What are the Data Center Components?

Course Outline

A. Servers:
- What are Servers?
- Differences between servers & PCs.
- What are the Servers components?
- Types of servers (Rack, towers, modular).
- Servers models (x86, mainframes, power sys., …).

B. Network:
- What is the meaning of Networking?
- OSI 7 layers model.
- Different types of network appliances (Switches, Routers, modems, load balancers, ….).
- Types of networks: (Campus north & south/ Data Center east & west).

C. Storage:
- What is the storage?
- Different types of storage (SAN, NAS, DAS, …).
- Storage components (Controller, enclosures, drivers, ….).
- Different Storage Architecture (Scale-up / Scale-out).
- Storage provisioning (Block, volume, LUN, Directories, Buckets).
- Storage Protocols (iSCSI, FC, NFS, SMB, CIFS, S3, …).
- Storage resilience (different types of Raids).
- Storage services (Data reduction, Replication, Snapshots, …).

D. Virtualization:
- What is virtualization?
- Virtual VS physical.
- Virtual compute (hypervisor).
- Virtual networking (SDN – Data plan/control plan).
- Virtual Storage (SDS).
- Containers (very high level)

What are the Data Center Components?

- Main components hosted in Data Centers
  - Servers
  - Storage systems
  - Network infrastructure
  - Security Systems (Cyber Security)

Servers

- What are Servers?

A **server** is a computer that provides information to other computers called "clients" on computer network.[1] This architecture is called the client–server model. Servers can provide various functionalities, often called "services", such as sharing data or resources among multiple clients or performing computations for a client.

A single server can serve multiple clients, and a single client can use multiple servers. A client process may run on the same device or may connect over a network to a server on a different device.[2] Typical servers are database servers, file servers, mail servers, print servers, web servers, game servers, and application servers.[3]

https://en.wikipedia.org/wiki/Server_(computing)

Servers

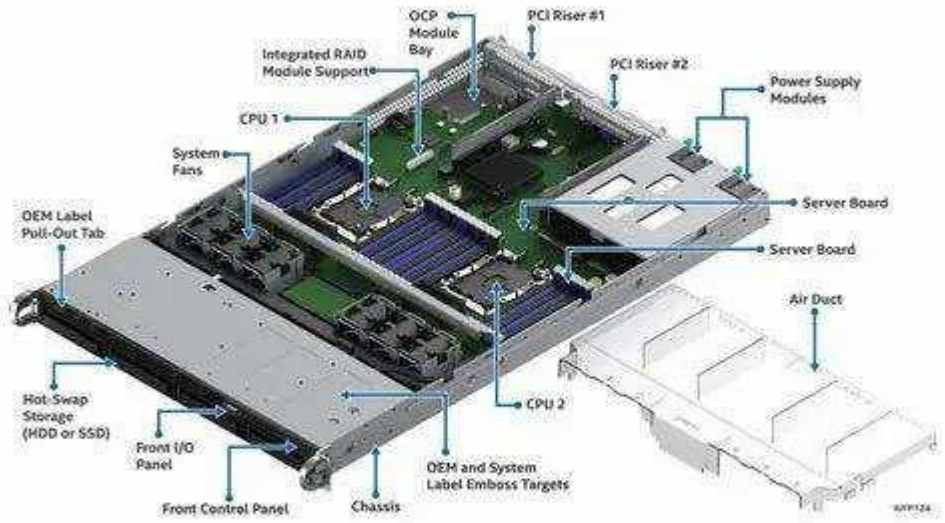
- Differences between Servers & PCs

The differences between servers and desktops are mainly in their purpose, operation and computational power:

- Servers provide services to clients, while desktops request services from servers
- Servers are designed to handle many requests, while desktop computers are designed to be used by one user at a time
- Servers are computationally more powerful than desktop computers

Servers

- What are the Servers components?
  - Motherboard.
  - Central Processing Unit (CPU) / Processor.
  - Random Access Memory (RAM)
  - Storage
  - Networking
  - Power and Cooling
  - GPU



Servers

- **Server Hardware Architecture**

Tower servers. These machines resemble traditional PC cases. Each tower is a standalone server that sits on a flat surface and requires cabling, power supply, and cooling technology. Tower servers are typically used in smaller businesses that require only a few servers.

Servers

- **Server Hardware Architecture**
  - **Rack-Mounted** Servers. These servers are designed to be mounted within a standard server rack, allowing multiple servers to be stacked vertically. Rackmount servers have a uniform width, but the height of these servers may vary from one rack unit (1U) to 4 rack units (4U), with each unit equal to 1.75 inches of vertical space. A server rack typically includes some combination of shared power, network, and storage connections for greater efficiency.

Servers

- **Server Hardware Architecture**
  - **Blade server** is a server on a single card that can be mounted alongside other blade servers within a chassis that provides power, cooling, cabling, and KVM switching to each blade, further minimizing space requirements, and reducing cable clutter.

Servers

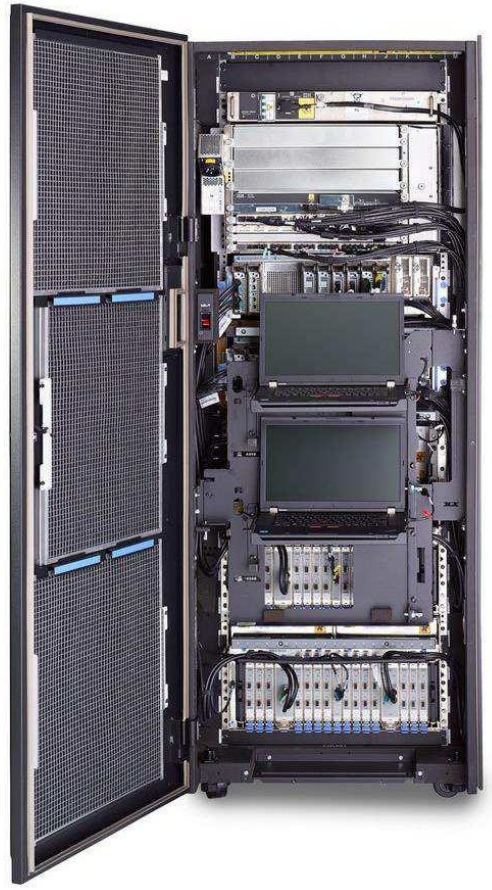
- **Server Hardware Architecture**
  - **Modular servers** consist of individual server modules that can be combined to create a custom configuration based on the organization's needs. They offer flexibility and scalability.

Servers

- **Server Hardware Architecture**
  - **Micro servers** are a type of server hardware that offer a compact and energy-efficient solution for low-power workloads. They are designed to provide targeted computing power for specific tasks, such as hosting web content, running dedicated applications, and serving as storage for small-scale data centers.

Servers

- **Server Hardware Architecture**
  - **Mainframe Servers** are highly specialized hardware designed to perform specific tasks as fast and as efficiently as possible. They cost millions and can perform billions of transactions every day.



Computer Network

- A **computer network** is a set of computers sharing resources located on or provided by network nodes. Computers use common communication protocols over digital interconnections to communicate with each other. These interconnections are made up of telecommunication network technologies based on physically wired, optical, and wireless radio-frequency methods that may be arranged in a variety of network topologies.

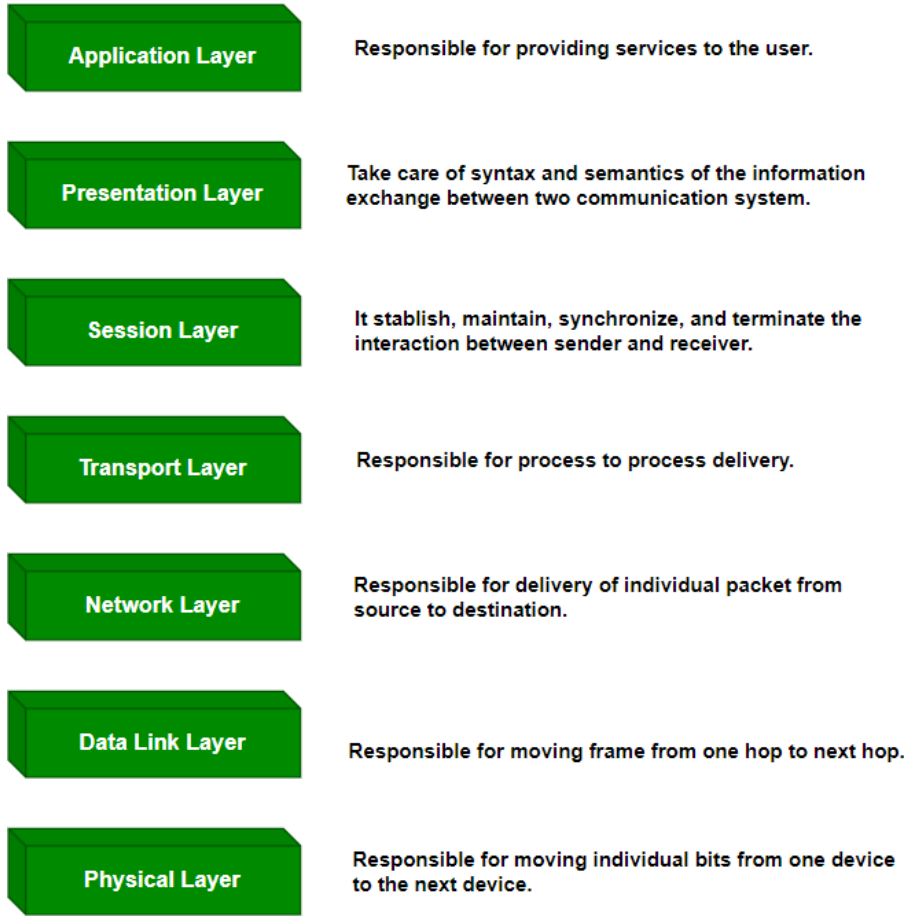
https://en.wikipedia.org/wiki/Computer_network

Computer Network

- **Network Infrastructure components**
  - **Passive network components**
    - Cables (fiber optic cable, coaxial cables)
    - Connectors
    - Patch panels
    - Plugs
  - **Active network components**
    - Switches
    - Routers
    - Firewalls
    - load balancers

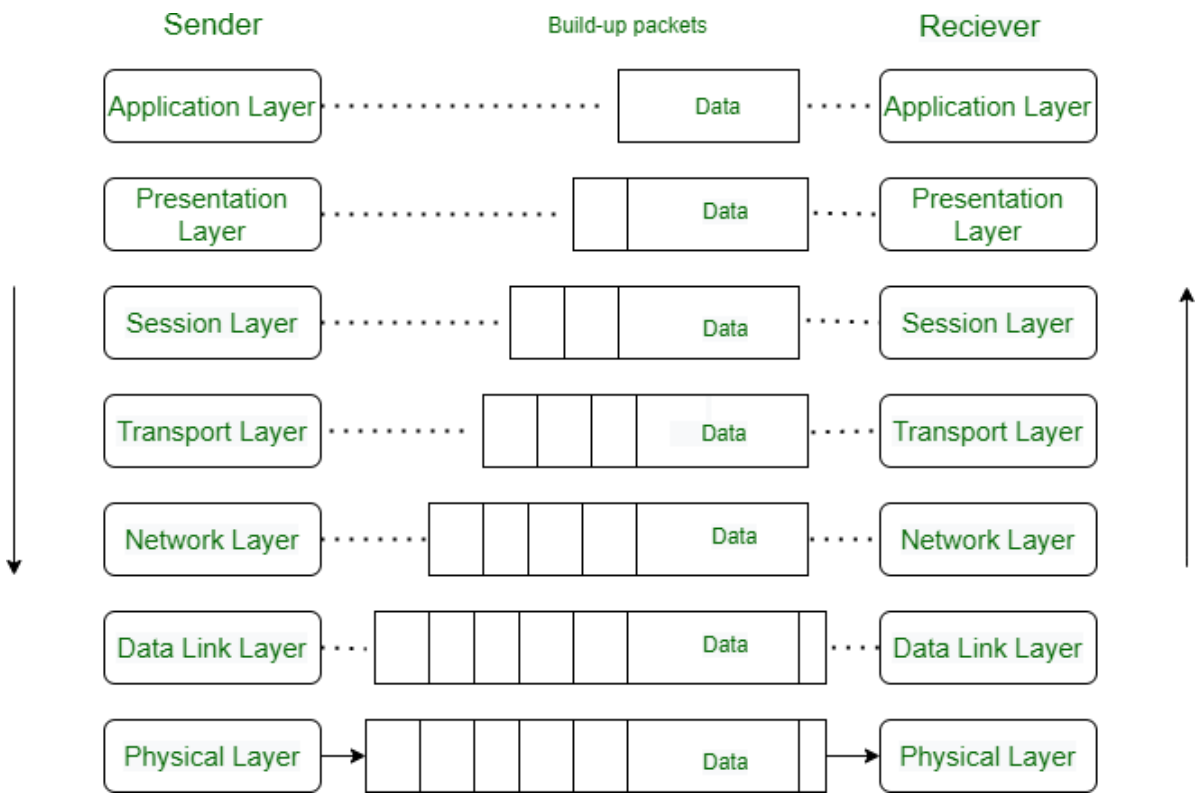
What is OSI Model? – Layers of OSI Model

- The OSI model, created in 1984 by ISO, is a reference framework that explains the process of transmitting data between computers. It is divided into **seven layers that work together** to carry out specialized **network functions**, allowing for a more systematic approach to networking.



What is OSI Model? – Layers of OSI Model

- Each layer adds specific information to ensure the data reaches its destination correctly, and these steps are reversed upon arrival.
  - **Application Layer:** Applications create the data.
  - **Presentation Layer:** Data is formatted and encrypted.
  - **Session Layer:** Connections are established and managed.
  - **Transport Layer:** Data is broken into segments for reliable delivery.
  - **Network Layer**: Segments are packaged into packets and routed.
  - **Data Link Layer:** Packets are framed and sent to the next device.
  - **Physical Layer:** Frames are converted into bits and transmitted physically.



Different types of network appliances

Switches are devices that are operating a secondary data link layer in the **OSI model**. They establish connectivity in any network and by the means of a packet data is received and sent. Multiple computers are plugged into it as it has many ports.

Different types of network appliances

Router is defined as a networking device that sends data packets further between computer networks. They are able to perform traffic directing functions over the internet

Different types of network appliances

- Load balancer is defined as the traffic cop, sitting in front of any server and routing client requests across all servers that are capable of fulfilling the former request. It is done in a way that maximizes speed and capacity utilization and ensures that no server happens to be overburdened.

Types of networks

- **Datacenter vs Campus Network**

Criticality and Availability

Campus:

A failure in a campus impact the users only who in the failure area (eg, if an access switch went down, only the connected users will be affected, and if a distribution switch went down only the connected access switches will be affected which not cause an interruption or outage to the rest of the network)

Data Center:

A failure in a data center can impact all the users who using the network (eg, if a server went down, all the users in the network will be affected)

Types of networks

- **Datacenter vs Campus Network**

Speed and Performance

Campus:

The speed rate within the campus will be normally 1G for access ports and 10G for uplink ports. In some cases we can see 20G combined of two 10G ports in a port-channel or 40G of uplink ports within the campus

Data Center:

The speed of the access ports can be 1/10/40G (huge difference between campus access and data center access layer!)

while the uplink sped can operate in 10/40/100G.

Types of networks

- **Datacenter vs Campus**

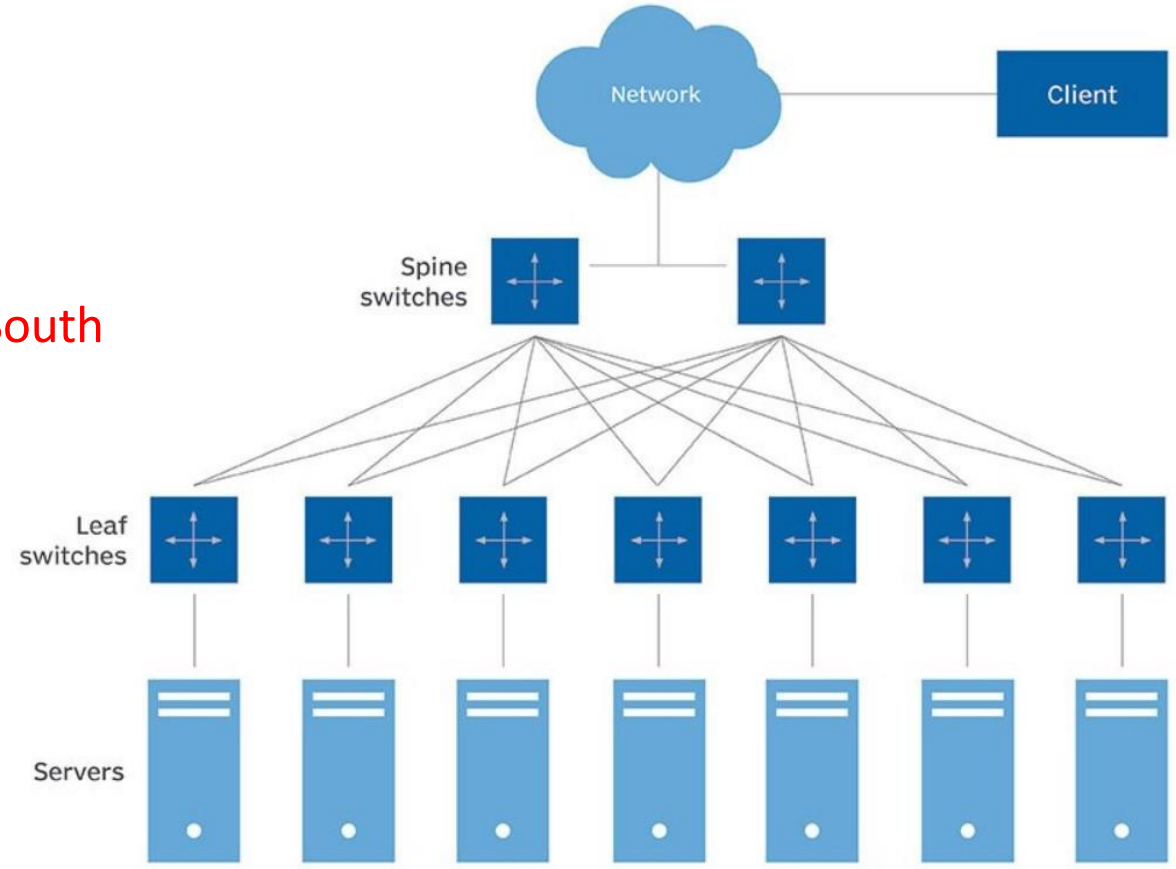
Network Traffic Flow

Campus:

Almost of the traffic within the campus goes North South

Data Center:

Operates in both North-South and East-West the perfect for of the VDI solution where all the data exchange happens inside the data center



Types of networks

- **Datacenter vs Campus Network**

Network Architecture

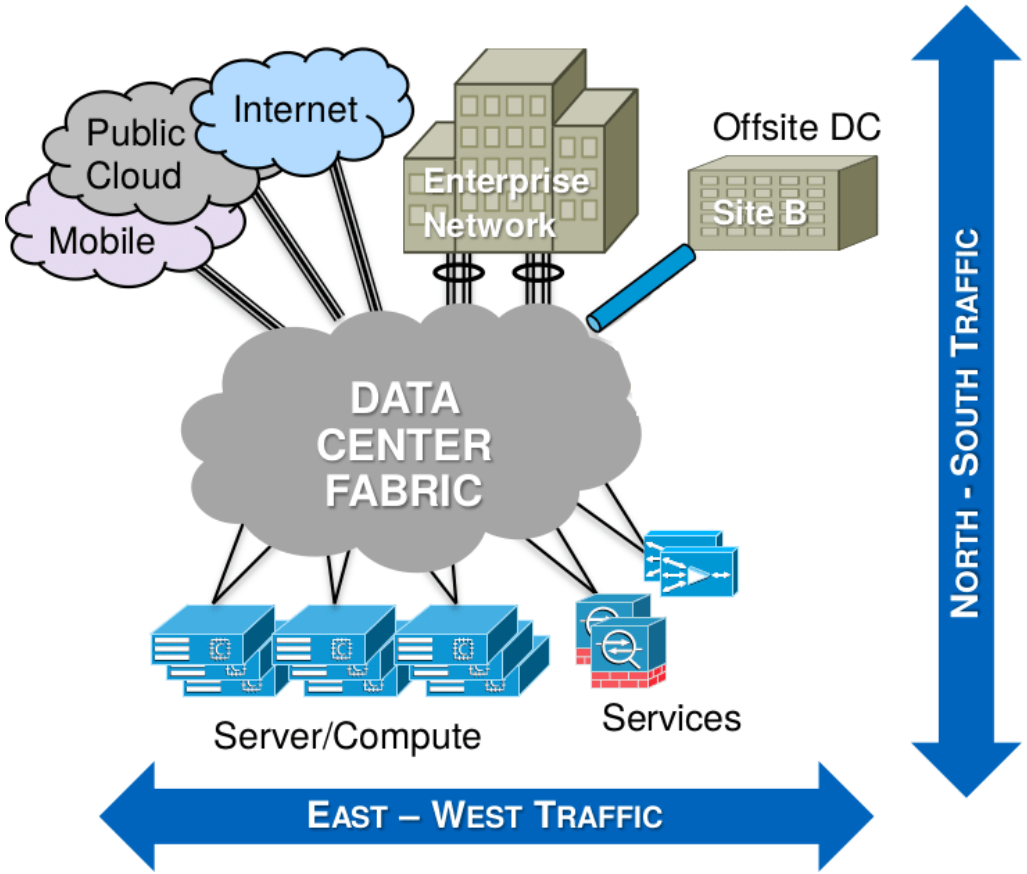
Campus:

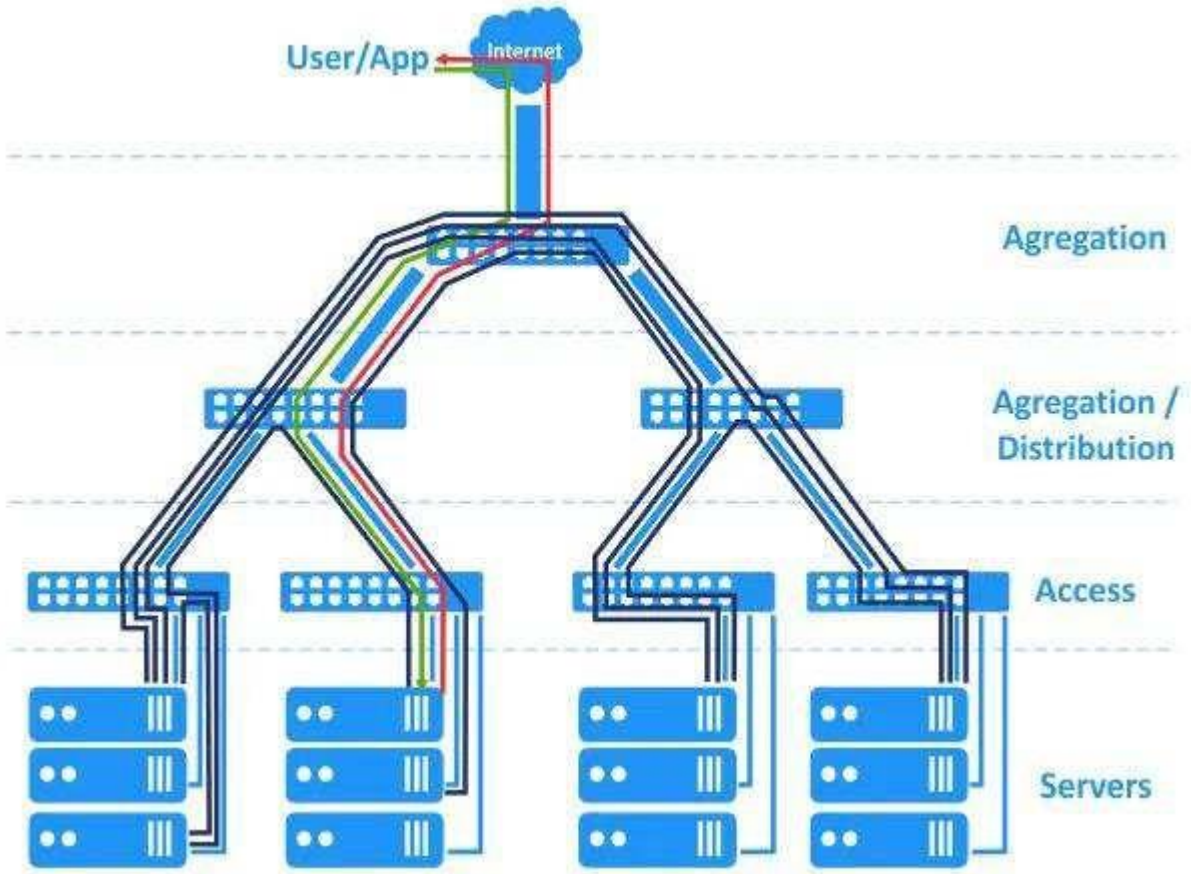
In the campus environment mainly the three layered hierarchical model (Access-Distribution-Core) is used, and it might be collapsed core depending the business requirements

Data Center:

Three layer hierarchical model (Access-Distribution-Core) and Spaine-Leaf architecture with Cisco ACI

Types of networks





Storage Systems

- Data center storage, a part of data center architecture, is a collective term for the devices, software technologies, and processes that design, manage and monitor data storage within a data center.
- Includes the policies and procedures used to govern the process of data storage and retrieval.
- Must abide by the government laws and regulations related to data storage and security under some circumstances.

Storage Systems

- **Direct attached storage (DAS)** typically refers to hard disk drives (HDDs) or solid-state drives (SSDs) attached directly to a host server.
  - **Advantages of DAS:**
    - **Cost-saving:** DAS is much cheaper than other storage technologies, such as NAS and SAN. And the price per GB for these types of storage devices is very low, which continues to trend downward. Because of this, it is more popular in small-to-medium-sized businesses.
    - **Better performance:** Compared with other networked storage solutions, DAS cannot be affected by network bottlenecks, such as network congestion. Therefore, the data hosted on DAS can be accessed without hindrance.
  - **Disadvantages of DAS:**
    - **Limited scalability:** Because the overall configuration is too simple, DAS is easily influenced by the server. A server can only support a few expansion slots or external ports. Besides, if the server fails, the data cannot be accessed.
    - **Not shareable enough:** Since data on DAS cannot be connected through the internet, data sharing can be a big problem.

Storage Systems

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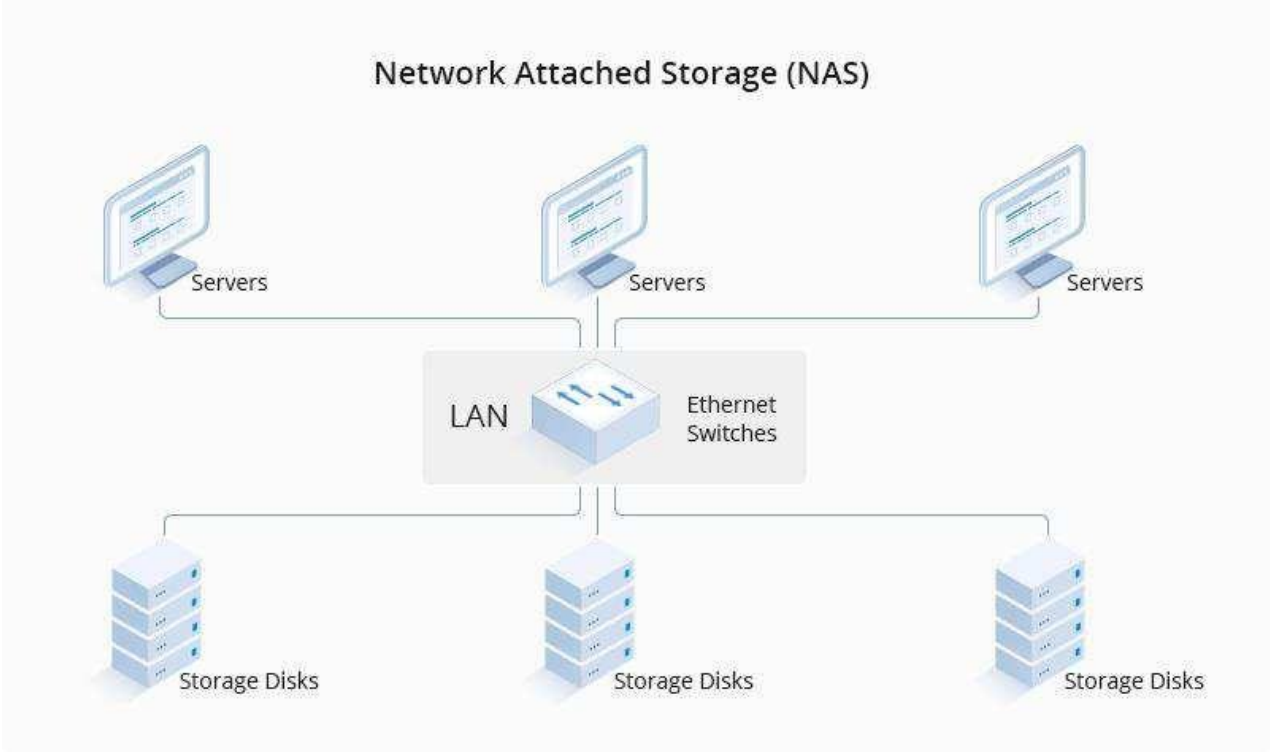
  - **Advantages of DAS**
    - **Cost-saving**
    - **Better performance**
  - **Disadvantages of DAS**
    - **Limited scalability**
    - **Not shareable enough**

Storage Systems

- **Network Attached Storage (NAS)** is a file-level data center storage device that supports multiple users to retrieve data from centralized disk capacity over a TCP/IP network.
- It usually has its node on the local area network (LAN), without the intervention of the application server, allowing users to access data on the network.
- Supports a variety of protocols, including Network File System (NFS), Common Internet File System (CIFS), File Transfer Protocol (FTP), Hyper Text Transfer Protocol (HTTP), etc.

Storage Systems

- **Advantages of NAS:**
  - **High-efficient file sharing**
  - **Easy deployment and operation**
- **Disadvantages of NAS:**
  - **Poor performance**
  - **Lack of scalability**

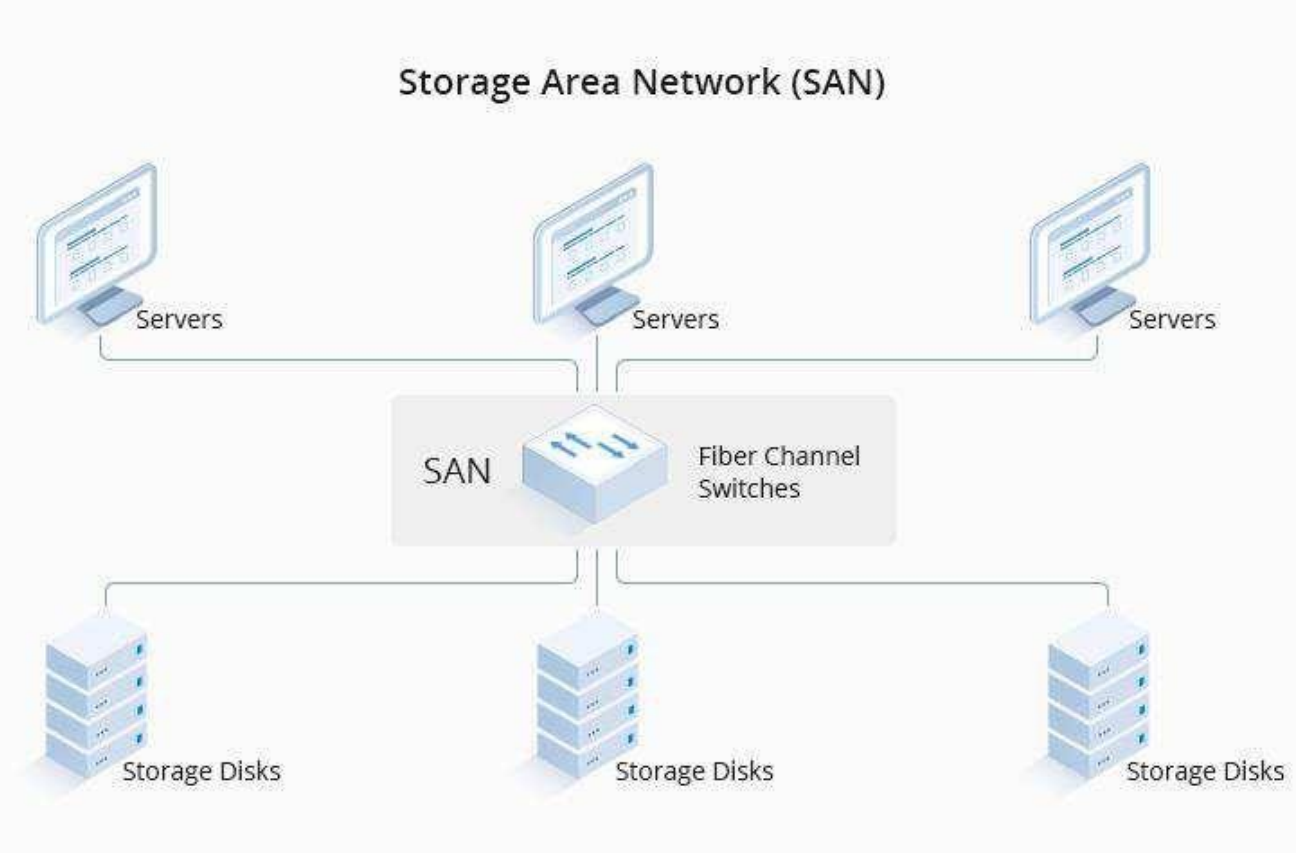


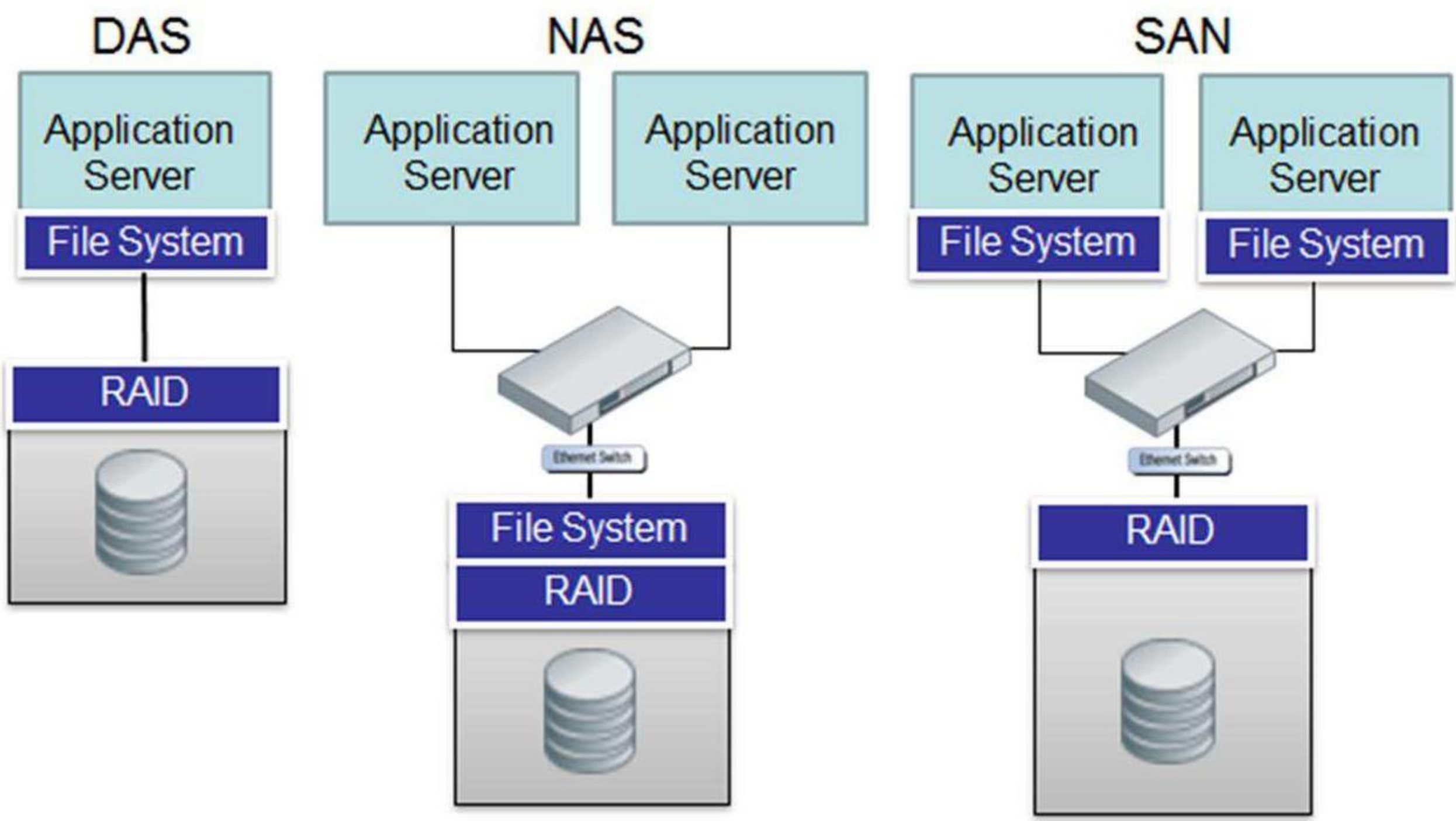
Storage Systems

- **Storage Area Network (SAN)** is a dedicated and high-speed network established for storage that is independent of the TCP/IP network. It connects servers to their logical disk units (LUNs) and provides block-level network access to data center storage.
- SAN typically adopts a high-end RAID array, which makes the performance of SAN stand out among other data center storage solutions.

Storage Systems

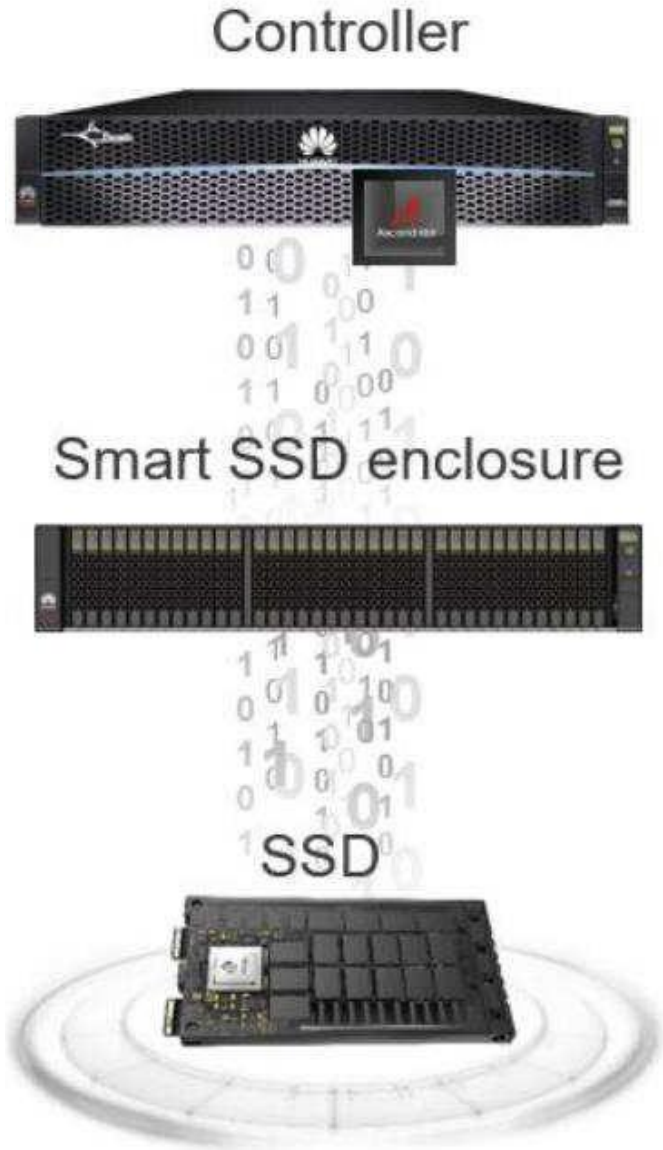
- **Advantages of SAN:**
  - **High scalability**
  - **High security**
- **Disadvantages of SAN**
  - **High cost**
  - **Complex and difficult installation**




DAS
Application Server
File System
RAID
NAS
Application Server
Application Server
Ethernet Switch
File System
RAID
SAN
Application Server
Application Server
File System
File System
Ethernet Switch
RAID

Storage Systems

- **San storage key components**
  - Storage Devices
  - SAN Switches
  - Host Bus Adapters (HBAs)
  - Management Software

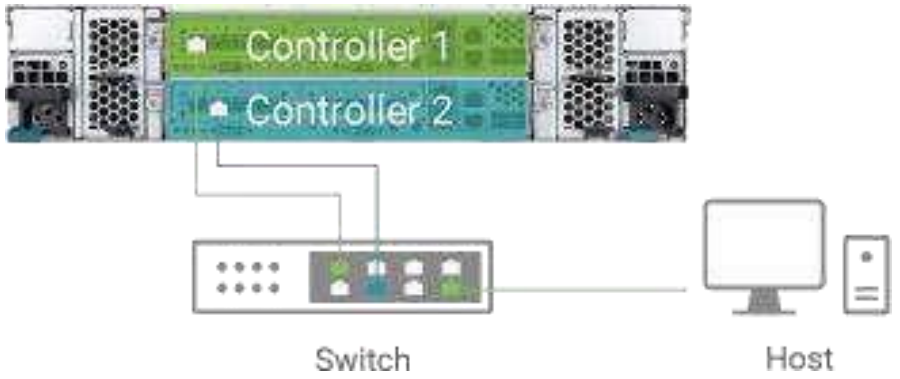


Storage Systems

- **Storage Devices**
  - **Hard Disk Drives (HDDs)**
    - Traditional spinning disk drives.
  - **Solid State Drives (SSDs)**
    - High-speed flash storage devices.
  - **Storage Arrays**
    - Enclosures containing multiple HDDs or SSDs.
    - Provide storage capacity and redundancy.

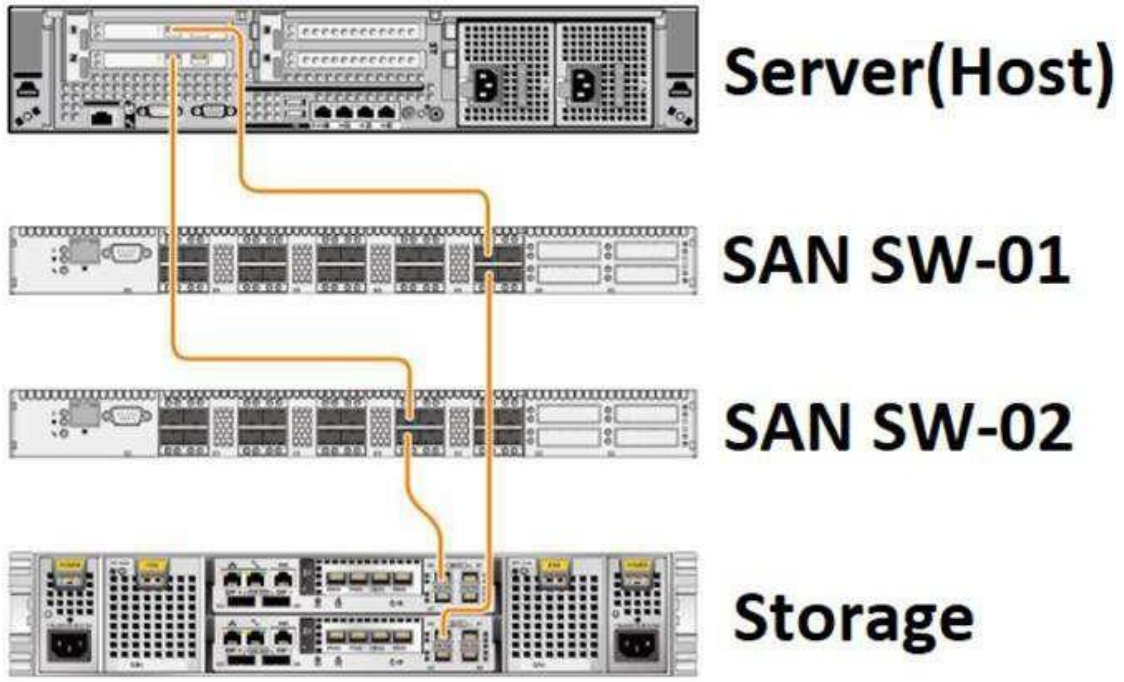
Storage Systems

- **Storage Controllers**
  - **Definition**
    - Hardware or software that manages the storage devices.
  - **Functions**
    - Handles data requests, RAID configurations, and caching.



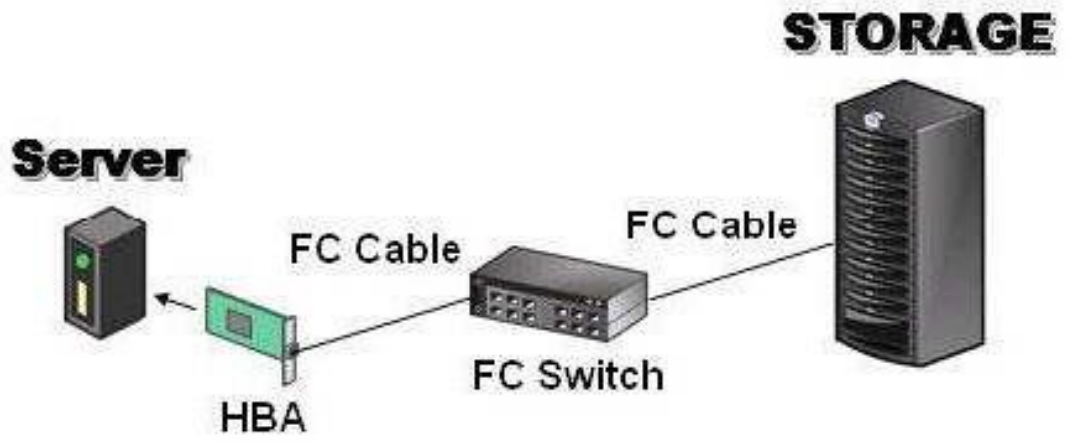
Storage Systems

- **SAN Switches**
  - **Definition**
    - Network switches specifically designed for SAN environments.
  - **Functions**
    - Connect servers to storage devices.
    - Manage data traffic within the SAN.
  - **Features**
    - High throughput, low latency, and multiple ports.



Storage Systems

- **Host Bus Adapters (HBAs)**
  - **Definition**
    - Interface cards installed in servers.
  - **Functions**
    - Provide connectivity between servers and SAN switches.
  - **Types**
    - Fibre Channel HBAs
    - iSCSI HBAs



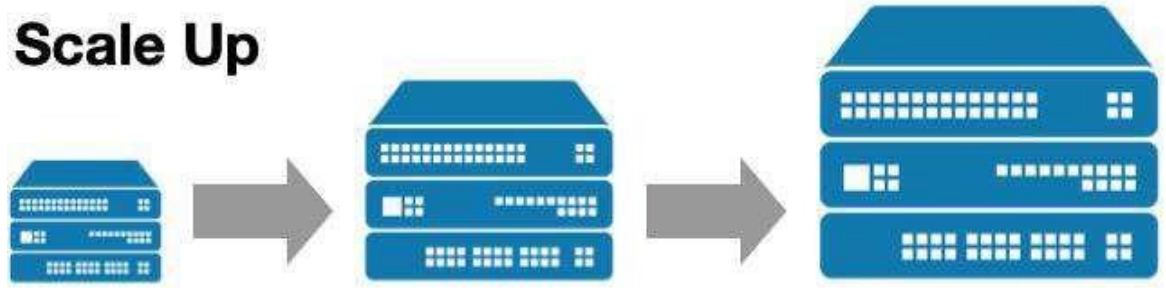
Storage Systems

- **SAN vs NAS**

	SAN	NAS
Fiber	Runs on high-speed Fiber Channel networks	Runs primarily on Ethernet using TCP/IP networks.
Data Processing	Block-level data access	File Level Data access
Protocols	Uses Small Computer System Interface (SCSI) protocol to communicate with servers	Can use a number of file transfer protocols such as CIFS/SMB, HTTP, etc.
Performance	Designed for high throughput and low latency	Generally has high latency an lower throughput due to its slower file system
Ease of Management	Requires more administration as compared to NAS	Easy to manage: device can be easily plugged in the LAN.
Uses	Used primarily for high performance block level data storage	Used for long distance small read and write operations

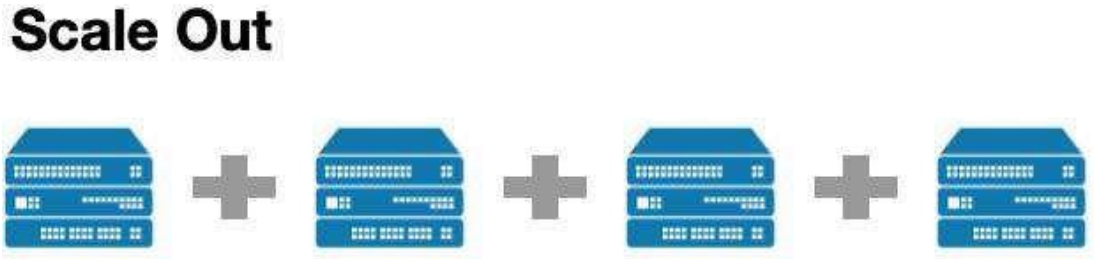
Storage Systems

- **Scale up storage**
  - Scale up means adding resources to a single node in the system.
  - For storage systems, vertical expansion only adds hard disks or flash disks to the existing architecture to increase storage capacity, but does not increase CPU and memory to help the entire system handle more capacity and deliver it to the host. This means that when storage capacity increases,storage performance tends to decrease.



Storage Systems

- **Scale out storage**
  - Scale out is the process of replacing or adding new hardware to an existing IT system. While expanding the capacity, the performance increases linearly with the capacity. Because each node of the expansion has an independent CPU, independent memory, etc., after the space is expanded, the performance of the entire cluster will not decrease with the increase of capacity, but will increase.

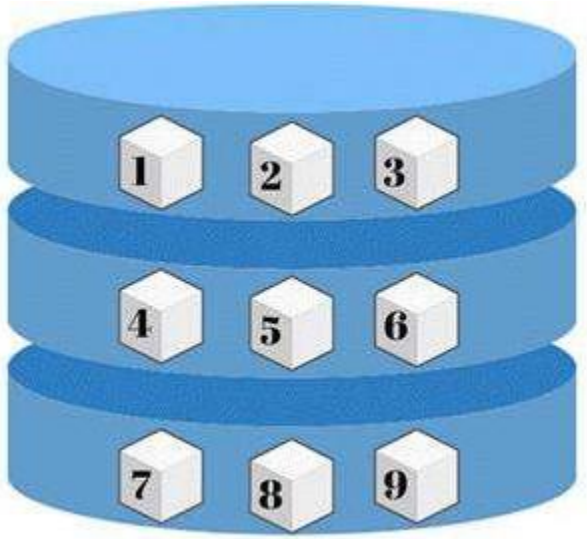


Storage Provisioning

- **What is Storage Provisioning?**
  - **Definition**
    - The process of allocating storage resources to applications, users, or services.
  - **Purpose**
    - Ensures efficient and effective use of storage infrastructure.

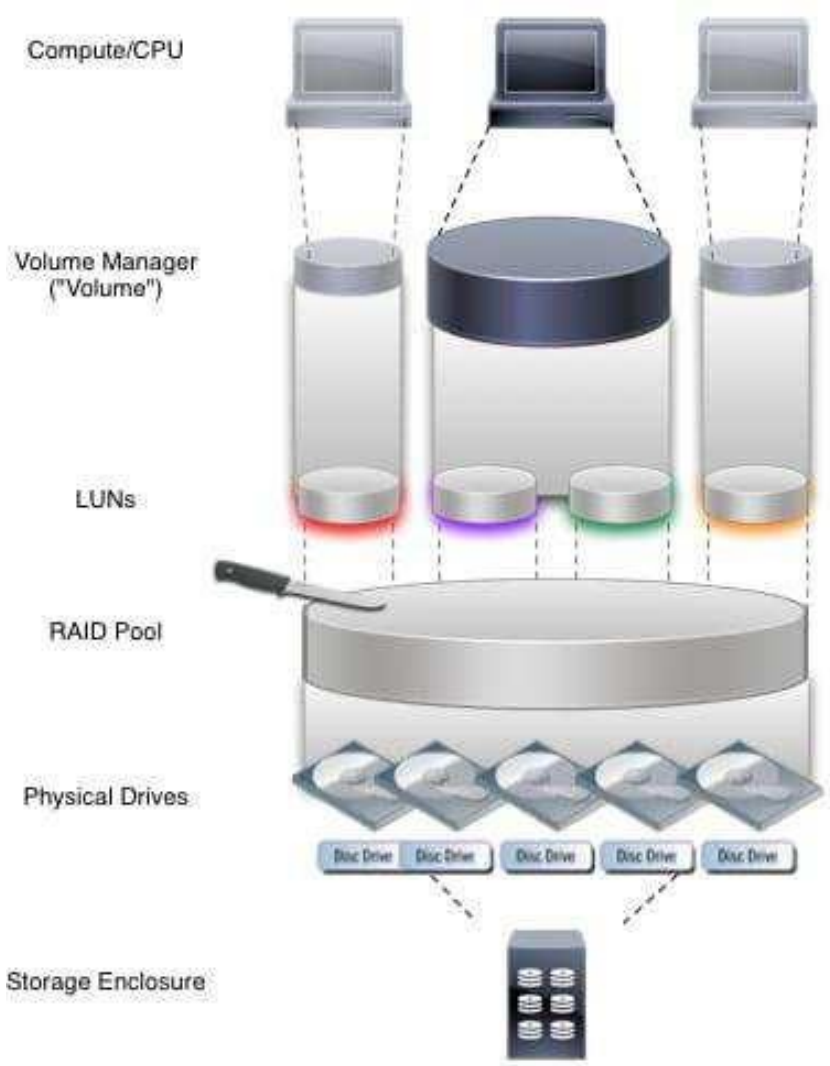
Storage Provisioning

- **Block Storage**
  - **Definition**
    - Storage type where data is stored in fixed-sized blocks.
  - **Characteristics**
    - Each block has a unique address but does not include metadata.
  - **Use Cases**
    - Databases,Virtual Machines, Transactional Applications.



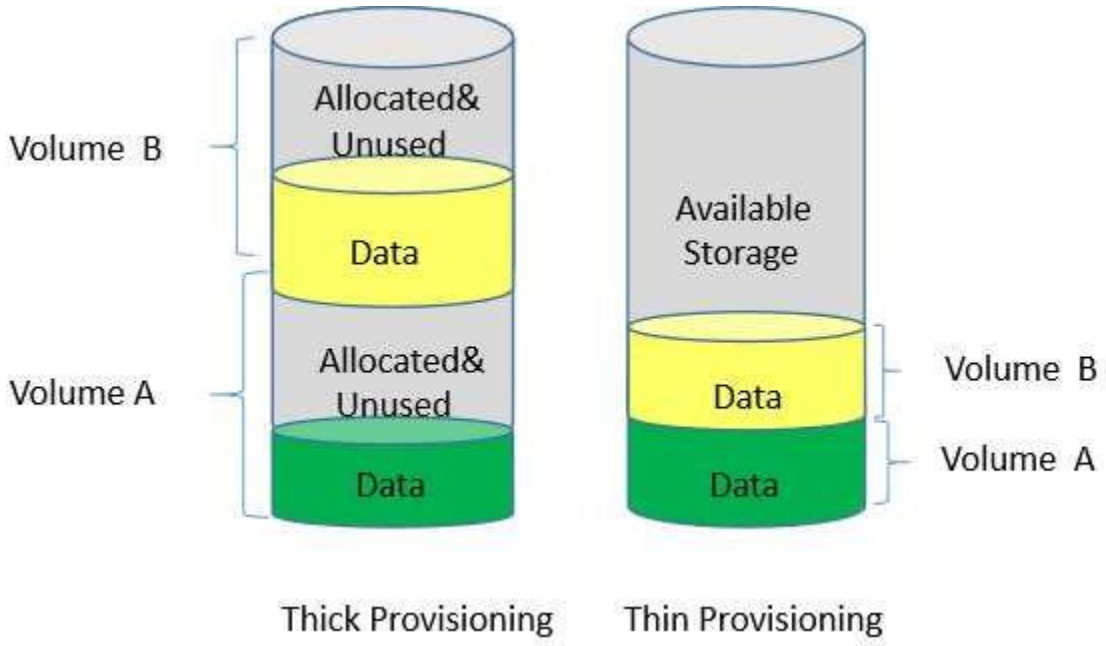
Storage Provisioning

- **Volumes**
  - **Definition**
    - A volume is a logical storage unit that can be managed independently within a storage system.
  - **Characteristics**
    - Can span multiple physical disks, appear as a single storage device to the OS.
  - **Use Cases**
    - Simplifies management of large storage pools.



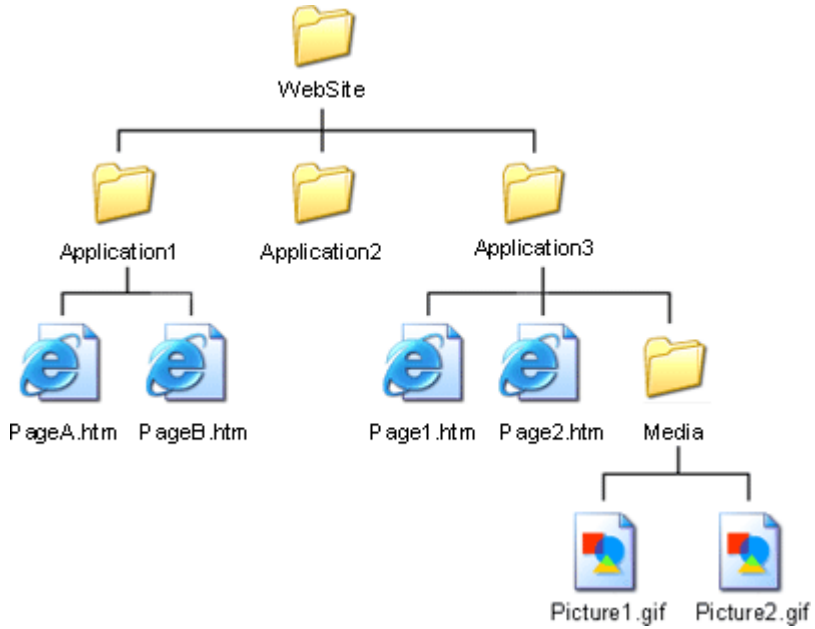
Storage Provisioning

- **Types of Storage Provisioning**
  - **Static Provisioning**
    - Pre-allocating storage resources based on predicted needs.
  - **Dynamic Provisioning (Thin Provisioning)**
    - Allocating storage resources on-demand as they are needed.



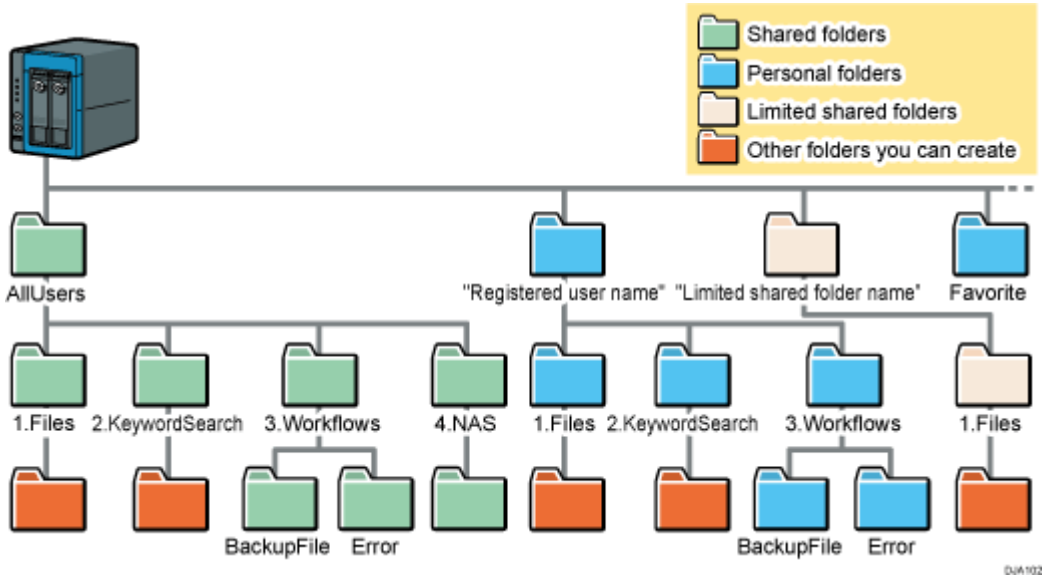
Storage Provisioning

- **Directories**
  - **Definition**
    - Hierarchical structure used to organize files within a file system.
  - **Characteristics**
    - Facilitates file organization and access management.
  - **Use Cases**
    - Common in NAS (Network Attached Storage) environments.



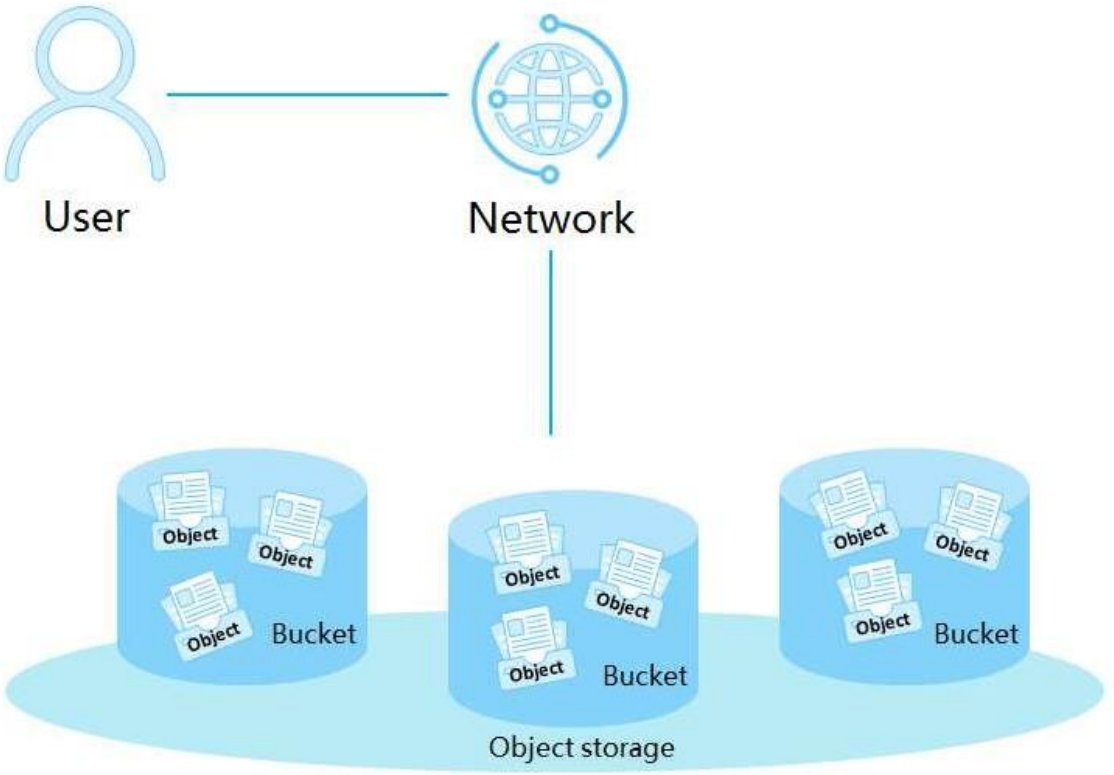
Storage Provisioning

- **Directories in Practice**
  - **Folder Structure**
    - Organizing directories within a file system.
  - **Example**
    - User directories in a shared network drive.



Storage Provisioning

- **Buckets**
  - **Definition**
    - Containers used to store objects in object storage systems.
  - **Characteristics**
    - Store unstructured data, each object includes data and metadata.
  - **Use Cases**
    - Cloud storage services (e.g., AWS S3, Google Cloud Storage).



Storage Provisioning

- **Buckets in Practice**
  - **Object Storage**
    - Storing files, images, backups, and other unstructured data.
  - **Example**
    - Creating buckets in AWS S3 for different projects.

Buckets

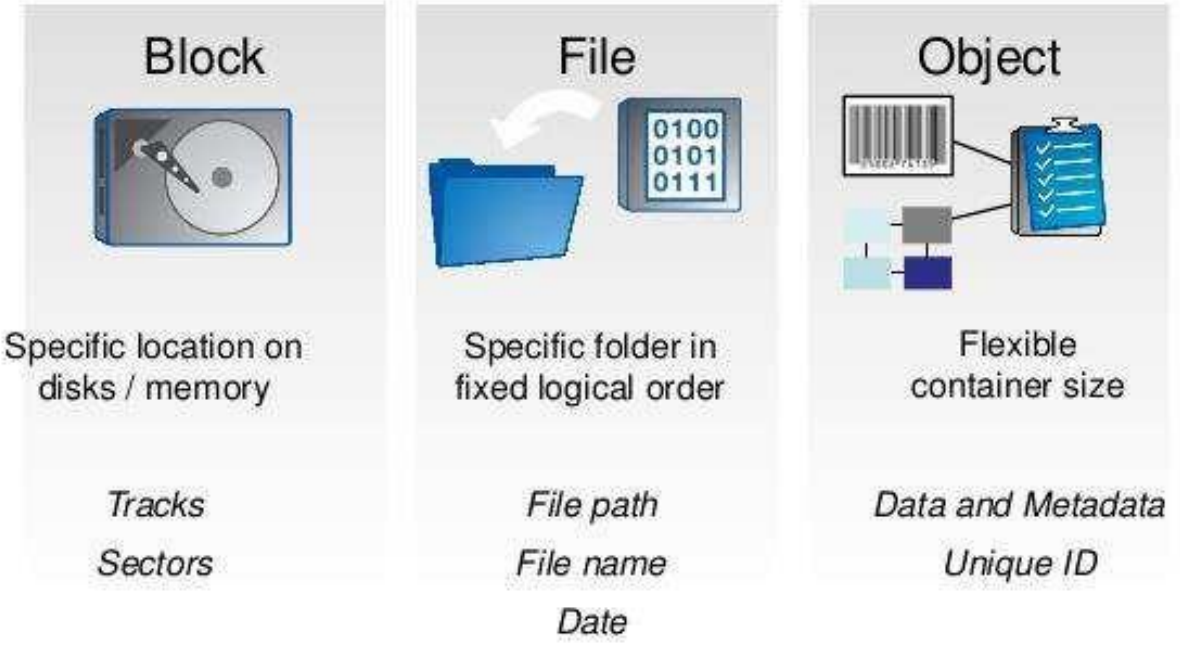
- Buckets are top-level containers for data (i.e. objects)
- Buckets exist in a global namespace
- PBs of storage across clusters, DCs, and regions
- Strict consistency within DC, eventual across DCs

Objects

- Objects go into buckets and are discrete data/files
- Billions objects per bucket
- Objects can be TBs in size
- Example: https://bucketname.domain.com/objectname.ext

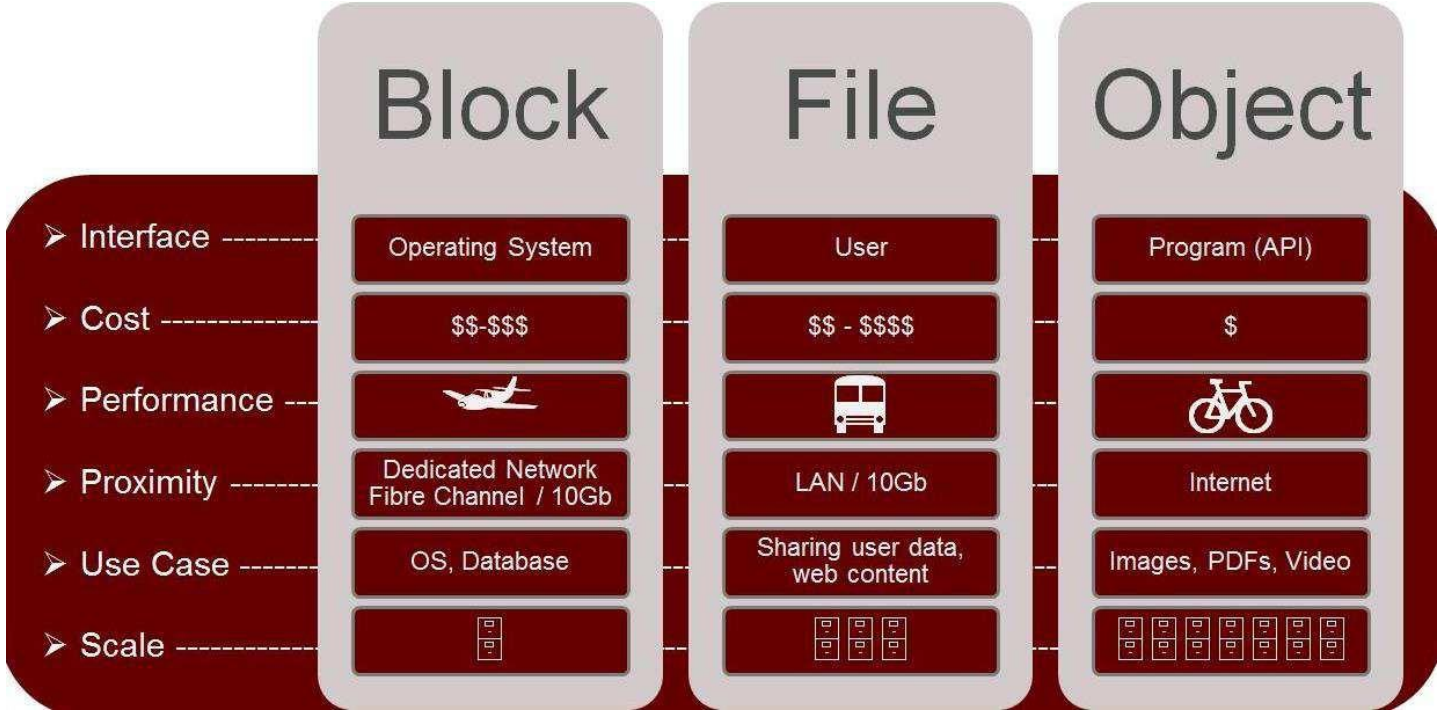
Storage Provisioning

- **Comparison of Storage Types**
  - **Block Storage vs. File Storage vs. Object Storage**
    - Block: Low latency, high performance (e.g., databases).
    - File: Simple file sharing and management (e.g., NAS).
    - Object: Scalable, cost-effective for unstructured data (e.g., cloud storage).



Storage Provisioning

- **Choosing the Right Storage Provisioning Method**
  - **Factors to Consider**
    - Performance Requirements
    - Scalability Needs
    - Cost
    - Management Complexity



Storage resilience: data protection

- **Overview of Storage Resilience**
  - Importance in Modern Data Centers
  - Key Concepts: RAID, Replication, Snapshots, Backup, and Disaster Recovery

- **What is Storage Resilience?**
  - **Definition**
    - The ability of a storage system to continue operating in the presence of failures.
  - **Purpose**
    - Ensures data availability, integrity, and recoverability.

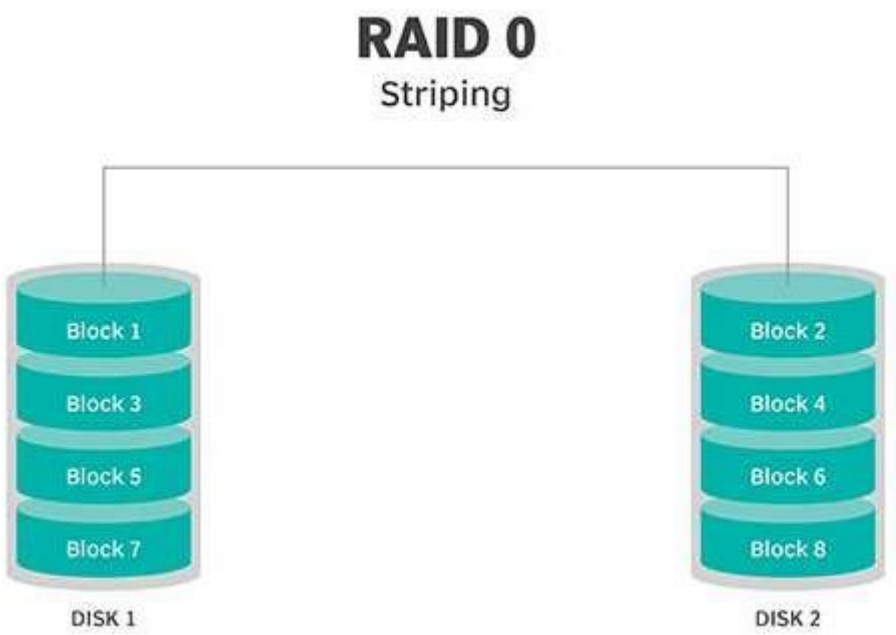
Storage resilience: data protection

- **Importance of Data Protection**
  - **Data Integrity**
    - Ensuring data remains accurate and unaltered.
  - **Data Availability**
    - Ensuring data is accessible when needed.
  - **Data Recoverability**
    - Ensuring data can be restored in case of loss or corruption.

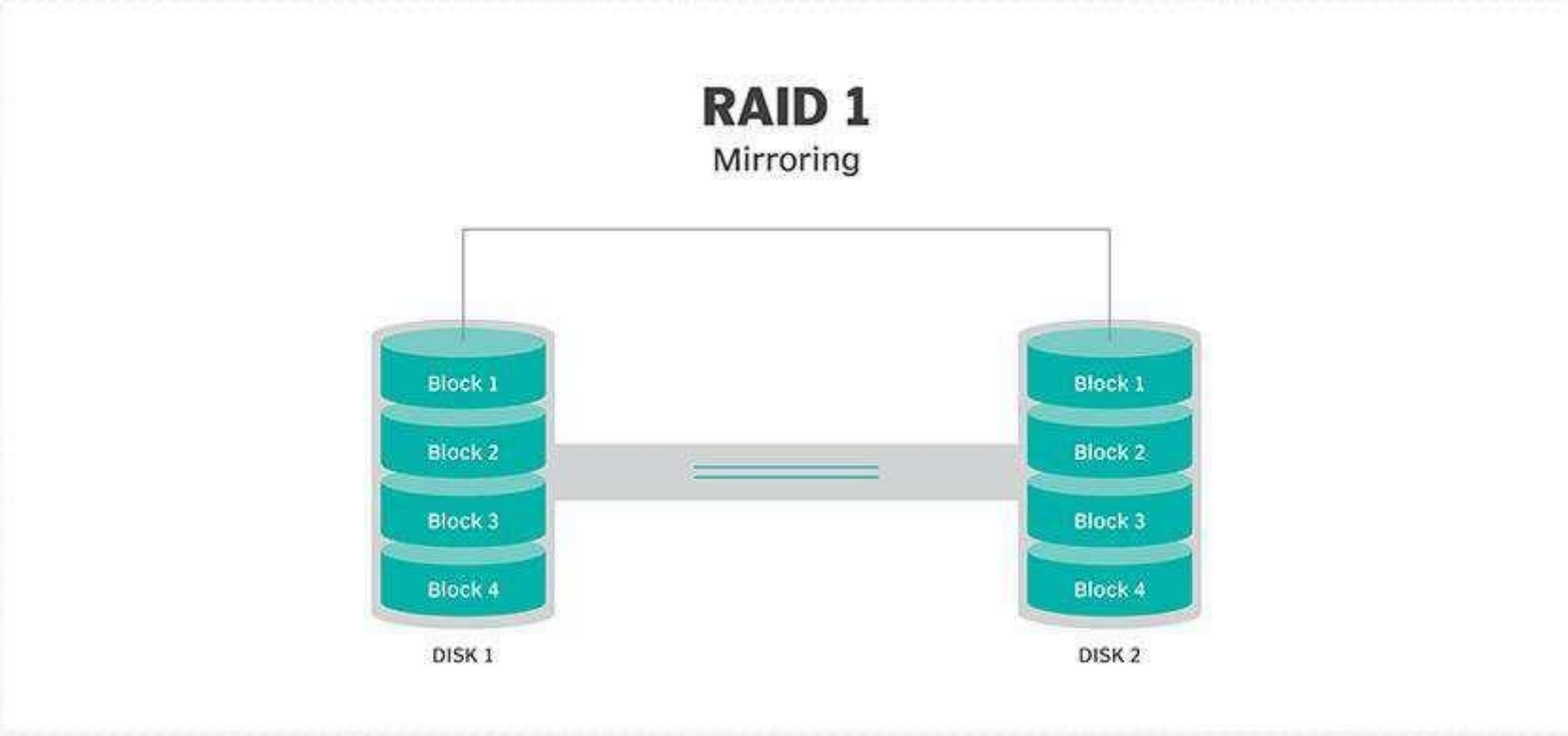
Storage resilience: data protection

- **RAID (Redundant Array of Independent Disks)**
- **Definition**
  - Technology that combines multiple disk drives into a single unit for redundancy and performance.
- **Types of RAID**
  - **RAID 0:** Striping, no redundancy.
  - **RAID 1:** Mirroring, full redundancy.
  - **RAID 5:** Striping with parity, good balance.
  - **RAID 6:** Striping with double parity, higher redundancy.
  - **RAID 10:** Combination of RAID 0 and RAID 1, high performance and redundancy.

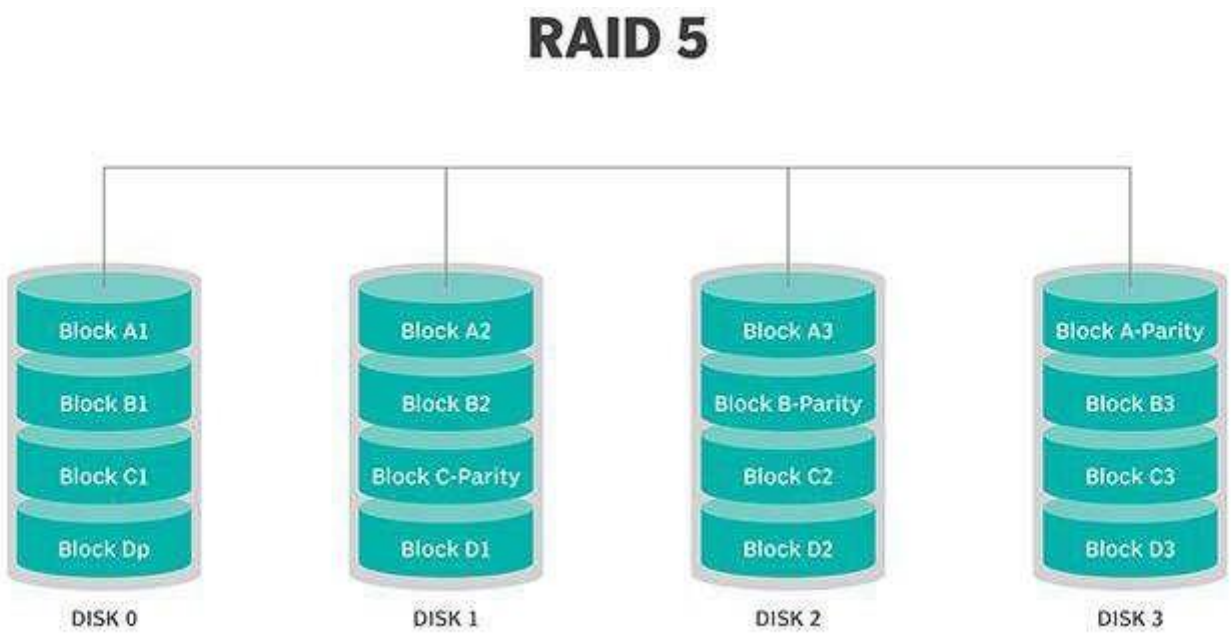
Storage resilience: data protection



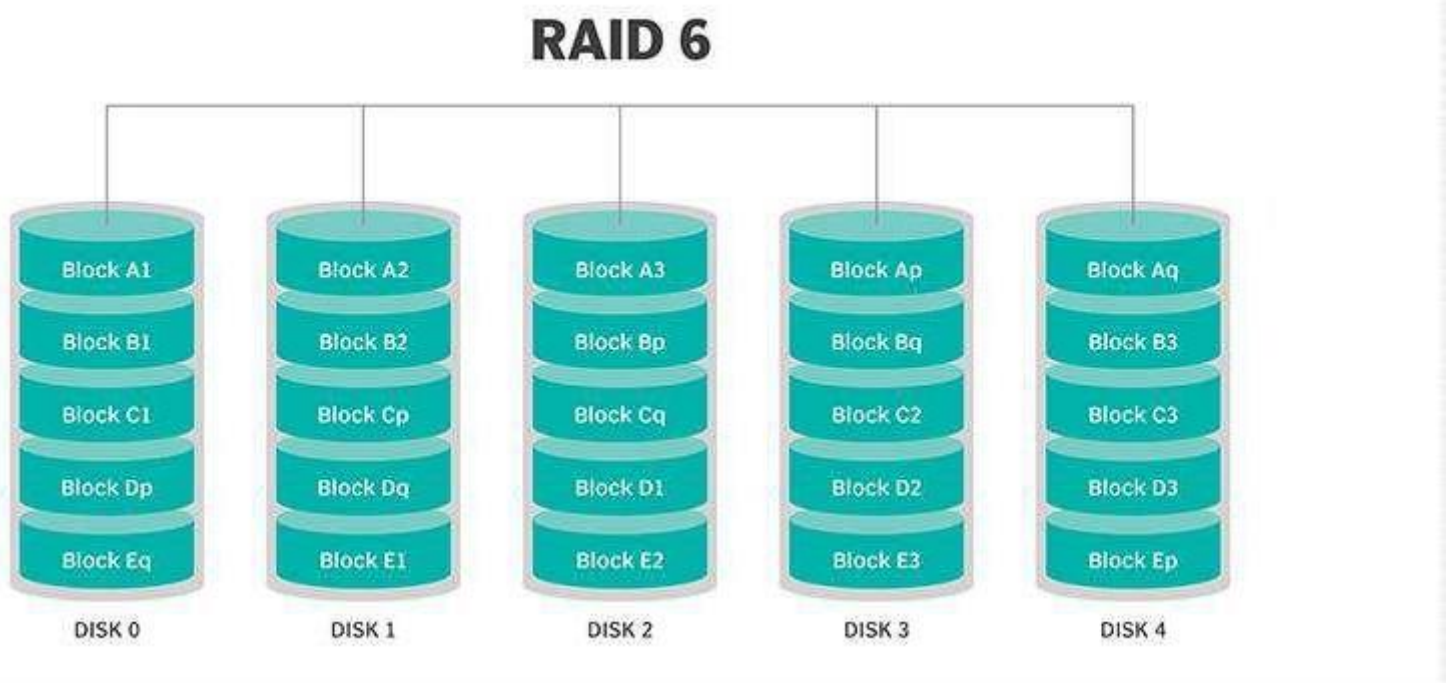
Storage resilience: data protection



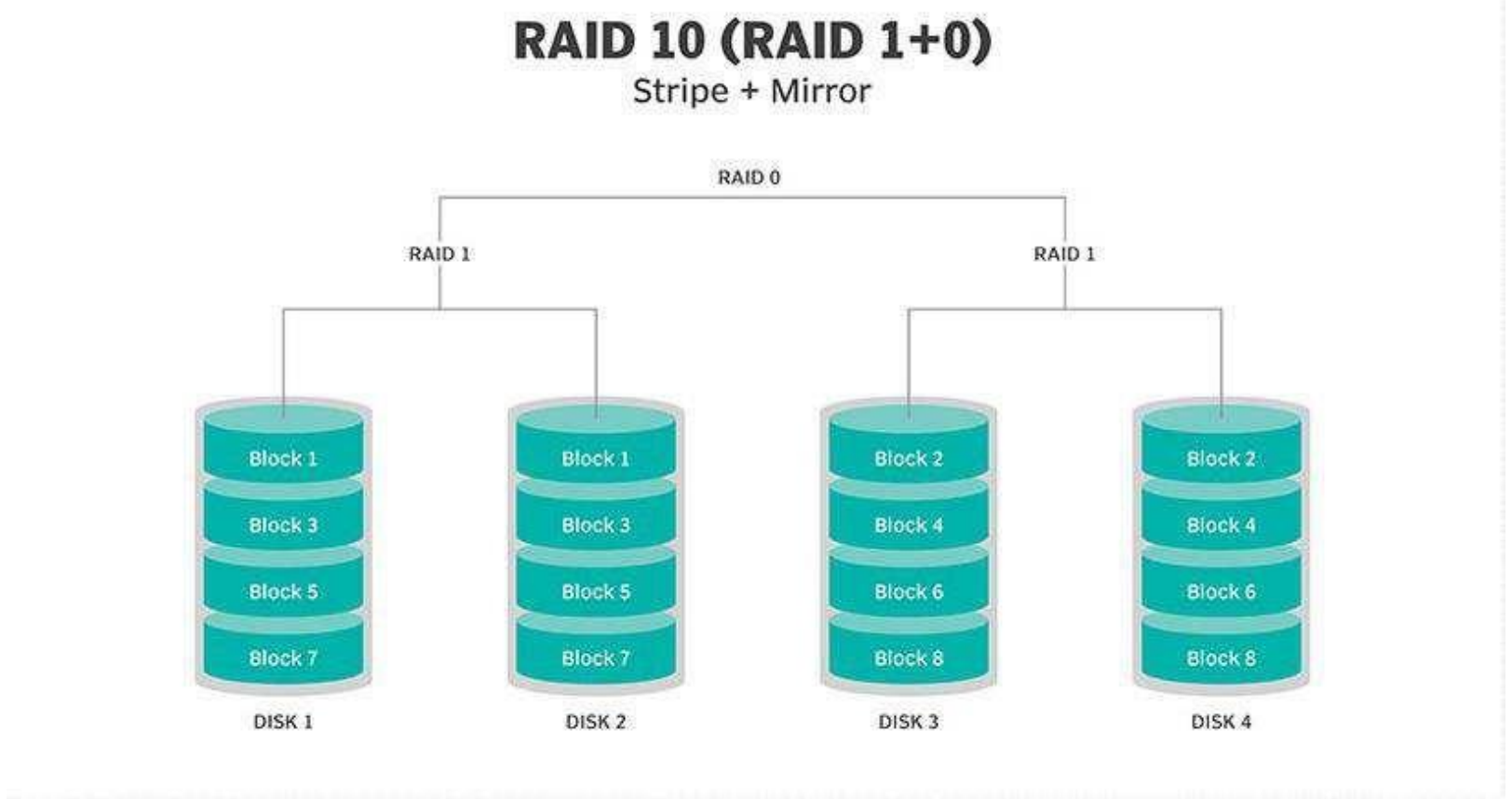
Storage resilience: data protection



Storage resilience: data protection



Storage resilience: data protection



Storage resilience: data protection

- **RAID in Practice**
  - **Use Cases**
    - RAID 1 for critical data mirroring.
    - RAID 5 and 6 for balanced performance and redundancy.
    - RAID 10 for high-performance applications.

Advantages

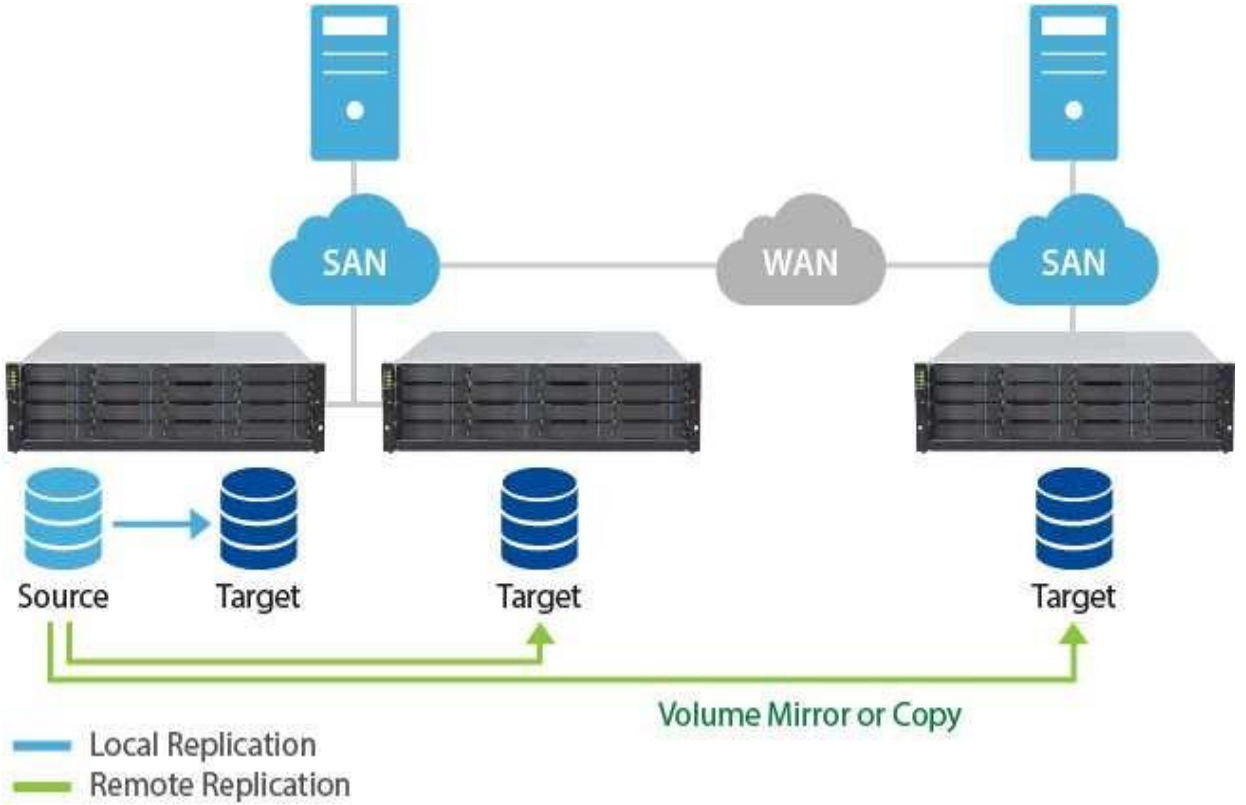
	RAID 0 Redundant Array of Independent Disk level 0	RAID 1 Redundant Array of Independent Disk level 1	RAID 5 Redundant Array of Independent Disk level 5	RAID 6 Redundant Array of Independent Disk level 6	RAID 10 Redundant Array of Independent Disk level 10
Process	Data Striping	Disk Mirroring	Striping+Parity	Striping +Double Parity	Mirroring+Striping
Minimum of Number of Disk	2	2	3	4	4
Read Performance	High	High	High	High	High
Write Performance	High	Medium	Low	Low	High
Fault Tolerance	Not Fault- Tolerant	Fault- Tolerant	Fault- Tolerant	Fault- Tolerant	Fault- Tolerant
Storage Efficiency	100%	50%	65%-95%	50%-90%	50%
Cost	Cheap	Expensive	Expensive	Very Expensive	Expensive

Storage resilience: data protection

- **Data Replication**
  - **Definition**
    - Copying data from one location to another in real-time or at scheduled intervals.
  - **Types of Replication**
    - **Synchronous Replication:** Real-time copying, high consistency.
    - **Asynchronous Replication:** Delayed copying, better performance over distance.
  - **Use Cases**
    - Disaster recovery, load balancing, data migration.

Storage resilience: data protection

- **Data Replication in Practice**
  - **Synchronous Replication**
    - Suitable for environments requiring immediate consistency.
  - **Asynchronous Replication**
    - Suitable for geographically dispersed environments.

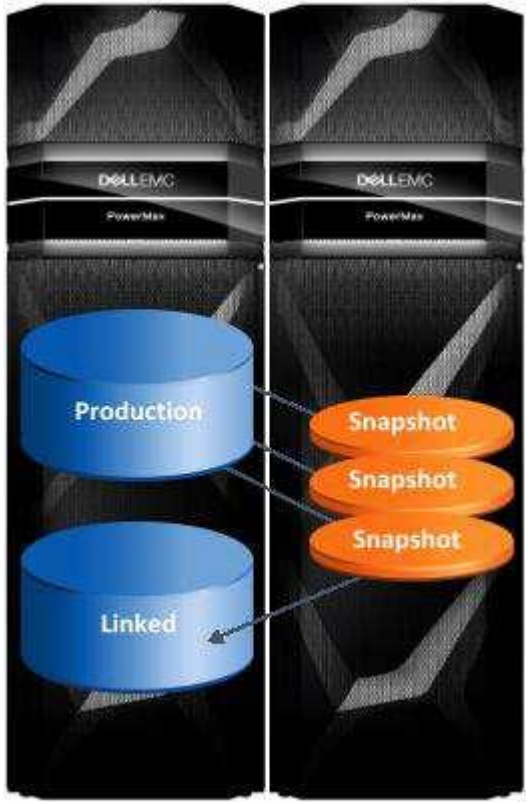


Storage resilience: data protection

- **Snapshots**
  - **Definition**
    - Point-in-time copies of data, capturing the state of the data at a specific moment.
  - **Features**
    - Fast creation and minimal storage overhead.
    - Used for quick recovery from data corruption or accidental deletions.
  - **Use Cases**
    - Backup, development and testing, quick recovery.

Storage resilience: data protection

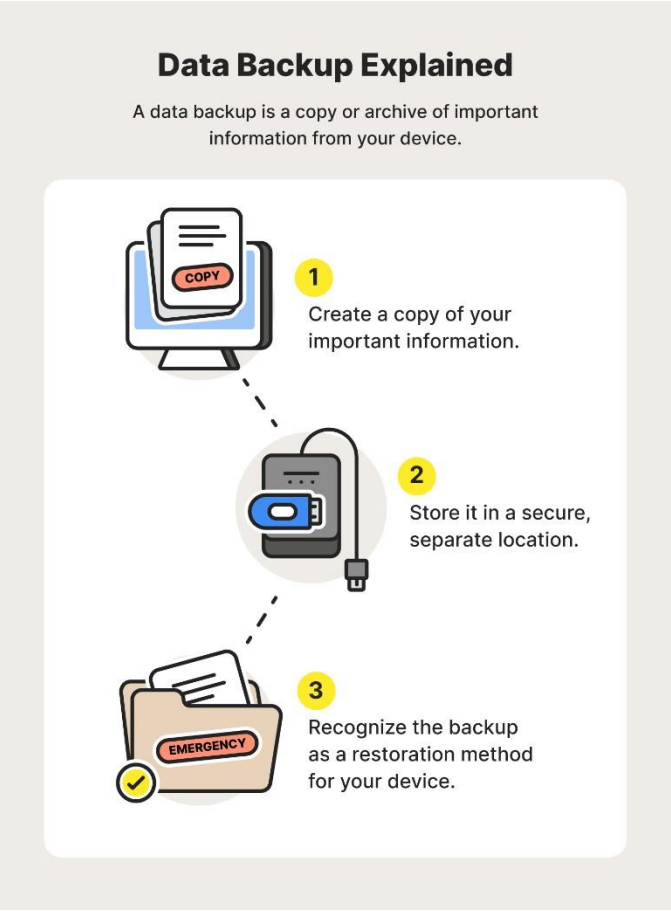
- **Snapshots in Practice**
  - **Creation and Management**
    - Scheduled or on-demand snapshot creation.
    - Managing snapshot retention policies.



Storage resilience: data protection

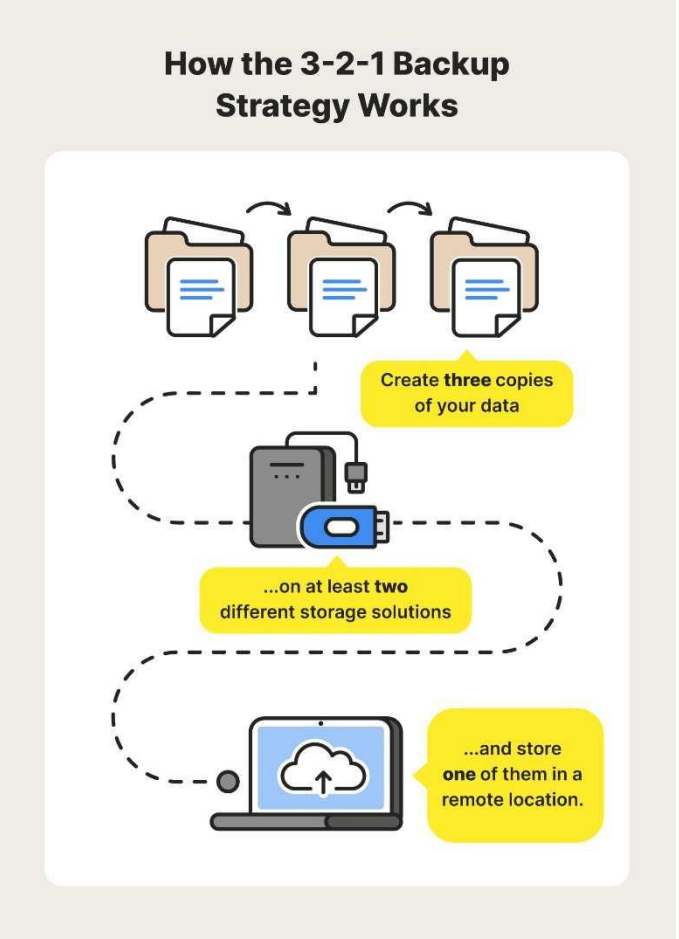
- **Backup**
  - **Definition**
    - Process of copying data to a separate storage system for protection against data loss.
  - **Types of Backups**
    - **Full Backup:** Complete copy of all data.
    - **Incremental Backup:** Copies data changed since the last backup.
    - **Differential Backup:** Copies data changed since the last full backup.
  - **Use Cases**
    - Long-term data retention, disaster recovery, compliance.

Storage resilience: data protection



Storage resilience: data protection

- **Backup Strategies**
  - **3-2-1 Backup Rule**
    - Three copies of data.
    - Two different storage media.
    - One copy offsite.
  - **Backup Frequency**
    - Determined by data change rate and criticality.



Storage resilience: data protection

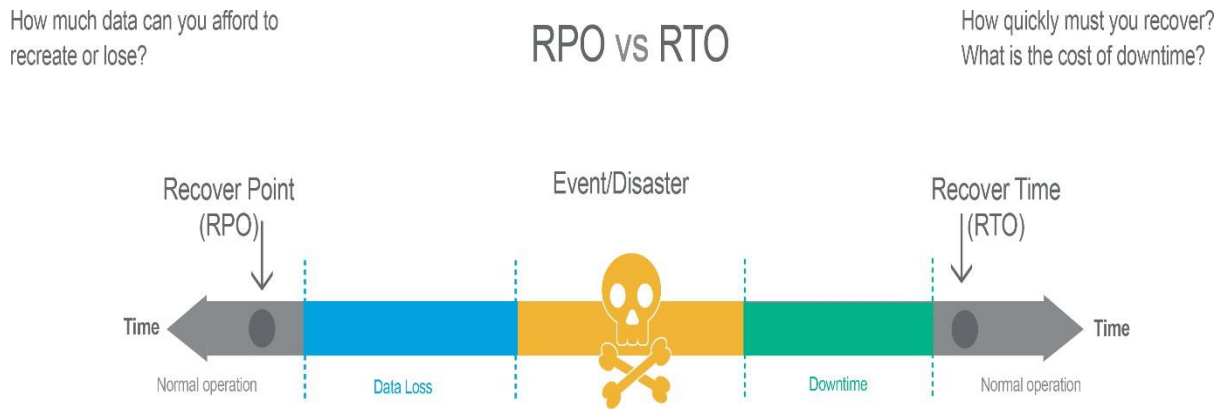
- **Disaster Recovery (DR)**
  - **Definition**
    - Strategies and processes to recover data and maintain operations after a catastrophic event.

Storage resilience: data protection

- **Components of DR**
  - **DR Plan:** Detailed procedures for data recovery.
  - **DR Site:** Secondary location for data recovery.
  - **DR Testing:** Regular testing of DR plans.

Storage resilience: data protection

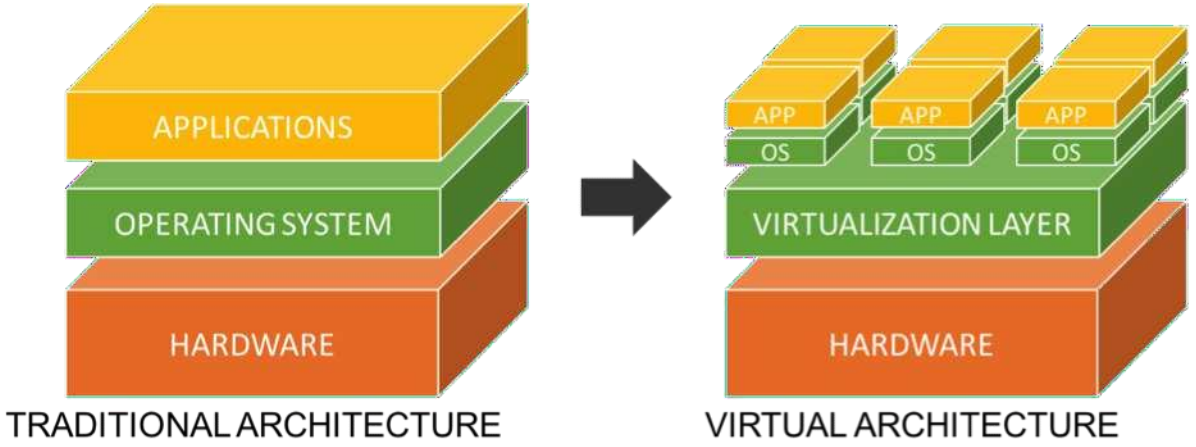
- **Disaster Recovery in Practice**
  - **Planning and Implementation**
    - Identifying critical data and applications.
    - Establishing RTO (Recovery Time Objective) and RPO (Recovery Point Objective).
    - Regularly updating and testing DR plans.



Virtualization in Data Centers

Virtualization in Data Centers

- **What is Virtualization?**
  - **Definition**
    - Virtualization is the process of creating virtual versions of physical components such as servers, storage devices, and network resources.
  - **Purpose**
    - Increases resource utilization, improves flexibility, and simplifies management.
  - **Types of Virtualization**
    - Server virtualization, storage virtualization, network virtualization, desktop virtualization.



Virtualization in Data Centers

- **Benefits of Virtualization**
  - **Resource Efficiency**
    - Better utilization of hardware resources.
  - **Cost Savings**
    - Reduced hardware costs and operational expenses.
  - **Flexibility and Scalability**
    - Easier to scale and adapt to changing workloads.
  - **Disaster Recovery and Backup**
    - Simplified backup and recovery processes.

Virtualization in Data Centers

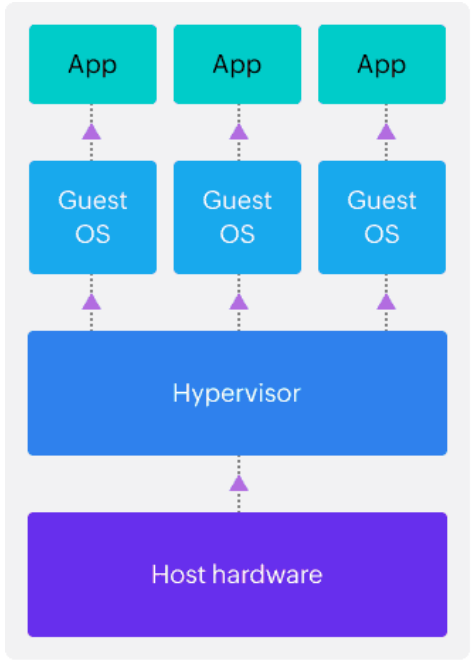
- **Virtual vs. Physical**
  - **Physical Infrastructure**
    - Dedicated hardware resources for each workload.
    - Higher costs and lower resource utilization.
  - **Virtual Infrastructure**
    - Shared hardware resources through virtual machines (VMs).
    - Higher resource utilization and cost efficiency.
  - **Comparison**
    - **Deployment:** Physical (slower, hardware-dependent) vs. Virtual (faster, hardware-agnostic).
    - **Management:** Physical (complex) vs. Virtual (simplified with management tools).
    - **Scalability:** Physical (limited by hardware) vs. Virtual (easier scaling).

Virtualization in Data Centers

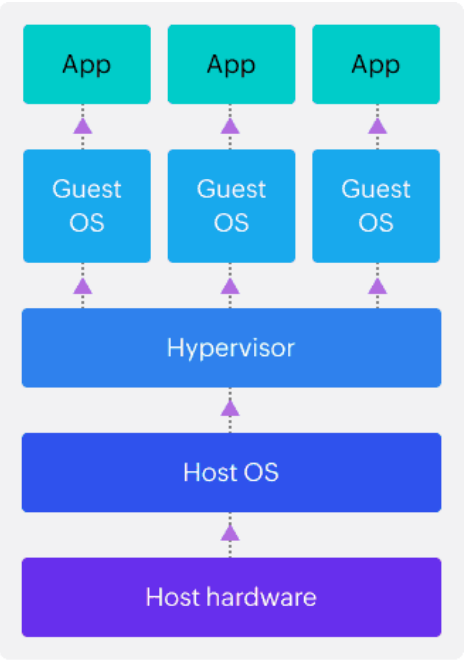
- **Case Study: Virtual vs. Physical**
  - **Scenario**
    - A company transitions from physical servers to virtualized infrastructure.
  - **Outcomes**
    - Reduced hardware costs by 40%.
    - Increased server utilization from 20% to 70%.
    - Improved disaster recovery capabilities.

Virtualization in Data Centers

- **Virtual Compute (Hypervisor)**
  - **Definition**
    - A hypervisor, or virtual machine monitor (VMM), is software that creates and manages virtual machines.
  - **Types of Hypervisors**
    - **Type 1 (Bare-Metal):** Runs directly on hardware (e.g., VMware ESXi, Microsoft Hyper-V).
    - **Type 2 (Hosted):** Runs on a host operating system (e.g., VMware Workstation, Oracle VirtualBox).
  - **Functions of Hypervisors**
    - Resource allocation, isolation of VMs, monitoring and management.



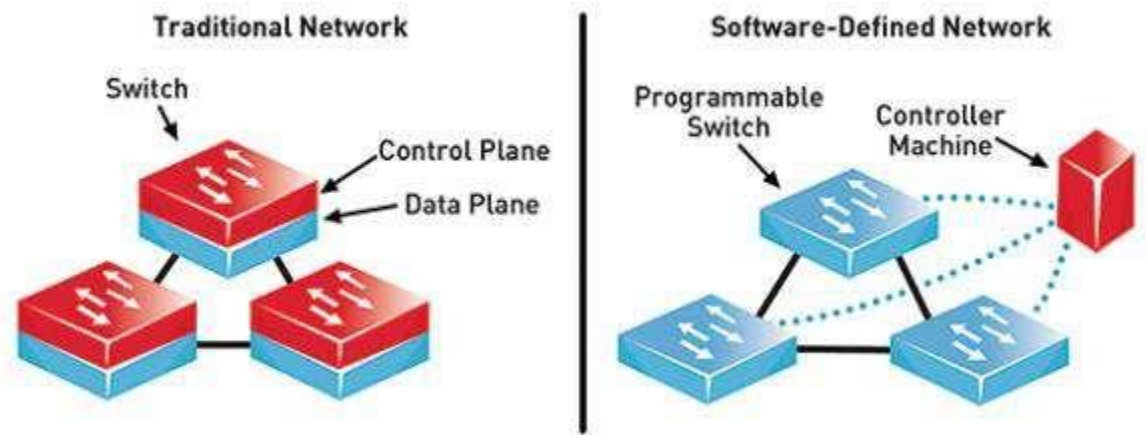
Bare-metal hypervisor



Hosted hypervisor

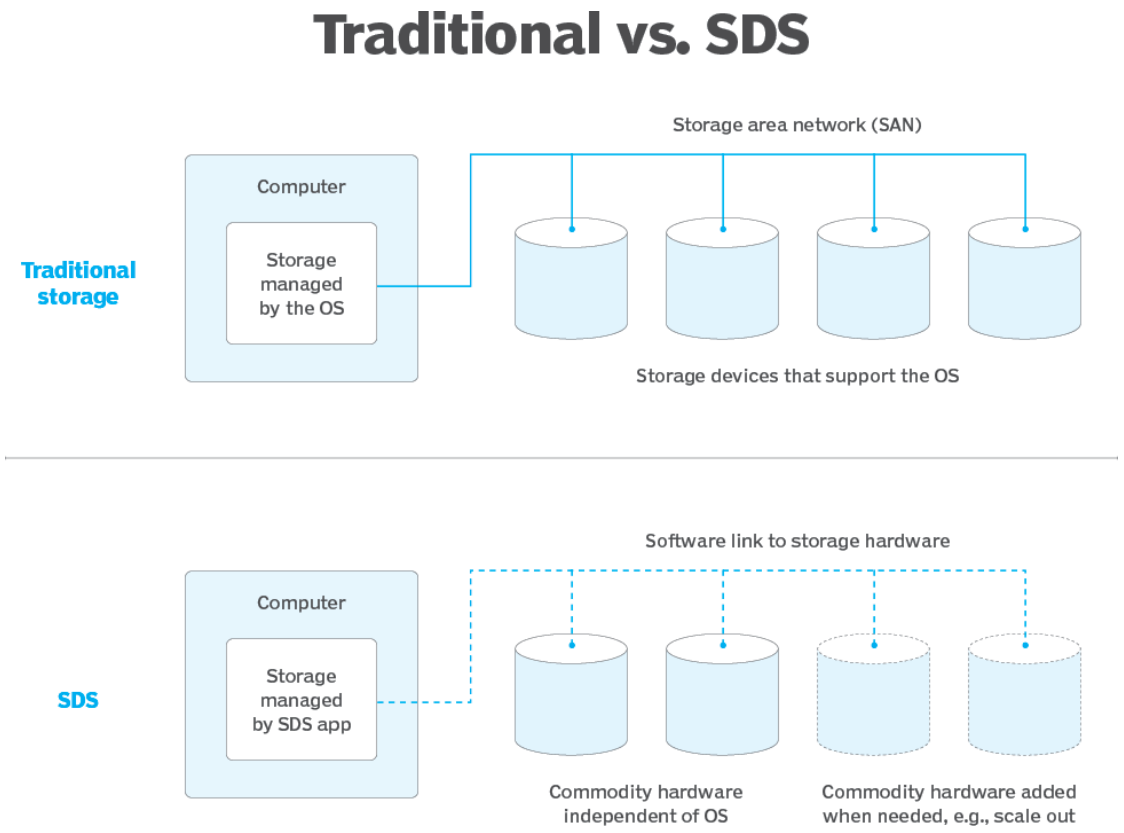
Virtualization in Data Centers

- **Virtual Networking (SDN)**
  - In traditional networks, devices (like routers and switches) make decisions about where data should go. In SDN, the control plane (which makes these decisions) is separated from the data plane (which forwards the data).This means that a central software controller can manage the entire network instead of each device acting independently.
  - Because the network is managed by software, it can be programmed to adapt to changing needs. For example, if there's a sudden increase in traffic, the network can automatically adjust to handle it better.



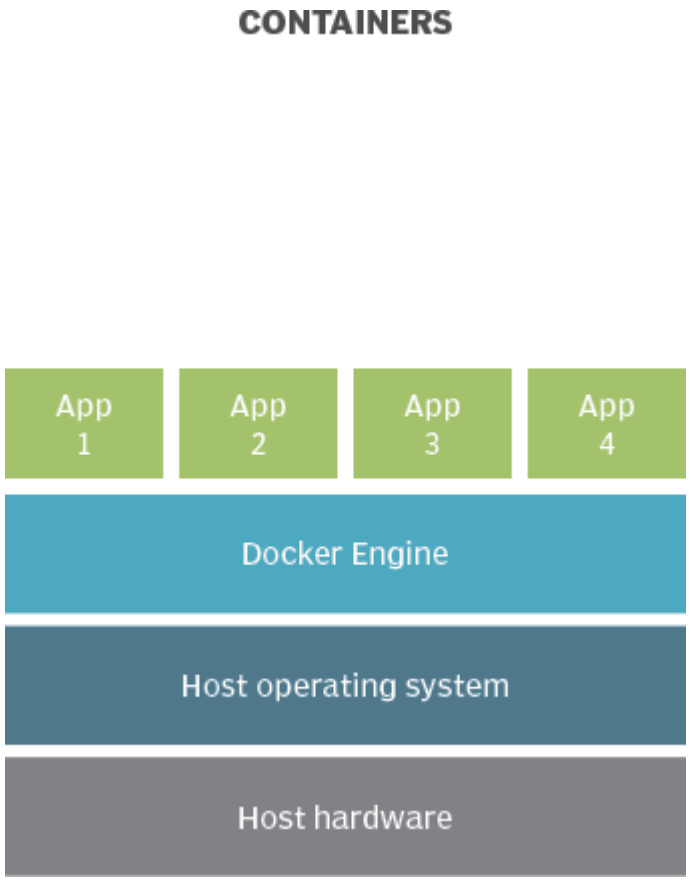
Virtualization in Data Centers

- **Virtual Storage (SDS)**
- Software-Defined Storage (SDS) separates storage hardware from the software that manages it. This means that the way you store and access data is controlled by software rather than being tied to specific physical devices.
- SDS allows organizations to use different types of storage hardware (like hard drives, SSDs, or cloud storage) and manage them as a single, unified storage system.

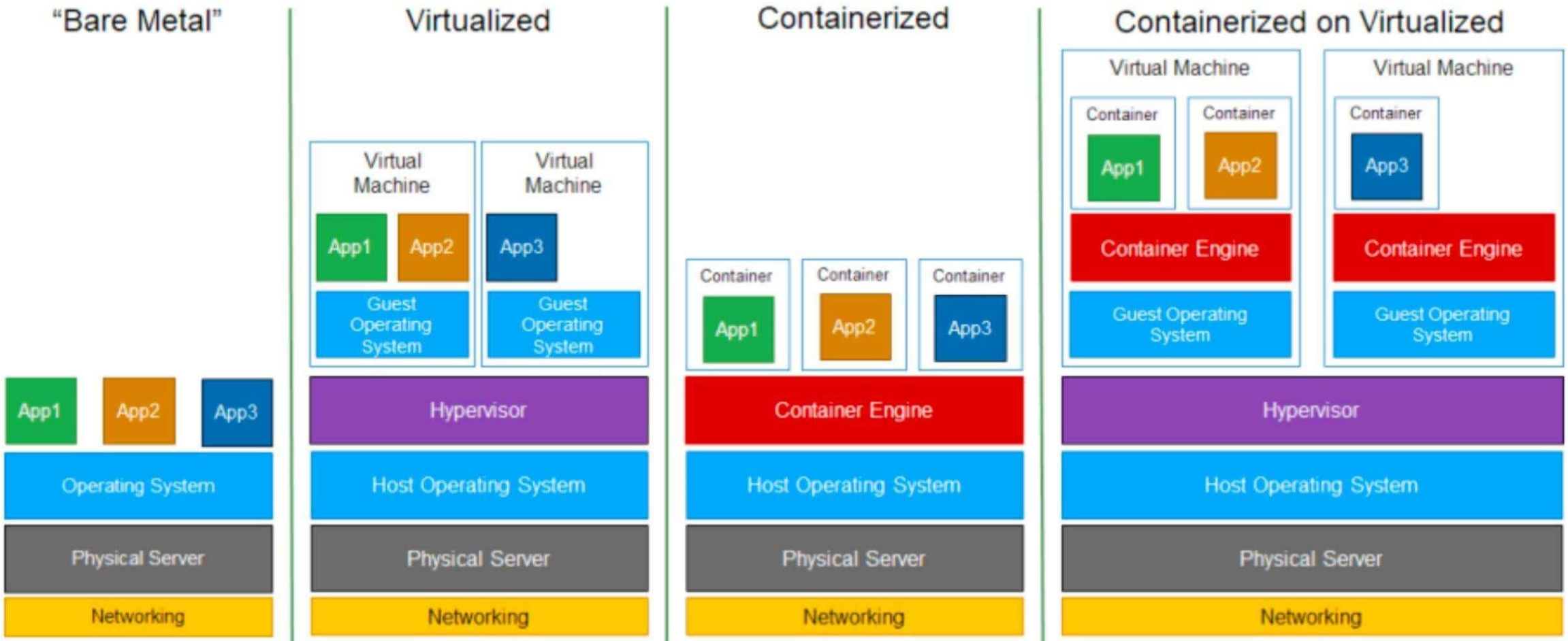


Virtualization in Data Centers

- **Containers**
  - **Definition**
    - Containers are lightweight, portable units that package an application and its dependencies, allowing it to run consistently across different environments.



Virtualization vs Containerization



Virtualization in Data Centers

- **Comparison of Virtualization Technologies**
  - **Hypervisors vs. Containers**
    - **Hypervisors:** Full OS isolation, higher resource overhead.
    - **Containers:** Shared OS kernel, lower resource overhead.
  - **SDN vs. Traditional Networking**
    - **SDN:** Centralized control, improved agility.
    - **Traditional Networking:** Decentralized control, less flexibility.
  - **SDS vs. Traditional Storage**
    - **SDS:** Software-managed, policy-driven.
    - **Traditional Storage:** Hardware-dependent, less flexible.

Virtualization in Data Centers

- **Case Studies**
  - **Example 1: Server Virtualization**
    - Implementing hypervisors to consolidate and manage server workloads.
  - **Example 2: Network Virtualization**
    - Using SDN to improve network management and security.
  - **Example 3: Storage Virtualization**
    - Deploying SDS to enhance storage efficiency and scalability.
  - **Example 4: Containerization**
    - Adopting containers for agile application development and deployment.

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