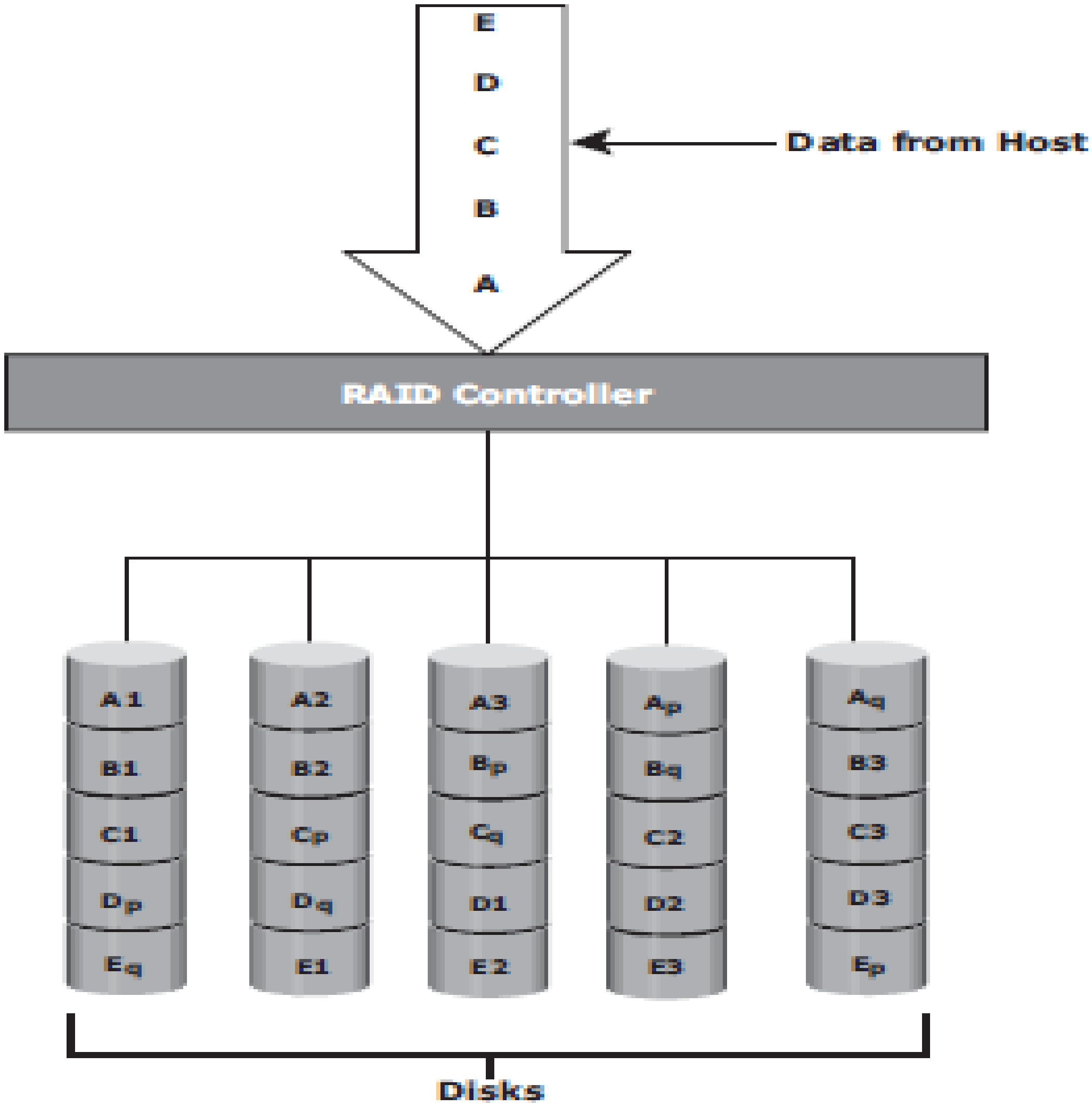
# RAID 5

- RAID 5 is a very versatile RAID implementation.
- It is similar to RAID 4 because it uses striping and the drives (strips) are independently accessible.
- The difference between RAID 4 and RAID 5 is the parity location.
- In RAID 4, parity is written to a dedicated drive, creating a write bottleneck for the parity disk.
- In RAID 5, parity is distributed across all disks. The distribution of parity in RAID 5 overcomes the write bottleneck.
- RAID 5 is preferred for messaging, data mining, medium-performance media serving, and relational database management system (RDBMS) implementations in which database administrators (DBAs) optimize data access.


E
D
C
B
A
Data from Host
RAID Controller
A1
B1
C1
D1
Ep
A2
B2
C2
Dp
E1
A3
B3
Cp
D2
E2
A4
Bp
C3
D3
E3
Ap
B4
C4
D4
E4
Disks

# RAID 6

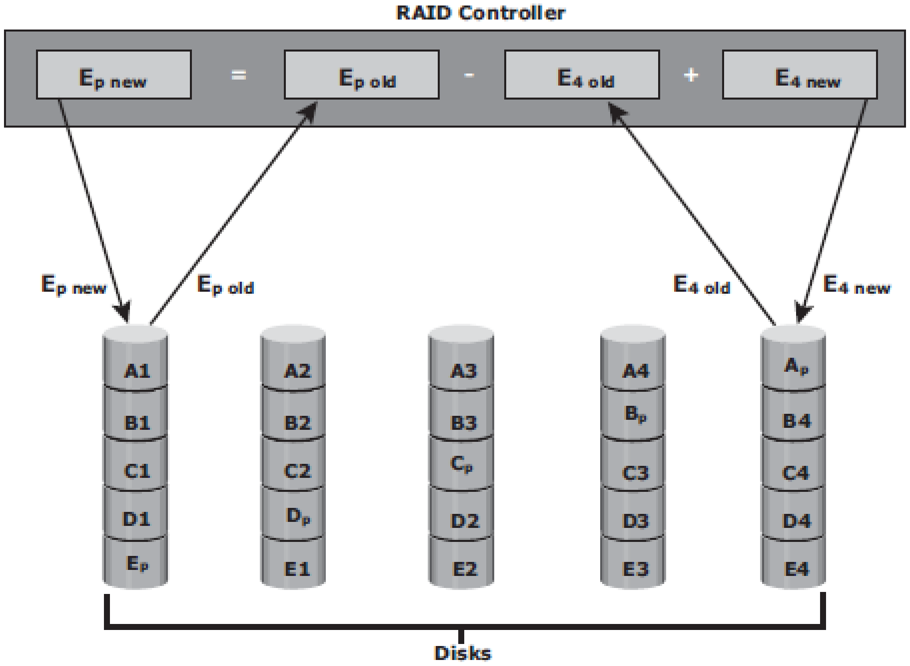
- RAID 6 works the same way as RAID 5 except that RAID 6 includes a second parity element to enable survival in the event of the failure of two disks in a RAID group.
- Therefore, a RAID 6 implementation requires at least four disks.
- RAID 6 distributes the parity across all the disks.
- The write penalty in RAID 6 is more than that in RAID 5; therefore, RAID 5 writes perform better than RAID 6.
- The rebuild operation in RAID 6 may take longer than that in RAID 5 due to the presence of two parity sets.


E
D
C
B
A
Data from Host
RAID Controller
A1
B1
C1
Dp
Eq
A2
B2
Cp
Dq
E1
A3
Bp
Cq
D1
E2
Ap
Bq
C2
D2
E3
Aq
B3
C3
D3
Ep
Disks

# RAID Impact on Disk Performance

- When choosing a RAID type, it is imperative to consider the impact to disk performance and application IOPS.
- In both mirrored and parity RAID configurations, every write operation translates into more I/O overhead for the disks which is referred to as *write penalty*.
- In a RAID 1 implementation, every write operation must be performed on two disks configured as a mirrored pair while in a RAID 5 implementation, a write operation may manifest as four I/O operations.
- When performing small I/Os to a disk configured with RAID 5, the controller has to read, calculate, and write a parity segment for every data write operation.

# RAID Impact on Disk Performance



# RAID Impact on Disk Performance

- Figure illustrates a single write operation on RAID 5 that contains a group of five disks.
- Four of these disks are used for data and one is used for parity.
- The parity (P) at the controller is calculated as follows:
- Ep = E1 + E2 + E3 + E4 (XOR operations)
- Here, D1 to D4 is striped data across the RAID group of five disks.
- Whenever the controller performs a write I/O, parity must be computed by reading the old parity (Ep old) and the old data (E4 old) from the disk, which means two read I/Os. The new parity (Ep new) is computed as follows:

• Ep new = Ep old – E4 old + E4 new (XOR operations)

# RAID Impact on Disk Performance

- After computing the new parity, the controller completes the write I/O by writing the new data and the new parity onto the disks, amounting to two write I/Os.
- Therefore, the controller performs two disk reads and two disk writes for every write operation, and the write penalty in RAID 5 implementations is 4.
- In RAID 6, which maintains dual parity, a disk write requires three read operations: for Ep1 old, Ep2 old, and E4 old. After calculating Ep1 new and Ep2 new, the controller performs three write I/O operations for Ep1 new, Ep2 new and E4 new.
- Therefore, in a RAID 6 implementation, the controller performs six I/O operations for each write I/O, and the write penalty is 6.

# Application IOPS(Input Output Per Second) and RAID Configurations

– When deciding the number of disks required for an application, it is important to consider the impact of RAID based on IOPS generated by the application.
– The total disk load should be computed by considering the type of RAID configuration and the ratio of read compared to write from the host.

# Example

- Consider an application that generates 5,200 IOPS, with 60 percent of them being reads.
- The disk load in RAID 5 is calculated as follows:
- **RAID 5 disk load = 0.6 × 5,200 + 4× (0.4 × 5,200) [because the write penalty for RAID 5 is 4]**

  = 3,120 + 4 × 2,080

  = 3,120 + 8,320

  = 11,440 IOPS
- The disk load in RAID 1 is calculated as follows:
- **RAID 1 disk load = 0.6 × 5,200 + 2 × (0.4 × 5,200) [because every write manifests as two writes to the disks]**

  = 3,120 + 2 × 2,080

  = 3,120 + 4,160

  = 7,280 IOPS

# Example

- The computed disk load determines the number of disks required for the application.
- **If in this example an HDD with a specification of a maximum 180 IOPS for the application needs to be used, the number of disks required to meet the workload for the RAID configuration would be as follows:**
  - RAID 5: 11,440 / 180 = 64 disks
  - RAID 1: 7,280 / 180 = 42 disks (approximated to the nearest even number)

Table 3-2: Comparison of Common RAID Types

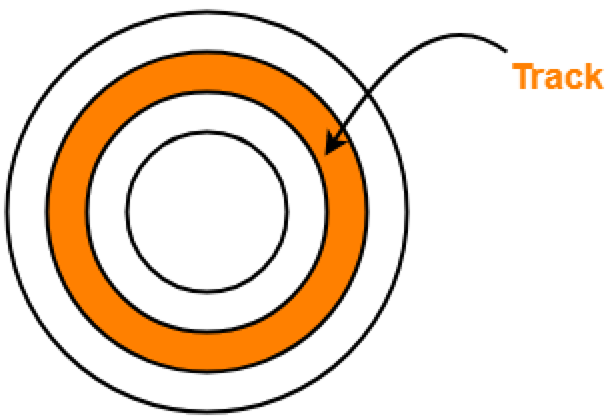
| RAID | MIN. DISKS | STORAGE EFFICIENCY % | COST | READ PERFORMANCE | WRITE PERFORMANCE | WRITE PENALTY | PROTECTION |
|---|---|---|---|---|---|---|---|
| 0 | 2 | 100 | Low | Good for both random and sequential reads | Good | No | No protection |
| 1 | 2 | 50 | High | Better than single disk | Slower than single disk because every write must be committed to all disks | Moderate | Mirror protection |
| 3 | 3 | [(n-1)/n] × 100 where n= number of disks | Moderate | Fair for random reads and good for sequential reads | Poor to fair for small random writes and fair for large, sequential writes | High | Parity protection for single disk failure |
| 4 | 3 | [(n-1)/n] × 100 where n= number of disks | Moderate | Good for random and sequential reads | Fair for random and sequential writes | High | Parity protection for single disk failure |
| 5 | 3 | [(n-1)/n] × 100 where n= number of disks | Moderate | Good for random and sequential reads | Fair for random and sequential writes | High | Parity protection for single disk failure |
| 6 | 4 | [(n-2)/n] × 100 where n= number of disks | Moderate but more than RAID 5. | Good for random and sequential reads | Poor to fair for random writes and fair for sequential writes | Very High | Parity protection for two disk failures |
| 1+0 and 0+1 | 4 | 50 | High | Good | Good | Moderate | Mirror protection |

# Magnetic Disk

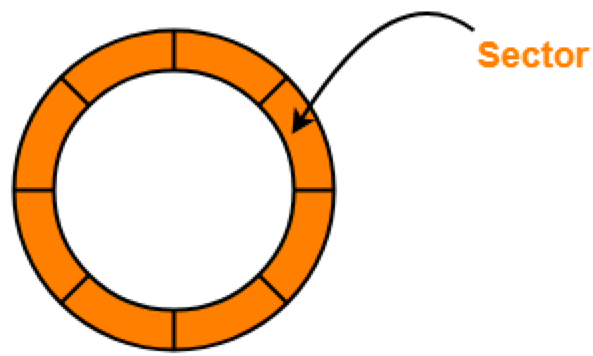
- Magnetic disk is a storage device that is used to write, rewrite and access data.
- It uses a magnetization process.

# Architecture-

- The entire disk is divided into **platters**.
- Each platter consists of concentric circles called as **tracks**.
- These tracks are further divided into **sectors** which are the smallest divisions in the disk.

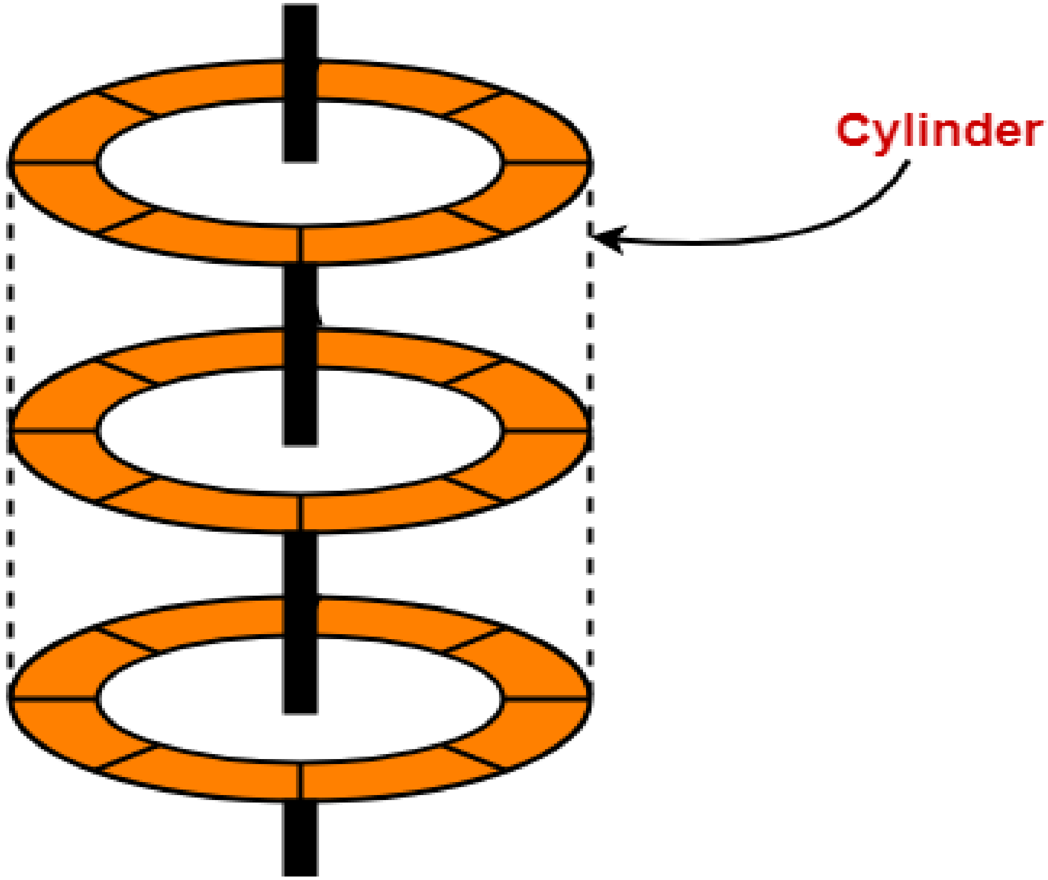



Disk divided into tracks

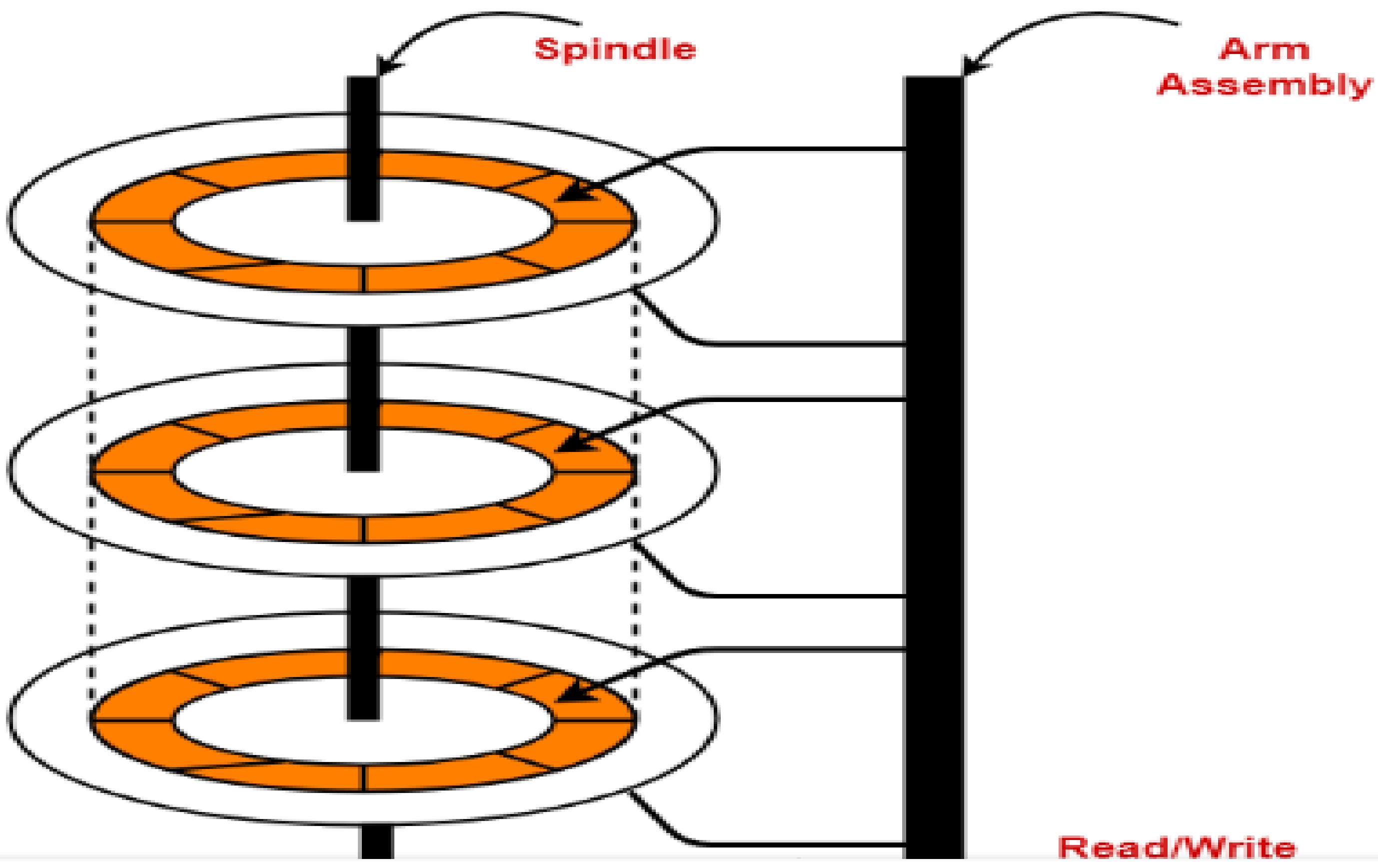



Track divided into sectors

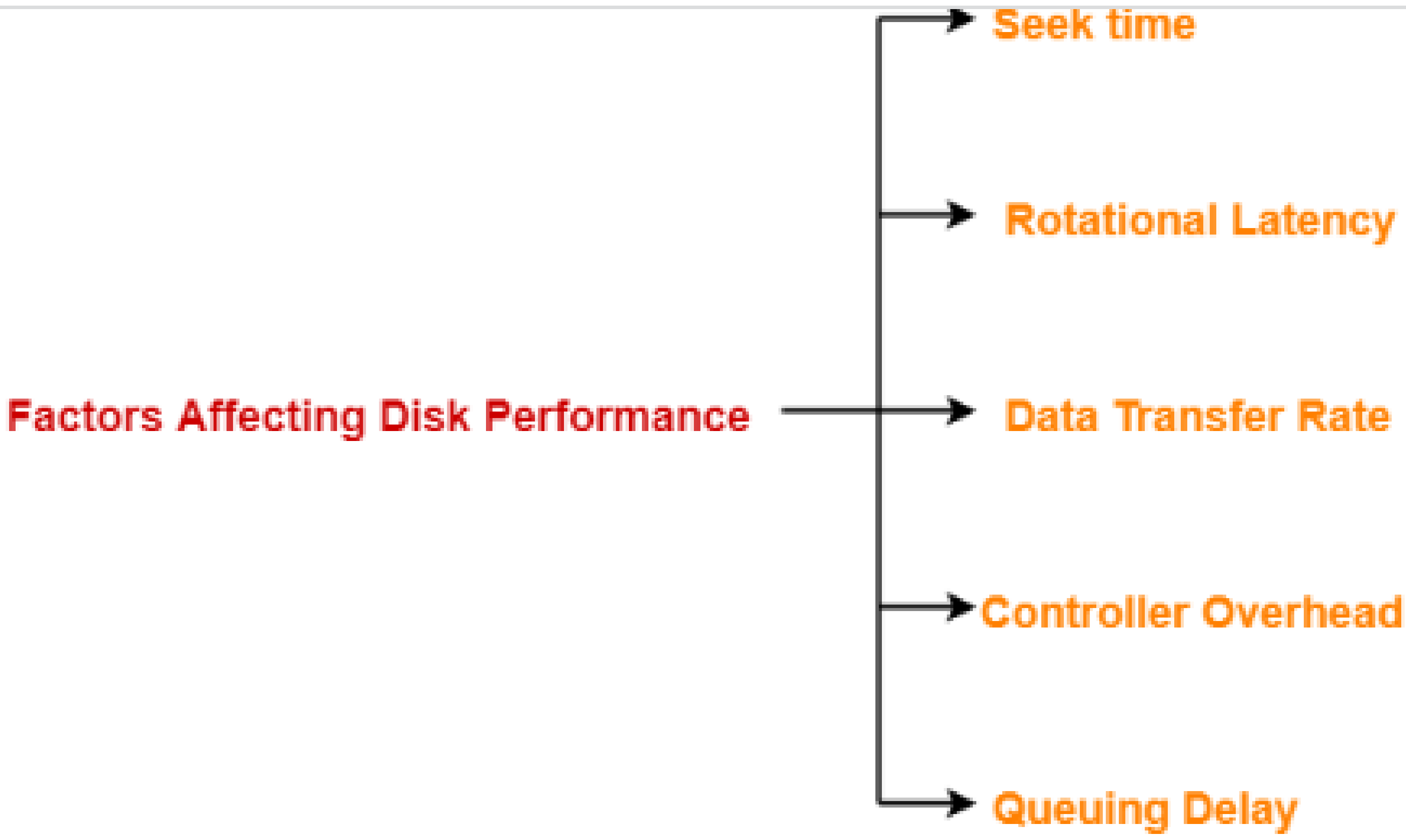
- A **cylinder** is formed by combining the tracks at a given radius of a disk pack.



- There exists a mechanical arm called as **Read / Write head**.
- It is used to read from and write to the disk.
- Head has to reach at a particular track and then wait for the rotation of the platter.
- The rotation causes the required sector of the track to come under the head.
- Each platter has 2 surfaces- top and bottom and both the surfaces are used to store the data.
- Each surface has its own read / write head.



# Disk Performance Parameters-



# 1. Seek Time-

- The time taken **by the read / write head to** reach the desired track is called as **seek time**. It is the component which contributes the largest percentage of the disk service time. The lower the seek time, the faster the I/O operation

# Specifications

Seek time specifications include-

1. Full stroke
2. Average
3. Track to Track

## 1. Full Stroke-

- It is the time taken by the read / write head to move across the entire width of the disk from the innermost track to the outermost track

## 2. Average-

- It is the average time taken by the read / write head to move from one random track to another.

| Average seek time = 1 / 3 x Full stroke |
|---|

## 3. Track to Track-

- It is the time taken by the read-write head to move between the adjacent tracks.

## 2. Rotational Latency-

- The time taken by the desired sector to come under the read / write head is called as **rotational latency**.
- It depends on the rotation speed of the spindle.

| Average rotational latency = 1 / 2 x Time taken for full rotation |
| --- |

## 3. Data Transfer Rate-

- The amount of data that passes under the read / write head in a given amount of time is called as **data transfer rate**.
- The time taken to transfer the data is called as **transfer time**.

It depends on the following factors-

1. Number of bytes to be transferred
2. Rotation speed of the disk
3. Density of the track
4. Speed of the electronics that connects the disk to the computer

## 4. Controller Overhead-

- The overhead imposed by the disk controller is called as **controller overhead**.
- Disk controller is a device that manages the disk.

## 5. Queuing Delay-

- The time spent waiting for the disk to become free is called as **queuing delay**.

## NOTE-

| |
|---|
| All the tracks of a disk have the same storage capacity. |

## Storage Density-

- All the tracks of a disk have the same storage capacity.
- This is because each track has different storage density.
- Storage density decreases as we from one track to another track away from the center.

## 1. Disk Access Time-

Disk access time is calculated as-

| |
|---|
| Disk access time<br>= Seek time + Rotational delay + Transfer time + Controller overhead + Queuing delay |

## 2. Average Disk Access Time-

Average disk access time is calculated as-

| |
|---|
| Average disk access time<br>= Average seek time + Average rotational delay + Transfer time + Controller overhead + Queuing delay |

## 3. Average Seek Time-

Average seek time is calculated as-

| |
|---|
| Average seek time<br><br>= 1 / 3 x Time taken for one full stroke |

**Alternatively**,

If time taken by the head to move from one track to adjacent track = t units and there are total k tracks, then-

Average seek time

= { Time taken to move from track 1 to track 1 + Time taken to move from track 1 to last track } / 2

= { 0 + (k-1)t } / 2

## 4. Average Rotational Latency-

Average rotational latency is calculated as-

| |
|---|
| Average rotational latency<br><br>= 1 / 2 x Time taken for one full rotation |

Average rotational latency may also be referred as-

- Average rotational delay
- Average latency
- Average delay

## 5. Capacity Of Disk Pack-

Capacity of a disk pack is calculated as-

Capacity of a disk pack

= Total number of surfaces x Number of tracks per surface x Number of sectors per track x Storage capacity of one sector

## 6. Formatting Overhead-

Formatting overhead is calculated as-

| |
|---|
| Formatting overhead<br><br>= Number of sectors x Overhead per sector |

## 7. Formatted Disk Space-

Formatted disk space also called as usable disk space is the disk space excluding formatting overhead.

It is calculated as-

| |
|---|
| Formatted disk space<br>= Total disk space or capacity – Formatting overhead |

## 8. Recording Density Or Storage Density-

Recording density or Storage density is calculated as-

| |
|---|
| Storage density of a track<br><br>= Capacity of the track / Circumference of the track |

From here, we can infer-

Storage density of a track $\propto$ 1 / Circumference of the track

## 9. Track Capacity-

Capacity of a track is calculated as-

| |
|---|
| Capacity of a track<br><br>= Recording density of the track x Circumference of the track |

## 10. Data Transfer Rate-

Data transfer rate is calculated as-

| |
|---|
| Data transfer rate<br><br>= Number of heads x Bytes that can be read in one full rotation x Number of rotations in one second |

## Problem-01:

Consider a disk pack with the following specifications- 16 surfaces, 128 tracks per surface, 256 sectors per track and 512 bytes per sector.

Answer the following questions-

1. What is the capacity of disk pack?
2. What is the number of bits required to address the sector?
3. If the format overhead is 32 bytes per sector, what is the formatted disk space?
4. If the format overhead is 64 bytes per sector, how much amount of memory is lost due to formatting?
5. If the diameter of innermost track is 21 cm, what is the maximum recording density?
6. If the diameter of innermost track is 21 cm with 2 KB/cm, what is the capacity of one track?
7. If the disk is rotating at 3600 RPM, what is the data transfer rate?
8. If the disk system has rotational speed of 3000 RPM, what is the average access time with a seek time of 11.5 msec?

## Solution-

Given-

- Number of surfaces = 16
- Number of tracks per surface = 128
- Number of sectors per track = 256
- Number of bytes per sector = 512 bytes

## Part-01: Capacity of Disk Pack-

Capacity of disk pack

= Total number of surfaces x Number of tracks per surface x Number of sectors per track x Number of bytes per sector

= 16 x 128 x 256 x 512 bytes

= $2^{28}$ bytes

## Part-02: Number of Bits Required To Address Sector-

Total number of sectors

= Total number of surfaces x Number of tracks per surface x Number of sectors per track

= 16 x 128 x 256 sectors

= $2^{19}$ sectors

Thus, Number of bits required to address the sector = 19 bits

## Part-03: Formatted Disk Space-

Formatting overhead

= Total number of sectors x overhead per sector

= $2^{19}$ x 32 bytes

= $2^{19}$ x $2^{5}$ bytes

= $2^{24}$ bytes

= 16 MB

Now, Formatted disk space

= Total disk space – Formatting overhead

= 256 MB – 16 MB

= 240 MB

## Part-04: Formatting Overhead-

Amount of memory lost due to formatting

= Formatting overhead

= Total number of sectors x Overhead per sector

= $2^{19}$ x 64 bytes

= $2^{19}$ x $2^{6}$ bytes

= $2^{25}$ bytes

= 32 MB