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Storage, ISS, RAID, SSD

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Part 1 - Introduction to Information Storage

Upon completion of this module, you should be able to:

- Describe digital data, types of digital data, and information
- Describe data center and its key characteristics
- Describe key data center management processes
- Describe the evolution of computing platforms

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The Growth of the Digital Universe

- **The digital universe is created and defined by software**
  - Digital data is continuously generated, collected, stored, and analyzed through software
- **The digital universe generates approximately 4.4 trillion GB of data annually**
  - Proliferation of IT, Internet usage, social media, and smart devices adds to data growth
- **The Internet of Things (IoT) is also adding to data growth**
  - IoT is made up of Internet-connected equipment and sensors

Why Information Storage and Management?

- **Organizations are dependent on continuous and reliable access to information**
- **Organizations seek to effectively store, protect, process, manage, and leverage information**
- **Organizations are increasingly implementing intelligent storage solutions**
  - To efficiently store and manage information
  - To gain competitive advantage
  - To derive new business opportunities

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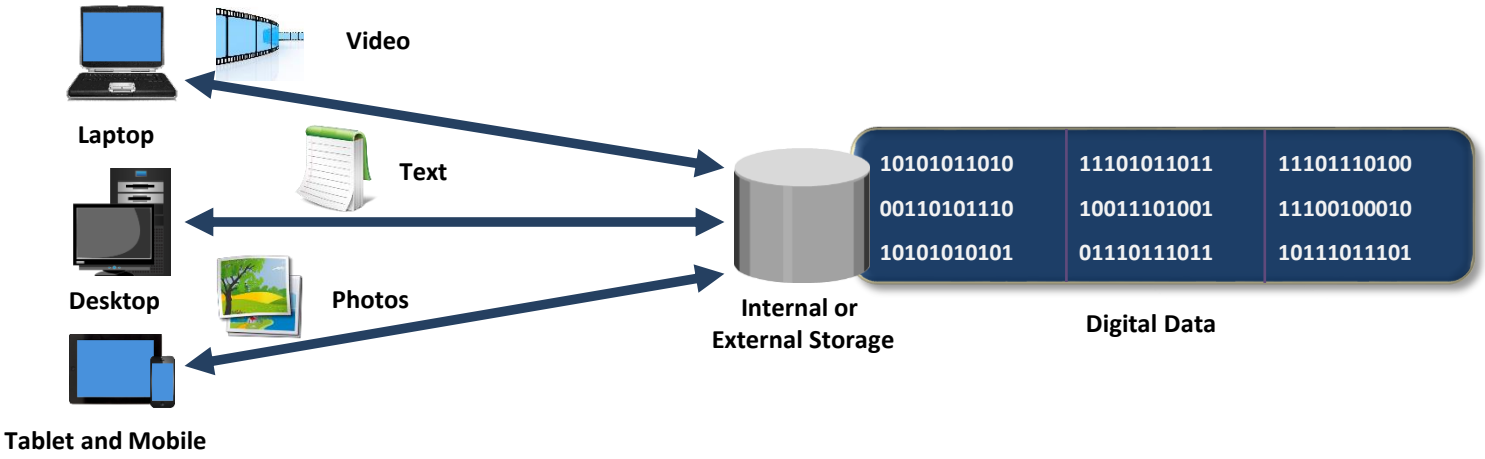
What is Digital Data?

Digital Data

A collection of facts that is transmitted and stored in electronic form, and processed through software.



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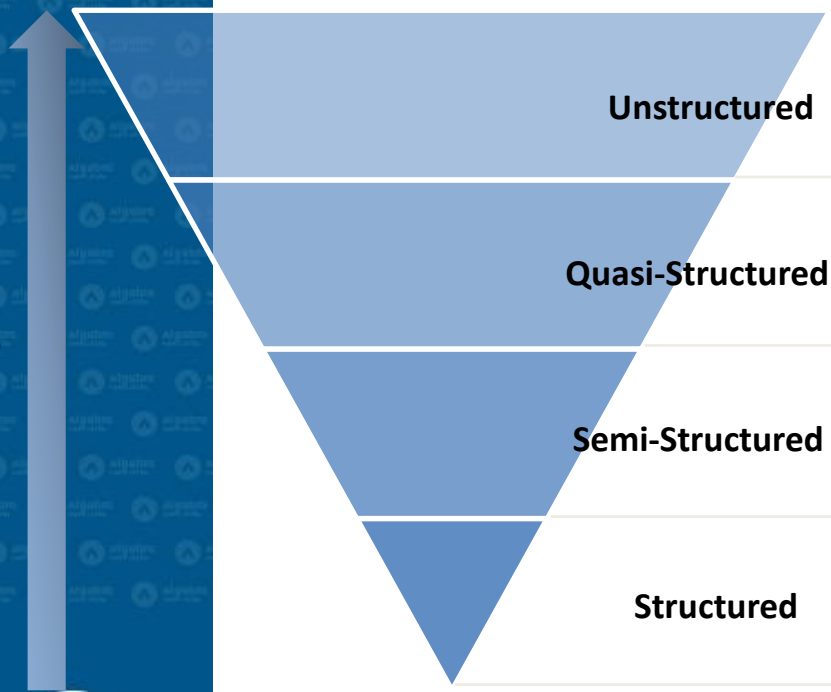
Types of Digital Data



- Data that has no inherent structure and is usually stored as different types of files.
- E.g. Text documents, PDFs, images, and videos

- Textual data with erratic formats that can be formatted with effort and software tools
- E.g. Clickstream data

- Textual data files with an apparent pattern, enabling analysis
- E.g. Spreadsheets and XML files

- Data having a defined data model, format, structure
- E.g. Database

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What is Information?

Information

Processed data that is presented in a specific context to enable useful interpretation and decision-making.

- **Example: Annual sales data processed into a sales report**
  - Enables calculation of the average sales for a product and the comparison of actual sales to projected sales
- **New architectures and technologies have emerged for extracting information from non-structured data**

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Information Storage

- **Information is stored on storage devices on non-volatile media**
- **Types of storage devices:**
  - **Magnetic storage devices**: Hard disk drive and magnetic tape
  - **Optical storage devices**: Blu-ray disc, DVD, and CD
  - **Flash-based storage devices**: Solid state drive, memory card, and USB thumb drive
- **Storage devices are assembled within a storage system or "array"**
  - Provides high capacity, scalability, performance, reliability, and security
- **Storage systems along with other IT infrastructure are housed in a data center**

What is a Data Center?

Data Center

A facility that houses IT equipment including compute, storage, and network components, and other supporting infrastructure for providing centralized data-processing capabilities.

- A data center comprises:
  - **Facility**: The building and floor space where the data center is constructed
  - **IT equipment**: Compute, storage, and network equipment
  - **Support infrastructure**: Power supply, fire detection, HVAC, and security systems

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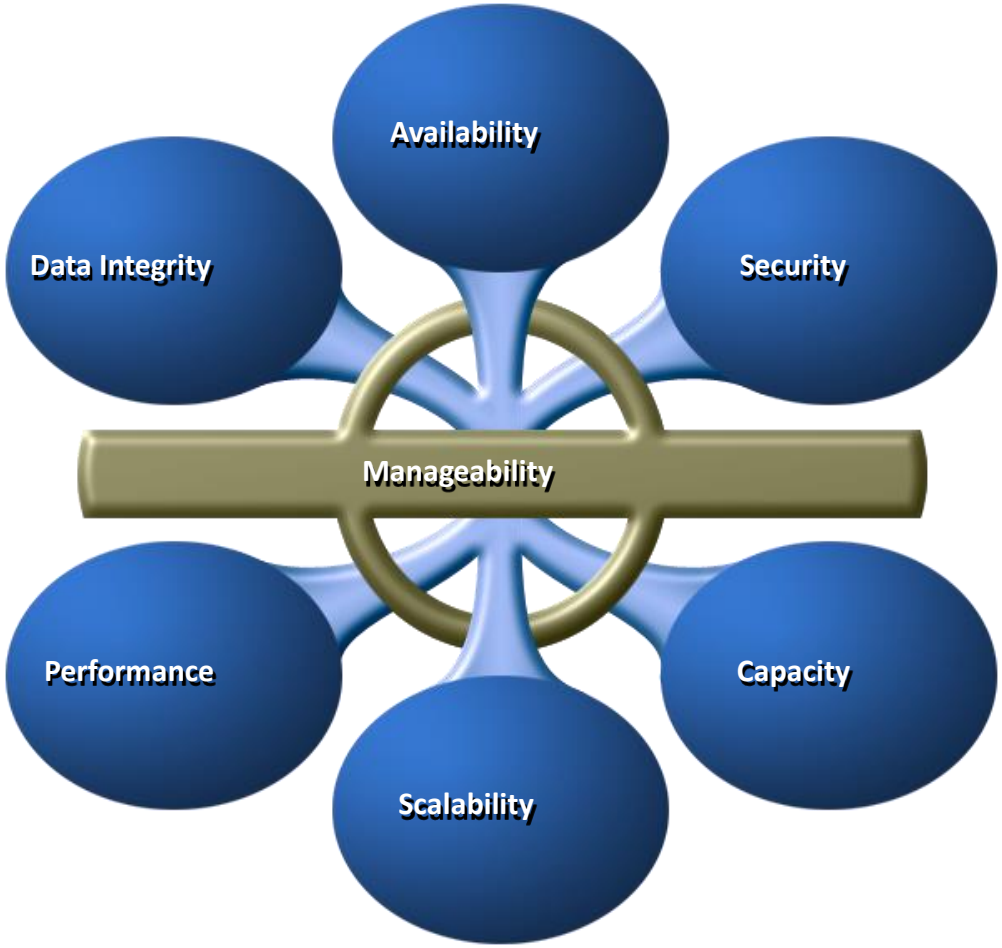
Key Characteristics of a Data Center



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Key Data Center Management Processes

Management Process	Description
Monitoring	Continuously gathering information on data center resources
Reporting	Presenting the details on resource performance, capacity, and utilization
Provisioning	Configuring and allocating resources to meet the capacity, availability, performance, and security requirements
Planning	Estimating the amount of resources required to support business operations
Maintenance	Ensuring the proper functioning of resources and resolving incidents

Evolution of Computing Platforms

BILLIONS OF USERS

Cloud Big Data Mobile Social

Mobile Devices

MILLIONS OF APPS

HUNDREDS OF MILLIONS OF USERS

LAN/Internet Client/Server

PC

TENS OF THOUSANDS OF APPS

MILLIONS OF USERS

Mainframe, Mini Computer

Terminals

THOUSANDS OF APPS

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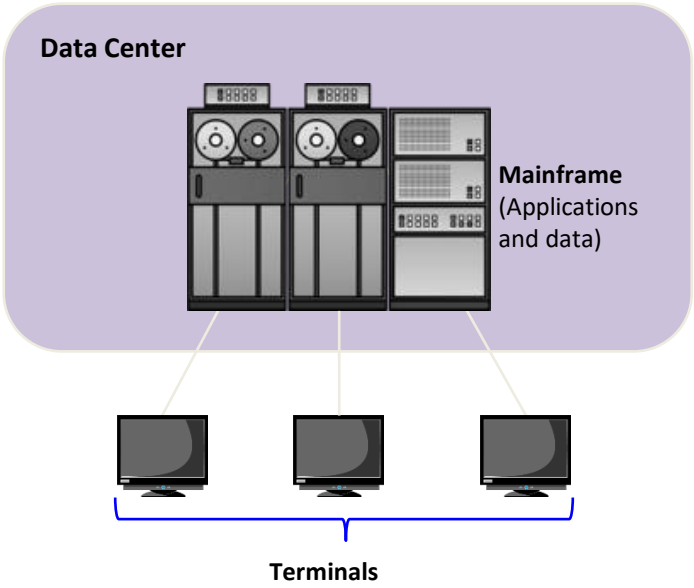
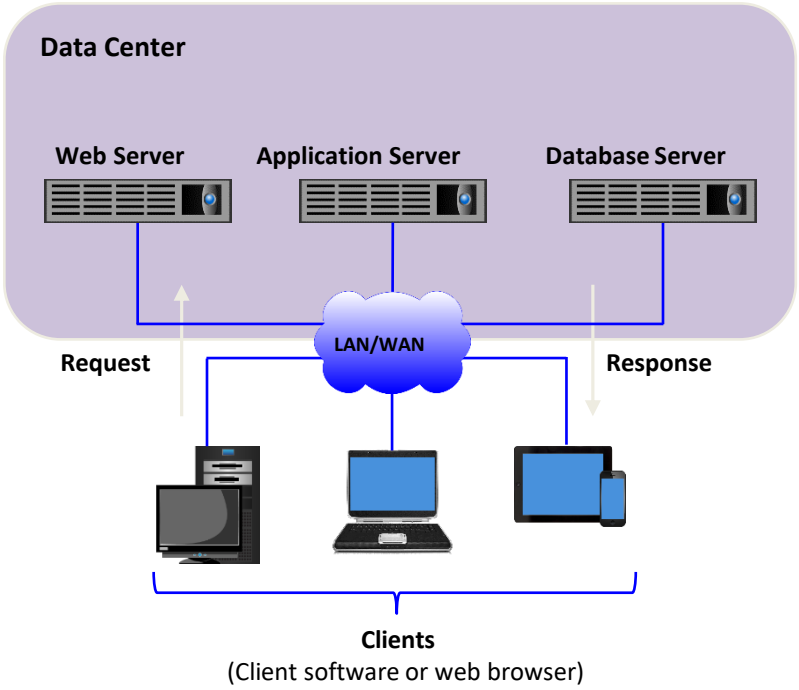
First Platform

- **Based on mainframes**
  - Applications and databases hosted centrally
  - Users connect to mainframes through terminals
- **Challenges with mainframes**
  - Substantial CAPEX and OPEX
    - High acquisition costs
    - Considerable floor space and energy requirements



Second Platform

- **Based on client-server model**
  - Distributed application architecture
  - Servers receive and process requests for resources from clients
  - Users connect through a client program or a web interface
- **Challenges with client-server model**
  - Creation of IT silos
  - Hardware and software maintenance overhead
  - Scalability to meet the growth of users and workloads



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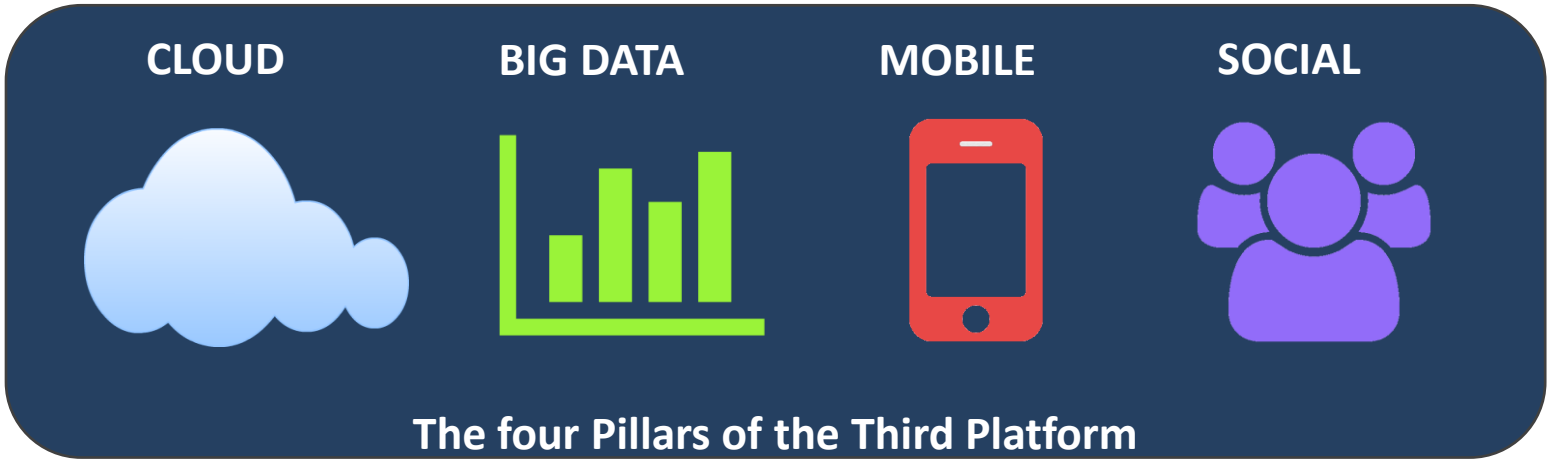
Third Platform



- The four pillars are transforming the way organizations are using technology for business operations

Part 2: Intelligent Storage Systems (ISS)

Upon completion of this module, you should be able to:

- Describe the key components of an intelligent storage system
- Describe HDD and SSD components, addressing, and performance
- Describe RAID, its techniques, and its levels
- Discuss the types of intelligent storage systems

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Third Platform Requirements for Storage

- Process massive amount of IOPS
- Elastic and non-disruptive horizontal scaling of resources
- Intelligent resource management
- Automated and policy driven configuration
- Support for multiple protocols for data access
- Supports APIs for software-defined and cloud integration
- Centralized management and chargeback in a multi-tenancy environment

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Technology Solution

- **Intelligent storage system**
  - Block-based storage system
  - File-based storage system
  - Object-based storage system
  - Unified storage system
- **Storage Virtualization**
- **Software-defined storage**

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Components of Intelligent Storage Systems – I

This lesson covers the following topics:

- **Components of intelligent storage systems**
- HDD components, addressing, and performance

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What is an Intelligent Storage System?

Intelligent Storage System

A feature-rich RAID array that provides highly optimized I/O processing capabilities.

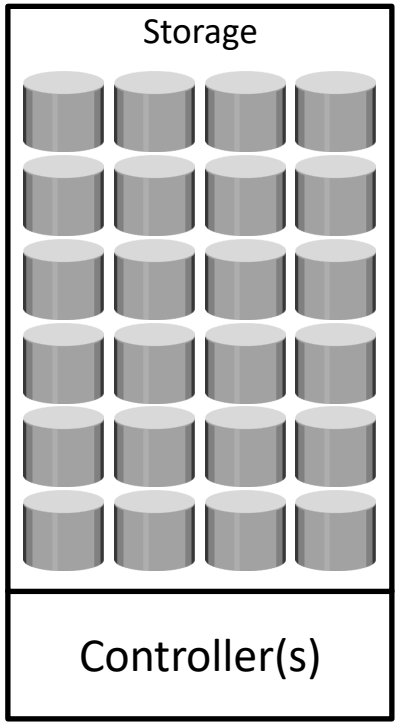
- **Has a purpose-built operating environment**
  - Provides intelligent resource management capability
- **Provides large amount of cache**
- **Provides multiple I/O paths**

Features

- Supports combination of HDD and SSD
- Service massive amount of IOPS
- Scale-out architecture
- Deduplication, compression, and encryption
- Automated storage tiering
- Virtual storage provisioning
- Multi-tenancy
- Supports APIs to integrate with SDDC and cloud
- Data protection

Components of Intelligent Storage System

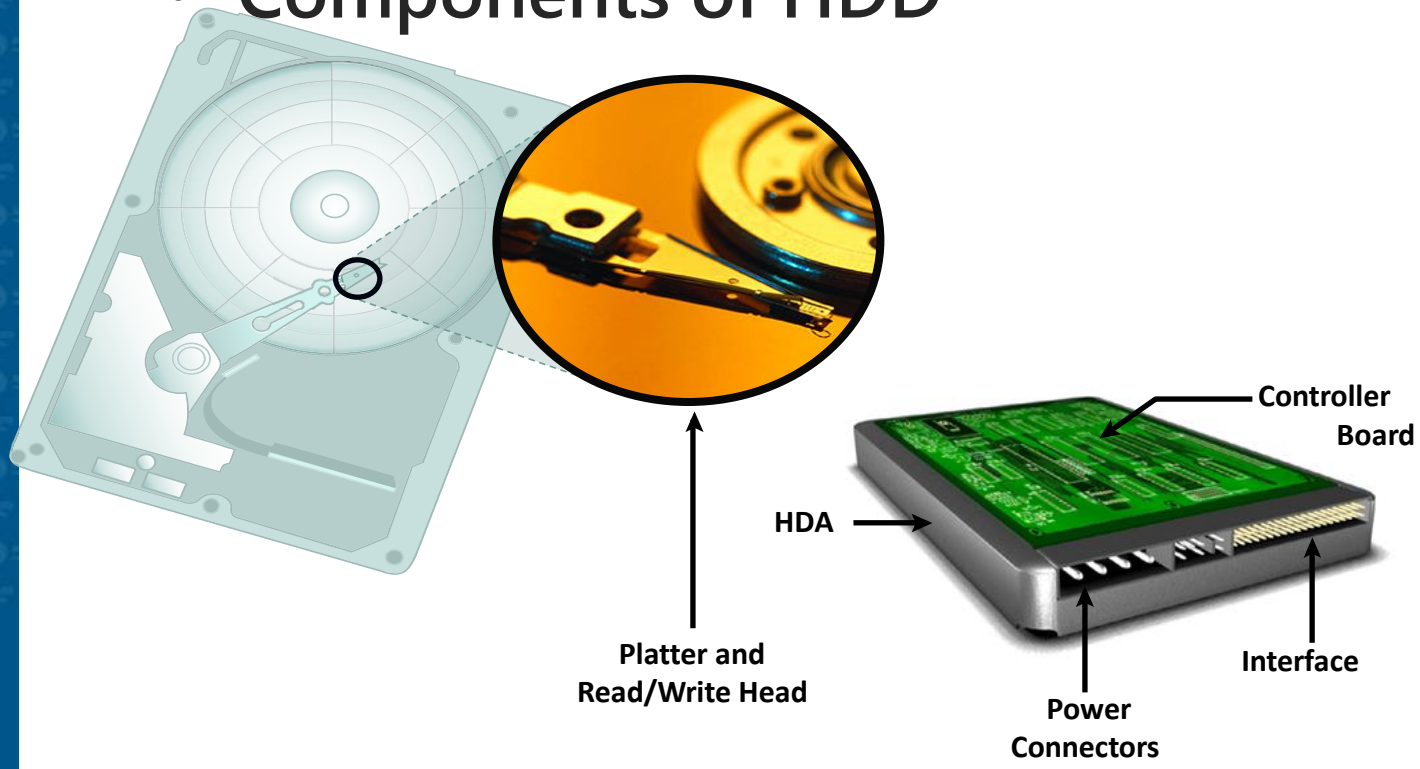
- **Two key components of an ISS**
  - Controller
    - Block-based
    - File-based
    - Object-based
    - Unified
  - Storage
    - All HDDs
    - All SSDs
    - Combination of both



Intelligent Storage System

Storage – Hard Disk Drives

- Components of HDD



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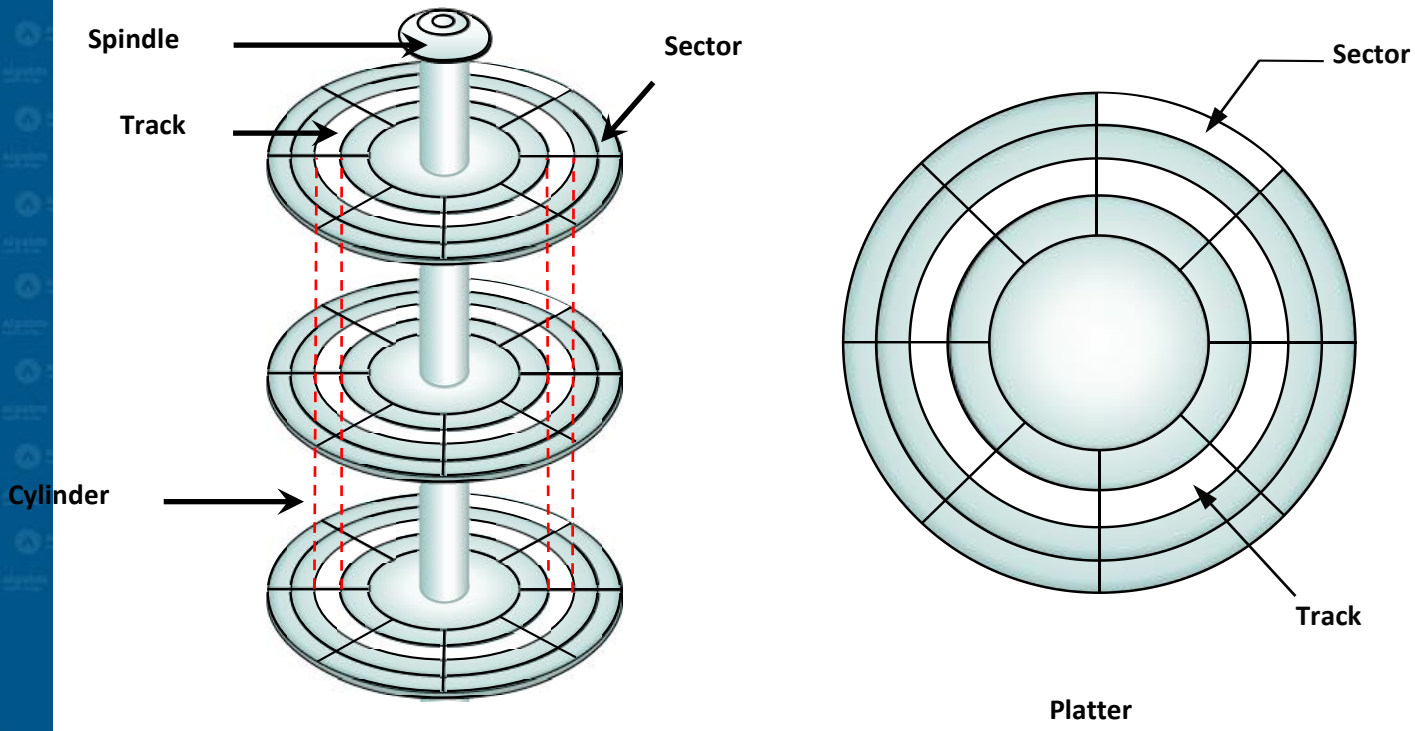
Physical Disk Structure



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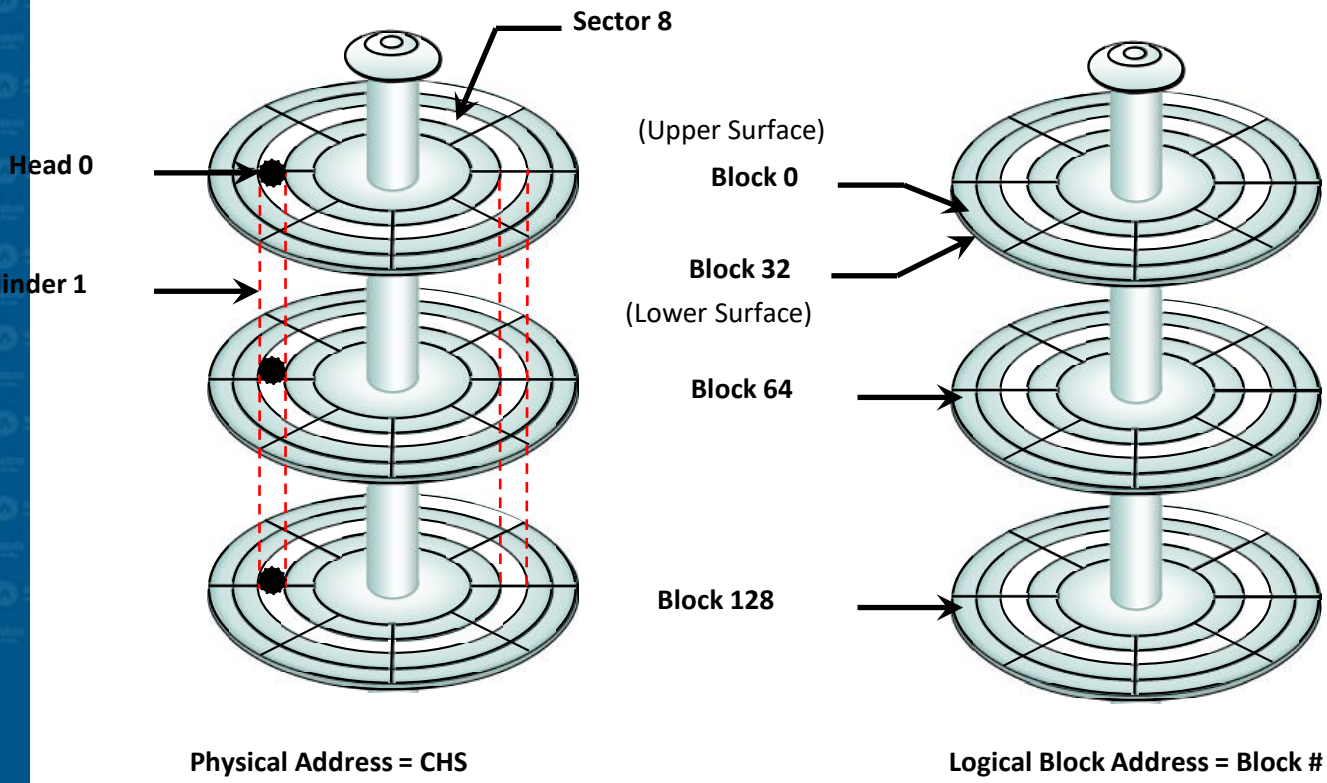
Logical Block Addressing



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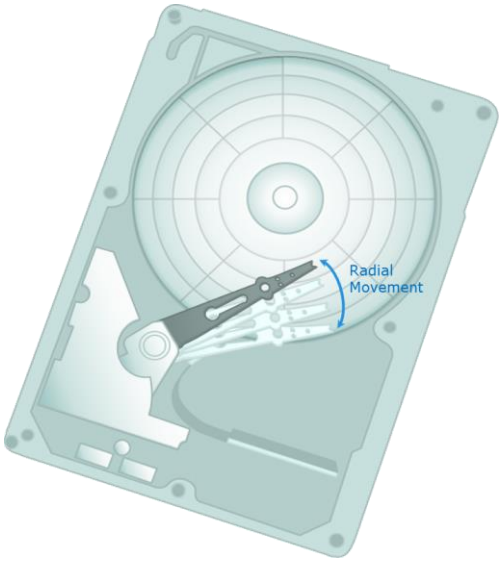
HDD Performance

- **Electromechanical device**
  - Impacts the overall performance of the storage system
- **Disk service time**
  - Time taken by a disk to complete an I/O request, depends on:
    - Seek time
    - Rotational latency
    - Data transfer rate

Disk service time = seek time + rotational latency + data transfer time

Seek Time

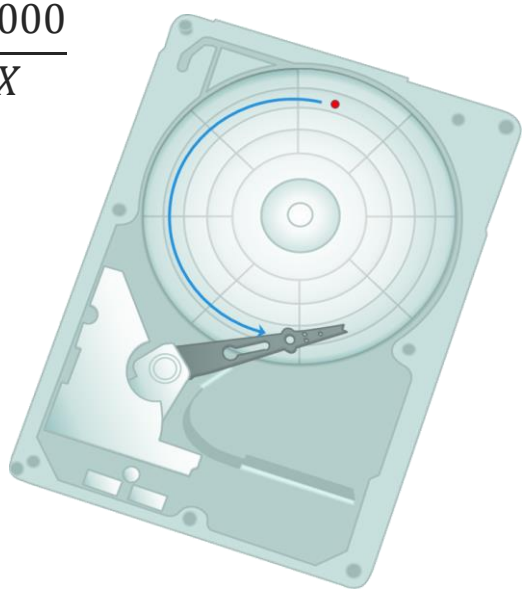
- Time taken to position the read/write head
- The lower the seek time, the faster the I/O operation
- Seek time specifications include
  - Full stroke
  - Average
  - Track-to-track
- The seek time of a disk is specified by the drive manufacturer



Rotational Latency

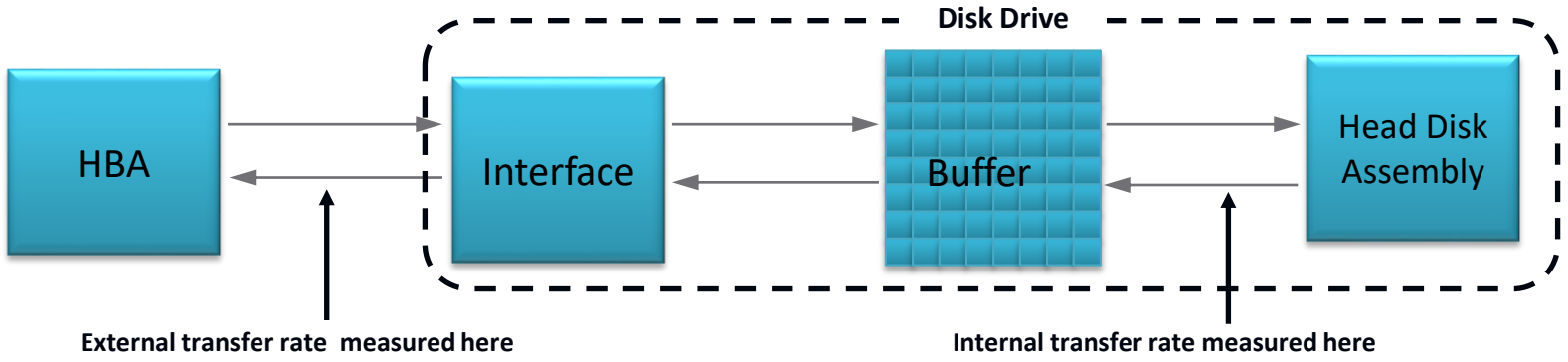
- **The time taken by the platter to rotate and position the data under the R/W head**
- **Depends on the rotation speed of the spindle**
- **Average rotational latency**
  - One-half of the time taken for a full rotation
  - For '*X*' rpm, drive latency is calculated in milliseconds as:

$$= \frac{(\frac{1}{2} \times 1000)}{(\frac{X}{60})} = \frac{500}{(\frac{X}{60})} = \frac{30000}{X}$$



Data Transfer Rate

- **Average amount of data per unit time that the drive can deliver to the HBA**
  - Internal transfer rate: Speed at which data moves from a platter's surface to the internal buffer of the disk
  - External transfer rate: Rate at which data move through the interface to the HBA

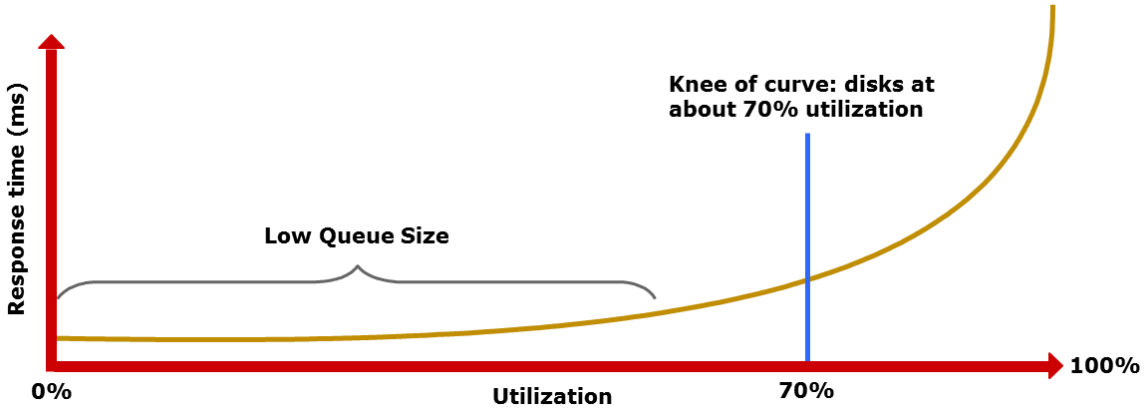


I/O Controller Utilization Vs. Response Time

- **Based on fundamental laws of disk drive performance:**

$$Avg.\,Response\ Time = \frac{Service\ Time}{(1 - Utilization)}$$

  - Service time is time taken by the controller to serve an I/O
- **For performance-sensitive applications disks are commonly utilized below 70% of their I/O serving capability**



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Storage Design Based on Application Requirements and Disk Drive Performance

- **Disks required to meet an application's capacity need (DC):**

$$D_c = \frac{Total\ capacity\ required}{Capacity\ of\ a\ single\ disk}$$

- **Disks required to meet application's performance need (DP):**

$$D_p = \frac{IOPS\ generated\ by\ an\ application\ at\ peak\ workload}{IOPS\ serviced\ by\ a\ single\ disk}$$

- **IOPS serviced by a disk (S) depends upon disk service time (T_S):**

$$T_s = Seek\ time + \frac{0.5}{(Disk\ rpm/60)} + \frac{Data\ block\ size}{Data\ transfer\ rate}$$

- **TS is time taken for an I/O to complete, therefore IOPS serviced by a disk (S) is equal to (1/TS)**
  - For performance sensitive application (S) $= 0.7\ \mathrm{X}\ \frac{1}{T_s}$

Disk required for an application = Max (DC, DP)

Components of Intelligent Storage Systems – II

This lesson covers the following topics:

- SSD components, addressing, and performance

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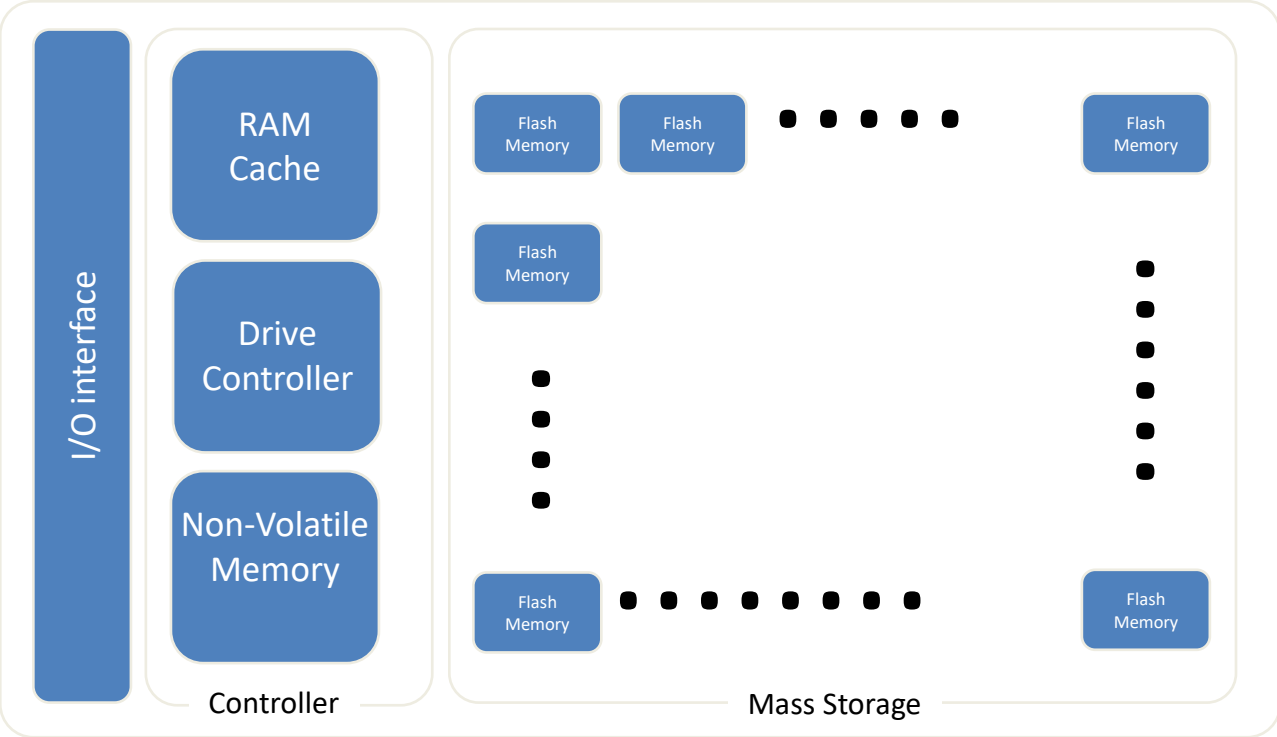
Storage – Solid State Drives

- Components of SSD



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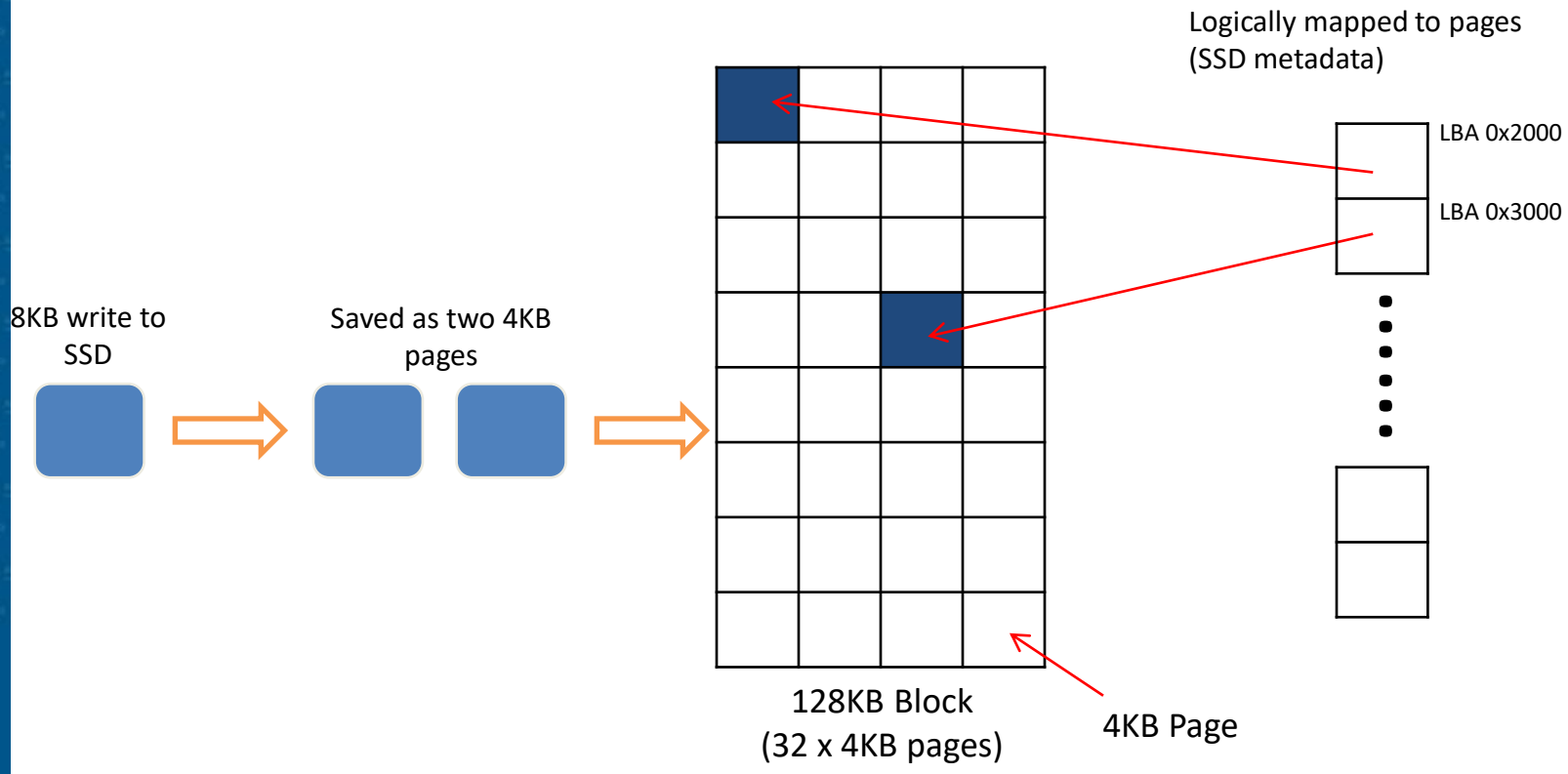
SSD Addressing



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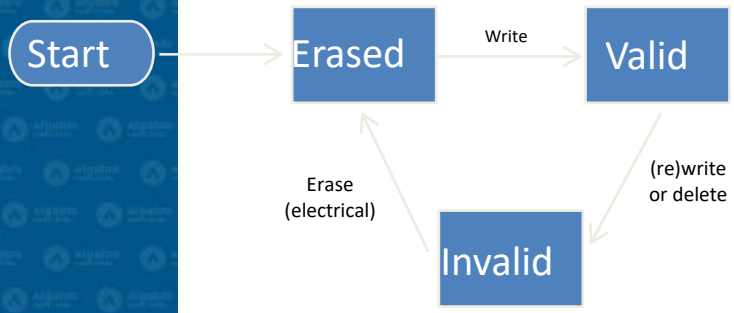
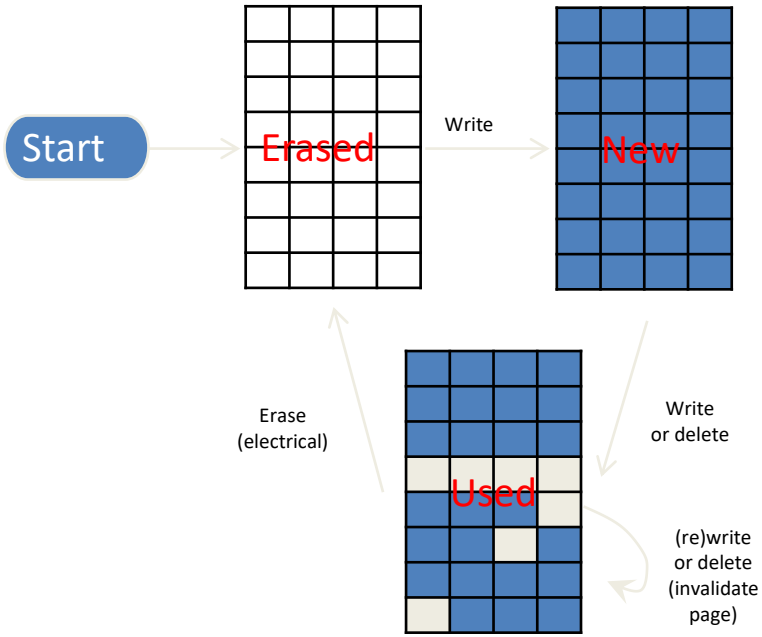
Page and Block States



Flash memory page states



Block state diagram

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SSD Performance

- **Access type**
  - SSD performs random reads the best
  - SSDs use all internal I/O channels in parallel for multi-threaded large block I/Os
- **Drive state**
  - New SSD or SSD with substantial unused capacity offers best performance
- **Workload duration**
  - SSDs are best for workloads with short bursts of activity

Part 4: RAID

This lesson covers the following topics:

- Describe RAID implementation methods
- Describe the three RAID techniques
- Describe commonly used RAID levels
- Describe the impact of RAID on performance
- Compare RAID levels based on their cost, performance, and protection

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Why RAID?

RAID

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

- **Provides data protection against drive failures**
- **Improves storage system performance by serving I/Os from multiple drives simultaneously**
- **Two implementation methods**
  - Software RAID implementation
  - Hardware RAID implementation

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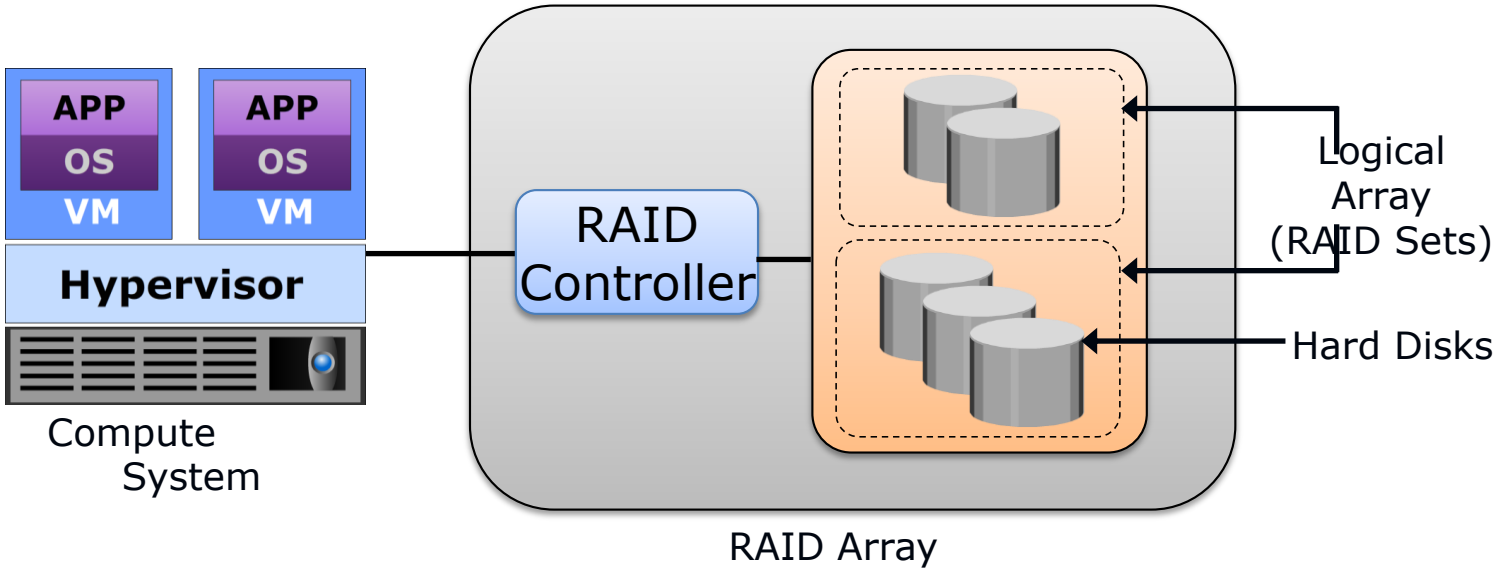
RAID Array Components



RAID Techniques

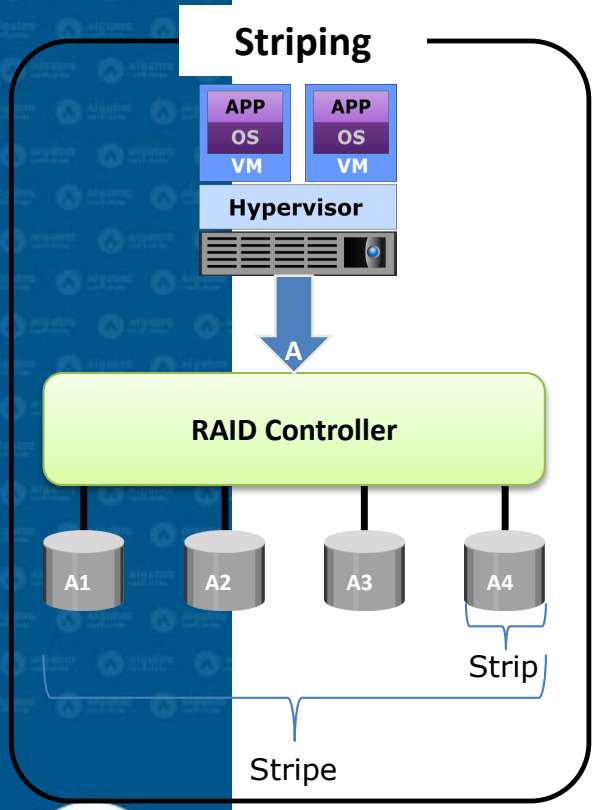


Figure 1

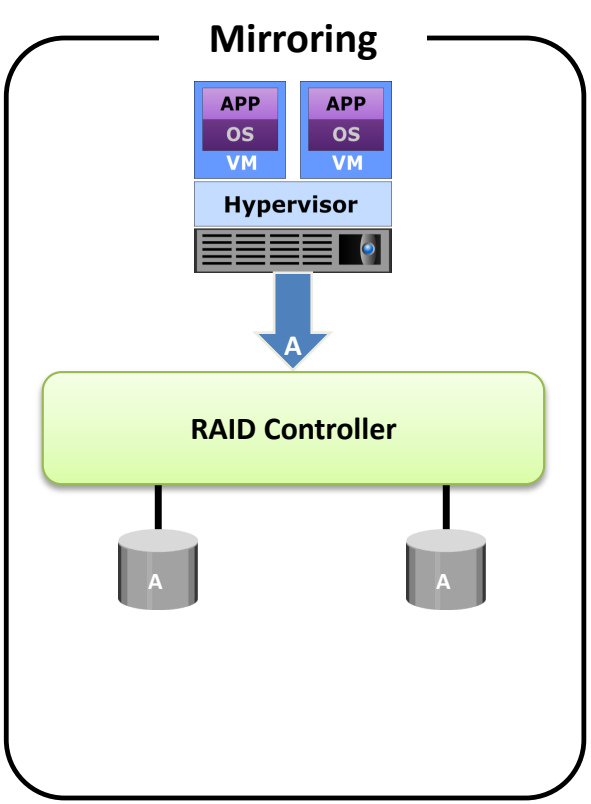


Figure 2

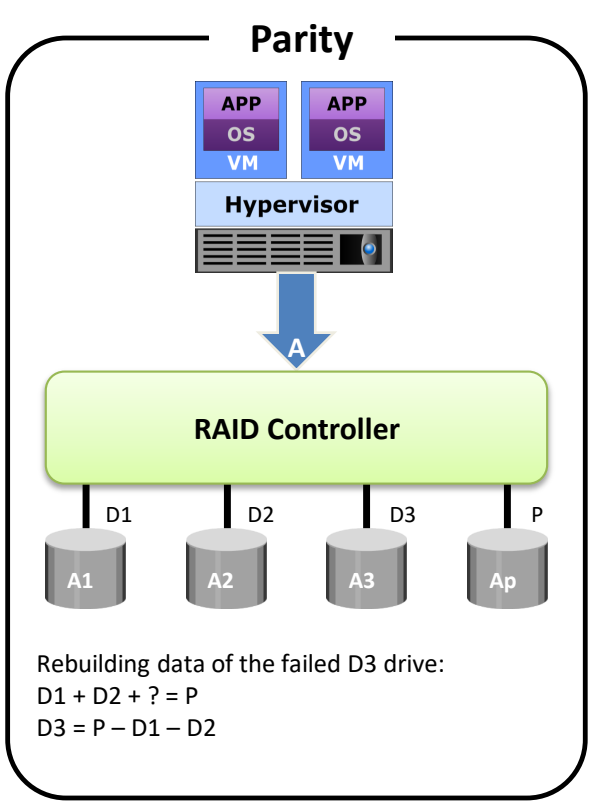


Figure 3

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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

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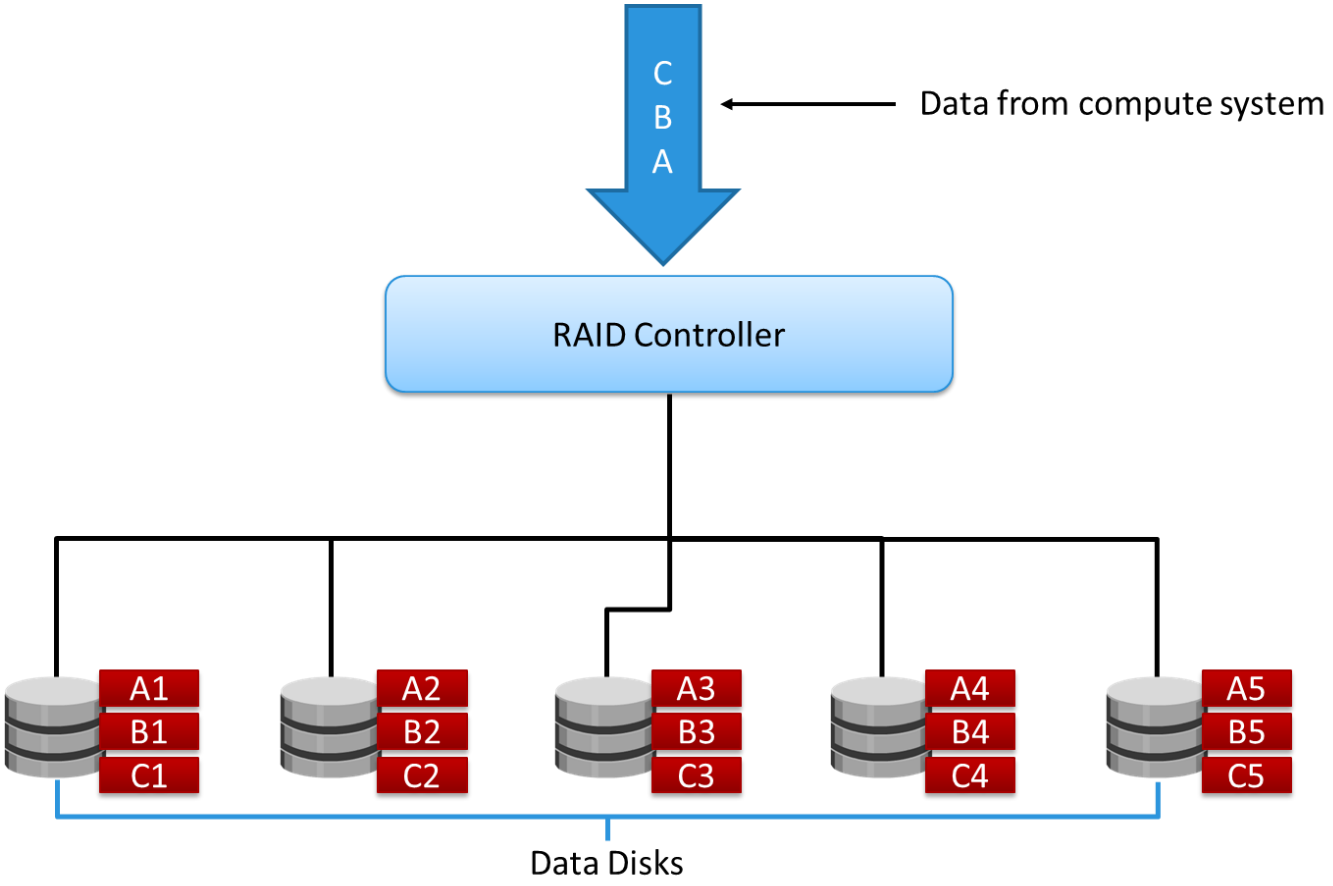
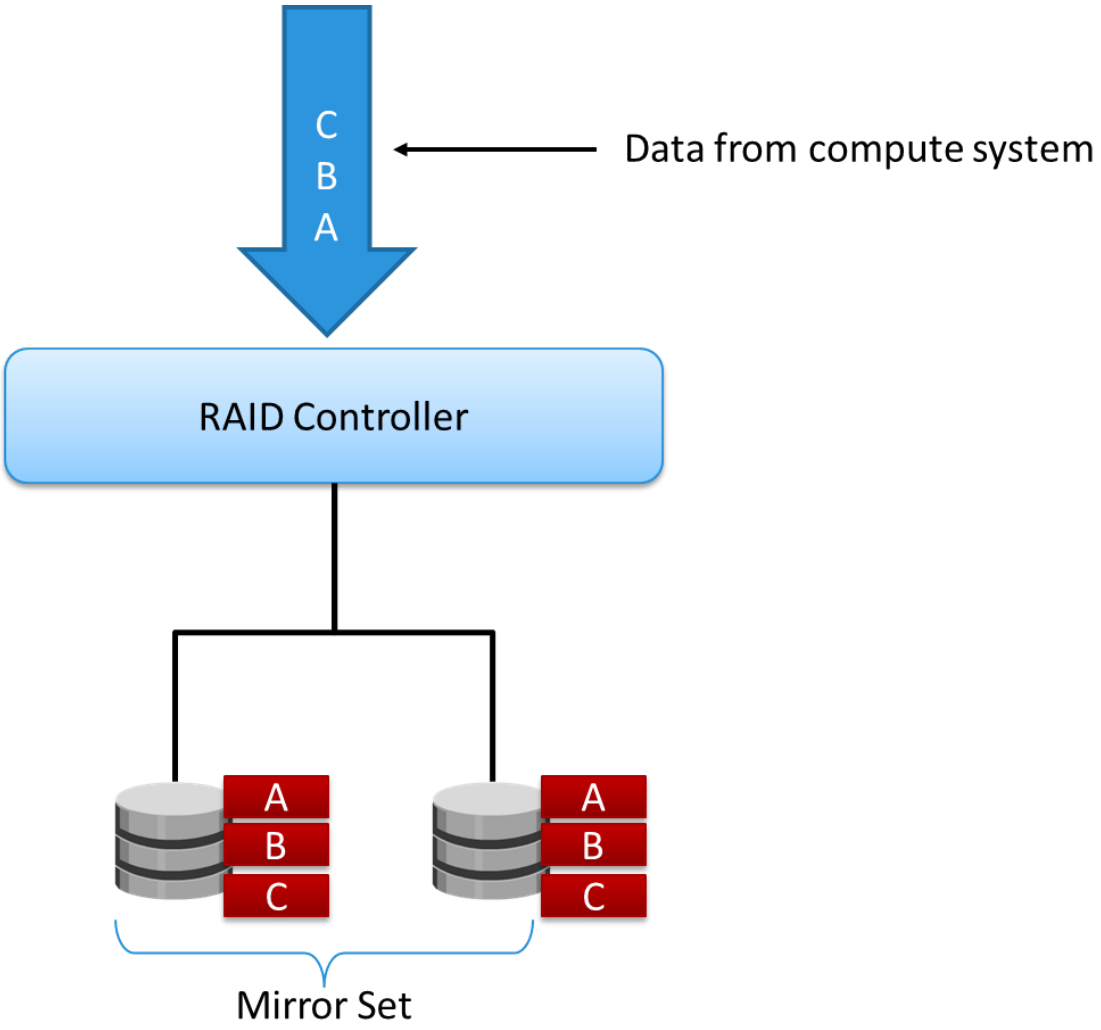
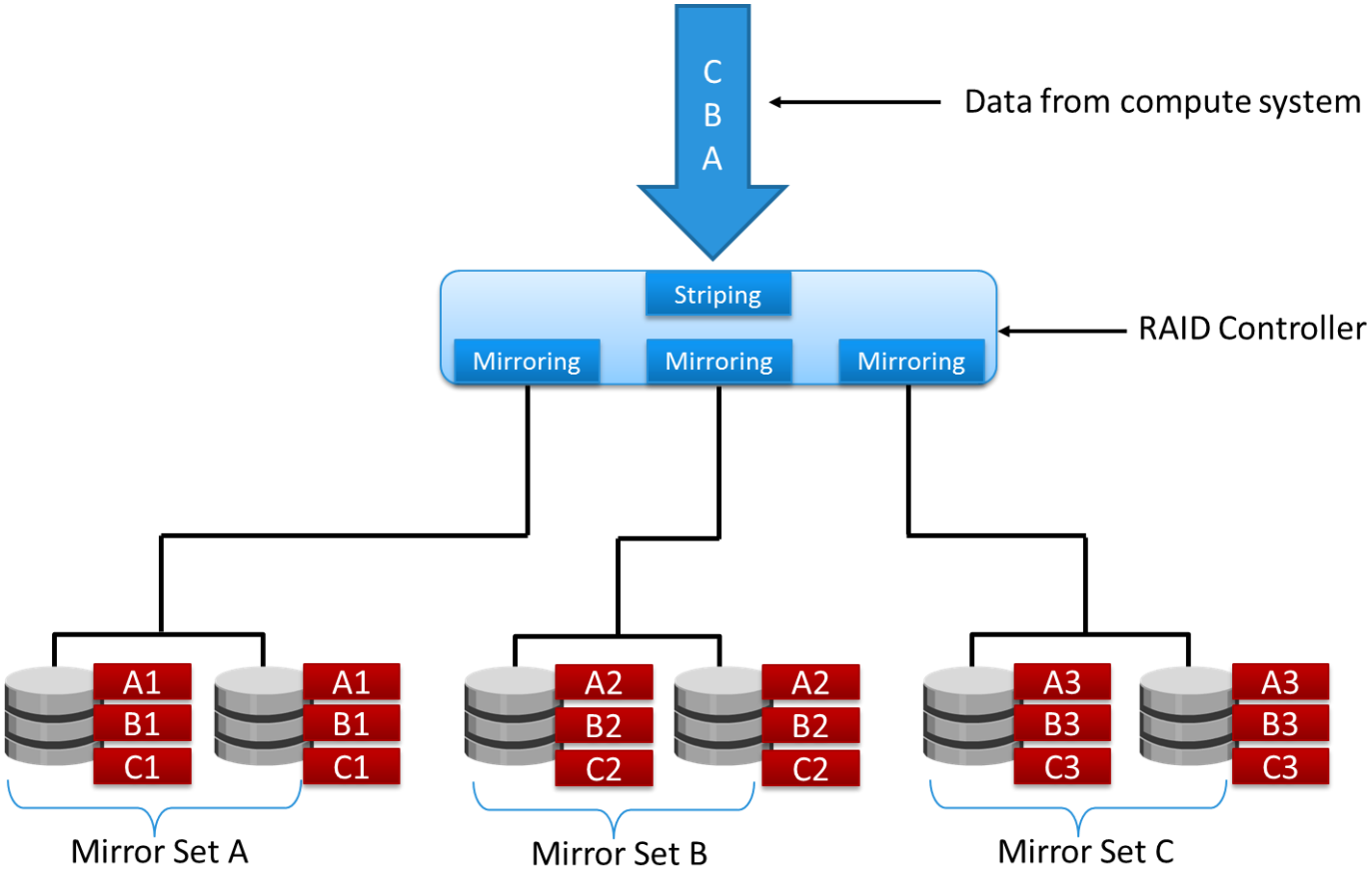
RAID 0



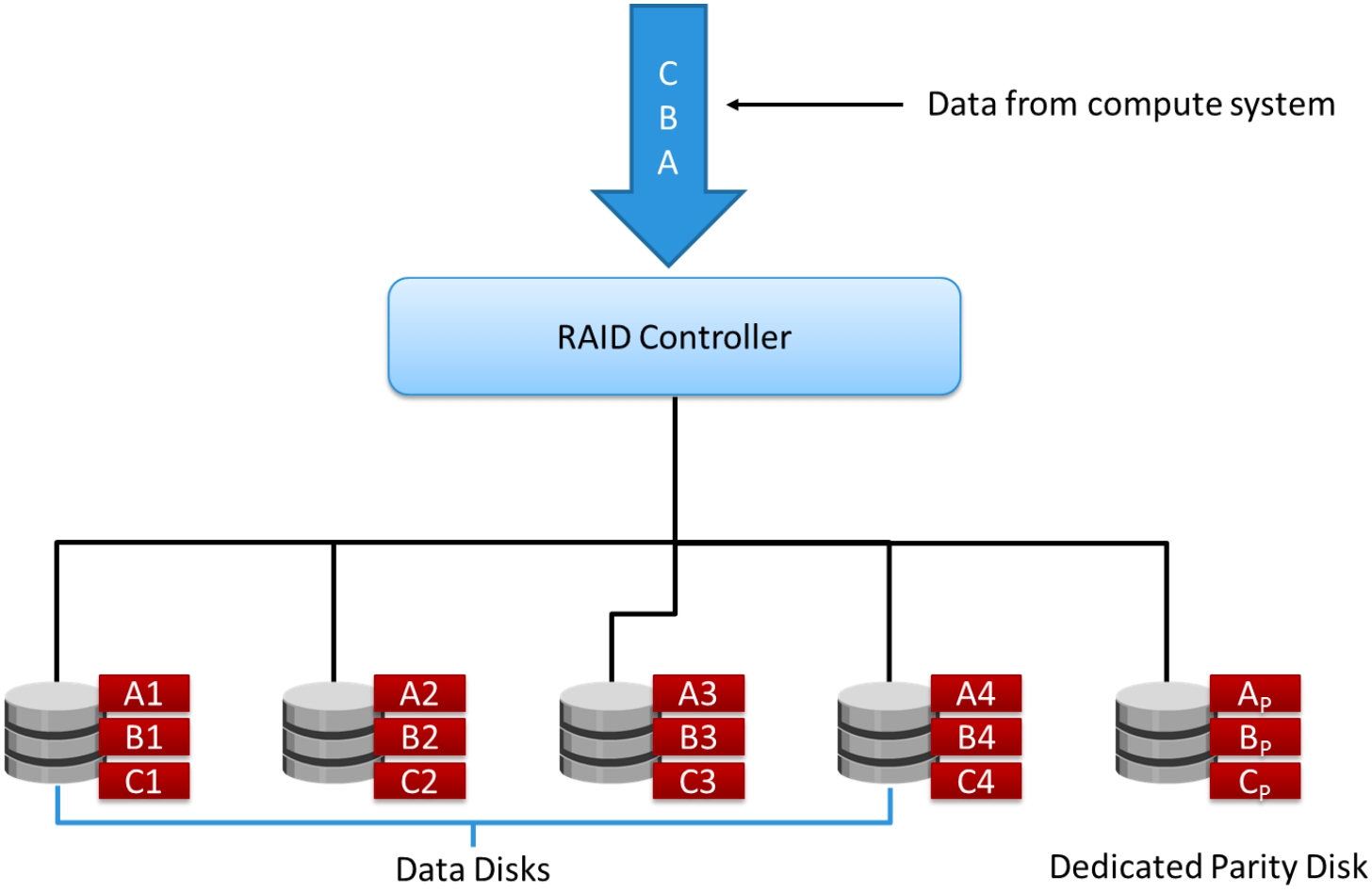
RAID 1



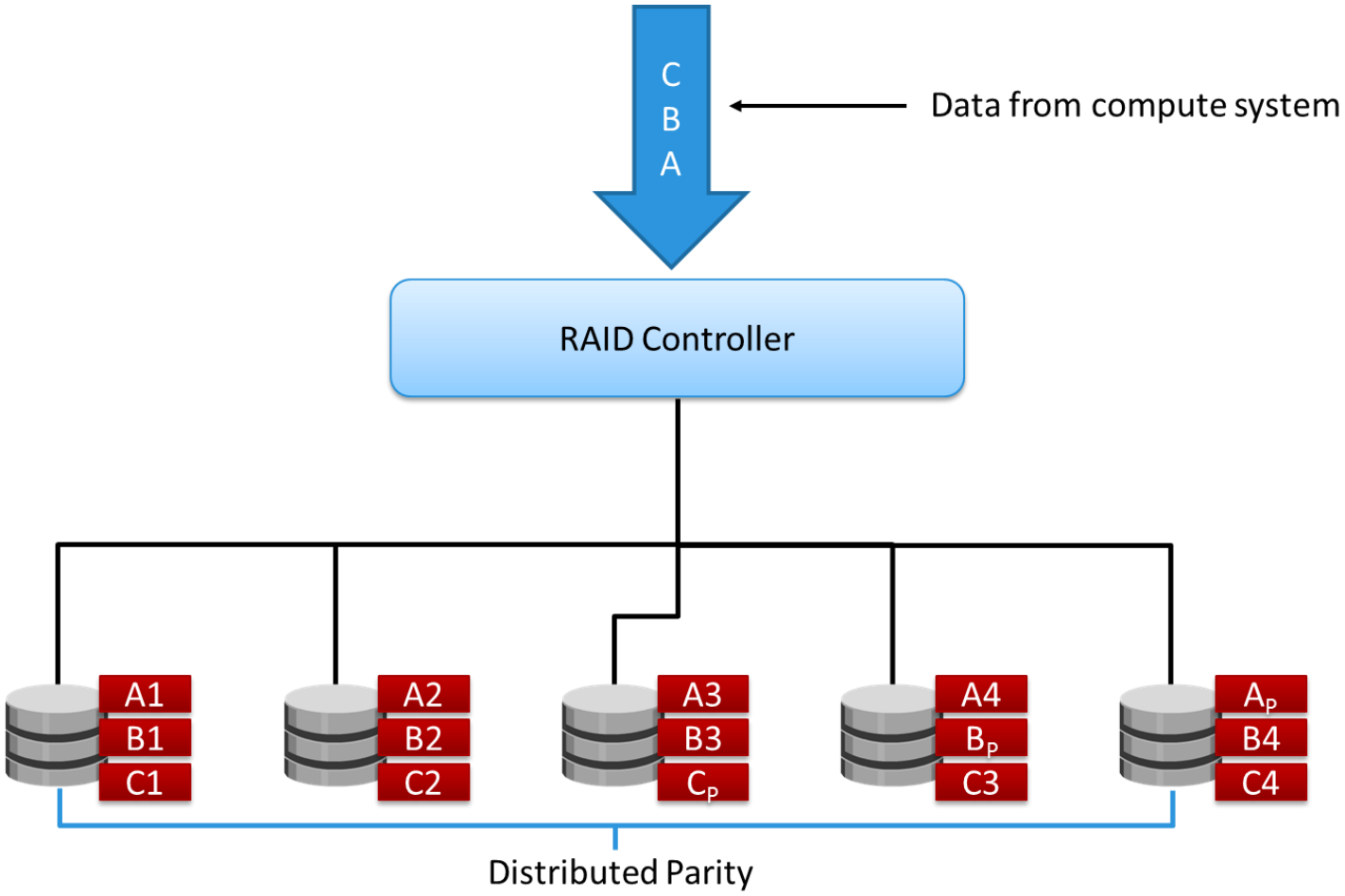
Nested RAID – 1+0



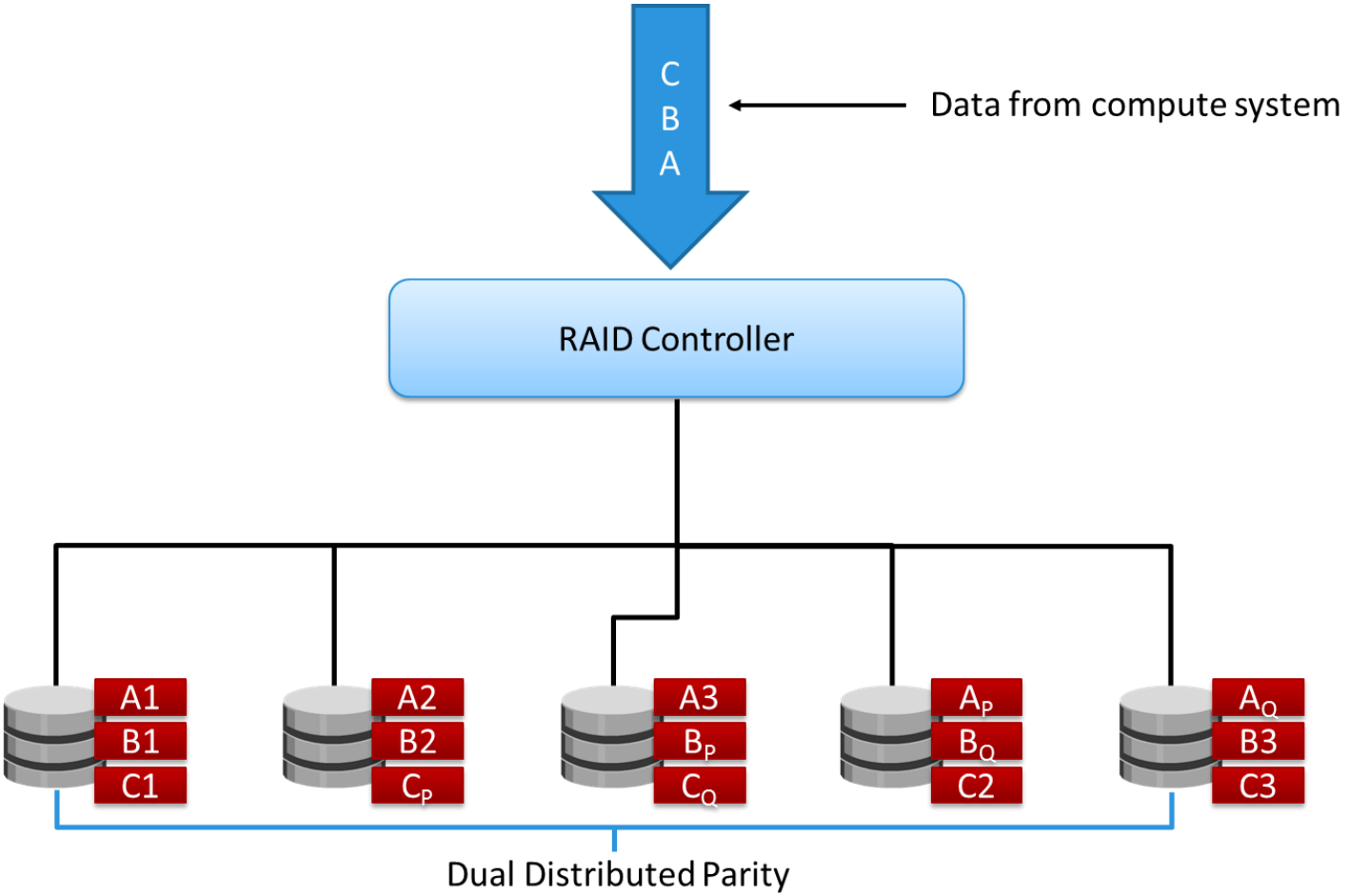
RAID 3



RAID 5



RAID 6



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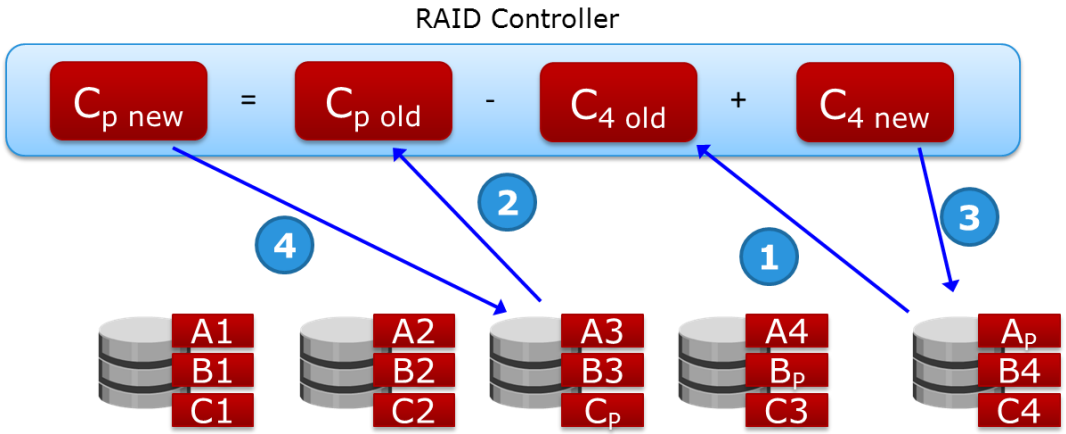
RAID Impacts on Performance

- In RAID 5, every write (update) to a disk manifests as four I/O operations (2 disk reads and 2 disk writes)
- **In RAID 6, every write (update) to a disk manifests as six I/O operations (3 disk reads and 3 disk writes)**
- **In RAID 1, every write manifests as two I/O operations (2 disk writes)**



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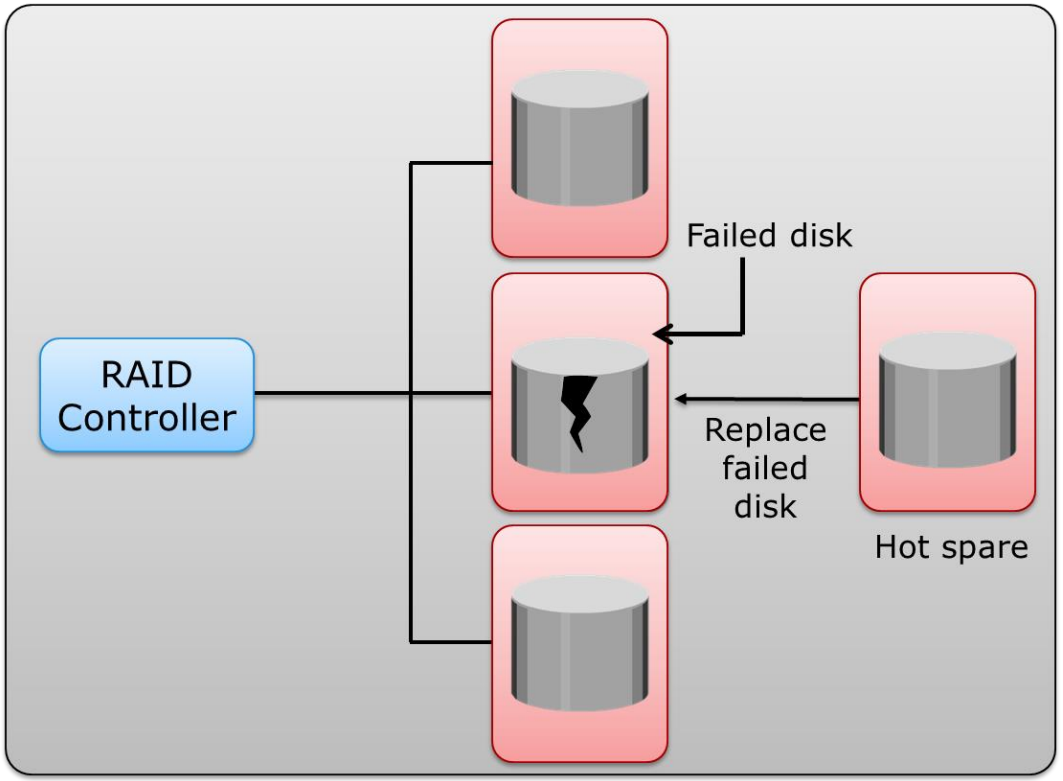
RAID Comparison

RAID level	Min disks	Available storage capacity (%)	Write penalty	Protection
1	2	50	2	Mirror
1+0	4	50	2	Mirror
3	3	[(n-1)/n]*100	4	Parity (Supports single disk failure)
5	3	[(n-1)/n]*100	4	Parity (Supports single disk failure)
6	4	[(n-2)/n]*100	6	Parity (Supports two disk failures)

Dynamic Disk Sparing (Hot Sparing)



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Part 5: Types of Intelligent Storage Systems

This lesson covers the following topics:

- Data access methods
- Types of intelligent storage systems
- Scale-up and scale-out architectures

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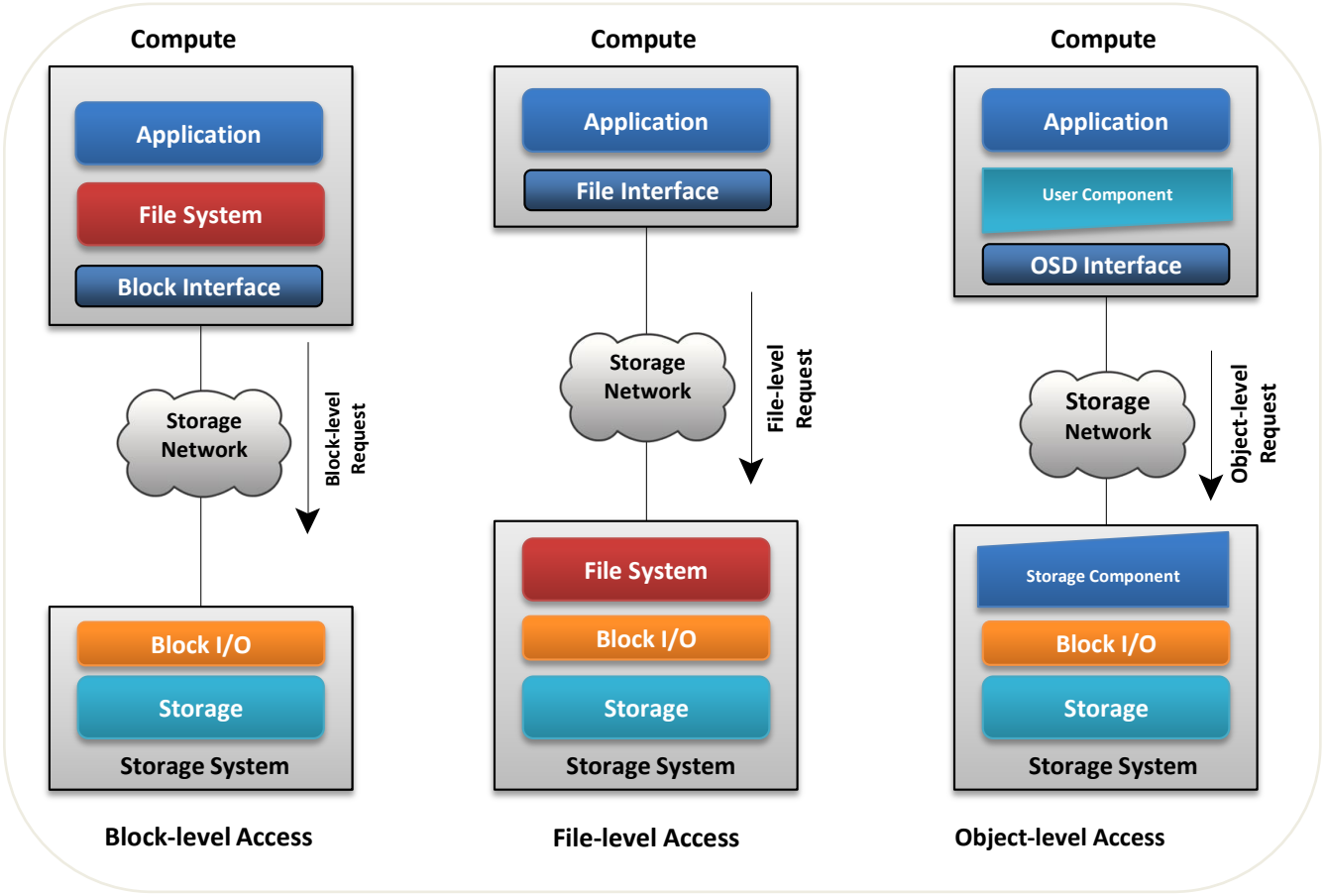
Data Access Methods



File System

User Component

Storage Component

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Types of Intelligent Storage Systems

- Block-based storage systems
- File-based storage systems
- Object-based storage systems
- Unified storage systems

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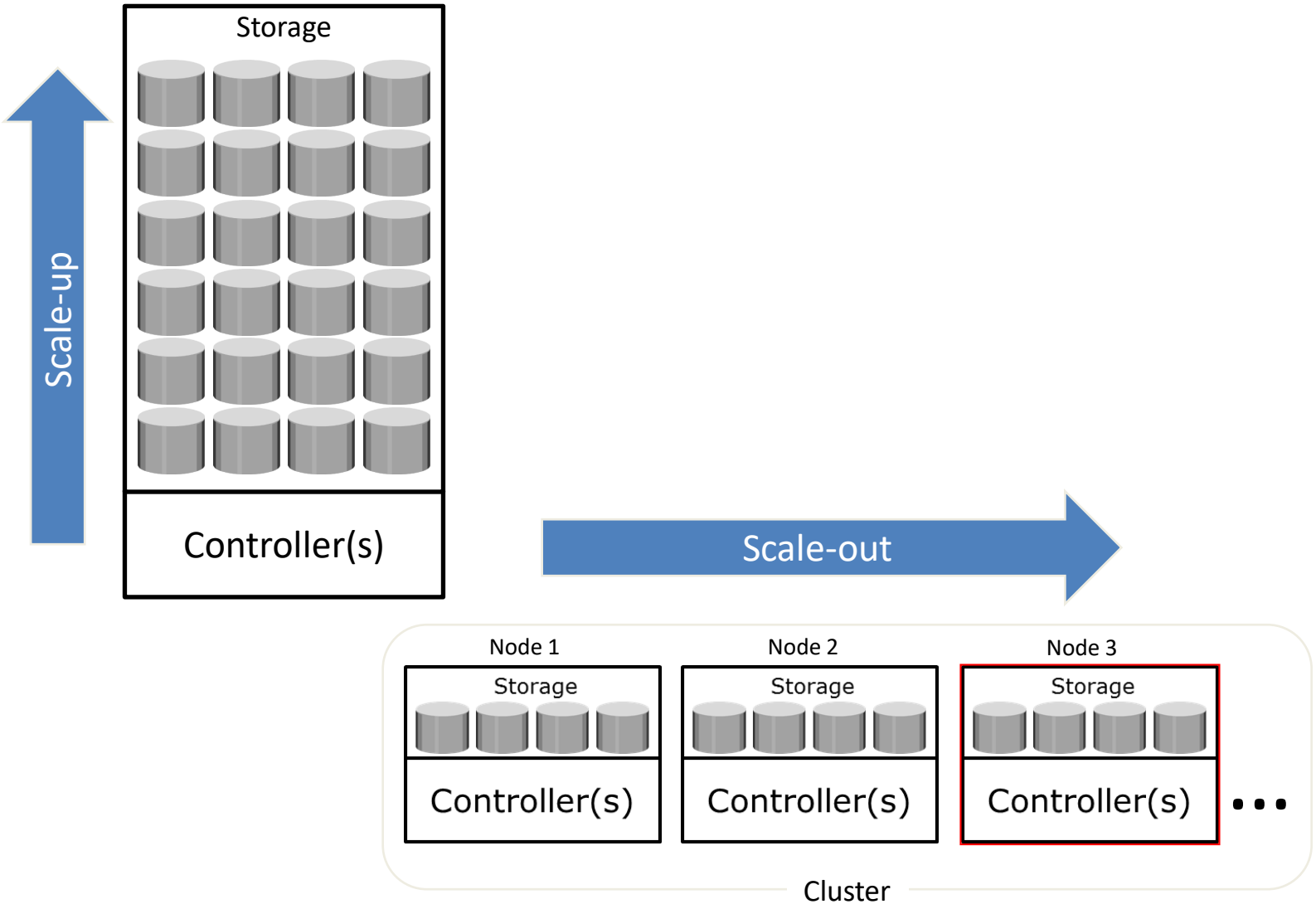
Scale-up Vs. Scale-out Architecture



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