Cloud Computing Technologies

Cloud-Enabling Technologies:

- Modern-day clouds are **strengthened** by a set of **primary technology components** that collectively **enable key features** and **characteristics** associated with modern-day cloud computing.

- The following such technologies are covered in this section:
  - **Broadband Networks and Internet Architecture**
  - **Data Center Technology**
  - **Virtualization Technology**
  - **Web Technology**
  - **Multitenant Technology**
  - **Service Technology**

Cloud Computing Technologies (Contd..)

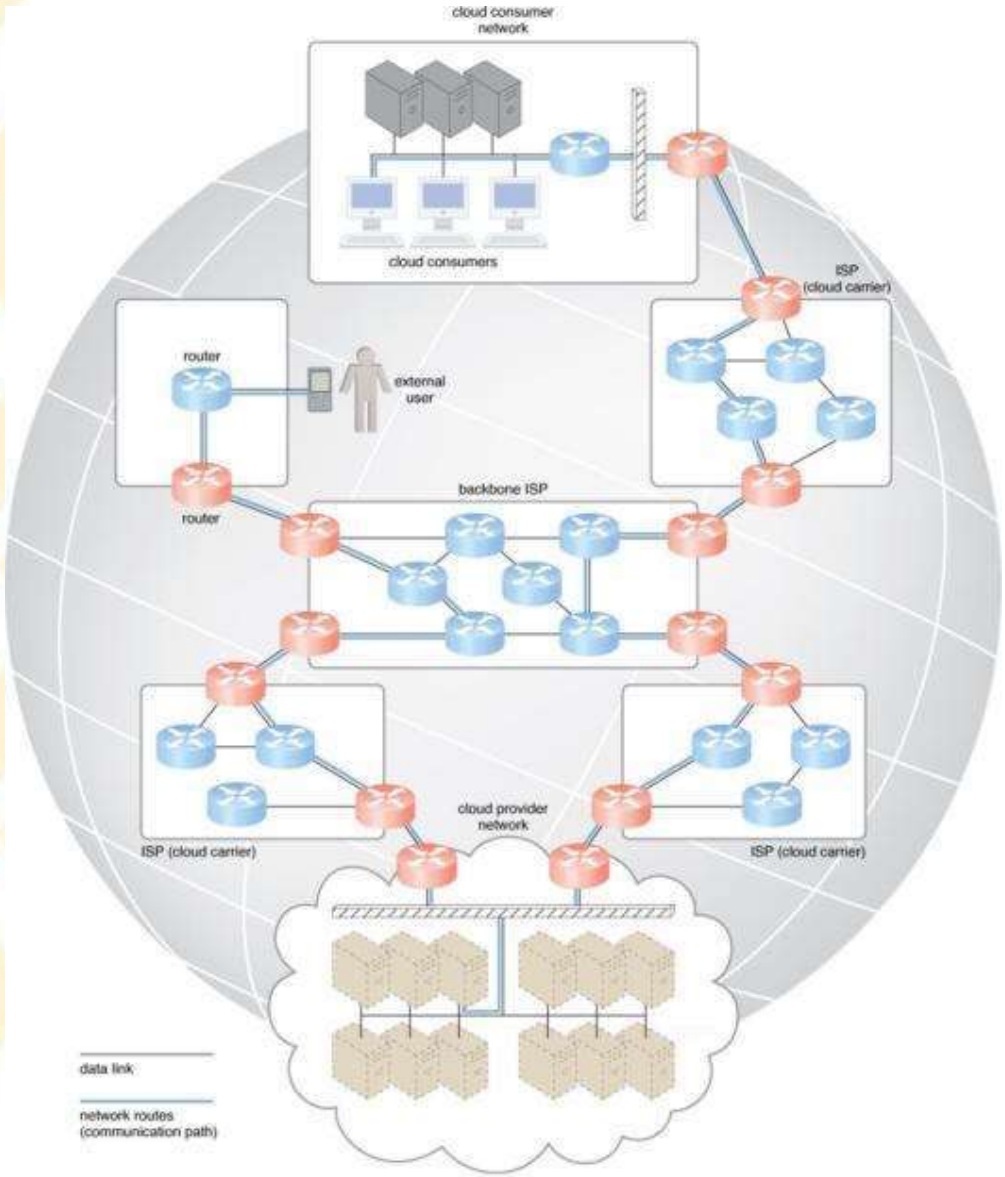
Broadband Networks and Internet Architecture:

- All clouds **must be connected** to a **network**.
  - This **inevitable/unavoidable** requirement forms an **essential dependency** on **internetworking**.
- **Internetworks**, or the **Internet**, allow for the **remote provisioning** of IT resources and are directly supportive of **ubiquitous network access**.
- The potential of cloud platforms therefore generally grows in parallel with advancements in **Internet connectivity** and **service quality**.

Internet Service Providers (ISPs):

- Established and deployed by ISPs, the **Internet's largest backbone networks** are **strategically interconnected** by **core routers** that connect the **world's multinational networks**.

Cloud Computing Technologies (Contd..)



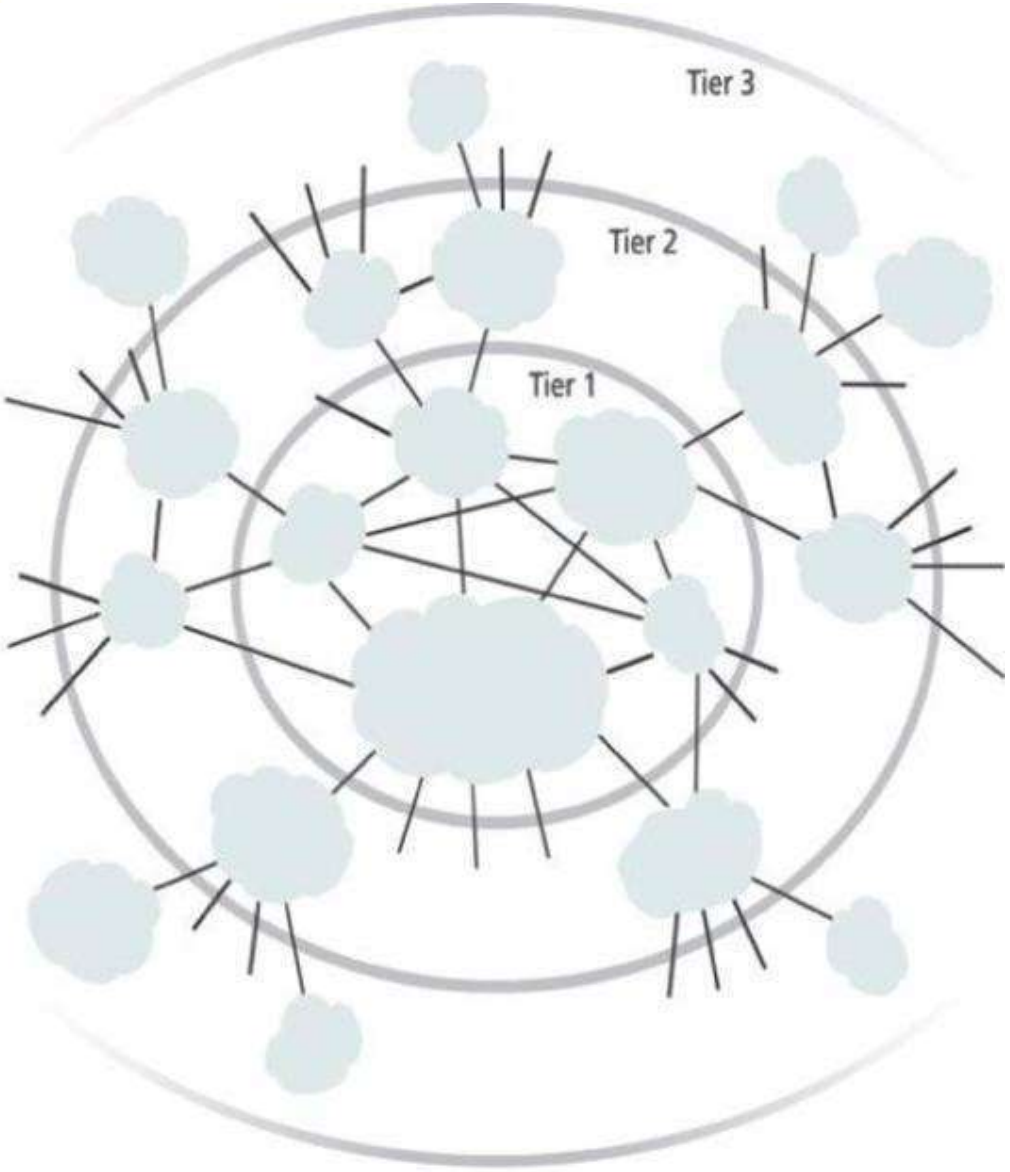
An ISP network **interconnects** to **other ISP networks** and various **organizations**.

Messages travel over **dynamic network routes** in this ISP internetworking configuration.

Cloud Computing Technologies (Contd..)

- The concept of the Internet was based on a **decentralized/distributed provisioning** and **management model**.
- ISPs can freely deploy, operate, and manage their networks in addition to selecting partner ISPs for interconnection.
- **I**nternet **C**orporation for **A**ssigned **N**ames and **N**umbers **(ICANN)** supervise and coordinate Internet communications.
- **Governmental and regulatory laws** order the **service provisioning conditions** for organizations and ISPs both **within** and **outside** of **national borders**.
- Worldwide connectivity is enabled through a **hierarchical topology** composed of **Tiers 1**, **2**, and **3**.

Cloud Computing Technologies (Contd..)



A generalization of the **internetworking structure** of the **Internet**.

Cloud Computing Technologies (Contd..)

- The core **Tier 1** is made of **large-scale**, **international cloud providers** that oversee **massive interconnected global networks**, which are connected to **Tier 2's large regional providers**.
- The **interconnected ISPs** of **Tier 2** connect with **Tier 1 providers**, as well as the **local ISPs of Tier 3**.
- Cloud consumers and cloud providers can connect **directly using a Tier 1 provider**, since any operational ISP can **enable Internet connection**.

- **Two fundamental components** used to construct the **internetworking architecture** are:
  - **Connectionless Packet Switching (Datagram Networks)**
  - **Router-Based Interconnectivity**

Cloud Computing Technologies (Contd..)

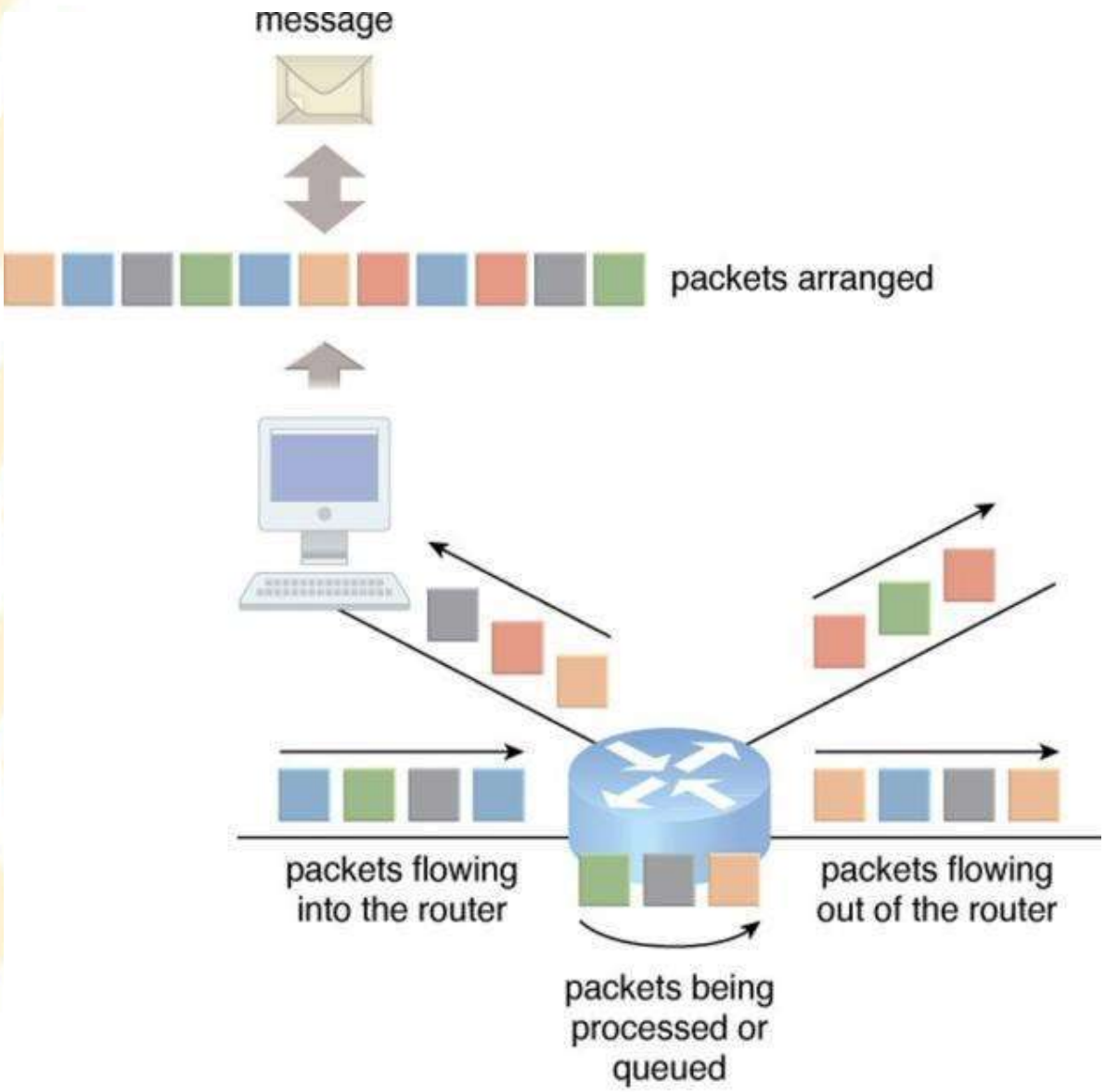
Connectionless Packet Switching (Datagram Networks):

- End-to-End (**sender-receiver pair**) data flows are divided into packets of a limited size that are received and processed through **network switches** and **routers**, then queued and forwarded from one intermediary node to the next.
- Each packet carries the necessary location information, such as the **Internet Protocol** (**IP**) or **Media Access Control** (**MAC**) address, to be processed and routed at every source, intermediary, and destination node.

Router-Based Interconnectivity:

- A *router* is a device that is connected to **multiple networks** through which it **forwards packets**.
- Routers manage **network traffic** and maintains the **network topology information** that **locates the next node** on the communication path between the source and destination nodes.

Cloud Computing Technologies (Contd..)



Packets traveling through the Internet are directed by a router that arranges them into a message.

Cloud Computing Technologies (Contd..)

- The **communication path** that connects a cloud consumer with its cloud provider may involve **multiple ISP networks**.
- This applies to ISPs that implement the **Internet's internetworking layer** and interact with other network technologies, as follows:

Physical Network:

- IP packets are transmitted through underlying physical networks that connect adjacent nodes, such as Ethernet, ATM network and so on.
- Physical networks comprise a **data link layer** that controls data transfer between neighboring nodes, and a physical layer that transmits data bits through both wired and wireless media.

Cloud Computing Technologies (Contd..)

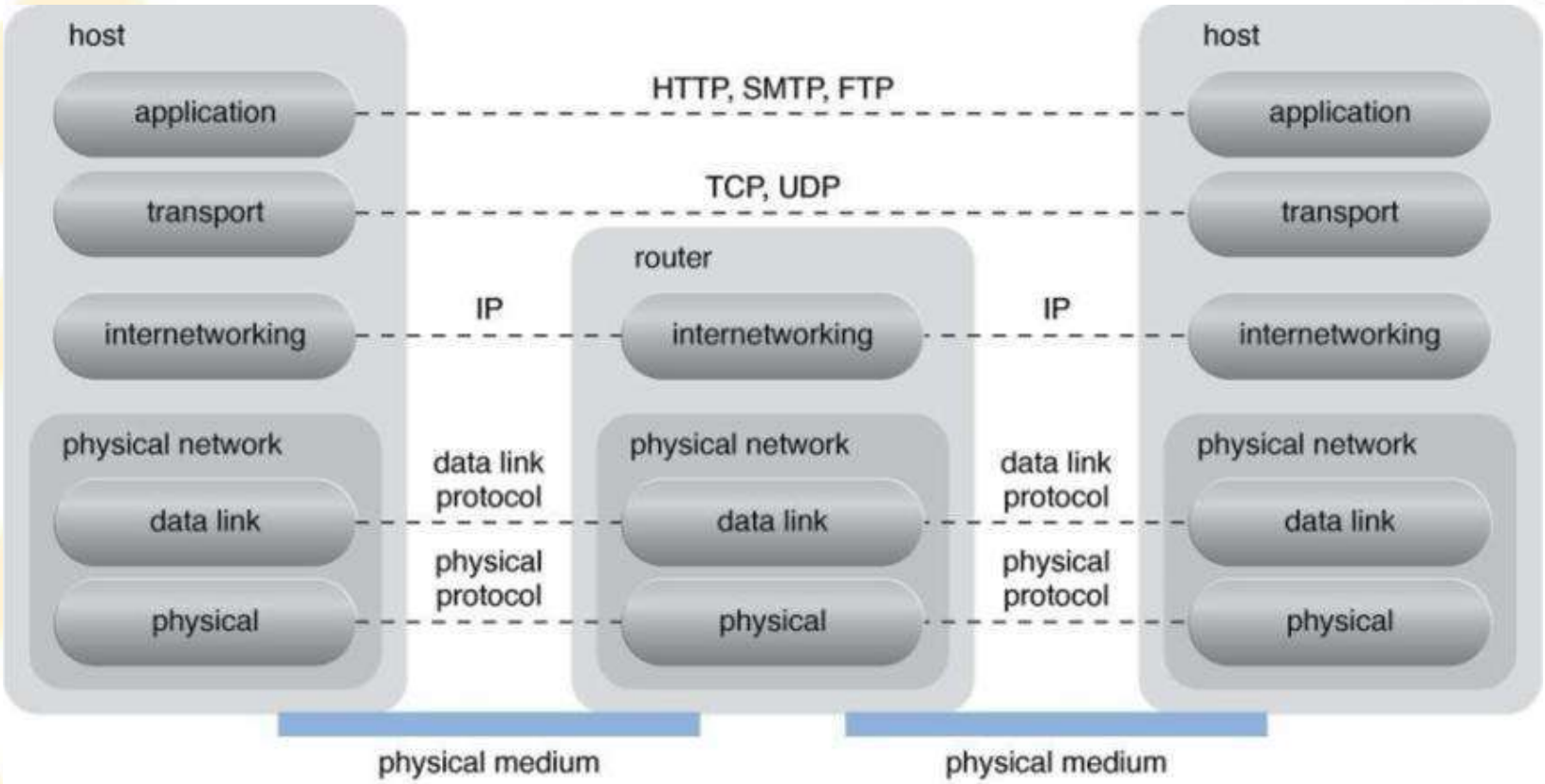
Transport Layer Protocol:

- IP Transport layer protocols, such as the **Transmission Control Protocol** (**TCP**) and **User Datagram Protocol** (**UDP**), use the IP to provide standardized, end-to-end communication support that facilitates the navigation of data packets across the Internet.

Application Layer Protocol:

- Protocols such as HTTP, SMTP for e-mail, BitTorrent for P2P, use **transport layer protocols** to standardize and enable specific data packet transferring methods over the Internet.
- Many other protocols also fulfill **application-centric requirements** and use either **TCP/IP** or **UDP** as their primary method of data transferring across the **Internet** and **LANs**.

Cloud Computing Technologies (Contd..)



A generic view of the Internet reference model and protocol stack

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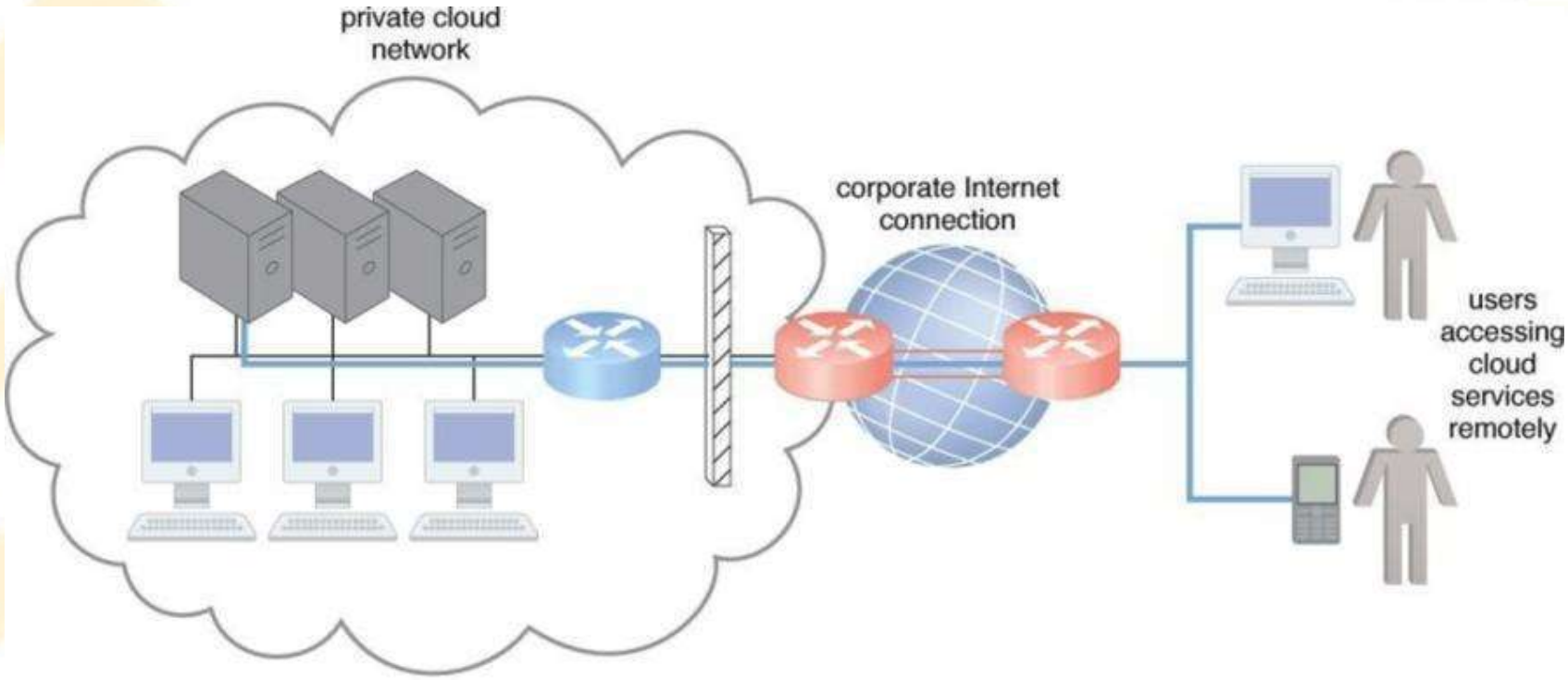
Technical and Business Considerations:

Connectivity Issues:

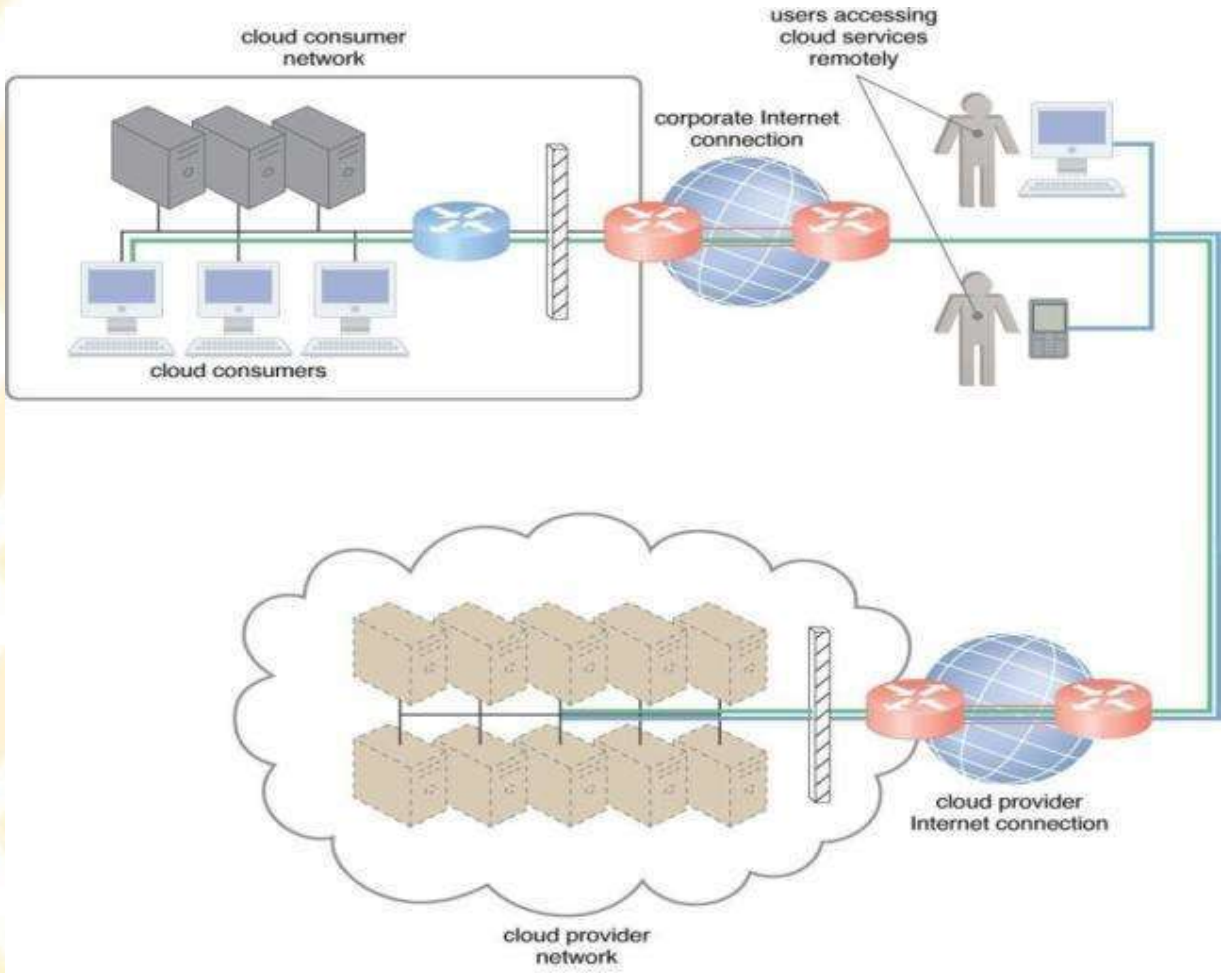
- In traditional, on-premise deployment models, enterprise applications and various IT solutions are commonly **hosted on centralized servers** and **storage devices** residing in the **organization's own data center**.
- End-user devices, such as smartphones and laptops, **access the data center** through the corporate network, which provides uninterrupted Internet connectivity.
- TCP/IP facilitates both Internet access and on-premise data exchange over LANs.

Cloud Computing Technologies (Contd..)



The internetworking architecture of a private cloud.
The physical IT resources that constitute the cloud are located and managed within the organization.

Cloud Computing Technologies (Contd..)



The internetworking architecture of an Internet-based cloud deployment model. The Internet is the connecting agent between non-proximate cloud consumers, roaming end-users, and the cloud provider's own network.

Cloud Computing Technologies (Contd..)

A comparison of on-premise and cloud-based internetworking.

On-Premise IT Resources	Cloud-Based IT Resources
internal end-user devices access corporate IT services through the **corporate** network	internal end-user devices access corporate IT services through an **Internet** connection
internal users access corporate IT services through the **corporate Internet connection** while roaming in external networks	internal users access corporate IT services while roaming in external networks through the **cloud provider's Internet connection**
external users access corporate IT services through the **corporate Internet connection**	external users access corporate IT services through the **cloud provider's Internet connection**

Cloud Computing Technologies (Contd..)

Network Bandwidth and Latency Issues:

- *Latency* is the amount of time it takes a packet to travel from one data node to another.
- Latency increases with every intermediary node on the data packet's path.
- IT solutions need to be assessed against business requirements that are affected by **network bandwidth** and **latency**, which are inherent to cloud interconnection.

Cloud Carrier and Cloud Provider Selection:

- The **service levels of Internet connections** between cloud consumers and cloud providers are determined by their **ISPs**, which are usually different and therefore include multiple ISP networks in their paths.
- **QoS** management across multiple ISPs is difficult to achieve in practice, requiring **collaboration of the cloud carriers** on both sides to ensure that their **end-to-end service levels** are sufficient for business requirements.

Cloud Computing Technologies (Contd..)

Data Center Technology:

- Grouping IT resources in **close proximity** with one another, rather than having them geographically dispersed, allows for **power sharing**, **higher efficiency** in shared IT **resource usage**, and **improved accessibility** for IT personnel.
  - These are the advantages that naturally popularized the **data center** concept.
- Modern data centers exist as **specialized IT infrastructure** used to house centralized IT resources, such as **servers**, **databases**, **networking** and **telecommunication devices**, and **software systems**.

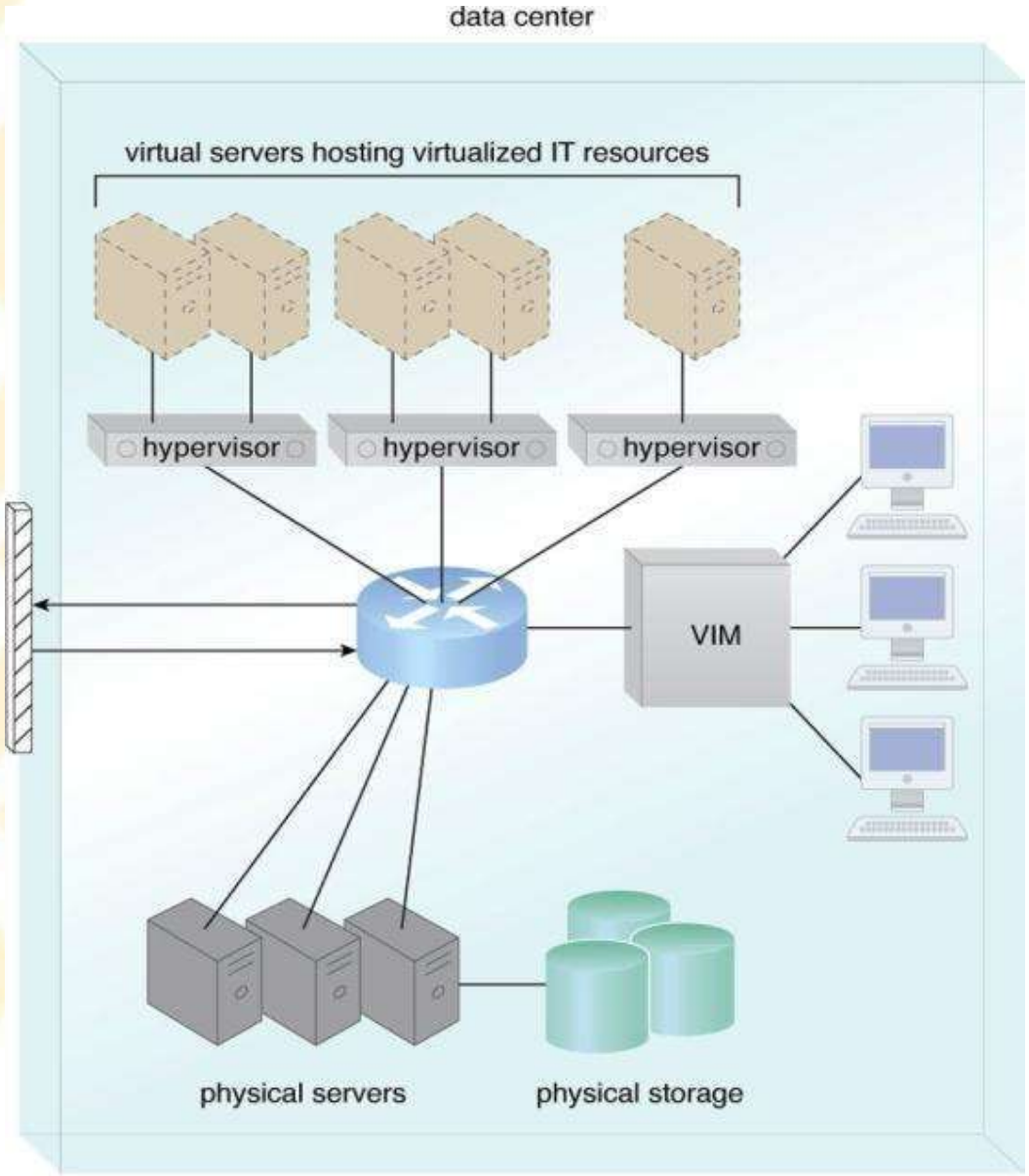
Cloud Computing Technologies (Contd..)

- Data centers are typically comprised of the following **technologies** and **components**:

Virtualization:

- Data centers consist of both **physical** and **virtualized** IT resources.
- The physical IT resource layer refers to the **facility infrastructure** that houses **computing/networking systems** and **equipment**, together with **hardware systems** and their **operating systems**.
- The **resource abstraction** and **control** of the **virtualization layer** is comprised of **operational** and **management tools** that are often based on **virtualization platforms** that abstract the physical computing and networking IT resources as virtualized components that are easier to **allocate**, **operate**, **release**, **monitor**, and **control**.

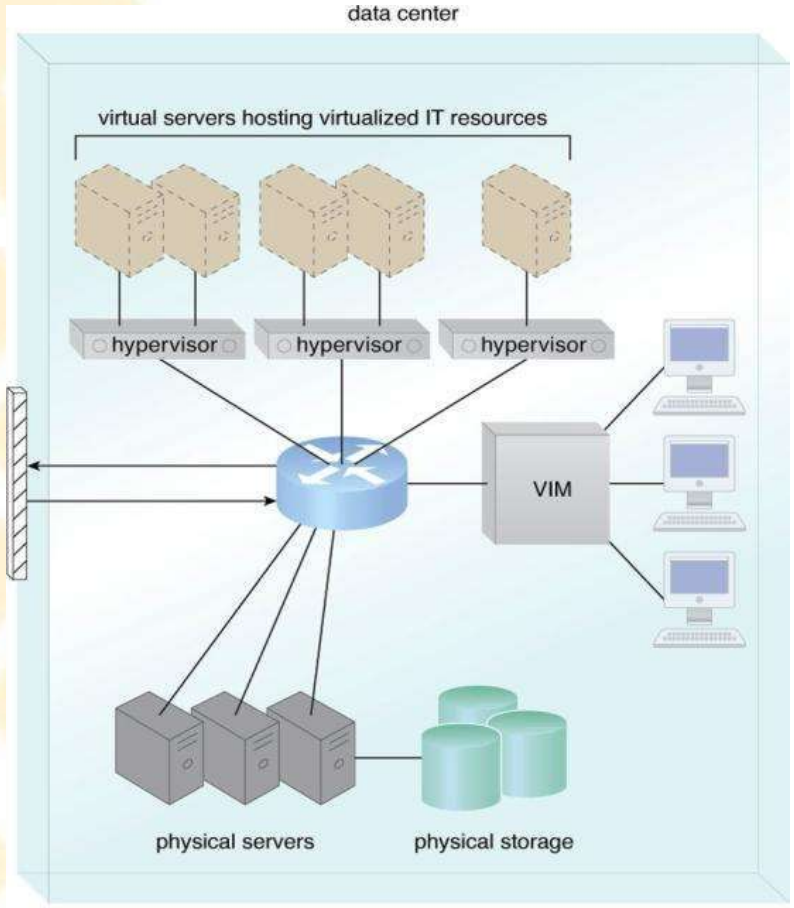
Cloud Computing Technologies (Contd..)



The common components of a data center working together to provide **virtualized IT resources** supported by **physical IT resources**.

VIM is composed of functions that are used to control and manage NFVI (computing, storage and network resources)of the domain infrastructure under the authority of the operator

Cloud Enabling Technologies(Contd..)



The common components of a data center working together to provide **virtualized IT resources** supported by **physical IT resources**. VIM(virtual infrastructure management) runs on top of a hypervisor in an NFV(Network function virtualization) environment. The hypervisor allocates and manages VM.VIM deals with allocation of resources in NFV infrastructure. NFV to reduce cost and accelerate service deployment for network operators by decoupling functions like firewall or encryption from dedicated hardware and moving them to virtual servers.

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Cloud Computing Technologies (Contd..)

Standardization and Modularity:

- Data centers are built upon **standardized commodity hardware** and designed with **modular architectures**.
  - Aggregating multiple identical building blocks of facility infrastructure and equipment to support **scalability**, **growth**, and **speedy hardware replacements**.
- Modularity and Standardization are key requirements for **reduced investment** and **operational costs** as they **enable** economies of scale for the **procurement**, **deployment**, **operation**, and **maintenance** processes.
- **Consolidated IT resources** can serve **different systems** and be shared among **different cloud consumers**.

Cloud Computing Technologies (Contd..)

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Automation:

- Data centers have **specialized platforms** that **automate** tasks like **provisioning**(process of setting up IT infrastructure), **configuration**, **patching**(process of keeping your laptops, desktops,servers and other devices free from vulnerabilities and centralizes it in cloud), and **monitoring** without supervision.
- Advances in data center management platforms and tools influence **autonomic computing** technologies to enable **self-configuration** and **self-recovery**.

Remote Operation and Management:

- Most of the operational and administrative tasks of IT resources in data centers are commanded through the **network's remote consoles** and **management systems**.
- Technical personnel are not required to visit the dedicated rooms that house servers, except to perform highly specific tasks, such as **equipment handling** and **cabling** or **hardware-level installation** and **maintenance**.

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High Availability:

- Since any form of data center significantly **impacts** business continuity for the organizations that use their services.
- Data centers are designed to operate with increasingly higher levels of **redundancy** to sustain **availability**.
- Data centers usually have **redundant**, **uninterruptable power supplies**, **cabling**, and **environmental control subsystems** in anticipation of **system failure**, along with **communication links** and **clustered hardware** for **load balancing**.

Security-Aware Design, Operation, and Management:

- Requirements for **security**, such as **physical** and **logical access controls** and **data recovery strategies**, need to be thorough and comprehensive for data centers.
  - Since they are **centralized structures** that store and process business data.

Cloud Computing Technologies (Contd..)

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Facilities:

- Data center facilities are **custom-designed locations** that are outfitted with **specialized computing**, **storage**, and **network** equipments.
- These facilities have several functional layout areas, as well as various **power supplies**, **cabling**, and **environmental control stations** that regulate **heating**, **ventilation**, **air conditioning**, **fire protection**, and other related subsystems.

Cloud Computing Technologies (Contd..)

Computing Hardware:

- Much of the **heavy processing** in data centers is often executed by **standardized commodity servers** that have substantial **computing power** and **storage capacity**.

- Several computing hardware technologies are integrated into these **modular servers**, such as:
  - **rackmount form factor server** design composed of **standardized racks** with interconnects for **power**, **network**, and **internal cooling**.
  - support for different **hardware processing architectures**, such as **x86-32 bits**, **x86-64 bits**, and **RISC**.
  - **power-efficient multi-core CPU architecture** that houses hundreds of processing cores in a space as small as a single unit of standardized racks.
  - **redundant** and **hot-swappable** components, such as **hard disks**, **power supplies**, **network interfaces**, and **storage controller cards**.
  - Difference between both server is rack server is an independent server, while blade server needs to work with each other in one server chassis(metal structure used to assemble servers in various different form factors). A server chasiss makes it possible to put multiple servers and other storage and peripheral equipment in a single physical body.

Cloud Computing Technologies (Contd..)

- Computing architectures such as **blade server** technologies use rack-embedded physical interconnections (**blade enclosures**), fabrics (**switches**), and shared power supply units and cooling fans.
- The interconnections enhance **intercomponent networking** and **management** while **optimizing** physical space and power.
- These systems typically support **individual server hot-swapping**, **scaling**, **replacement**, and **maintenance**, which benefits the deployment of fault-tolerant systems that are based on computer clusters.

Rackmount Server

Blade Server

Cloud Computing Technologies (Contd..)

Storage Hardware:

- Data centers have **specialized storage systems** that maintain enormous amounts of digital information in order to fulfill considerable storage capacity needs.
- These storage systems are **containers** housing numerous **hard disks** that are organized into **arrays**.
- Storage systems usually involve the following technologies:
  - **Hard Disk Arrays** – These arrays inherently divide and replicate data among multiple physical drives, and increase performance and redundancy by including spare disks.
    - This technology is often implemented using **R**edundant **A**rrays of **I**ndependent **D**isks (**RAID**) schemes, which are typically realized through hardware disk array controllers.

Cloud Computing Technologies (Contd..)

- **I/O Caching** – This is generally performed through hard disk array controllers, which enhance disk access times and performance by data caching.(A non-volatile memory based buffer cache policy to improve storage performance)
- **Hot-Swappable Hard Disks** – These can be safely removed from arrays without requiring prior powering down.
- **Storage Virtualization** – This is realized through the use of virtualized hard disks and storage sharing.
- **Fast Data Replication Mechanisms** – These include **snapshotting**, which is saving a **virtual machine's memory** into a **hypervisor-readable file** for future reloading, and **volume cloning**, which is copying virtual or physical hard disk volumes and partitions.

Cloud Computing Technologies (Contd..)

- Networked storage devices usually fall into one of the following categories:
  - **Storage Area Network (SAN)** – Physical data storage media are connected through a dedicated network and provide block-level data storage access using industry standard protocols, such as the **S**mall **C**omputer **S**ystem **I**nterface (**SCSI**).
  - **Network-Attached Storage (NAS)** – Hard drive arrays are contained and managed by this dedicated device, which connects through a network and facilitates access to data using file-centric data access protocols like the **N**etwork **F**ile **S**ystem (**NFS**) or **S**erver **M**essage **B**lock (**SMB**).

Cloud Computing Technologies (Contd..)

Network Hardware:

- Data centers require **extensive network hardware** in order to **enable** multiple levels of connectivity.
- For a simplified version of networking infrastructure, the data center is broken down into **five network subsystems**.

Carrier and External Networks Interconnection:

- A subsystem related to the internetworking infrastructure.
- This interconnection is usually comprised of **backbone routers** that provide routing between **external WAN connections** and the **data center's LAN**, as well as perimeter network security devices such as **firewalls** and **VPN gateways**.

Cloud Computing Technologies (Contd..)

Web-Tier Load Balancing and Acceleration:

- This subsystem comprises **Web acceleration devices**, such as **XML preprocessors**, **encryption/decryption appliances**, and **layer 7 switching devices** that perform **content-aware routing**.

LAN Fabric:

- The LAN fabric constitutes the **internal LAN** and provides **high-performance** and **redundant connectivity** for all of the data center's **network-enabled IT resources**.
- It is often implemented with **multiple network switches** that facilitate network communications and operate at speeds of up to **ten gigabits per second**.
- These advanced network switches can also perform several **virtualization functions**, such as **LAN segregation into VLANs**, **link aggregation**, controlled routing between **networks**, **load balancing**, and **failover**.

Cloud Computing Technologies (Contd..)

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SAN Fabric:

- Related to the implementation of **S**torage **A**rea **N**etworks (SANs) that provide **connectivity** between **servers** and **storage** systems.
- The SAN fabric is usually implemented with **Fibre Channel** (**FC**), **Fibre Channel over Ethernet** (**FCoE**), and **InfiniBand network switches**.

NAS Gateways:

- This subsystem supplies attachment points for NAS-based storage devices and implements **protocol conversion hardware** that facilitates data transmission between **SAN** and **NAS** devices.

Cloud Computing Technologies (Contd..)

Virtualization Technology:

- Virtualization is the process of **converting** a **physical IT resource** into a **virtual IT resource**.
- Most types of IT resources can be virtualized, including:
  - **Servers** – A physical server can be abstracted into a virtual server.
  - **Storage** – A physical storage device can be abstracted into a virtual storage device or a virtual disk.
  - **Network** – Physical routers and switches can be abstracted into logical network fabrics, such as VLANs.
  - **Power** – A physical UPS and power distribution units can be abstracted into what are commonly referred to as virtual UPSs.

Cloud Computing Technologies (Contd..)

- This section focuses on the **creation** and **deployment** of **virtual servers** through **server virtualization technology**.
- The first step in creating a new virtual server through **virtualization software** is the allocation of physical IT resources, followed by the installation of an **operating system**.
- Virtual servers use their **own guest operating systems**, which are independent of the operating system (**Host OS**) in which they were created.
- Both the **guest operating system** and the **application software** running on the virtual server are unaware of the virtualization process.
  - meaning these virtualized IT resources are installed and executed as if they were running on a **separate physical server**.
- This **uniformity of execution** that allows programs to run on physical systems as they would on virtual systems is a **vital characteristic** of virtualization.

Cloud Computing Technologies (Contd..)

- **Virtualization software** runs on a physical server called a ***host*** or ***physical host***, whose underlying hardware is made accessible by the virtualization software.
- The virtualization software functionality involves system services that are specifically related to **Virtual Machine Management** and not normally found on standard operating systems.
- This is why this software is sometimes referred to as a **Virtual Machine Manager** or a **Virtual Machine Monitor** (VMM), but most commonly known as a **Hypervisor**.

Cloud Computing Technologies (Contd..)

Hardware Independence:

- The installation of an operating system's configuration and application software in a unique IT hardware platform results in many **software-hardware dependencies**.
- In a **non-virtualized environment**, the operating system is configured for specific hardware models and requires **reconfiguration** if these IT resources need to be modified.
- **Virtualization** is a conversion process that translates **unique IT hardware** into **emulated** and **standardized software-based copies**.
- Through hardware independence, virtual servers can easily be moved to another **virtualization host**, automatically resolving multiple hardware-software incompatibility issues.
- As a result, **cloning** and **manipulating** virtual IT resources is much easier than duplicating physical hardware.

Cloud Computing Technologies (Contd..)

Server Consolidation:

- The coordination function that is provided by the virtualization software allows multiple virtual servers to be simultaneously created in the same virtualization host.
- **Virtualization technology** enables **different virtual servers** to share **one physical server**.
- This process is called **Server Consolidation**.
- It is commonly used to increase **hardware utilization**, **load balancing**, and **optimization** of available IT resources. The resulting **flexibility** is such that **different virtual servers** can run **different guest operating systems** on the **same host**.
- This fundamental capability directly supports common **cloud characteristics**, such as on-demand usage, resource pooling, elasticity, scalability, and resiliency.

Cloud Computing Technologies (Contd..)

Resource Replication:

- The Virtual servers are created as **Virtual Disk Images** that contain binary file copies of hard disk content.
- These virtual disk images are accessible to the host's operating system, meaning simple file operations, such as copy, move, and paste, can be used to replicate, migrate, and back up the virtual server.
- This ease of **manipulation** and **replication** is one of the most prominent features of virtualization technology as it enables:
  - The creation of **standardized virtual machine images** commonly configured to include virtual hardware capabilities, guest operating systems, and additional application software, for pre-packaging in virtual disk images in support of **instantaneous deployment**.
  - Increased capability in the migration and deployment of a virtual machine's new instances by being able to rapidly **scale out** and **up**.

Cloud Computing Technologies (Contd..)

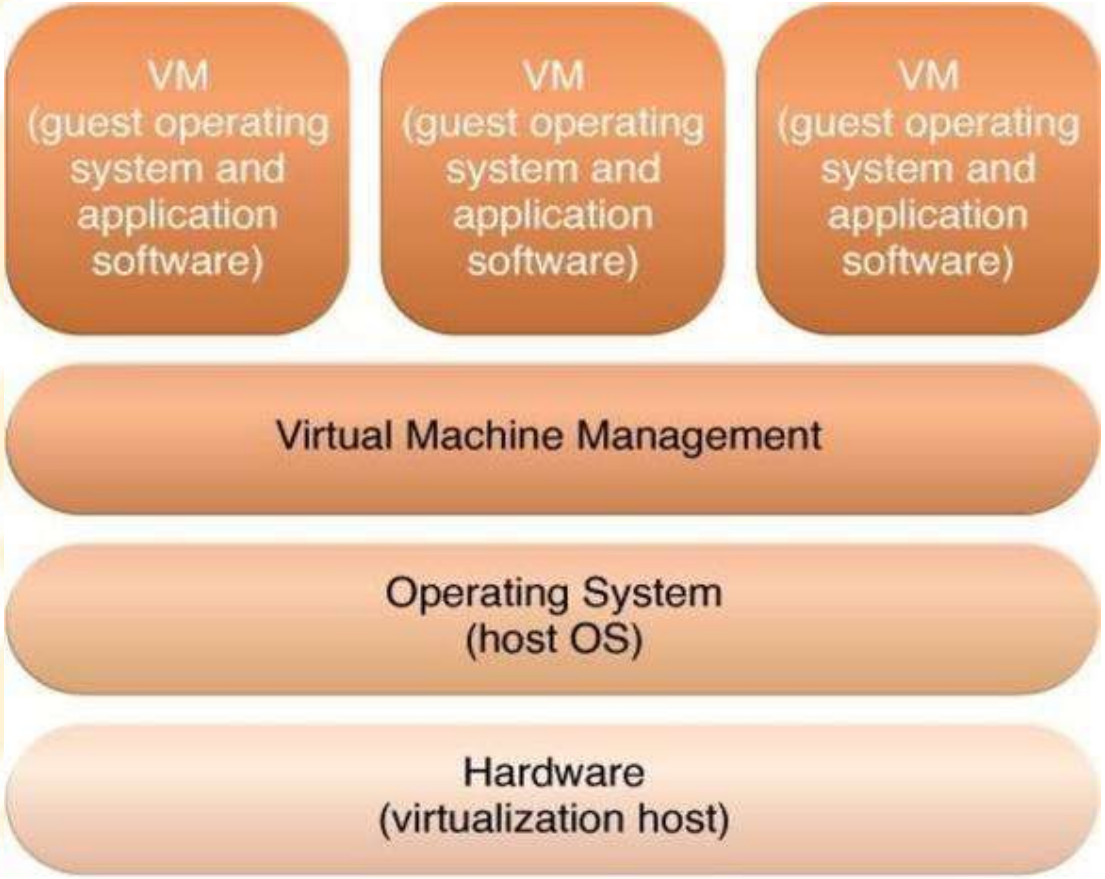
- The ability to **roll back**, which is the instantaneous creation of **VM Snapshots** by saving the state of the **virtual server's memory** and **hard disk image** to a host-based file.
  - (Operators can easily revert to these snapshots and restore the virtual machine to its prior state.)
- The support of business continuity with efficient **backup** and **restoration** procedures, as well as the creation of multiple instances of critical IT resources and applications.

Cloud Computing Technologies (Contd..)

Operating System-Based Virtualization:

- *Operating system-based virtualization* is the installation of virtualization software in a **pre-existing operating system**, which is called the **host operating system**.
- Virtualization software translates hardware IT resources that require unique software for operation into virtualized IT resources that are **compatible** with a **range of operating systems**.
- Since the host operating system is a complete operating system in itself, many operating system-based services that are available as **administration tools** can be used to manage the physical host.
- Examples of such services include:
  - Backup and Recovery
  - Integration to Directory Services
  - Security Management

Cloud Computing Technologies (Contd..)



The different logical layers of operating system-based virtualization, in which the VM is first installed into a full host operating system and subsequently used to generate virtual machines.

Cloud Computing Technologies (Contd..)

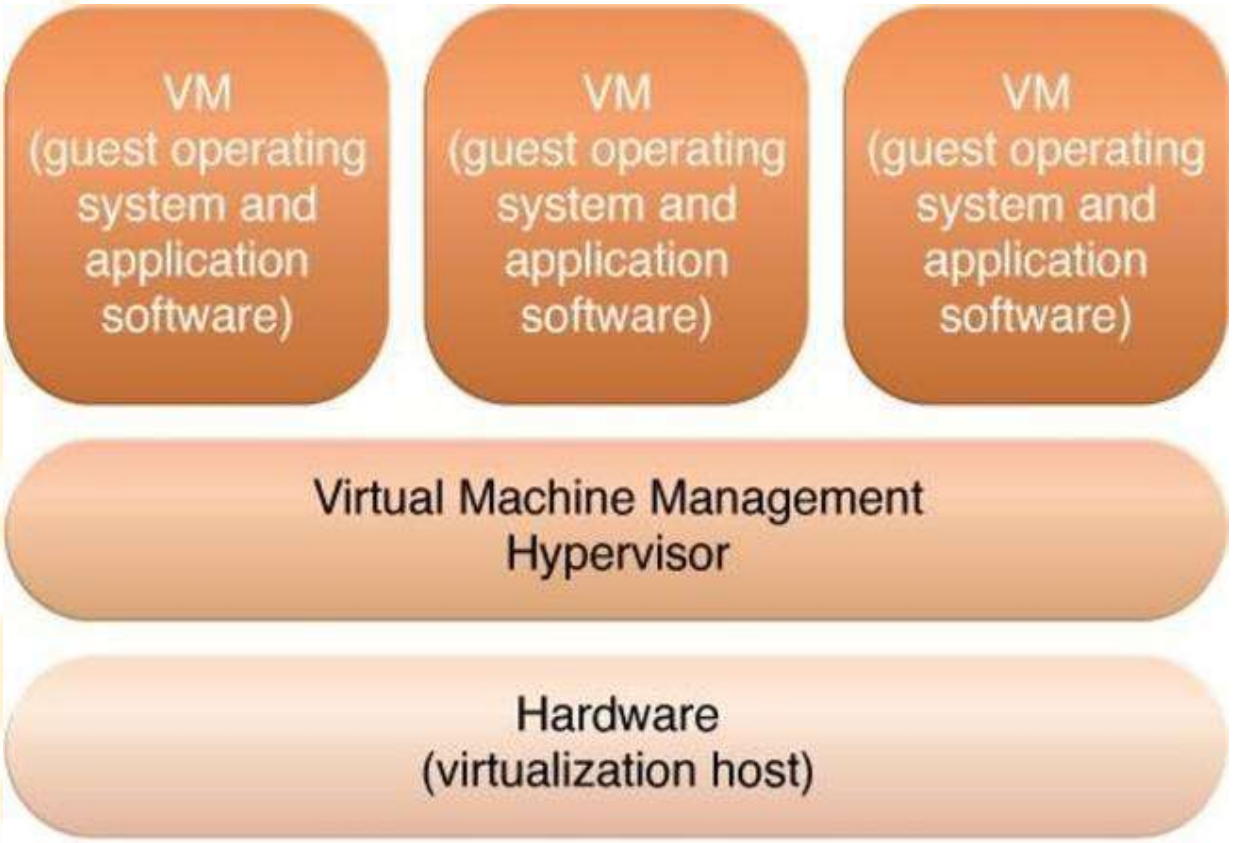
- Operating system-based virtualization can introduce **demands** and **issues** related to **performance overhead** such as:
  - The host operating system consumes CPU, memory, and other hardware IT resources.
  - Hardware-related calls from guest operating systems need to traverse several layers to and from the hardware, which decreases overall performance.
  - Licenses are usually required for host operating systems, in addition to individual licenses for each of their guest operating systems.
- A concern with operating system-based virtualization is the **processing overhead** required to run the **virtualization software** and **host operating systems**.

Cloud Computing Technologies (Contd..)

Hardware-Based Virtualization:

- *Hardware-based virtualization* represents the installation of virtualization software **directly on the physical host hardware** so as to **bypass** the host operating system.
- Allowing the virtual servers to interact with hardware **without requiring intermediary action** from the host operating system generally makes hardware-based virtualization more efficient.
- **Virtualization software** is typically referred to as a **hypervisor** for this type of processing.
- A *hypervisor* has a simple **user-interface** that requires a negligible amount of storage space.
- It exists as a thin layer of software that handles **hardware management functions** to establish a **virtualization management layer**.

Cloud Computing Technologies (Contd..)



The different logical layers of hardware-based virtualization, which does not require another host operating system.

Cloud Computing Technologies (Contd..)

- One of the main issues of hardware-based virtualization concerns **compatibility with hardware devices**.
- The virtualization layer is designed to communicate directly with the host hardware, meaning all of the associated **device drivers** and **support software** need to be **compatible with the hypervisor**.
- Hardware device drivers **may not be** as available to hypervisor platforms as they are to operating systems.
- **Host management** and **administration** features may further not include the range of **advanced functions** that are common to operating systems.

Cloud Computing Technologies (Contd..)

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Virtualization Management:

- Many **administrative tasks** can be performed more easily using **virtual servers** as opposed to using their physical counterparts.
- Modern **virtualization software / hypervisor** provides several **advanced management functions** that can **automate administration tasks** and reduce the **overall operational burden** on virtualized IT resources.
- Virtualized IT resource management is often supported by **Virtualization Infrastructure Management** (**VIM**) tools that collectively manage virtual IT resources and rely on a **centralized management module**, otherwise known as a **controller**, that runs on a dedicated computer.
- VIMs are commonly incorporated by the **Resource Management System (RMS)** mechanism.

Cloud Computing Technologies (Contd..)

Other Considerations:

Performance Overhead:

- Virtualization may not be ideal for **complex systems** that have **high workloads** with little use for **resource sharing** and **replication**.
- A poorly formulated virtualization plan can result in **excessive performance overhead**.
- A common strategy used to **rectify** the **overhead issue** is a technique called **para-virtualization**.(enhancement of VT in which guest OS is modified prior to installation inside a VM in order to allow all guest OSes within system to share resources & successfully collaborate rather than attempt to emulate an entire h/w environment)
  - represents a software interface to the virtual machines that is not identical to that of the underlying hardware.
- A **major drawback** of this approach is the need to adapt the **guest operating system** to the **para-virtualization API**, which can impair the use of standard guest operating systems while **decreasing solution portability**.

Cloud Computing Technologies (Contd..)

Special Hardware Compatibility:

- Many **hardware vendors** that distribute **specialized hardware** may not have **device driver versions** that are **compatible with virtualization software**.
- Conversely, the software itself may be **incompatible** with recently released **hardware versions**.
- These types of **incompatibility issues** can be resolved using established **commodity hardware platforms** and mature **virtualization software products**.

Portability:

- The **programmatic** and **management** interfaces that establish **administration environments** for a **virtualization program** to operate with various virtualization solutions can introduce **portability gaps** due to **incompatibilities**.
- Initiatives such as the **Open Virtualization Format** (**OVF**) for the standardization of virtual disk image formats are dedicated to improving this concern.

Cloud Computing Technologies (Contd..)

Web Technology:

- Due to cloud computing's **fundamental dependence** on **internetworking**, **Web browser** universality, and the ease of **Web-based service** development,
  - *Web Technology* is generally used as both the **implementation medium** and the **management interface** for **cloud services**.

Basic Web Technology:

- The **World Wide Web** is a system of interlinked IT resources that are accessed through the Internet.
- The two basic components of the Web are the **Web browser client** and the **Web server**.
- Other components, such as **caching services**, **gateways**, and **load balancers**, are used to improve Web application characteristics such as **scalability** and **security**.

Cloud Computing Technologies (Contd..)

- These additional components reside in a **layered architecture** that is positioned between the **client** and the **server**.
- **Three fundamental elements** comprise the technology architecture of the Web:
  - **Uniform Resource Locator** (**URL**) – A standard syntax used for creating **identifiers** that point to Web-based resources, the URL is often structured using a **logical network location**.
  - **Hypertext Transfer Protocol** (**HTTP**) – This is the primary **communications protocol** used to exchange content and data throughout the World Wide Web. **URLs** are typically transmitted via **HTTP**.
  - **Markup Languages** (**HTML**, **XML**) – Markup languages provide a lightweight means of expressing **Web-centric data** and **metadata**.
    - The two primary markup languages are **HTML** (which is used to express the presentation of Web pages) and **XML** (which allows for the definition of vocabularies used to associate meaning to Web-based data via metadata).

HTML	XML
HTML stands for Hyper Text Markup Language.	XML stands for extensible Markup Language.
HTML is static.	XML is dynamic.
HTML is a markup language.	XML provides framework to define markup languages.
HTML can ignore small errors.	XML does not allow errors.
HTML is not Case sensitive.	XML is Case sensitive.
HTML tags are predefined tags.	XML tags are user defined tags.
There are limited number of tags in HTML.	XML tags are extensible.
HTML does not preserve white spaces.	White space can be preserved in XML.
HTML tags are used for displaying the data.	XML tags are used for describing the data not for displaying.
In HTML, closing tags are not necessary.	In XML, closing tags are necessary.
HTML is used to display the data.	XML is used to store data.
HTML does not carry data it just display it.	XML carries the data to and from database.

Cloud Computing Technologies (Contd..)

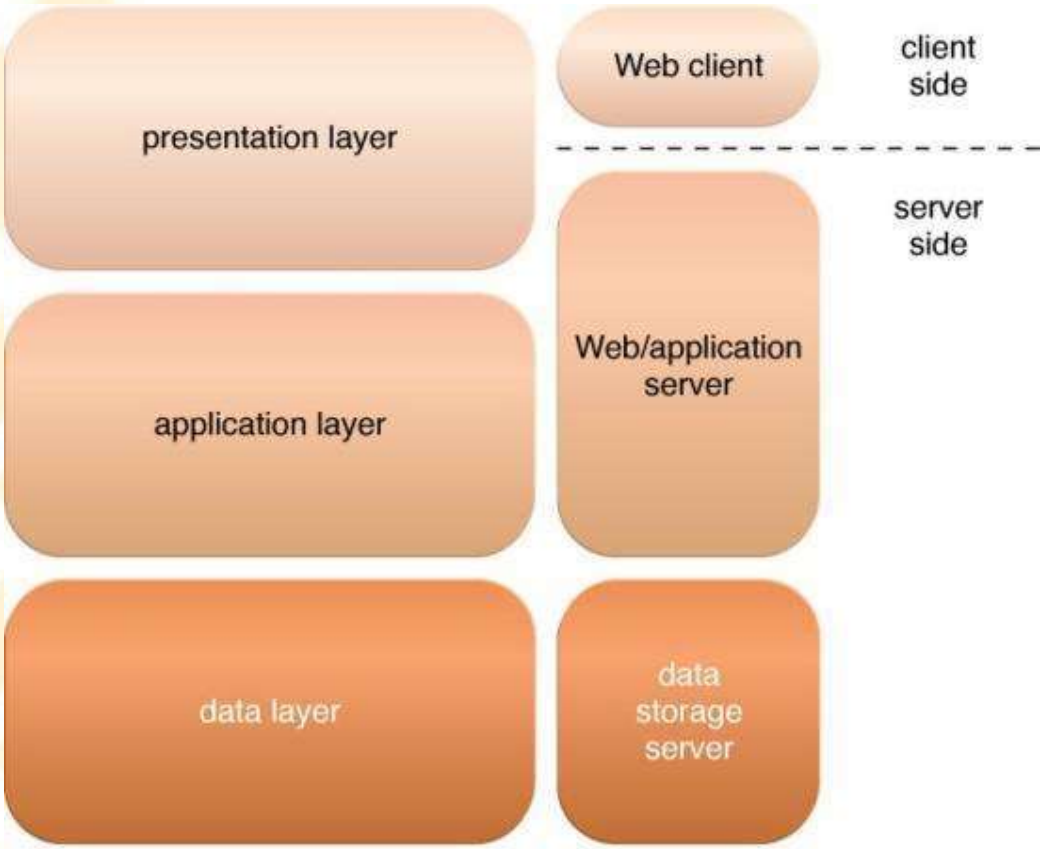
- For more details on URLs, HTTP, HTML & XML, visit to: https://servicetechspecs.com
- For example, a **Web browser** can request to execute an action like **read**, **write**, **update**, or **delete** on a **Web resource** on the Internet, and proceed to **identify** and **locate** the Web resource through its **URL**.
- The request is sent using **HTTP** to the **resource host**, which is also identified by a **URL**.
- The **Web server** locates the **Web resource** and performs the requested operation, which is followed by a **response** being sent back to the client.
- The **response** may be comprised of **content** that includes **HTML** and **XML** statements.

Cloud Computing Technologies (Contd..)

Web Applications:

- A **distributed application** that uses **Web-based technologies** (and generally relies on **Web browsers** for the presentation of user-interfaces) is typically considered a *Web application*.
- These applications can be found in all kinds of **cloud-based environments** due to their **high accessibility**.
- Common architectural abstraction for Web applications that is based on the basic **three-tier model**.
  - The first tier is called the **presentation layer**, which represents the user-interface.
  - The middle tier is the **application layer** that implements application logic.
  - The third tier is the **data layer** that is comprised of persistent data stores.

Cloud Computing Technologies (Contd..)



The three basic architectural tiers of Web applications.

Cloud Computing Technologies (Contd..)

- The presentation layer has components on both the **client** and **server-side**.
- **Web servers** receive client requests and retrieve requested resources directly as **static Web content** and indirectly as **dynamic Web content**, which is generated according to the **application logic**.
- **Web servers** interact with **application servers** in order to execute the requested application logic, which then typically involves interaction with one or more underlying **databases**.
- **PaaS ready-made environments** enable cloud consumers to develop and deploy **Web applications**.
- Typical PaaS offerings have **separate instances** of the **Web server**, **application server**, and **data storage** server environments.

Cloud Computing Technologies (Contd..)

Multitenant Technology:

- The multitenant application design was created to enable multiple users (**tenants**) to access the **same application logic simultaneously**.
- Each tenant has its own view of the application that it **uses**, **administers**, and **customizes** as a dedicated instance of the software while remaining **unaware of other tenants** that are using the same application.
- Multitenant applications ensure that tenants do not have access to data and configuration information that is not their own.
- Tenants can individually customize features of the application, such as:
  - ***User Interface*** – Tenants can define a specialized "look and feel" for their application interface.
  - ***Business Process*** – Tenants can customize the rules, logic, and workflows of the business processes that are implemented in the application.
  - ***Data Model*** – Tenants can extend the data schema of the application to include, exclude, or rename fields in the application data structures.
  - ***Access Control*** – Tenants can independently control the access rights for users and groups.

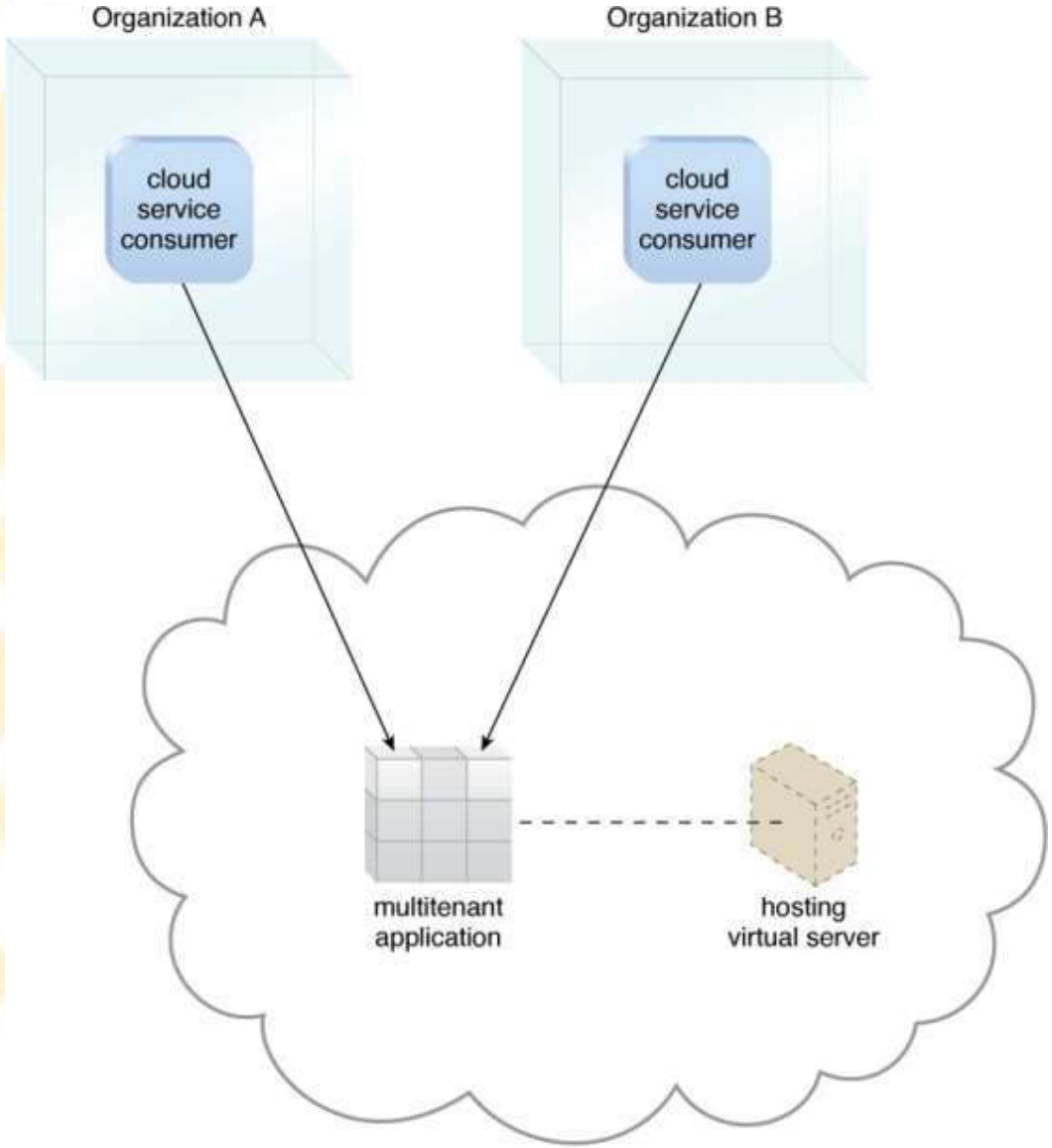
Cloud Computing Technologies (Contd..)

- Multitenant application architecture is often significantly more complex than that of single-tenant applications.
- Multitenant applications need to support the sharing of various artifacts by multiple users (including **portals**, **data schemas**, **middleware**, and **databases**), while maintaining **security levels** that segregate individual tenant operational environments.
- Common **characteristics** of multitenant applications include:
  - **Usage Isolation** – The usage behavior of one tenant does not affect the application availability and performance of other tenants.
  - **Data Security** – Tenants cannot access data that belongs to other tenants.
  - **Recovery** – Backup and restore procedures are separately executed for the data of each tenant.

Cloud Computing Technologies (Contd..)

- **Application Upgrades** – Tenants are not negatively affected by the synchronous upgrading of shared software artifacts.
- **Scalability** – The application can scale to accommodate increases in usage by existing tenants and/or increases in the number of tenants.
- **Metered Usage** – Tenants are charged only for the application processing and features that are actually consumed.
- **Data Tier Isolation** – Tenants can have individual databases, tables, and/or schemas isolated from other tenants.
  - Alternatively, databases, tables, and/or schemas can be designed to be intentionally shared by tenants.

Cloud Computing Technologies (Contd..)



A multitenant application that is serving **multiple cloud service consumers simultaneously**.

This type of application is typical with **SaaS** implementations.

Cloud Computing Technologies (Contd..)

Service Technology:

- The field of service technology is a **keystone foundation** of cloud computing that formed the basis of the **"as-a-service"** cloud delivery models.

Web-Based Services:

- Reliant on the use of **standardized protocols**, *Web-based services* are self-contained units of logic that support **machine-to-machine** interaction over a network.
- These services are generally designed to communicate via technologies in accordance with **industry standards** and **conventions**.
- Web-based services main function is to process **data between computers**, these services expose **APIs** and **do not have user interfaces**.
- **Web services** and **REST services** represent two common forms of Web-based services.

Cloud Computing Technologies (Contd..)

Web Services:

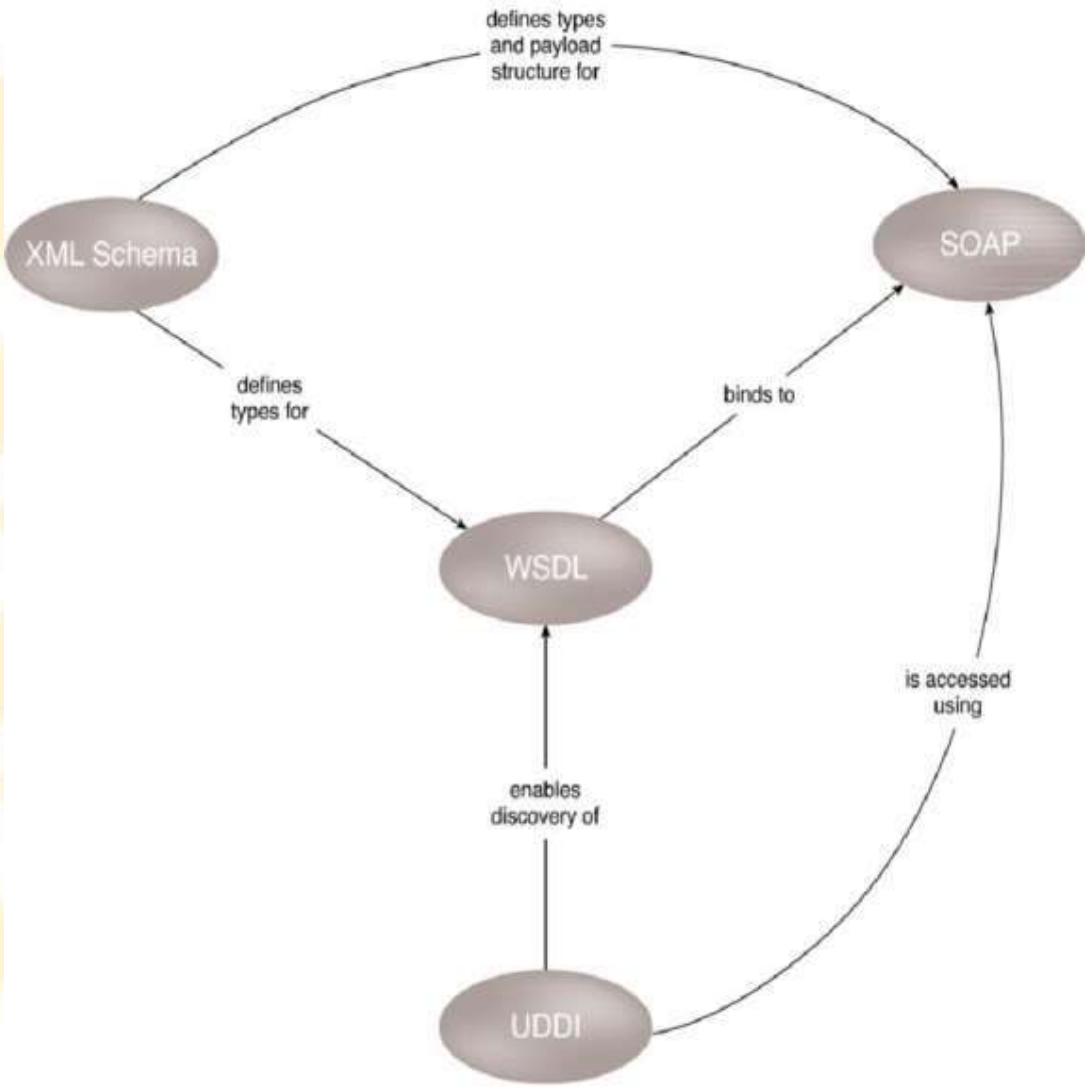
- Also commonly prefixed with **"SOAP-based"** Web services represent an established and common medium for **sophisticated**, **Web-based service logic**.
- Along with **XML**, the **core technologies** behind Web services are represented by the following industry standards:
  - **Web Service Description Language** (**WSDL**) – This markup language is used to create a **WSDL definition** that defines the application programming interface (**API**) of a Web service, including its individual operations (functions) and each operation's **input** and **output messages**.
  - **XML Schema Definition Language** (**XML Schema**) – Messages exchanged by Web services must be expressed using XML. XML schemas are created to define the **data structure** of the **XML-based input** and **output messages** exchanged by Web services.

    – XML schemas can be directly linked to or embedded within **WSDL definitions**.

Cloud Computing Technologies (Contd..)

- **SOAP** – Formerly known as the **Simple Object Access Protocol**, this standard defines a common **messaging format** used for **request** and **response messages** exchanged by Web services.
  - SOAP messages are comprised of **body** and **header** sections.
  - The **body** section contains the **main message content** and the **header** section is used to contain **metadata** that can be processed at runtime.
- **Universal Description, Discovery, and Integration** (**UDDI**) – This standard **regulates service registries** in which WSDL definitions can be published as part of a **service catalog** for discovery purposes.

Cloud Computing Technologies (Contd..)



An overview of how first-generation Web service technologies commonly relate to each other.

Cloud Computing Technologies (Contd..)

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REST Services:

- REST stands for **Representational State Transfer**.
- *REST services* are designed according to a **set of constraints** that shape the **service architecture** to **emulate the properties** of the **World Wide Web**, resulting in **service implementations** that rely on the use of core Web technologies.
- Unlike Web services, **REST services** do not have individual technical interfaces but instead share a **common technical interface** that is known as the **uniform contract**, which is typically established via the use of **HTTP** methods.
- The **six REST design constraints** are:
  - Client-Server
  - Stateless
  - Cache
  - Interface/Uniform Contract
  - Layered System
  - Code-On-Demand

Each design constraint is described in detail at www.whatisrest.com

Cloud Computing Technologies (Contd..)

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Service Agents:

- Service agents are **event-driven programs** designed **to intercept messages** at runtime.
- There are **active** and **passive service agents**, both of which are common in cloud environments.
- **Active service agents** perform an action upon **intercepting** and **reading** the contents of a message.
- The action typically requires making changes to the message contents (most commonly **message header data** and less commonly the **body content**) or changes to the **message path** itself.
- **Passive service agents** do not change message contents.
- The action is to **read the message** and may then **capture** certain parts of its contents, usually for **monitoring**, **logging**, or **reporting** purposes.

Cloud Computing Technologies (Contd..)

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Service Middleware:

- *Service middleware* platforms that evolved from **messaging-oriented middleware** (**MOM**) platforms used primarily to facilitate integration, to sophisticated service middleware platforms designed to accommodate **complex service compositions**.
- The two most common types of middleware platforms relevant to services computing are the **enterprise service bus** (**ESB**) and the **orchestration platform**.
- The **ESB** encompasses a range of intermediary processing features, including **service brokerage**, **routing**, and **message queuing**.
- **Orchestration** environments are designed to **host** and **execute** workflow logic that drives the **runtime composition of services**.

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UNIT - 2

- **Cloud Infrastructure Mechanisms**

Cloud Infrastructure Mechanisms

- *Cloud infrastructure mechanisms* are **foundational building blocks** of cloud environments that establish **primary artifacts** to form the basis of **fundamental cloud technology architecture**.
- The following cloud infrastructure mechanisms are described in this unit are:
  - **Logical Network Perimeter**
  - **Virtual Server**
  - **Cloud Storage Device**
  - **Cloud Usage Monitor**
  - **Resource Replication**
  - **Ready-Made Environment**

Cloud Infrastructure Mechanisms (Contd..)

Logical Network Perimeter:

- Defined as the **isolation of a network environment** from the rest of a **communications network**.
- The *logical network perimeter* establishes a **virtual network boundary** that can **incorporate** and **isolate** a group of related **cloud-based IT resources** that may be physically distributed.

The dashed line notation used to indicate the boundary of a logical network perimeter.

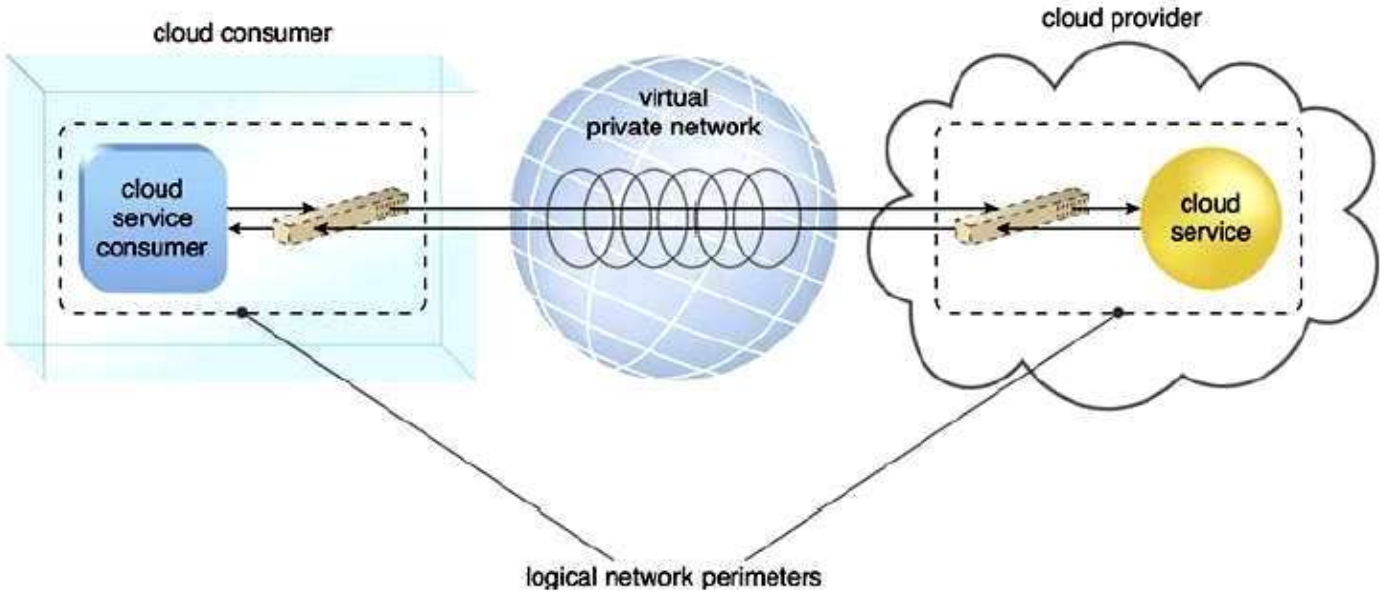
Cloud Infrastructure Mechanisms (Contd..)

- This mechanism can be implemented to:
  - isolate IT resources in a cloud from non-authorized users.
  - isolate IT resources in a cloud from non-users.
  - isolate IT resources in a cloud from cloud consumers.
  - control the bandwidth that is available to isolated IT resources.
- Logical network perimeters are typically established via **network devices** that **supply** and **control** the **connectivity of a data center** and are commonly deployed as **virtualized IT environments** that include:
  - **Virtual Firewall** – An IT resource that actively **filters network traffic** to and from the **isolated network** while controlling its interactions with the Internet.
  - **Virtual Network** – Usually acquired through vLANs, this IT resource **isolates the network environment** within the **data center infrastructure**.

Cloud Infrastructure Mechanisms (Contd..)

Virtual Firewall

Virtual Network



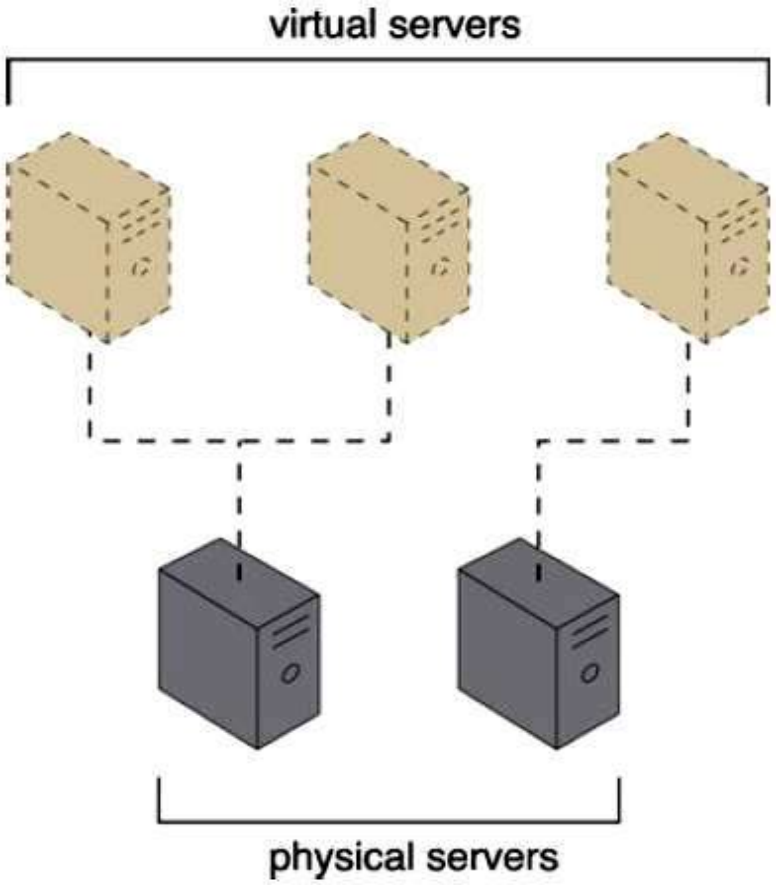
Two logical network perimeters surround the cloud consumer and cloud provider environments.

Cloud Infrastructure Mechanisms (Contd..)

Virtual Server:

- A *virtual server* is a form of **virtualization software** that emulates a physical server.
- Virtual servers are used by cloud providers to share the same physical server with multiple cloud consumers by providing cloud consumers with **individual virtual server instances**.
- As a commodity mechanism, the virtual server represents the most **foundational building block** of cloud environments.
- Each virtual server can host **numerous IT resources**, **cloud-based solutions**, and various other **cloud computing mechanisms**.

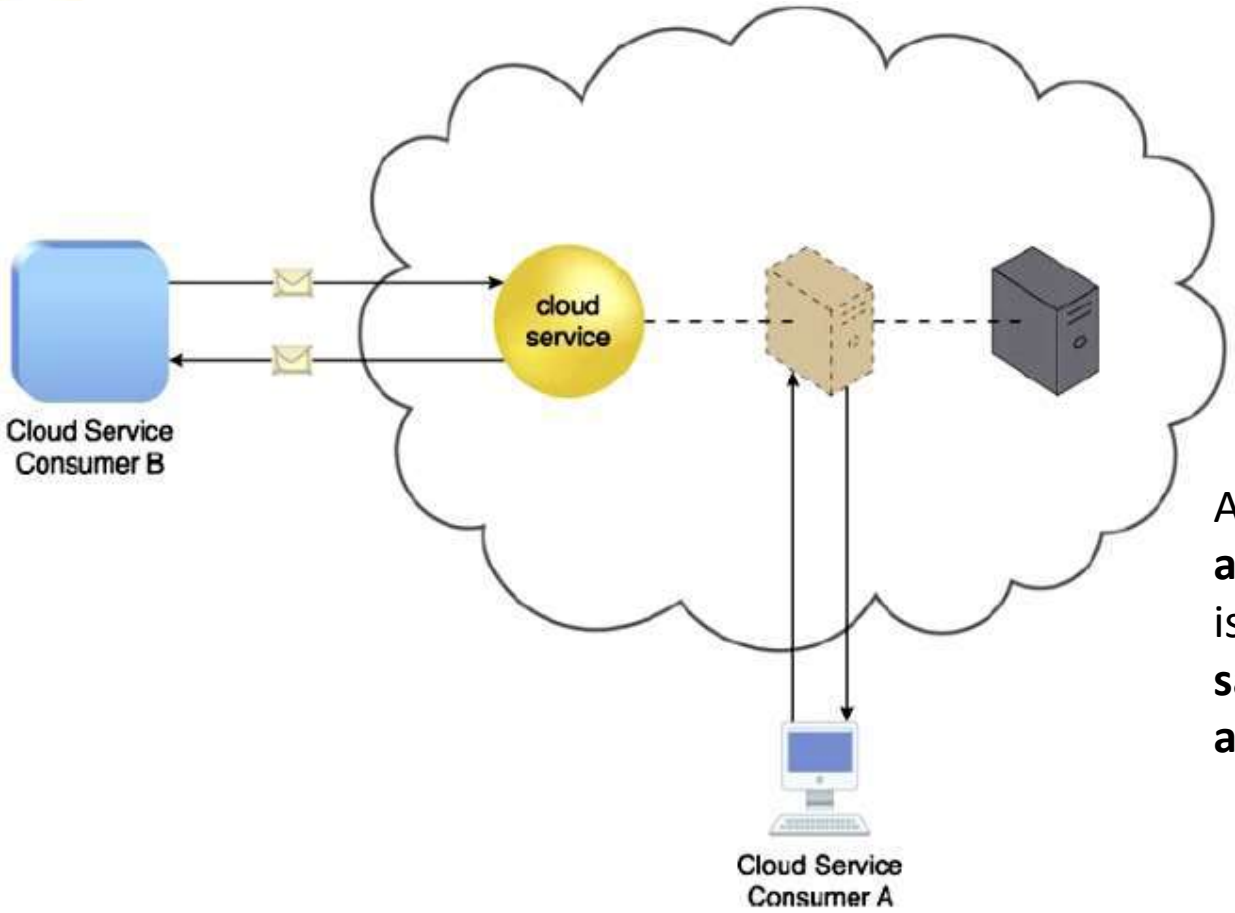
Cloud Infrastructure Mechanisms (Contd..)



The **first physical server** hosts **two virtual servers**, while the **second physical server** hosts **one virtual server**.

- **Cloud consumers** that install or lease virtual servers can **customize** their environments **independently** from other cloud consumers that may be using **virtual servers hosted** by the **same underlying physical server**.

Cloud Infrastructure Mechanisms (Contd..)



A **virtual server** hosts an **active cloud service** and is further accessed by a **same cloud consumer** for **administrative purposes**.

- A **virtual server** that hosts a **cloud service** being accessed by **Cloud Service Consumer B**, while **Cloud Service Consumer A** accesses the **virtual server** directly to perform an **administration task**.

Cloud Infrastructure Mechanisms (Contd..)

Cloud Storage Device:

- The *cloud storage device* mechanism represents **storage devices** that are designed specifically for **cloud-based provisioning**.
- Instances of these devices can be **virtualized**, similar to how physical servers can host virtual servers.
- Cloud storage devices are commonly able to provide **fixed-increment capacity** allocation in support of the **pay-per-use mechanism**.
- Cloud storage devices can be exposed for **remote access** via **cloud storage services**.
- A **primary concern** related to cloud storage is the **security**, **integrity**, and **confidentiality of data**, which becomes more likely to being compromised when **entrusted to external cloud providers** and other third parties.

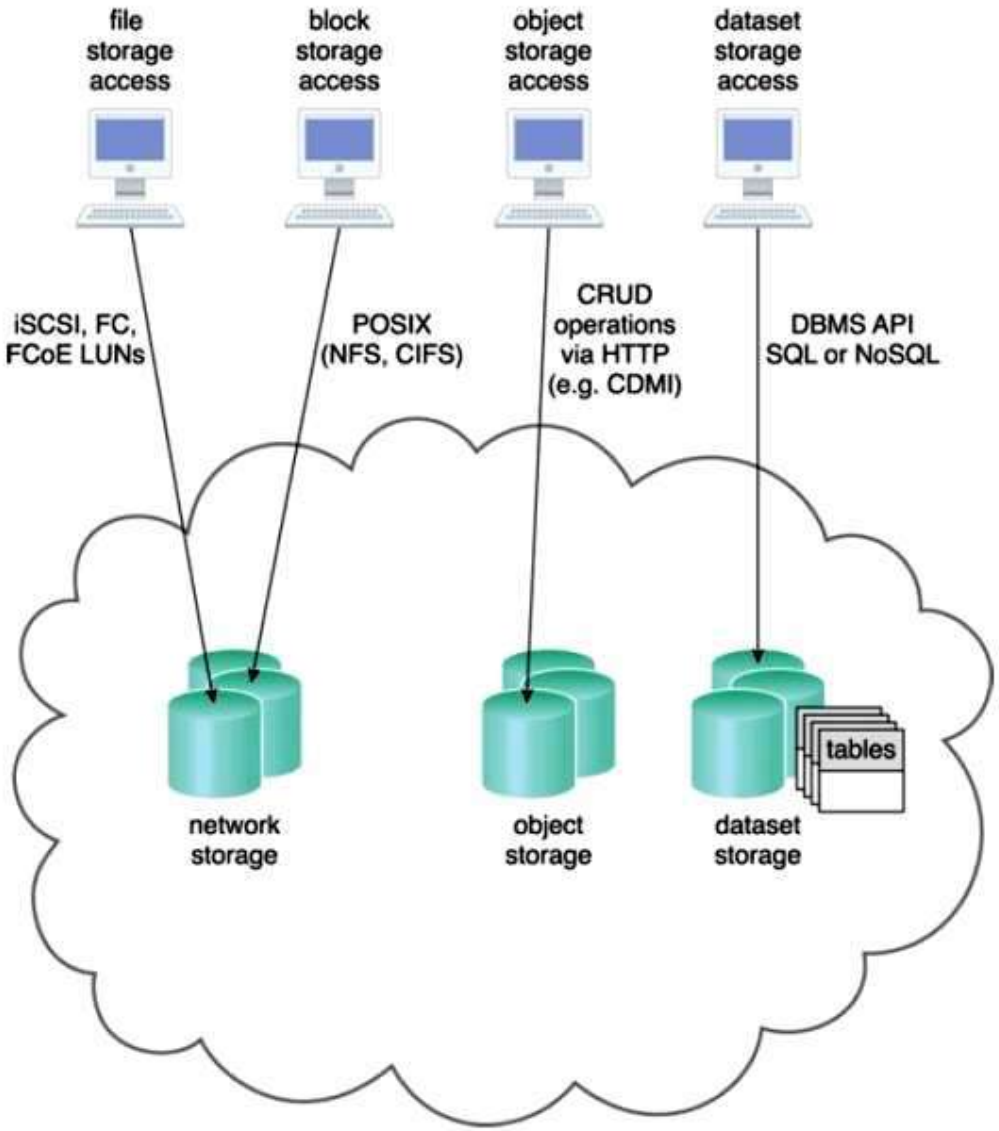
Cloud Infrastructure Mechanisms (Contd..)

- Another issue applies specifically to the **performance of large databases**.
- LANs provide locally stored data with network reliability and latency levels that are superior to those of WANs.

Cloud Storage Levels:

- Cloud storage device mechanisms provide common logical units of data storage, such as:
  - **Files** – Collections of data are grouped into files that are located in folders.
  - **Blocks** – **The lowest level of storage** and the **closest to the hardware**, block is the **smallest unit of data** that is still individually accessible.
  - **Datasets** – Sets of data are organized into a table-based, delimited, or record format.
  - **Objects** – Data and its associated metadata are organized as Web-based resources.

Cloud Infrastructure Mechanisms (Contd..)



Different cloud service consumers utilize different technologies to interface with virtualized cloud storage devices.

(Adapted from the CDMI Cloud Storage Reference Model)

CDMI: Cloud Data Management Interface

Cloud Infrastructure Mechanisms (Contd..)

- Each of these **data storage levels** is commonly **associated with** a certain type of **technical interface** which corresponds to a **particular type of cloud storage device** and **cloud storage service** used to expose its **API**.

Network Storage Interfaces:

- Legacy network storage most commonly falls under the category of *network storage interfaces*.
- It includes storage devices in compliance with industry standard protocols, such as **Small Computer System Interface** (**SCSI**) for **storage blocks** and the **Server Message Block** (**SMB**), **Common Internet file System** (**CIFS**), and **Network File System** (**NFS**) for **file** and **network storage**.

Cloud Infrastructure Mechanisms (Contd..)

- **File storage** entails storing individual data in separate files that can be different sizes and formats and organized into **folders** and **subfolders**.
- **Original files** are often **replaced** by the **new files** that are created when data has been modified.
- **Storage processing levels** and **thresholds** for file allocation are usually determined by the **file system** itself.
- **Block storage** requires data to be in a fixed format (known as a **data block**), which is the **smallest unit** that can be stored and accessed and the storage format closest to hardware.
- Using either the **Logical Unit Number** (**LUN**) or **virtual volume block-level storage** will typically have better performance than **file-level storage**.

Cloud Infrastructure Mechanisms (Contd..)

Object Storage Interfaces:

- Various types of data can be referenced and stored as **Web resources**.
- This is referred to as **object storage**, which is based on technologies that can support a range of data and media types.
- **Cloud Storage Device mechanisms** that implement this interface can typically be accessed via **REST** or **Web service-based** (**SOAP**) cloud services using **HTTP** as the prime protocol.
- The **Storage Networking Industry Association**'s **Cloud Data Management Interface** (**SNIA's CDMI**) supports the use of *object storage interfaces*.

Cloud Infrastructure Mechanisms (Contd..)

Database Storage Interfaces:

- **Cloud storage device mechanisms** based on *database storage interfaces* typically support a **query language** in addition to basic storage operations.
- Storage management is carried out using a **standard API** or an **administrative user interface**.
- This classification of storage interface is divided into **two main categories** according to **storage structure**, as follows:

Relational Data Storage:

- Working with relational storage commonly involves the use of the industry standard **Structured Query Language** (**SQL**).
- A cloud storage device mechanism implemented using relational data storage could be based on any number of commercially available database products, such as **IBM DB2**, **Oracle Database**, **Microsoft SQL Server**, and **MySQL**.

Cloud Infrastructure Mechanisms (Contd..)

Non-Relational Data Storage:

- *Non-relational storage* (also commonly referred to as **NoSQL storage**) moves away from the traditional relational database model in that it establishes a "looser" structure for stored data with less emphasis on defining relationships and realizing data normalization.
- The primary motivation for using non-relational storage is to avoid the **potential complexity** and **processing overhead** that can be imposed by relational databases.
- **Cloud providers** often offer **non-relational storage** that provides **scalability** and **availability** of stored data over **multiple server environments**.

Cloud Infrastructure Mechanisms (Contd..)

Cloud Usage Monitor:

- The *cloud usage monitor* mechanism is a **lightweight** and **autonomous software program** responsible for **collecting** and **processing** IT resource **usage data**.
- Depending on the type of **usage metrics** they are designed to **collect** and the manner in which **usage data** needs to be collected, **cloud usage monitors** can exist in different formats.
- It is described in **three common agent-based implementation** formats.
- Each can be designed to **forward collected usage data** to a **log database** for **post-processing** and **reporting** purposes.
  - Monitoring Agent
  - Resource Agent
  - Polling Agent

Cloud Infrastructure Mechanisms (Contd..)

Monitoring Agent:

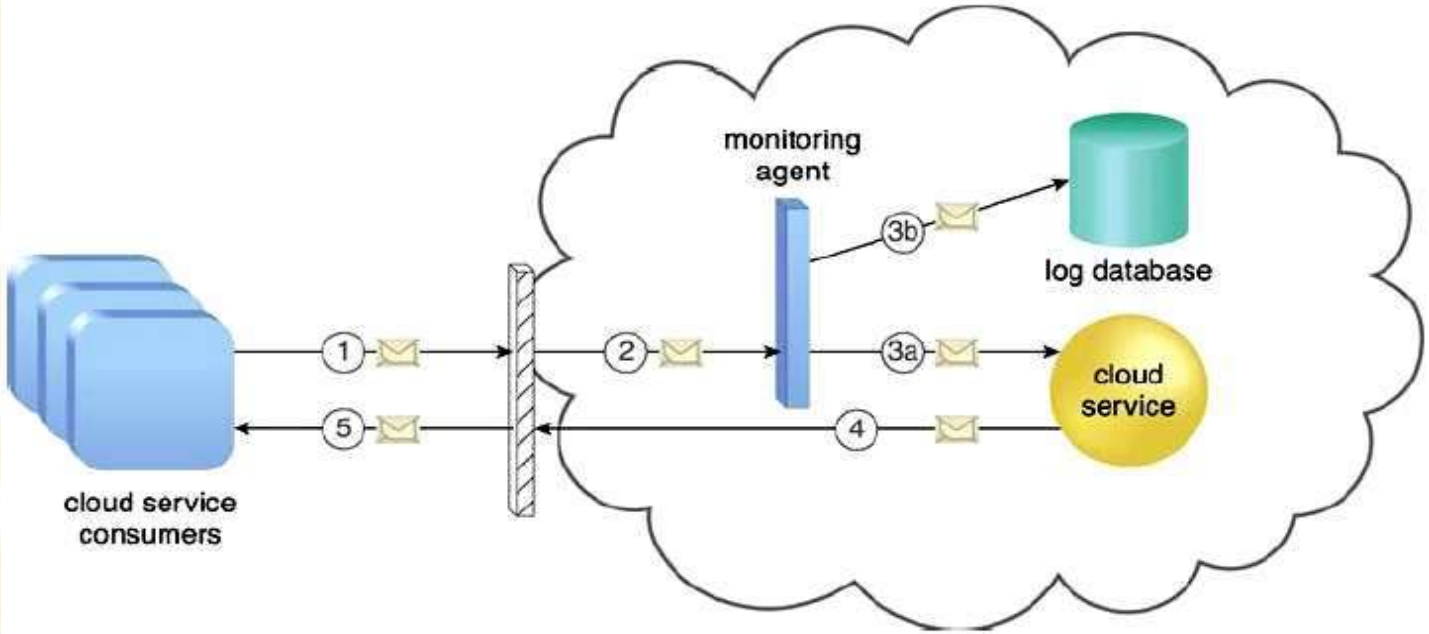
- A *monitoring agent* is an **intermediary**, **event-driven program** that exists as a **service agent** and resides along existing **communication paths** to transparently **monitor** and **analyze** dataflows.
- This type of cloud usage monitor is commonly used to measure **network traffic** and **message metrics**.

Resource Agent:

- A *resource agent* is a **processing module** that collects **usage data** by having **event-driven interactions** with **specialized resource software**.
- This module is used to **monitor usage metrics** based on **pre-defined**, **observable events** at the **resource software level**, such as **initiating**, **suspending**, **resuming**, and **vertical scaling**.

Cloud Infrastructure Mechanisms (Contd..)

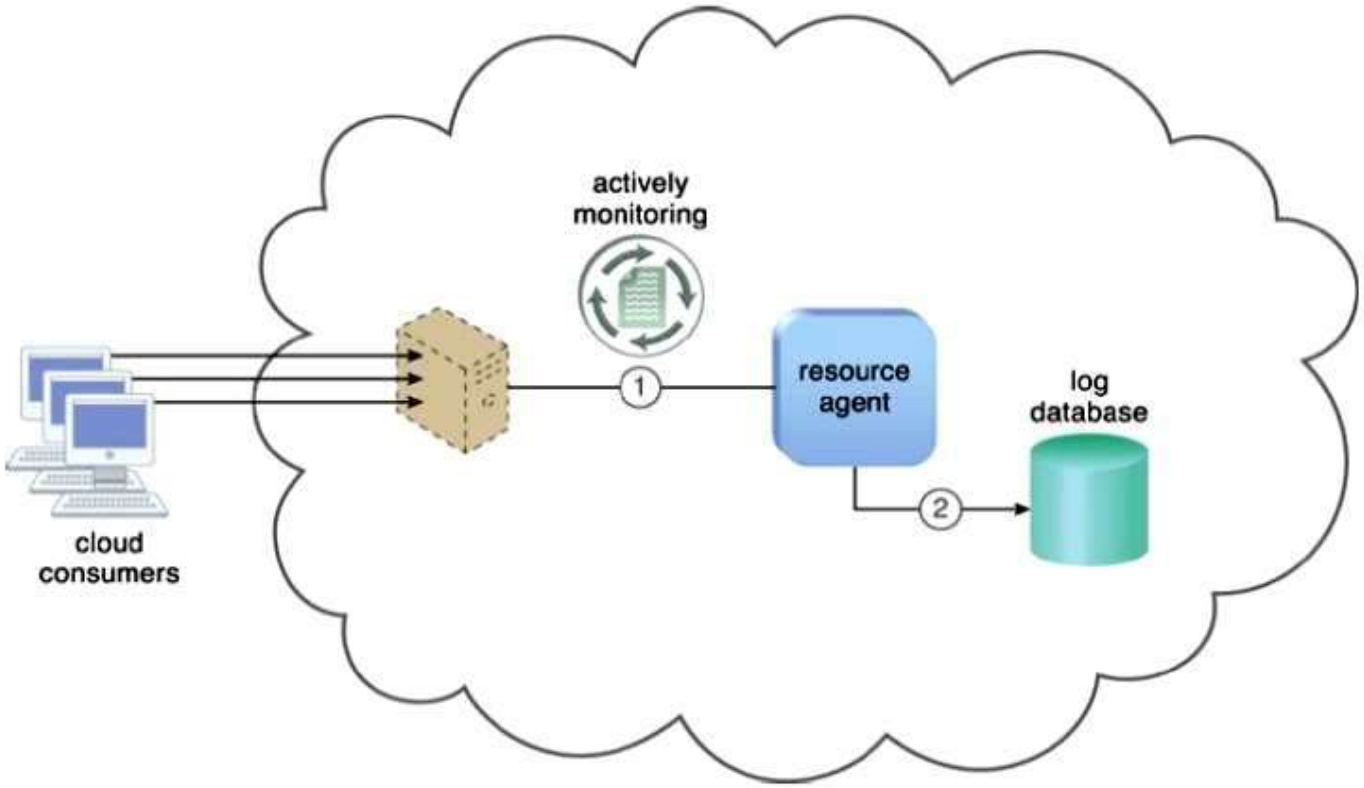
Monitoring Agent:



(1) A cloud service consumer sends a request message to a cloud service.
(2) The monitoring agent intercepts the message to collect relevant usage data
(3a) before allowing it to continue to the cloud service.
(3b) The monitoring agent stores the collected usage data in a log database.
(4) The cloud service replies with a response message
(5) that is sent back to the cloud service consumer without being intercepted by the monitoring agent.

Cloud Infrastructure Mechanisms (Contd..)

Resource Agent:



(1) The resource agent is actively monitoring a virtual server and detects an increase in usage.

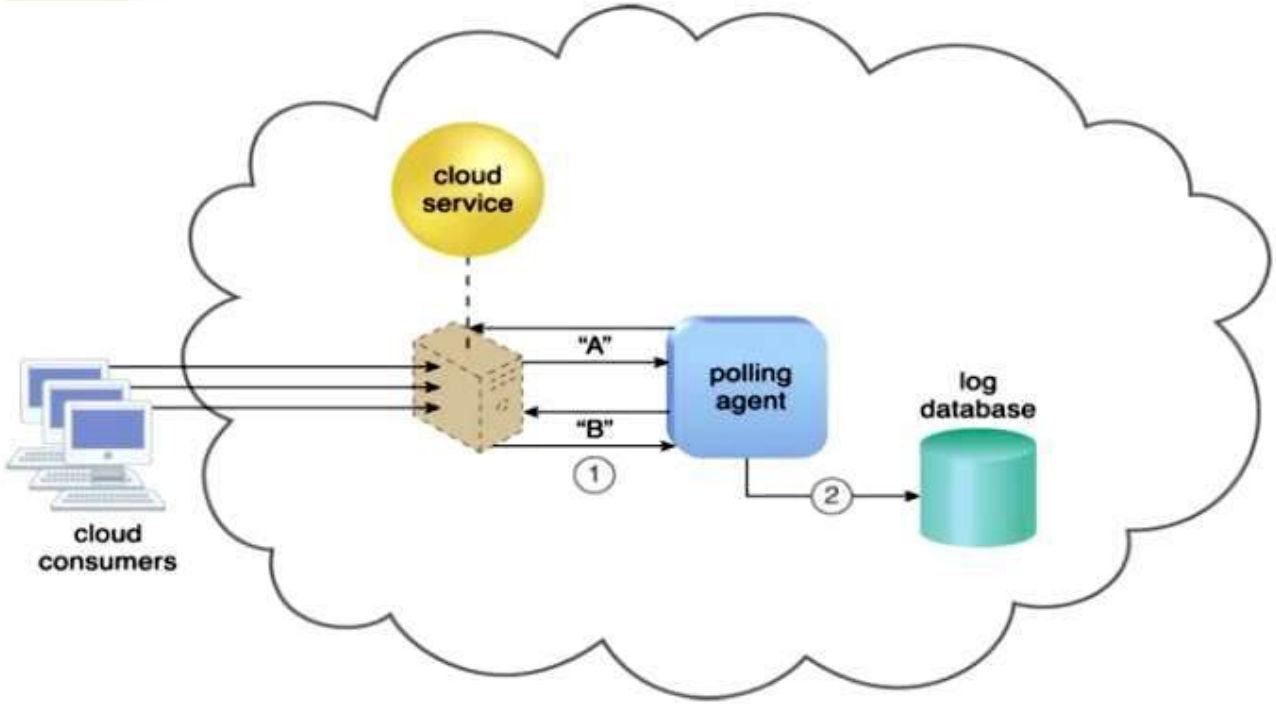
(2) The resource agent receives a notification from the underlying resource management program that the virtual server is being scaled up and stores the collected usage data in a log database, as per its monitoring metrics.

Cloud Infrastructure Mechanisms (Contd..)

Polling Agent:

- A *polling agent* is a **processing module** that collects **cloud service usage data** by **polling IT resources**.
- This type of cloud service monitor is commonly used to **periodically monitor** IT resource **status**, such as **uptime** and **downtime**.
- '**Polling**' is the **continuous checking** of other programs or devices by one program or device to see **what state they are in**, usually to see whether they are still connected or want to communicate.
- **Cloud uptime** is the amount of time that a cloud service hosted by a cloud provider is **accessible to end users**.
- **Cloud downtime** is a period of time during which cloud services are **unavailable**.
- It can be caused by a number of different factors: **Loss of power**, **Network connectivity** issues, **data center** going **offline** for **maintenance** (**scheduled or unscheduled**)

Cloud Infrastructure Mechanisms (Contd..)



(1) A polling agent monitors the status of a cloud service hosted by a virtual server by sending periodic polling request messages and receiving polling response messages that report usage status "A" after a number of polling cycles, until it receives a usage status of "B",

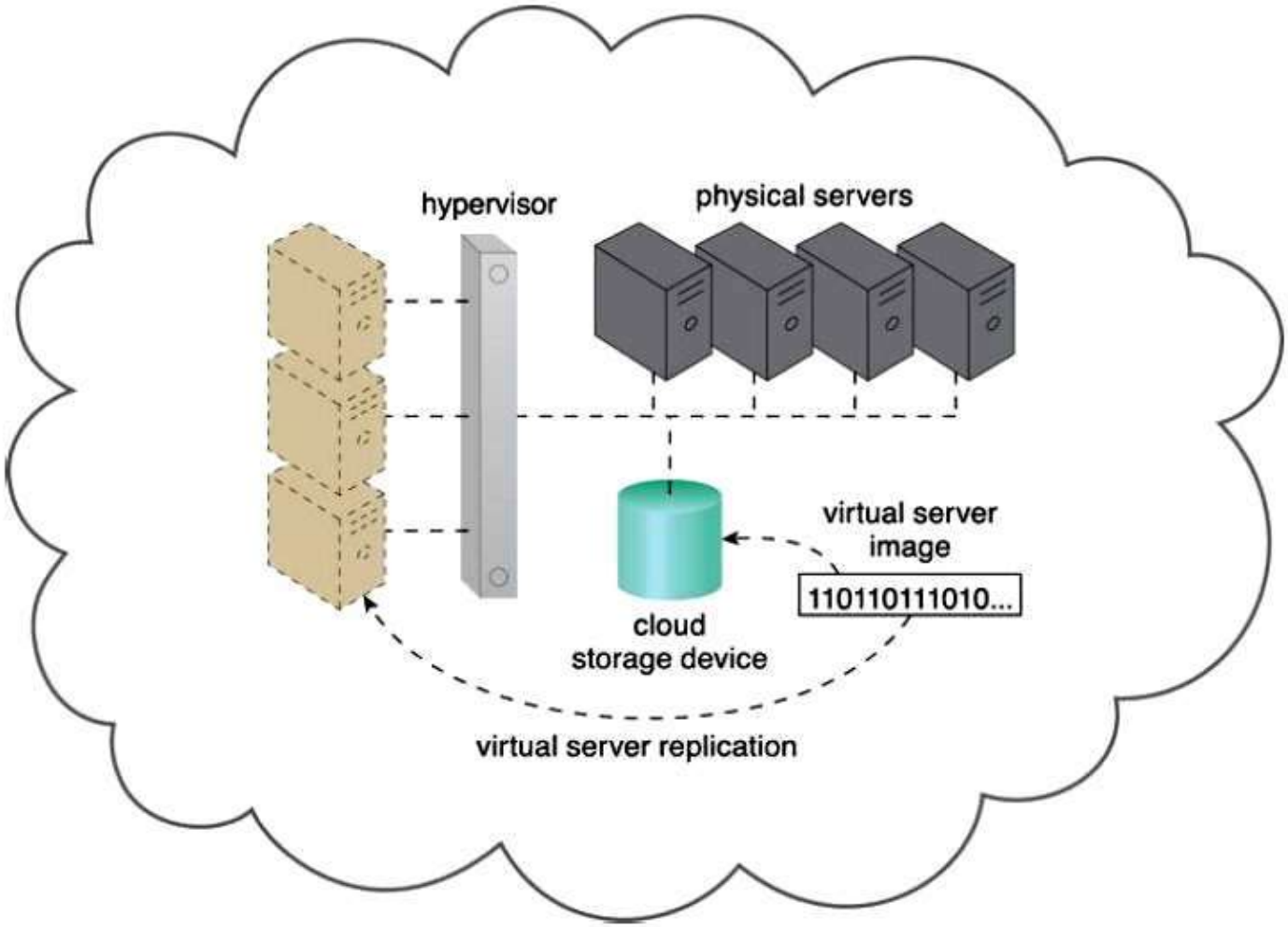
(2) upon which the polling agent records the new usage status in the log database.

Cloud Infrastructure Mechanisms (Contd..)

Resource Replication:

- Defined as the **creation of multiple instances** of the **same IT resource**, *replication* is typically performed when an **IT resource's availability** and **performance** need to be **enhanced**.
- **Virtualization Technology** is used to implement the **resource replication** mechanism to **replicate cloud-based IT resources**.
- Two Types of Replication / Cloning of VMs:
  - **OVF – Open Virtualization Format** (Export and Import)
  - **Folder Method** (Download and Upload)

Cloud Infrastructure Mechanisms (Contd..)



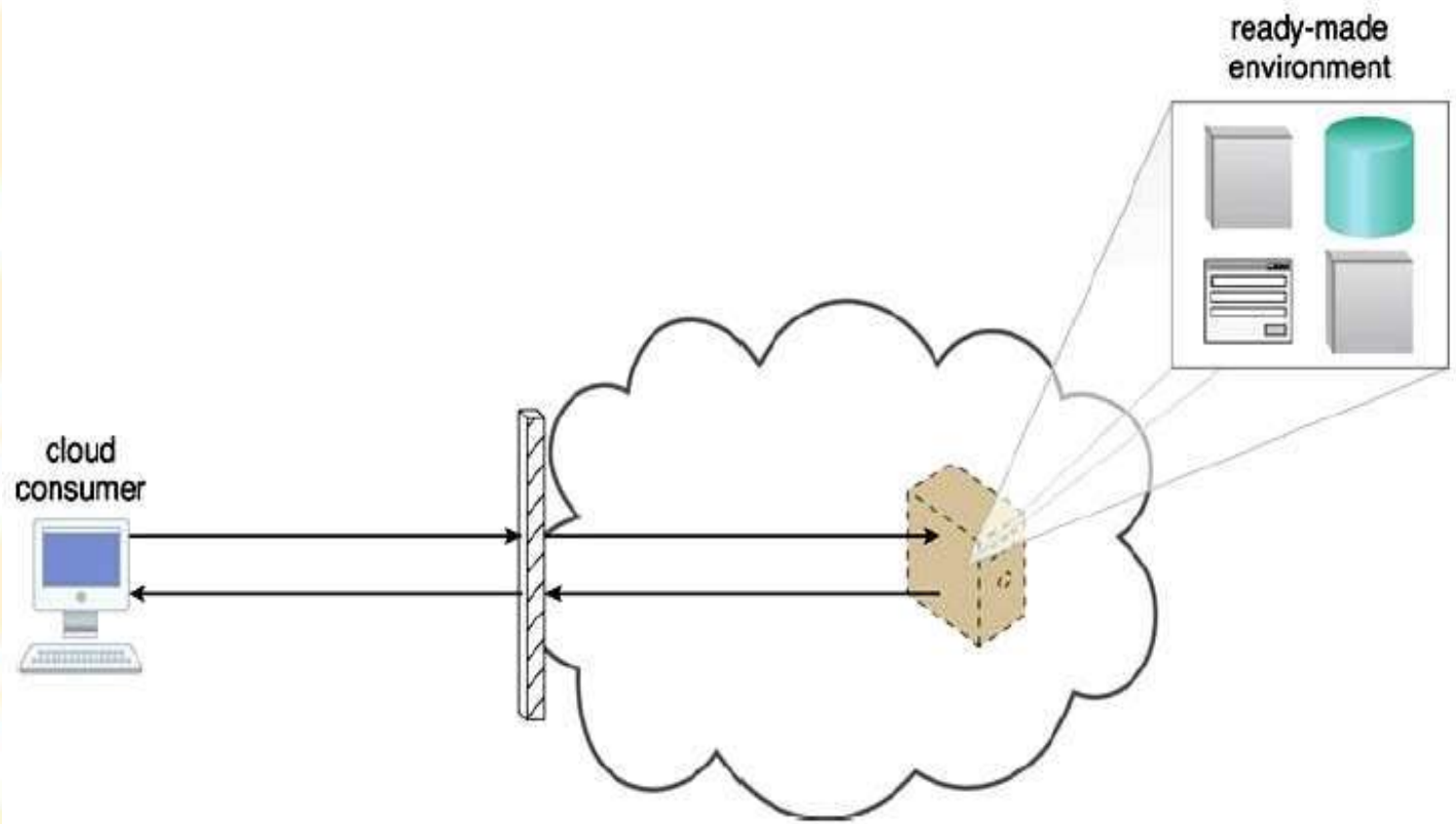
The hypervisor replicates several instances of a virtual server, using a stored virtual server image.

Cloud Infrastructure Mechanisms (Contd..)

Ready-Made Environment:

- The *ready-made environment* mechanism is a **defining component** of the **PaaS** cloud delivery model that represents a **pre-defined**, **cloud-based platform** comprised of a set of **already installed IT resources**, **ready to be used** and **customized** by a cloud consumer.
- These environments are utilized by cloud consumers to **remotely develop** and **deploy their own services** and **applications** within a cloud.
- Typical ready-made environments include **pre-installed IT resources**, such as **databases**, **development tools**, and **governance tools**.
- A **ready-made environment** is generally equipped with a complete Software Development Kit (**SDK**) that provides cloud consumers with programmatic access to the development technologies that comprise their preferred programming stacks.

Cloud Infrastructure Mechanisms (Contd..)



A cloud consumer accesses a ready-made environment hosted on a virtual server.

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