Introduction to Cloud Computing

Cloud Computing:

- It is a specialized form of **distributed computing** that introduces **utilization models** for **remotely provisioning scalable** and **measured resources**.

Virtualization:

- It is a technique in which a complete installation of one machine is run on another machine.
- The result is a system in which all software running on the server is within virtual machine.

Introduction to Cloud Computing
(Contd..)

Virtual Machine:

- The fundamental idea behind a virtual machine is to abstract the hardware of a single computer (CPU, Memory, I/O, Network Interface Card and so on) into several different execution environments.
- Thereby creating the illusion that each separate execution environment is running its own private computer.

Internet:

- It is the global system of interconnected computer networks that use the Internet Protocol Suite (TCP / IP) to link devices worldwide.

Origins and Influences

A Brief History:

- The idea of computing in a “cloud” traces back to the origins of Utility Computing in 1961.
- **Utility Computing:** It is a service provisioning model in which a service provider makes computing resources and infrastructure management available to the customers as needed and charges them for specific usage.
- The general public has been leveraging forms of Internet-based computer utilities since the mid-1990s through various incarnations of:
  - search engines (Yahoo!, Google)
  - e-mail services (Gmail)
  - open publishing platforms (MySpace, Facebook, YouTube)
  - other types of social media (Twitter, WhatsApp, LinkedIn).
- Though consumer-centric, these services popularized and validated core concepts that form the **basis of modern-day cloud computing**.

Origins and Influences (Contd..)

- In the late 1990s, **Salesforce.com** pioneered the notion of bringing **remotely provisioned services** into the enterprise.
- In 2002, **Amazon.com** launched the **Amazon Web Services (AWS)** platform, a suite of enterprise-oriented services that provide remotely provisioned storage, computing resources, and business functionality.
- A slightly different evocation of the term “Network Cloud” or “Cloud” was introduced in the early 1990s throughout the networking industry.
- It referred to an abstraction layer derived in the delivery methods of data across heterogeneous public and semi-public networks that were primarily packet-switched.

*(Refer to **ATN**: is a company that provides network equipment to telecommunications industries across the globe.)*

Origins and Influences (Contd..)

- In 2006, the term **"Cloud Computing"** emerged in the commercial arena.
- During this time, **Amazon** launched its **Elastic Compute Cloud (EC2)** services that enabled organizations to "lease" computing capacity and processing power to run their enterprise applications.
- **Google Apps** also began providing browser-based enterprise applications in the same year.
- Three years later, the **Google App Engine** became another historic milestone.

Definitions of Cloud Computing

Gartner:

- A style of computing in which massively scalable IT-enabled capabilities are delivered as a service to external customers using Internet technologies.

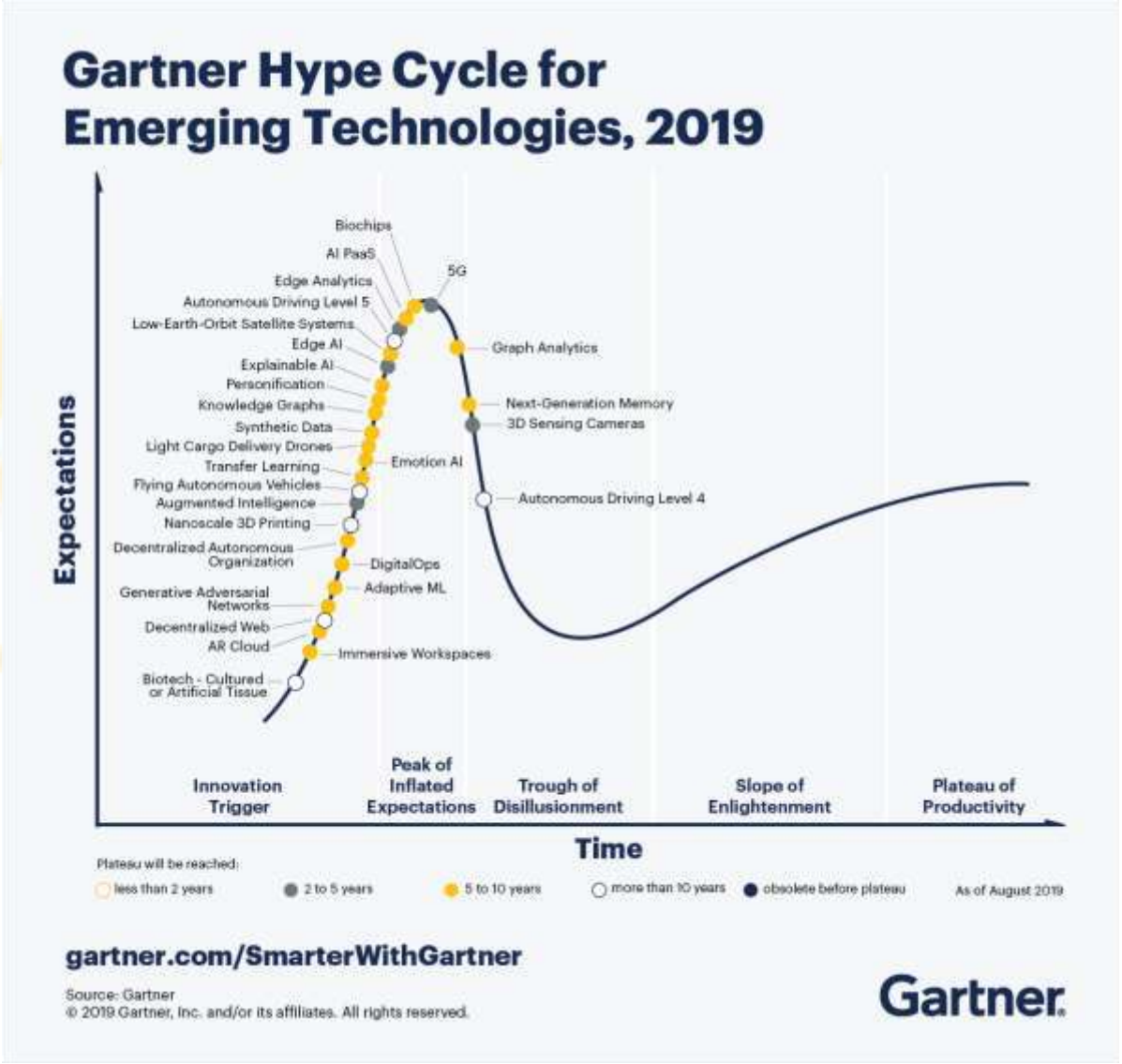
Forrester Research:

- A standardized IT capability (services, software, or infrastructure) delivered via Internet technologies in a pay-per-use, self-service way.

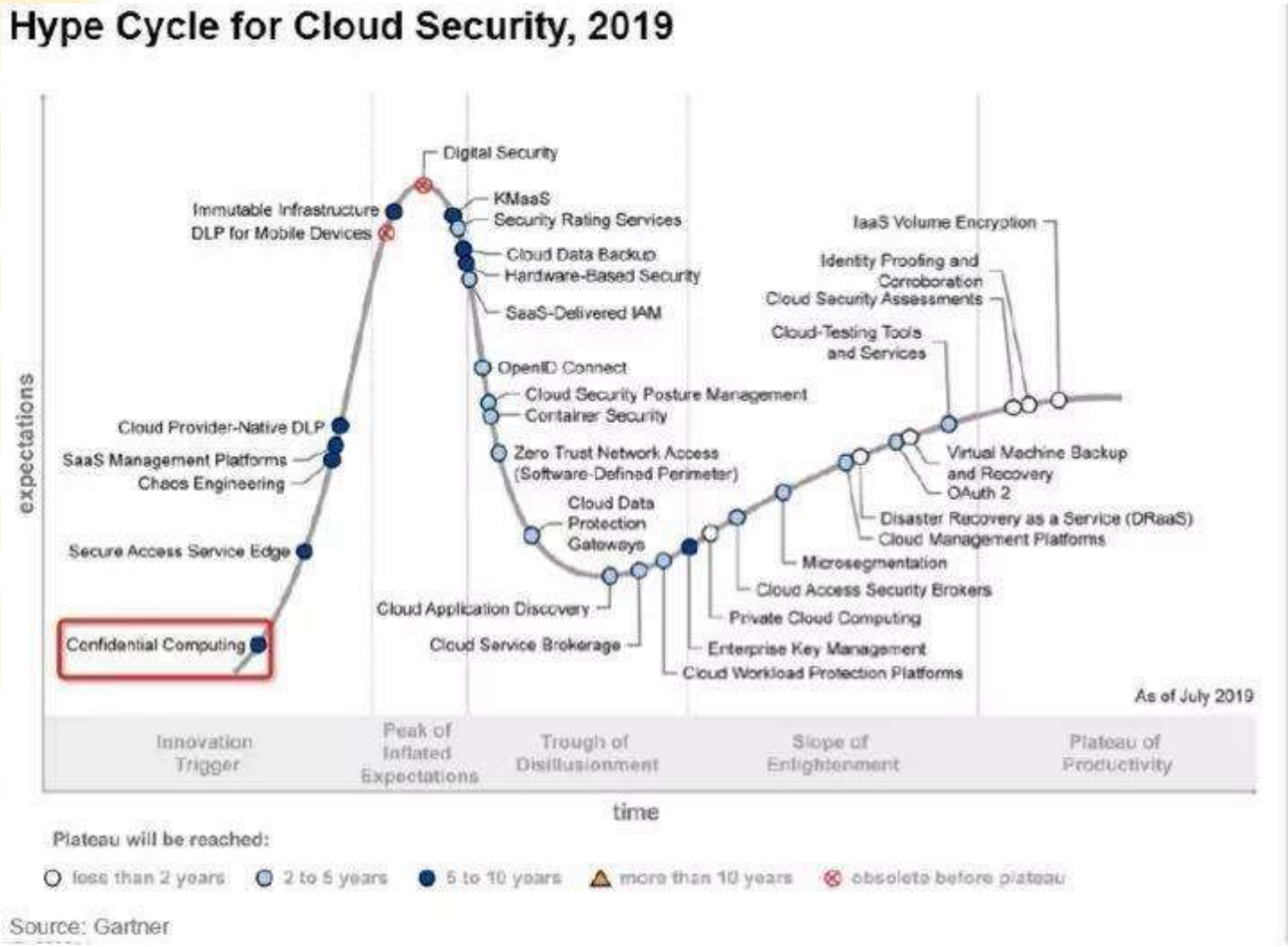
National Institute of Standards and Technology (NIST):

- Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models."

Gartner Hype Cycle



Gartner Hype Cycle



Source: Gartner

Business Drivers (Influences)

Business Drivers:

- That fostered modern cloud-based technology.
- These influences shaped clouds and the overall cloud computing market from both ends.
- They have motivated organizations to adopt cloud computing in support of their business automation requirements.
- They have correspondingly motivated other organizations to become providers of cloud environments and cloud technology vendors in order to create and meet the demand to fulfill consumer needs.
  - Capacity Planning
  - Cost Reduction
  - Organizational Agility

Business Drivers (Contd..)

Capacity Planning:

- It is the process of determining and fulfilling future demands of an organization's IT resources, products, and services.
- Here, ***capacity*** represents the maximum amount of work that an IT resource is capable of delivering in a given period of time.
- A discrepancy between the capacity of an IT resource and its demand can result in a system becoming either inefficient **(over-provisioning)** or unable to fulfill user needs **(under-provisioning)**.
- Capacity planning is focused on minimizing this discrepancy to achieve predictable efficiency and performance.

Different **capacity planning strategies** exist:

- **Lead Strategy** – adding capacity to an IT resource in anticipation of demand(expectation/prediction)
- **Lag Strategy** – adding capacity when the IT resource reaches its full capacity(actual increase in demand)
- **Match Strategy** – adding IT resource capacity in small increments, as demand increases.

Business Drivers (Contd..)

Cost Reduction:

- Two costs need to be accounted for:
  - the cost of acquiring new infrastructure.
  - the cost of its ongoing ownership.
- **Operational overhead** represents a considerable share of IT budgets, often exceeding up-front investment costs.

- Common forms of infrastructure-related operating overhead includes:
  - technical personnel required to keep the environment operational.
  - upgrades and patches that introduce additional testing and deployment cycles.
  - utility bills and capital expense investments for power and cooling.
  - security and access control measures that need to be maintained and enforced to protect infrastructure resources.
  - administrative and accounts staff that may be required to keep track of licenses and support arrangements.

Business Drivers (Contd..)

Organizational Agility:

- Businesses need the ability to adapt and evolve to successfully face change caused by both internal and external factors.
- *Organizational Agility* is the measure of an organization's responsiveness to change.
- For Example: **VMware APPDEFENSE**

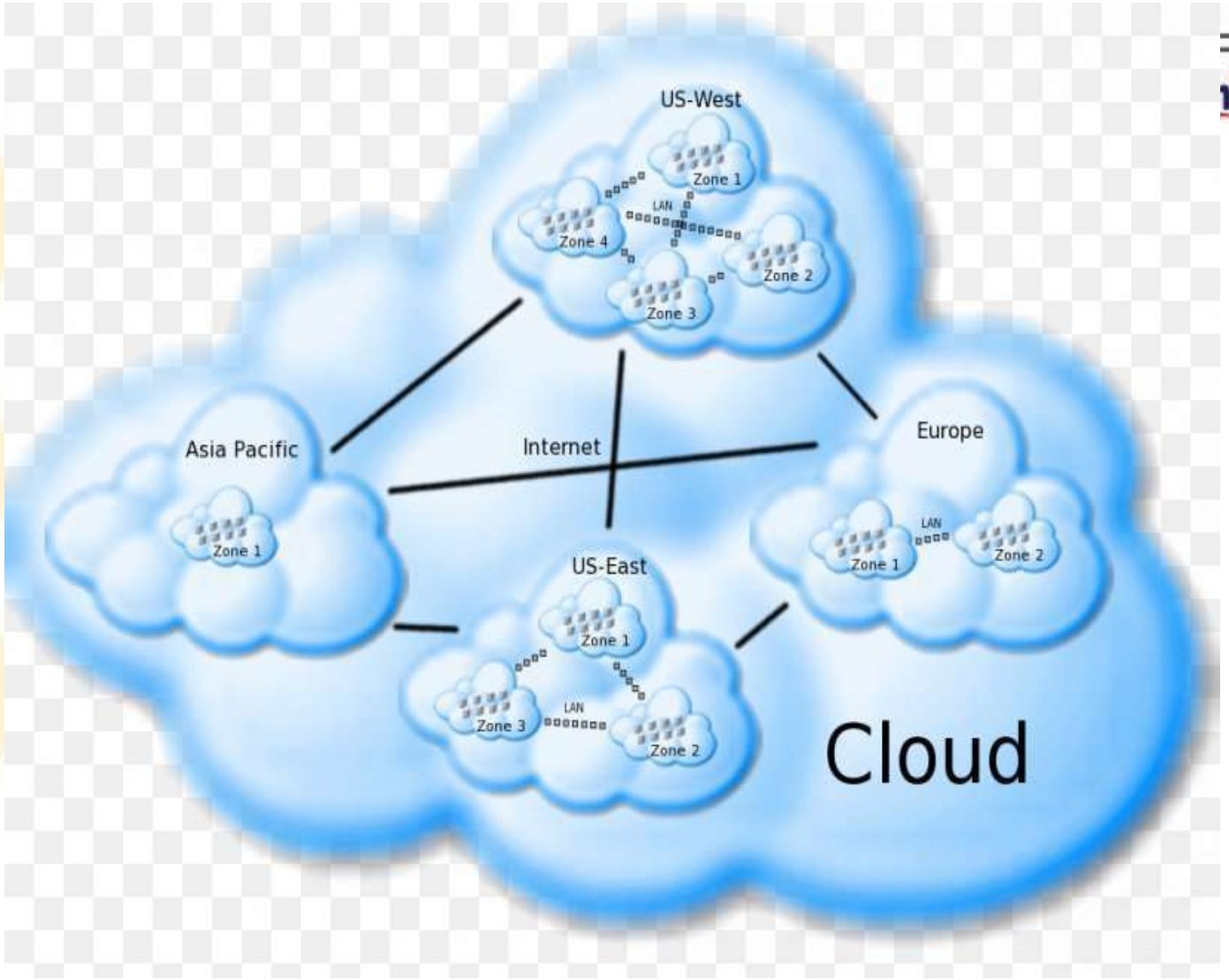
  (working towards to CYBER SECURITY)

Technology Innovations

- Established technologies are often used as inspiration and, at times, the actual foundations upon which new technology innovations are derived and built.
- pre-existing technologies considered to be the primary influences on cloud computing.
  - Clustering
  - Grid Computing
  - Virtualization

Clustering:

- A cluster is a group of independent IT resources that are interconnected and work as a single system.


US-West
Zone 1
LAN
Zone 4
Zone 2
Zone 3
Asia Pacific
Internet
Europe
Zone 1
LAN
Zone 1
Zone 2
US-East
Zone 1
Zone 3
LAN
Zone 2
Cloud

Technology Innovations (Contd..)

Grid Computing:

- A computing grid (or “computational grid”) provides a platform in which computing resources are organized into one or more logical pools.
- These pools are collectively coordinated to provide a high performance distributed grid, sometimes referred to as a **“super virtual computer”**.
- **Grid computing** is a group of networked **computers** which work together as a virtual supercomputer to perform large tasks, such as analysing huge sets of data or weather modeling.

TECHNOLOGY INNOVATIONS

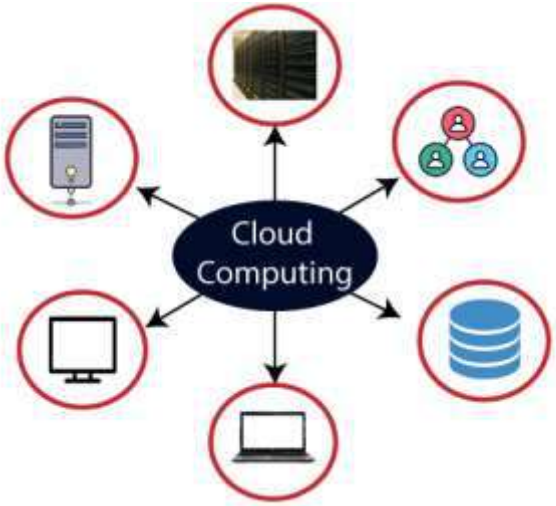
Cloud computing uses a **client-server** architecture to deliver computing resources such as servers, storage, databases, and software over the cloud (Internet) with pay-as-you-go pricing.

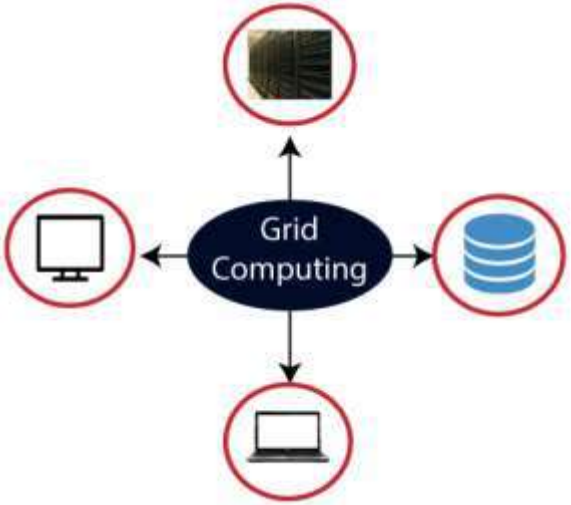
Cloud computing becomes a very popular option for organizations by providing various advantages, including cost-saving, increased productivity, efficiency, performance, data back-ups, disaster recovery, and security.

Grid computing is also called as "**distributed computing**." It links multiple computing resources (PC's, workstations, servers, and storage elements) together and provides a mechanism to access them.

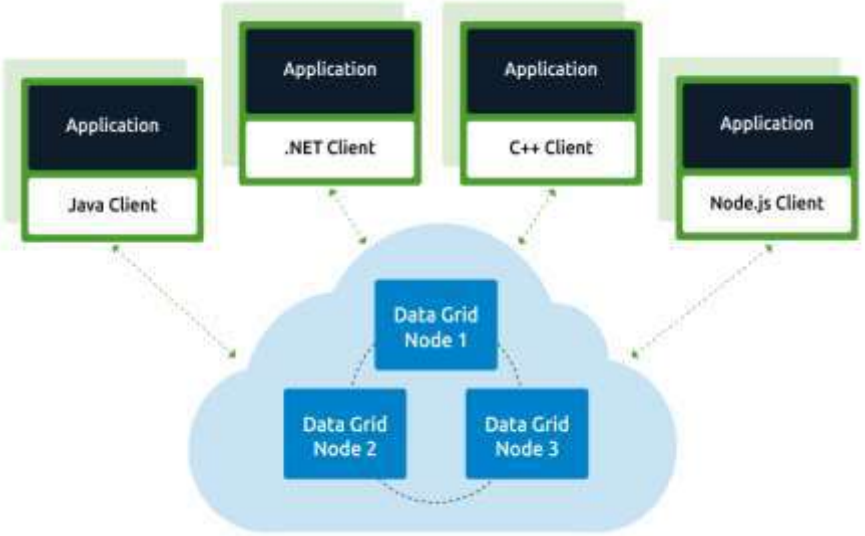
The main advantages of grid computing are that it increases user productivity by providing transparent access to resources, and work can be completed more quickly.

TECHNOLOGY INNOVATIONS





TECHNOLOGY INNOVATIONS



TECHNOLOGY INNOVATIONS

Cloud Computing	Grid Computing
Cloud Computing follows client-server computing architecture.	Grid computing follows a distributed computing architecture.
Scalability is high.	Scalability is normal.
Cloud Computing is more flexible than grid computing.	Grid Computing is less flexible than cloud computing.
Cloud operates as a centralized management system.	Grid operates as a decentralized management system.
In cloud computing, cloud servers are owned by infrastructure providers.	In Grid computing, grids are owned and managed by the organization.
Cloud computing uses services like Iaas, PaaS, and SaaS.	Grid computing uses systems like distributed computing, distributed information, and distributed pervasive.
Cloud Computing is Service-oriented.	Grid Computing is Application-oriented.
It is accessible through standard web protocols.	It is accessible through grid middleware.

TECHNOLOGY INNOVATIONS - GRID COMPUTING

Grid Computing VS Cloud Computing

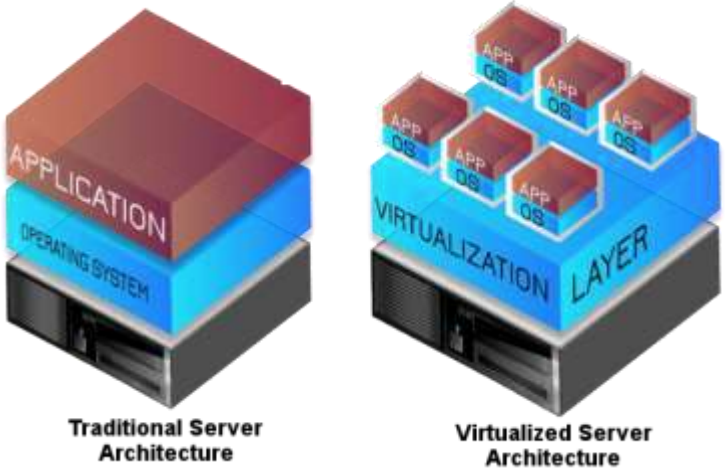
Criteria	Grid Computing	Cloud Computing
User Management	Decentralised management	Centralised management
Dependancy	Other computer picks up the work whenever the computer stops	Totally dependent on internet
Operation	Operates within a corporate network	Can also operate through the internet
Accessibility	Through Grid middleware	Through standard Web protocols
Domains	Multiple Domains	Single Domain
Scalability	Normal	High
Architecture	Distributed computing architecture	Client-server architecture
Virtualization	Data and computing resources	Hardware and software platforms
Computation	Maximum computing	On-demand
Application Type	Batch	Interactive

TECHNOLOGY INNOVATIONS

Virtualization:

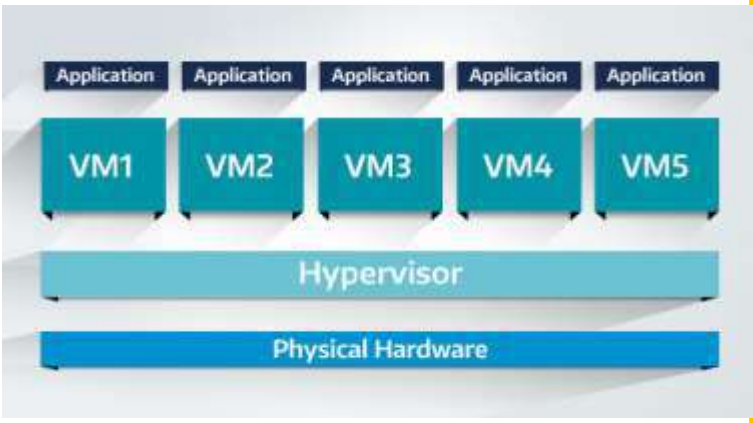
Virtualization represents a technology platform used for the creation of virtual instances of IT resources.

A layer of virtualization software allows physical IT resources to provide multiple virtual images of themselves so that their underlying processing capabilities can be shared by multiple users.

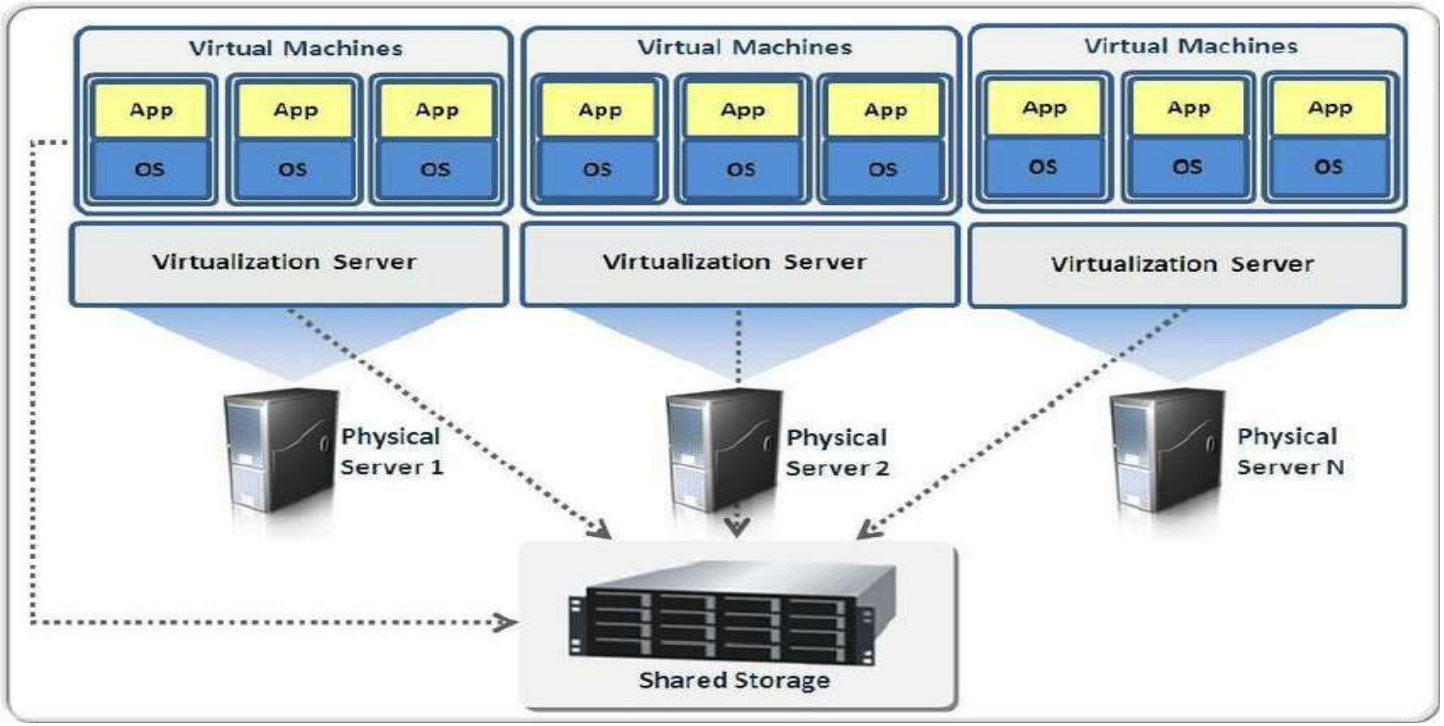


Traditional Server Architecture

Virtualized Server Architecture



TECHNOLOGY INNOVATIONS - VIRTUALIZATION



Technology Innovations (Contd..)

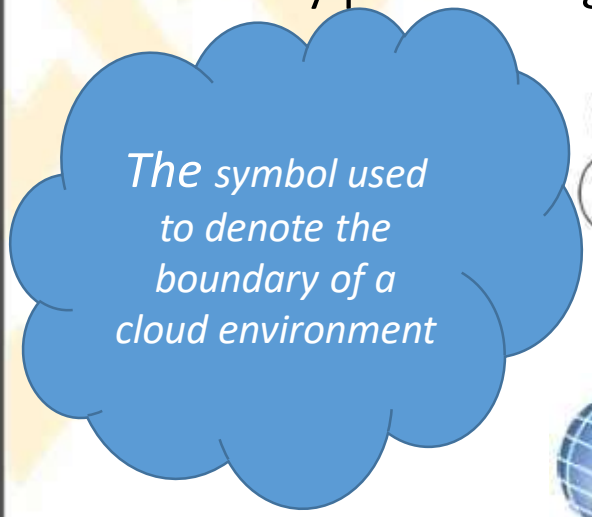
- other areas of technology **(cloud-enabling technologies)** that continue to contribute to modern-day cloud-based platforms.
  - Broadband Networks and Internet Architecture
  - Data Center Technology
  - (Modern) Virtualization Technology
  - Web Technology
  - Multitenant Technology
  - Service Technology

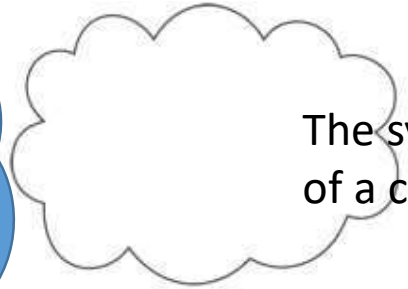
Basic Concepts and Terminology

- This section establishes a set of basic terms that represent the fundamental concepts and aspects pertaining to the insight of a cloud and its most primitive artifacts.

Cloud:

- A *cloud* refers to a distinct IT environment that is designed for the purpose of remotely provisioning scalable and measured IT resources.





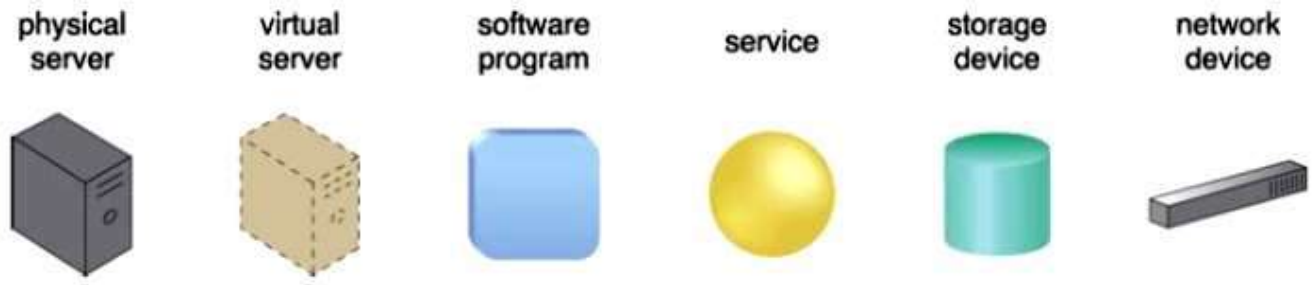
The symbol used to denote the boundary of a cloud environment.

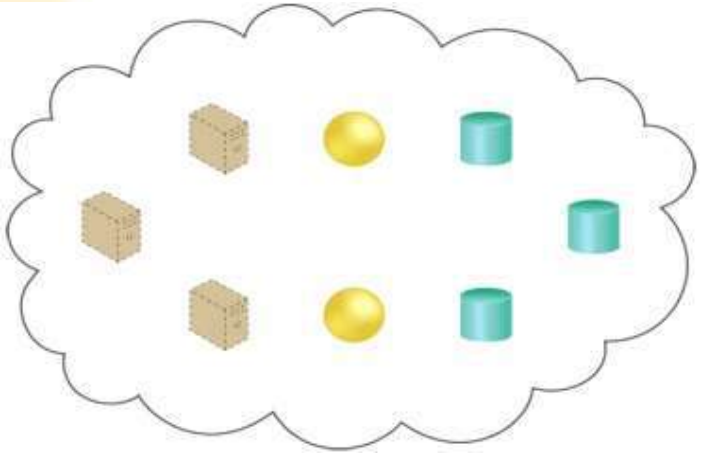
The symbol used to denote Internet.

Basic Concepts and Terminology
(Contd..)

IT Resource:

- An *IT resource* is a physical or virtual IT-related artifact that can be either ***software-based*** (virtual server or a custom software program), or ***hardware-based*** (physical server or a network device).





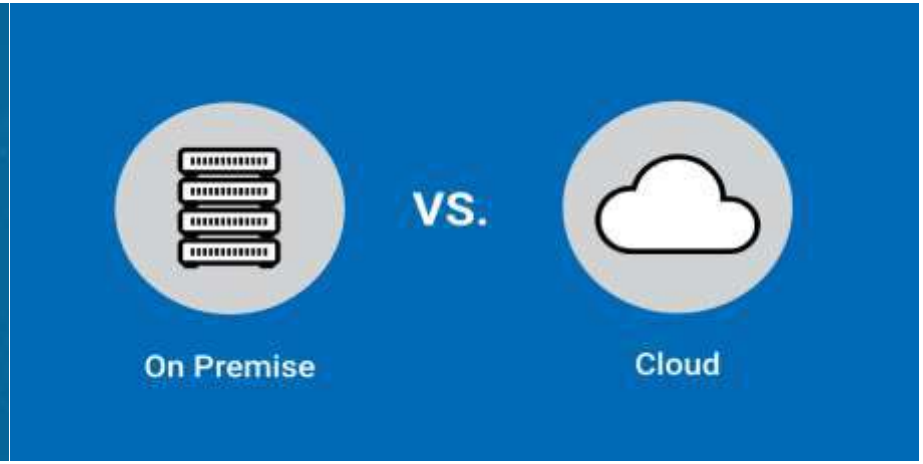
A cloud is hosting **eight** IT resources:
three virtual servers,
two cloud services, and
three storage devices.

Basic Concepts and Terminology
(Contd..)

On-Premise:

- An IT resource that is hosted in a conventional IT enterprise within an organizational boundary **(that does not specifically represent a cloud)** is considered to be located on the premises of the IT enterprise, or *on-premise* for short.
- In other words, the term "on-premise" is another way of stating "on the premises of a controlled IT environment that is not cloud-based."
- This term is used to qualify an IT resource as an alternative to "cloud-based." An IT resource that is on-premise cannot be cloud-based, and vice-versa.
- Note the following key points:
  - An on-premise IT resource can access and interact with a cloud-based IT resource.
  - An on-premise IT resource can be moved to a cloud, thereby changing it to a cloud-based IT resource.
  - Redundant deployments of an IT resource can exist in both on-premise and cloud-based environments.

BASIC CONCEPTS AND TERMINOLOGY



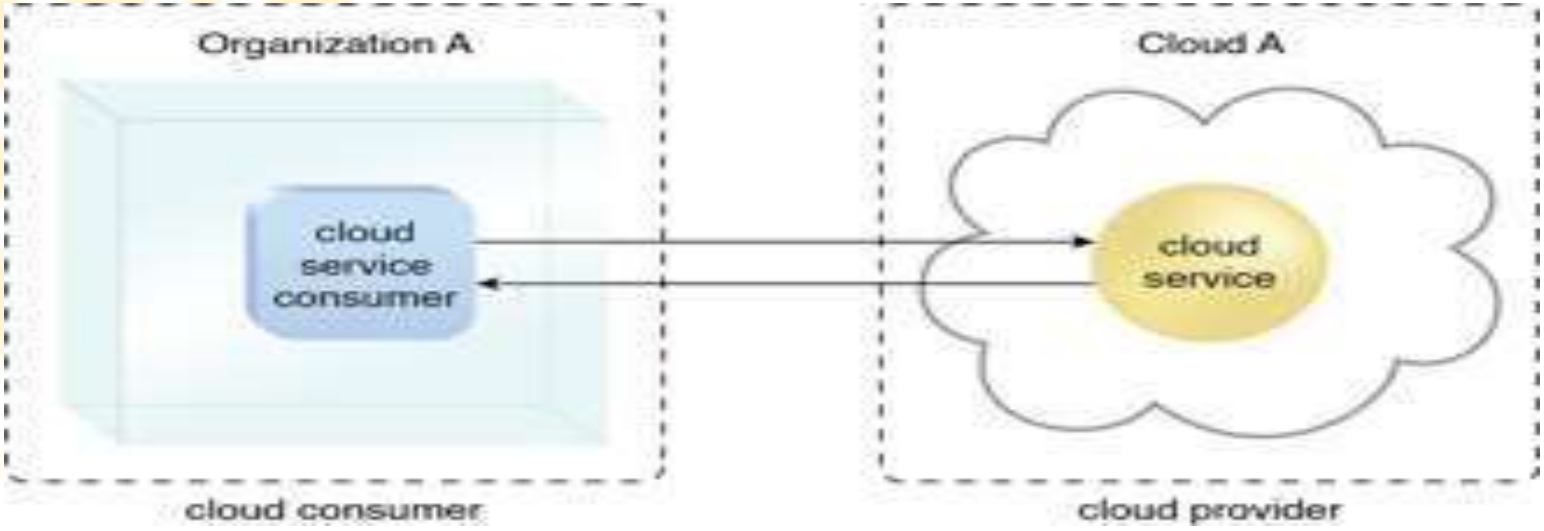
BASIC CONCEPTS AND TERMINOLOGY-ON-PREMISE

- An on-premise IT resource can access and interact with a cloud-based IT resource.
- An on-premise IT resource can be moved to a cloud, thereby changing it to a cloud-based IT resource.
- Redundant deployments of an IT resource can exist in both on-premise and cloud-based environments.

Basic Concepts and Terminology
(Contd..)

Cloud Providers and Cloud Consumers:

- The party / company that provides cloud-based IT resources is the **cloud provider**.
- The party / company that uses cloud-based IT resources is the **cloud consumer**.



Scaling:

- *Scaling*, from an IT resource perspective, represents the ability of the IT resource to handle **increased or decreased usage demands**.
- The following are types of scaling:
  - **Horizontal Scaling** – Adding or removing more resources
  - **Vertical Scaling** – increasing or decreasing the capacity or capability

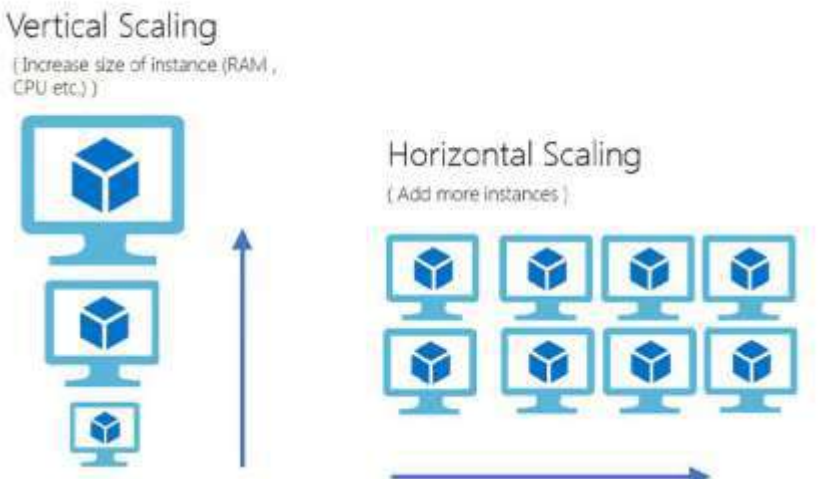
BASIC CONCEPTS AND TERMINOLOGY

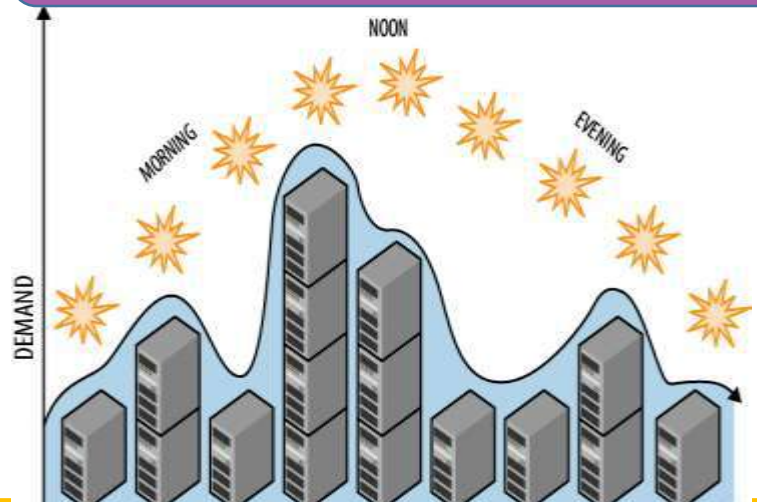
Scaling:

Scaling, from an IT resource perspective, represents the ability of the IT resource to handle **increased or decreased usage demands**.

Horizontal Scaling – scaling out and scaling in

Vertical Scaling – scaling up and scaling down

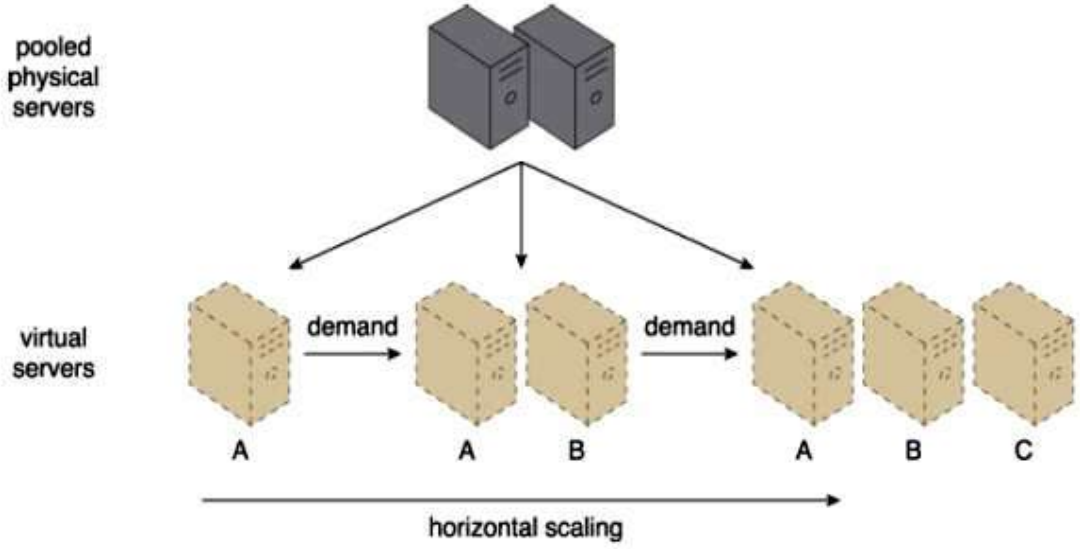




Basic Concepts and Terminology
(Contd..)

Horizontal Scaling:

- The allocating or releasing of IT resources that are of the same type is referred to as *horizontal scaling*.
- The **horizontal allocation of resources** is referred to as **scaling out**.
- The **horizontal releasing of resources** is referred to as **scaling in**.
- Horizontal scaling is a common form of scaling within cloud environments.

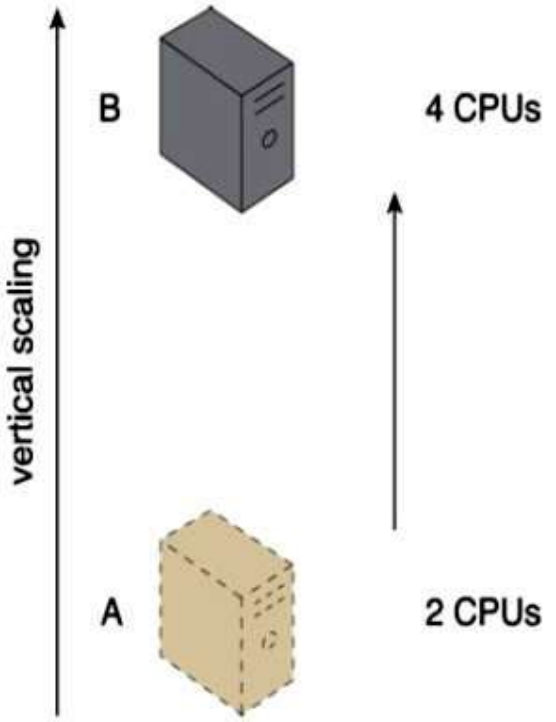


An IT resource **(Virtual Server A)** is **scaled out** by adding more of the same IT resources **(Virtual Servers B and C)**.

Basic Concepts and Terminology
(Contd..)

Vertical Scaling:

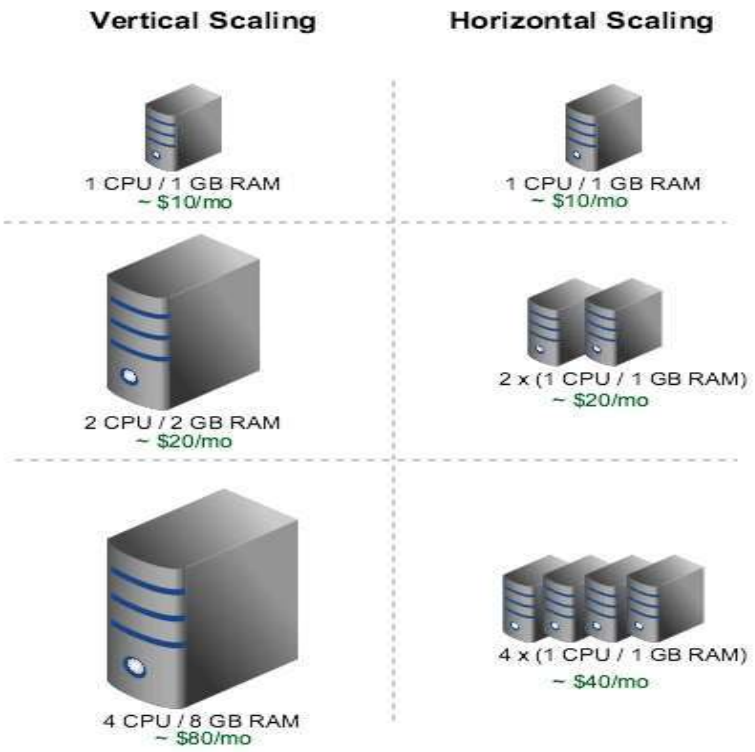
- When an existing IT resource is replaced by another with higher or lower capacity, *vertical scaling* is considered to have occurred.
- The replacing of an IT resource with another that has a **higher capacity** is referred to as **scaling up**.
- The replacing an IT resource with another that has a **lower capacity** is considered **scaling down**.
- Vertical scaling is less common in cloud environments due to the downtime (stoppage) required while the replacement is taking place.



An IT resource **(a virtual server with two CPUs)** is scaled up by replacing it with a more powerful IT resource with increased capacity for data storage **(a physical server with four CPUs)**.

Basic Concepts and Terminology
(Contd..)

Common pros and cons associated with horizontal and vertical scaling

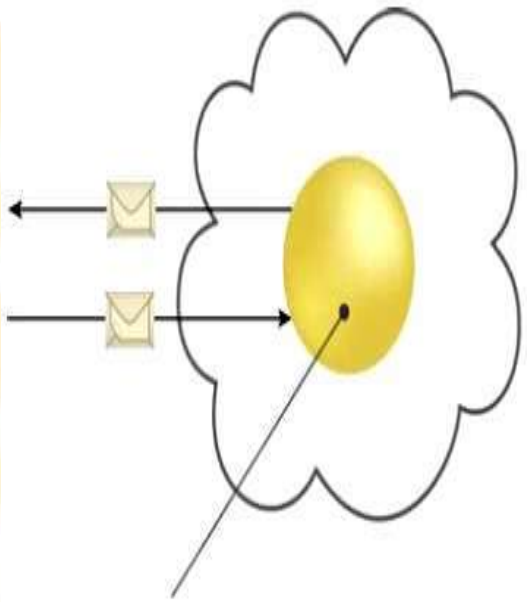


Horizontal Scaling	Vertical Scaling
less expensive (through commodity hardware components)	more expensive (specialized servers)
IT resources instantly available	IT resources normally instantly available
resource replication and automated scaling	additional setup is normally needed
additional IT resources needed	no additional IT resources needed
not limited by hardware capacity	limited by maximum hardware capacity

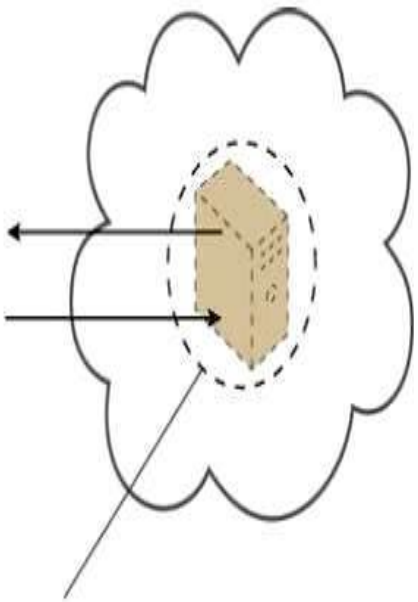
Basic Concepts and Terminology
(Contd..)

Cloud Service:

- A *cloud service* is any IT resource that is made remotely accessible via a cloud.



remotely accessed Web service acting as a cloud service



remotely accessed virtual server acting as a cloud service

Basic Concepts and Terminology
(Contd..)

Cloud Service Consumer:

- The *cloud service consumer* is a temporary runtime role assumed by a software program when it accesses a cloud service.

Examples of cloud service consumers

Depending on the nature of a given diagram, an artifact labeled as a cloud service consumer may be a **software program** or a **hardware device** (in which case it is implied that it is running a software program capable of acting as a cloud service consumer).

software program or a **hardware device**

Goals and Benefits

- The common benefits associated with adopting cloud computing are explained in this section.
  - Reduced Investments and Proportional Costs
  - Increased Scalability
  - Increased Availability and Reliability

Reduced Investments and Proportional Costs:

- Similar to a **product wholesaler** that purchases goods in bulk for lower price points,
  - **public cloud providers** base their business model on the mass-acquisition of IT resources that are then made available to cloud consumers via attractively priced leasing packages.
- This opens the door for organizations to gain access to powerful infrastructure without having to purchase it themselves.

Goals and Benefits (Contd..)

- The most common economic way of **investing** in cloud-based IT resources is in the **reduction or outright elimination** of up-front IT investments (hardware & software purchases and ownership costs).

  – This is referred to as ***Reduced Investments***.

- A cloud's **Measured Usage** characteristic represents a feature-set that allows measured operational expenditures (i.e., directly related to business performance) to replace anticipated capital expenditures.

  – This is referred to as ***Proportional Costs***.

- In its most basic form, opportunities to decrease costs are derived from the **deployment and operation of large-scale data centers** by major cloud providers.

- Such data centers are commonly located in destinations where *real estate*, *IT professionals*, and *network bandwidth* can be obtained at lower costs, resulting in both capital and operational savings.

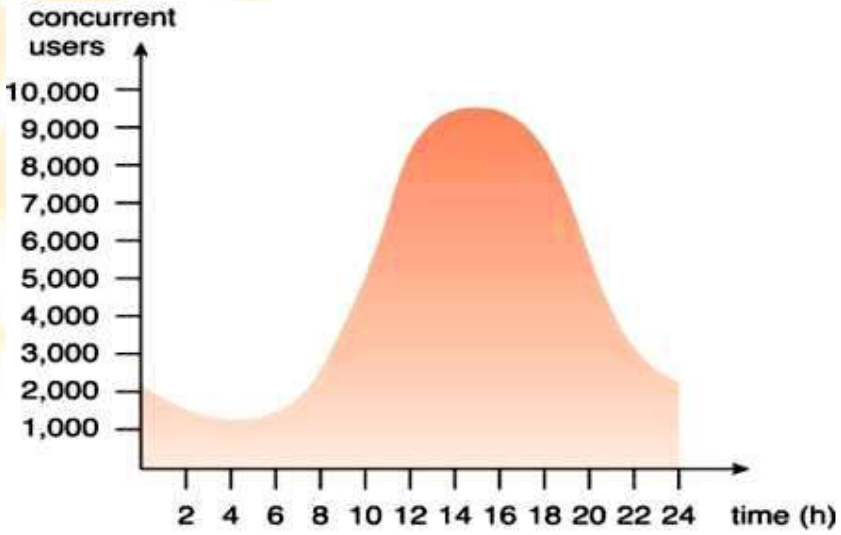
Goals and Benefits (Contd..)

- Common measurable benefits to cloud consumers include:
  - **On-demand access** to pay-as-you-go computing resources on a short-term basis (such as processors by the hour), and the ability to release these computing resources when they are no longer needed.
  - The perception of having **unlimited computing resources** that are available on demand, thereby reducing the need to prepare for provisioning.
  - The **ability to add or remove IT resources** at a fine-grained level, such as modifying available storage disk space by single gigabyte increments.
  - **Abstraction of the infrastructure** so applications are not locked into devices or locations and can be easily moved if needed.

Goals and Benefits (Contd..)

Increased Scalability:

- By providing pools of IT resources, along with tools and technologies designed to manage them collectively,
  - clouds can **instantly and dynamically** allocate IT resources to cloud consumers, on-demand or via the cloud consumer's direct configuration.
- This empowers cloud consumers to scale their cloud-based IT resources to accommodate processing fluctuations and peaks automatically or manually.



An example of an organization's changing demand for an IT resource over the course of a day (24 Hours).

Goals and Benefits (Contd..)

Increased Availability and Reliability:

- The availability and reliability of IT resources are directly associated with **noticeable business benefits**.
- A hallmark of the typical cloud environment is its key ability to provide extensive support for:
  - increasing the availability of a cloud-based IT resource to minimize or even eliminate outages.
  - increasing its reliability so as to minimize the impact of runtime failure conditions.
- **RAS**: **R**eliability, **A**vailability and **S**erviceability.
  – First used by IBM for their Mainframes (only to hardware).

Risks and Challenges

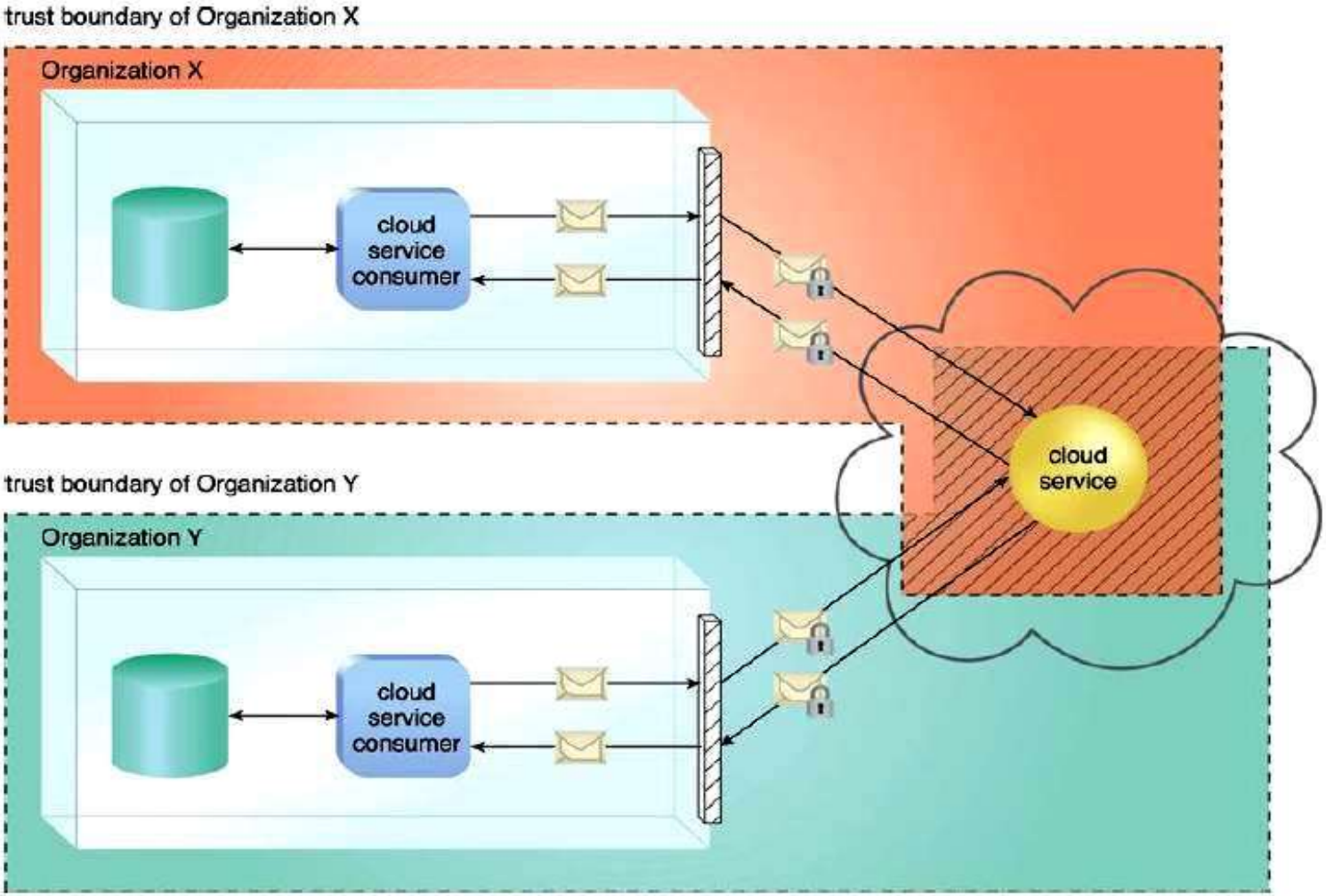
- Several of the most critical cloud computing challenges pertaining mostly to cloud consumers that use IT resources located in **public clouds** are presented and examined.
  - Increased Security Vulnerabilities
  - Reduced Operational Governance Control
  - Limited Portability Between Cloud Providers
  - Multi-Regional Compliance and Legal Issues

Risks and Challenges (Contd..)

Increased Security Vulnerabilities:

- The moving of business data to the cloud means that the responsibility over data security becomes shared with the cloud provider.
- The remote usage of IT resources requires an expansion of trust boundaries by the cloud consumer to include the external cloud.
- It can be difficult to establish a **security architecture** that spans such a trust boundary without introducing vulnerabilities,
  - unless cloud consumers and cloud providers happen to support the same or compatible security frameworks — which is unlikely with public clouds.
- The **overlapping of trust boundaries** and the **increased exposure of data** can provide **malicious cloud consumers** (human and automated) with greater opportunities to attack IT resources and steal or damage business data.

Risks and Challenges (Contd..)



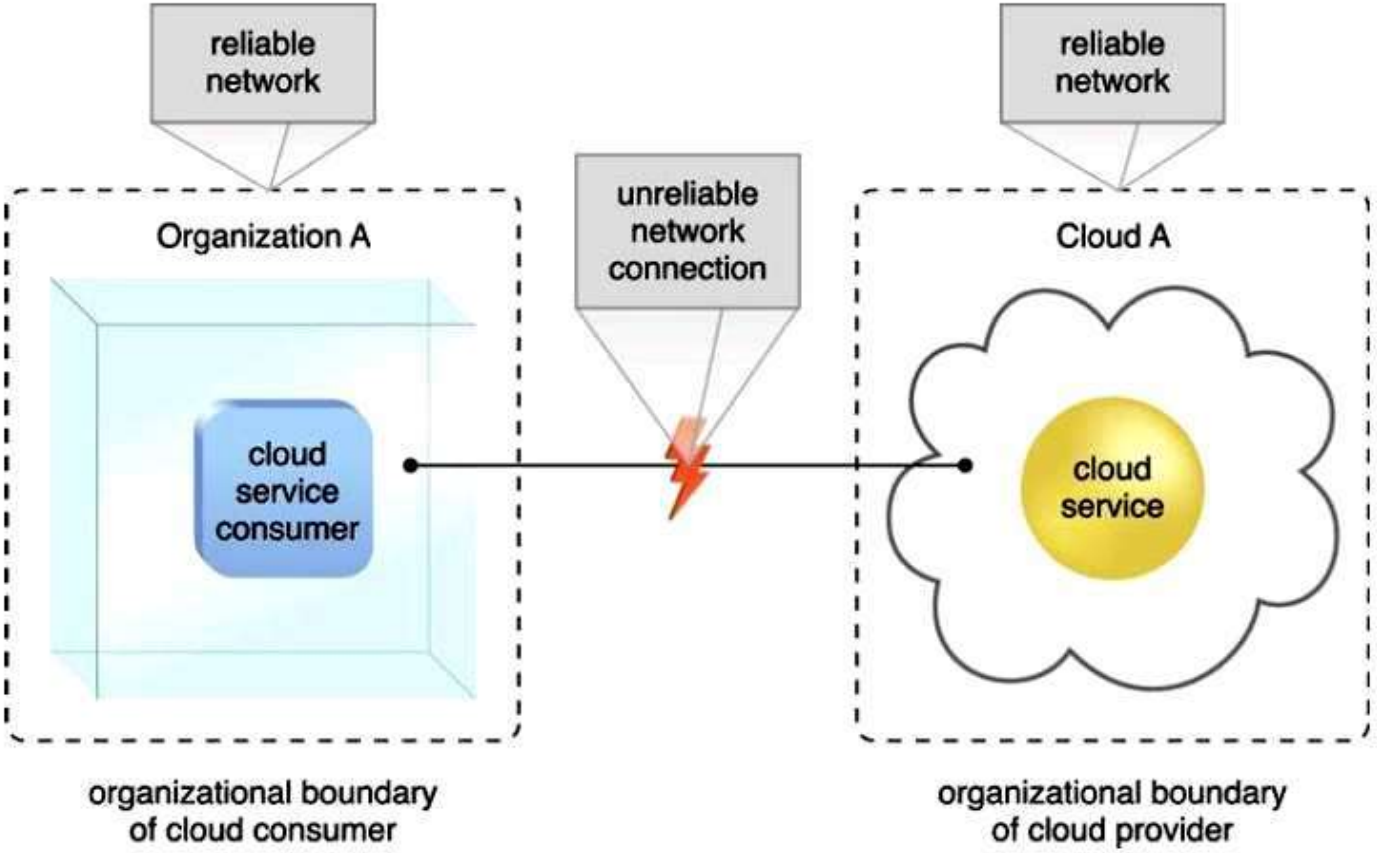
The shaded area with diagonal lines indicates the overlap of two organizations' trust boundaries.

Risks and Challenges (Contd..)

Reduced Operational Governance Control:

- Cloud consumers are usually allotted a level of governance control that is lower than that over on-premise IT resources.
- This can introduce **risks** associated with how the cloud provider operates its cloud, as well as the external connections that are required for communication between the cloud and the cloud consumer.
- Consider the following examples:
  - An unreliable cloud provider may not maintain the guarantees it makes in the **SLAs** that were published for its cloud services. This can risk the quality of the cloud consumer solutions that rely on these cloud services.
  - **Longer geographic distances** between the cloud consumer and cloud provider can require additional network hops that introduce fluctuating latency and potential bandwidth constraints.

Risks and Challenges (Contd..)



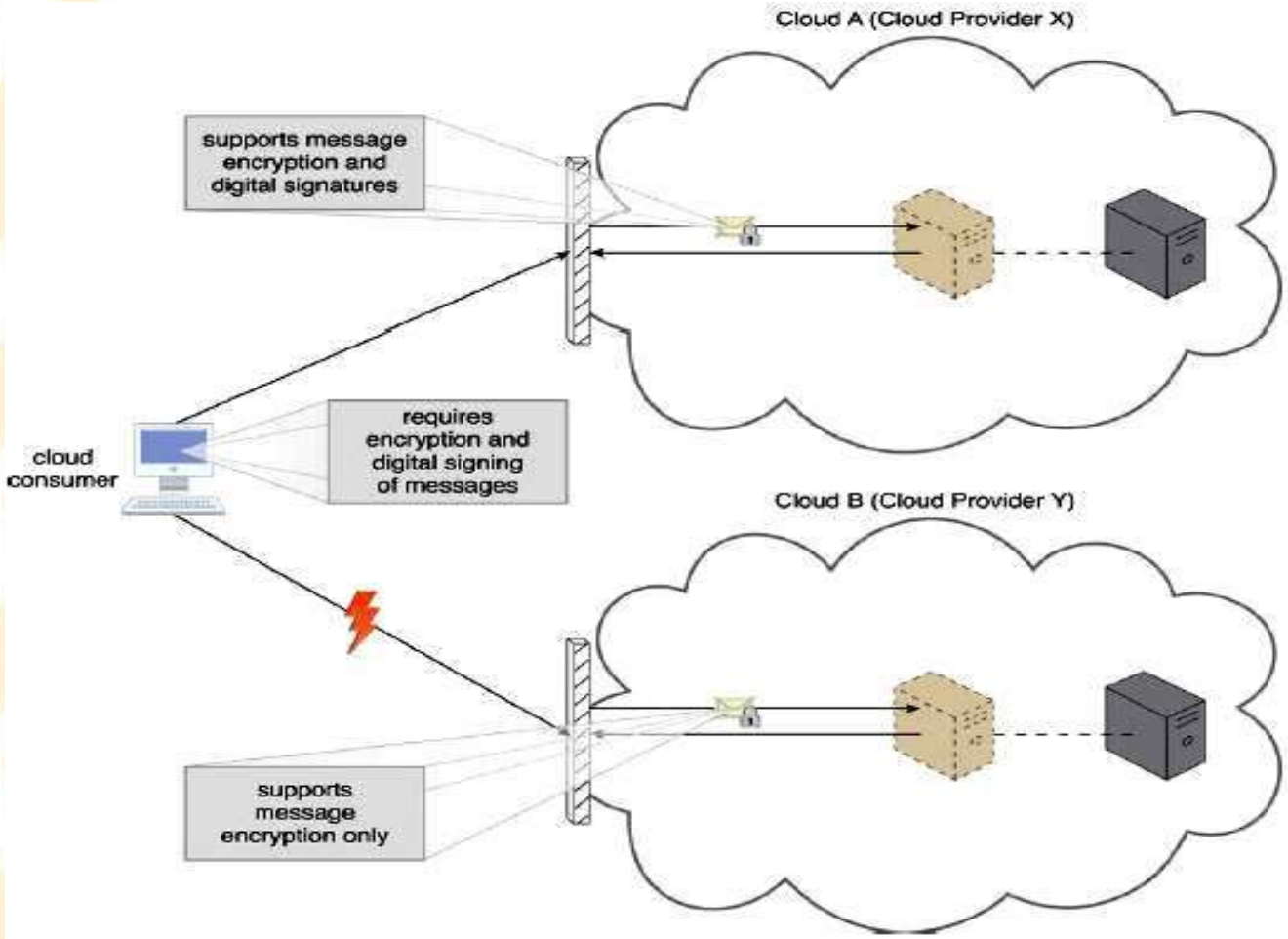
An unreliable network connection compromises the quality of communication between cloud consumer and cloud provider environments.

Risks and Challenges (Contd..)

Limited Portability Between Cloud Providers:

- Due to a lack of established industry standards within the cloud computing industry, public clouds are commonly exclusive to various extents.
- For cloud consumers that have **custom-built solutions** with dependencies on these exclusive environments, it can be challenging to move from one cloud provider to another.
- **Portability** is a measure used to determine the impact of moving cloud consumer IT resources and data between clouds.

Risks and Challenges (Contd..)



A cloud consumer's application has a decreased level of portability when assessing a potential migration from **Cloud A to Cloud B**, because the cloud provider of Cloud B **does not support** the same security technologies as Cloud A.

Risks and Challenges (Contd..)

Multi-Regional Compliance and Legal Issues:

- Third-party cloud providers will frequently establish data centers in **affordable or convenient geographical locations**.
- Cloud consumers will often **not be aware** of the physical location of their IT resources and data when hosted by **public clouds**.
- For some organizations, this can pose serious legal concerns pertaining to industry or government regulations that specify data privacy and storage policies.
- *For example*, some **UK laws** require personal data belonging to UK citizens to be kept within the United Kingdom.

Risks and Challenges (Contd..)

- Another potential legal issue pertains to the **accessibility and disclosure of data**.
- Countries have laws that require some types of data to be disclosed to certain **government agencies** or to the **subject of the data**.
- *For example*, a **European cloud consumer's data** that is located in the U.S. can be more easily accessed by government agencies (due to the U.S. Patriot Act) when compared to data located in many European Union countries.

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UNIT - 1

- **Fundamental Concepts and Models**

Roles and Boundaries

- Organizations and Customers can assume different types of pre-defined roles depending on how they relate to and/or interact with a cloud and its hosted IT resources.
- Each of the upcoming roles participates in and carries out responsibilities in relation to cloud-based activity.
- The following sections define these roles and identify their main interactions.

Cloud Provider:

- The organization that provides cloud-based IT resources is the *cloud provider*.
- When assuming the role of *cloud provider*, an organization is responsible for making cloud services available to cloud consumers, as per agreed upon Service Legal Agreement (**SLA)** guarantees.

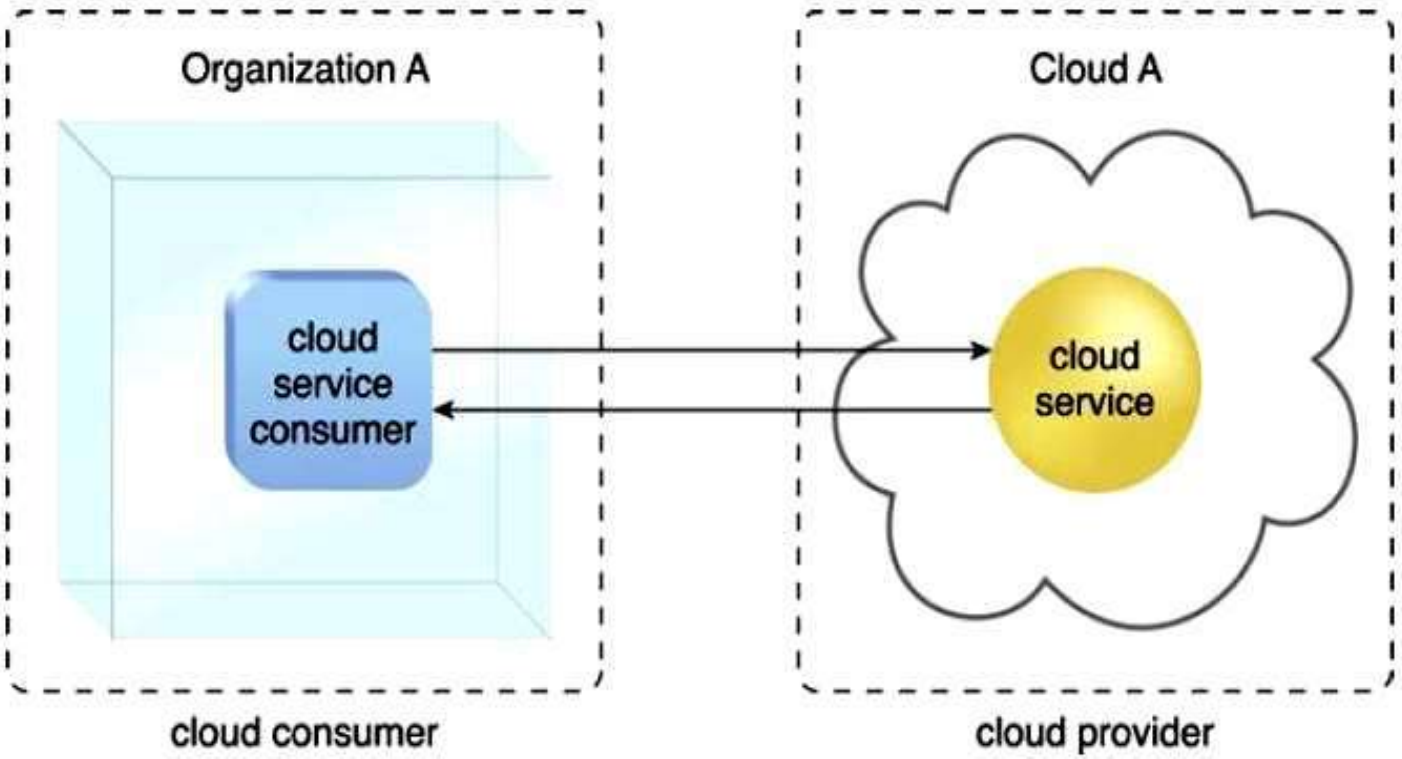
Roles and Boundaries (Contd..)

- The *cloud provider* is further tasked with any required **management** and **administrative** duties to ensure the on-going operation of the overall cloud infrastructure.
- Cloud providers normally **own the IT resources** that are made available for lease by cloud consumers;
  - However, some cloud providers also **"resell"** IT resources leased from other cloud providers.

Cloud Consumer:

- A *cloud consumer* is an organization (or an individual) that has a formal contract or arrangement with a *cloud provider* to use IT resources made available by the cloud provider.
- The *cloud consumer* uses a **cloud service consumer** to access a cloud service.

Roles and Boundaries (Contd..)

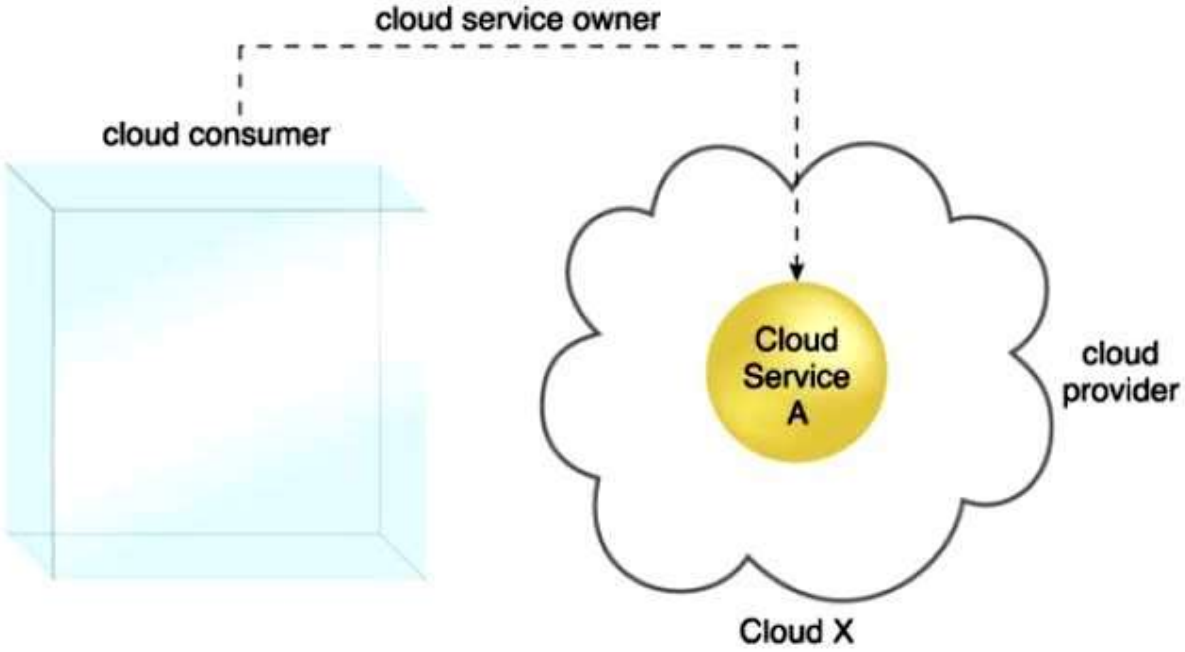


A cloud consumer (**Organization A**) interacts with a **cloud service** from a cloud provider (**that owns Cloud A**).
Within **Organization A**, the **cloud service consumer** is being used to access the **cloud service**.

Roles and Boundaries (Contd..)

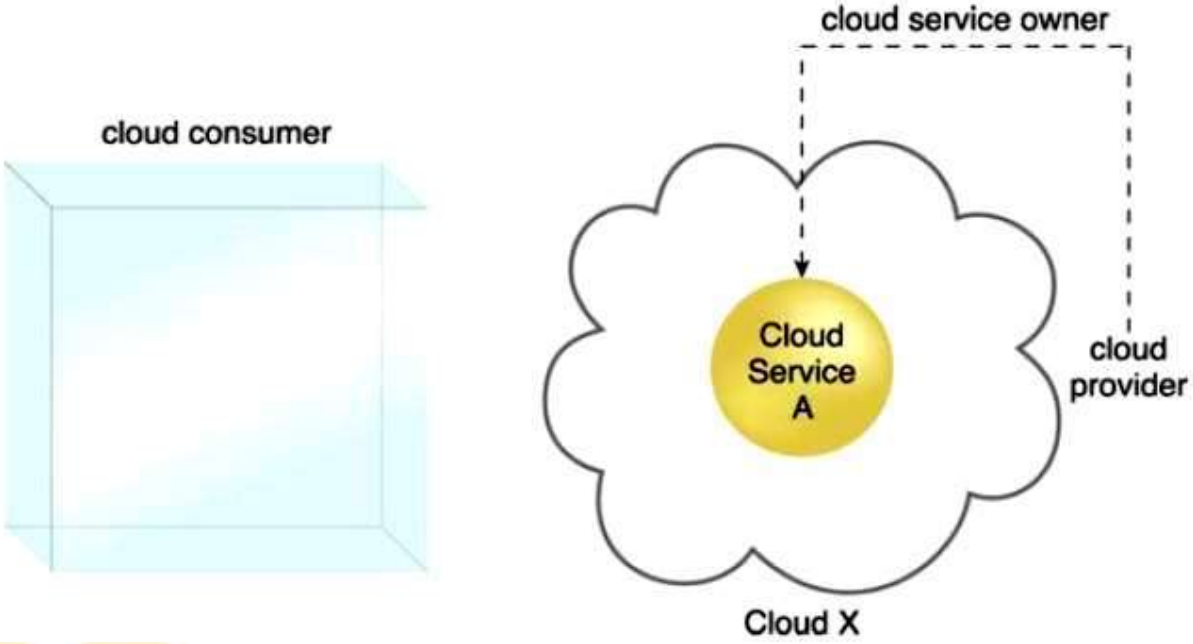
Cloud Service Owner:

- The individual or organization that legally owns a cloud service is called a *cloud service owner*.
- The *cloud service owner* **can be** the **cloud consumer**, or the **cloud provider** that owns the cloud within which the cloud service resides.



A cloud consumer can be a cloud service owner when it deploys its own service in a cloud.

Roles and Boundaries (Contd..)



A cloud provider becomes a cloud service owner if it deploys its own cloud service, typically for other cloud consumers to use.

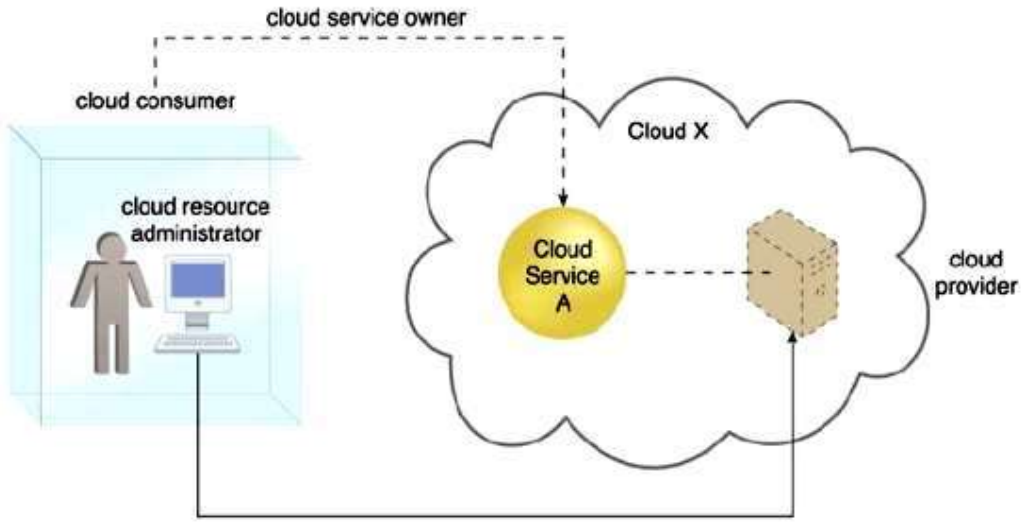
NOTE:

- Several cloud consumer organizations develop and deploy cloud services in clouds owned by other parties for the purpose of making the cloud services available to the general public.
- A *cloud service owner* **is not called** a *cloud resource owner* is because the cloud service owner role **only applies to cloud services**.

Roles and Boundaries (Contd..)

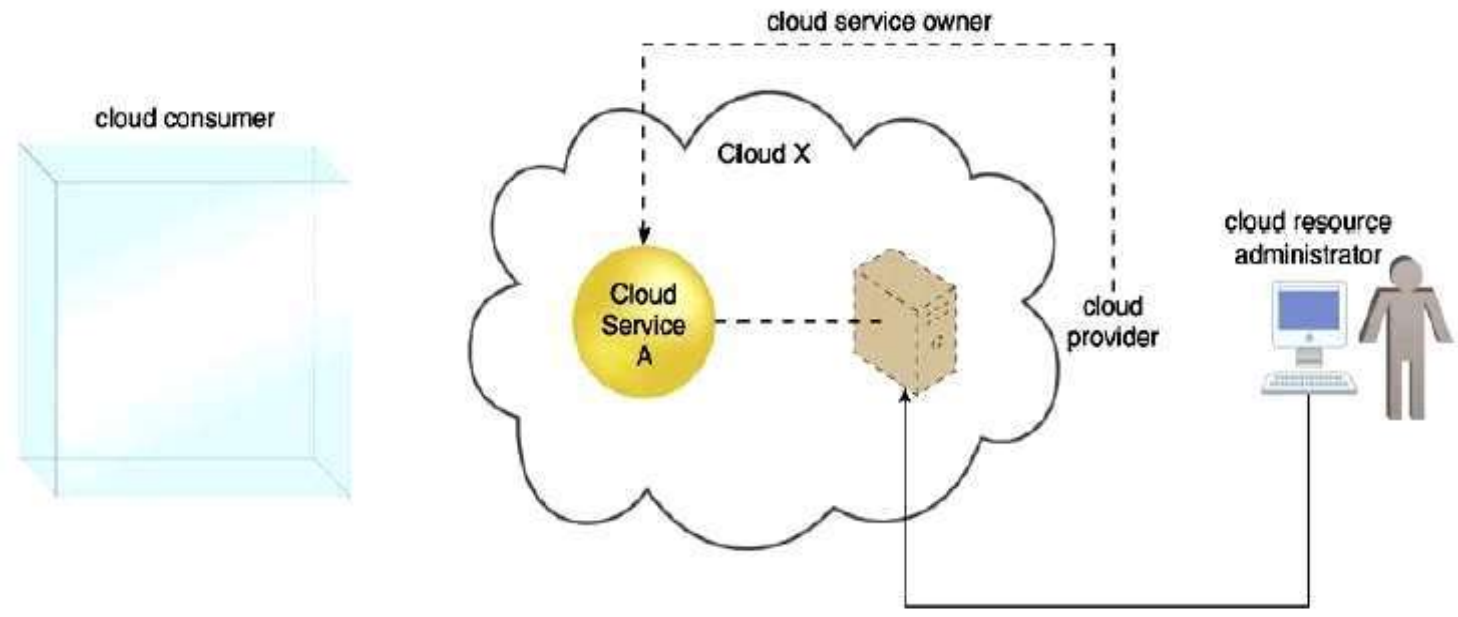
Cloud Resource Administrator:

- A *cloud resource administrator* is the person or organization responsible for administering a cloud-based IT resource (including cloud services).
- The cloud resource administrator **can be (or belong to)** the cloud consumer or cloud provider of the cloud within which the cloud service resides.
- Alternatively, it **can be (or belong to)** a third-party organization contracted to administer the cloud-based IT resource.



The **cloud consumer's** cloud resource administrator **remotely accesses** the virtual server hosting **Cloud Service A** (which is owned by the cloud consumer)

Roles and Boundaries (Contd..)



The **cloud provider's** cloud resource administrator **accesses** the virtual server that's hosting **Cloud Service A** (which is owned by the cloud provider)

- The reason a cloud resource administrator **is not referred to** as a **"cloud service administrator"** is because this role may be responsible for administering cloud-based IT resources that don't exist as cloud services.

Roles and Boundaries (Contd..)

Additional Roles:

- The NIST Cloud Computing Reference Architecture defines the following supplementary roles:

Cloud Auditor:

- A third-party (often accredited) that conducts **independent assessments** of cloud environments assumes the role of the *cloud auditor*.
- The typical responsibilities associated with this role include the **evaluation** of **security controls**, **privacy impacts**, and **performance**.
- The main purpose of the cloud auditor role is to provide an **unbiased assessment (and possible certification)** of a cloud environment to help **strengthen the trust relationship** between cloud consumers and cloud providers.

Roles and Boundaries (Contd..)

Cloud Broker:

- This role is assumed by a party that assumes the responsibility of **managing** and **negotiating** the usage of cloud services between cloud consumers and cloud providers.
- Mediation services provided by *cloud brokers* include **service intermediation**, **aggregation(packages & integrates multiple cloud computing services into one (or) more composite services**, more cost-effective to customer than purchasing each service separately) and **arbitrage (buying something to resell immediately at a profit)**.

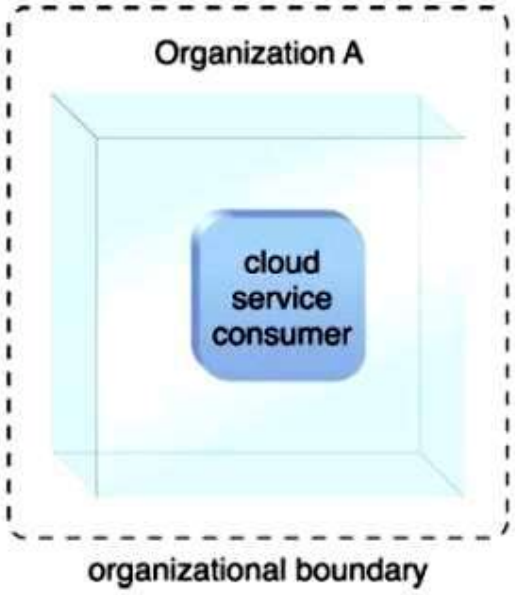
Cloud Carrier:

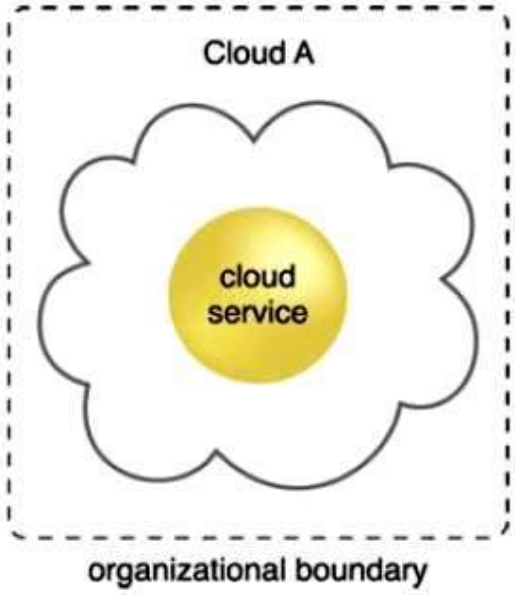
- The party responsible for providing the **wire-level connectivity** between cloud consumers and cloud providers assumes the role of the *cloud carrier*.
- This role is often assumed by **network** and **telecommunication** providers(ISP).

Roles and Boundaries (Contd..)

Organizational Boundary:

- An *organizational boundary* represents the **physical perimeter** that surrounds a **set of IT resources** that are **owned** and **governed** by an organization.
- The organizational boundary **does not represent** the boundary of an actual organization, **only an organizational set of IT assets and IT resources**.





Organizational boundaries of a **cloud consumer** (left), and a **cloud provider** (right), represented by a **broken line notation**.

Roles and Boundaries (Contd..)

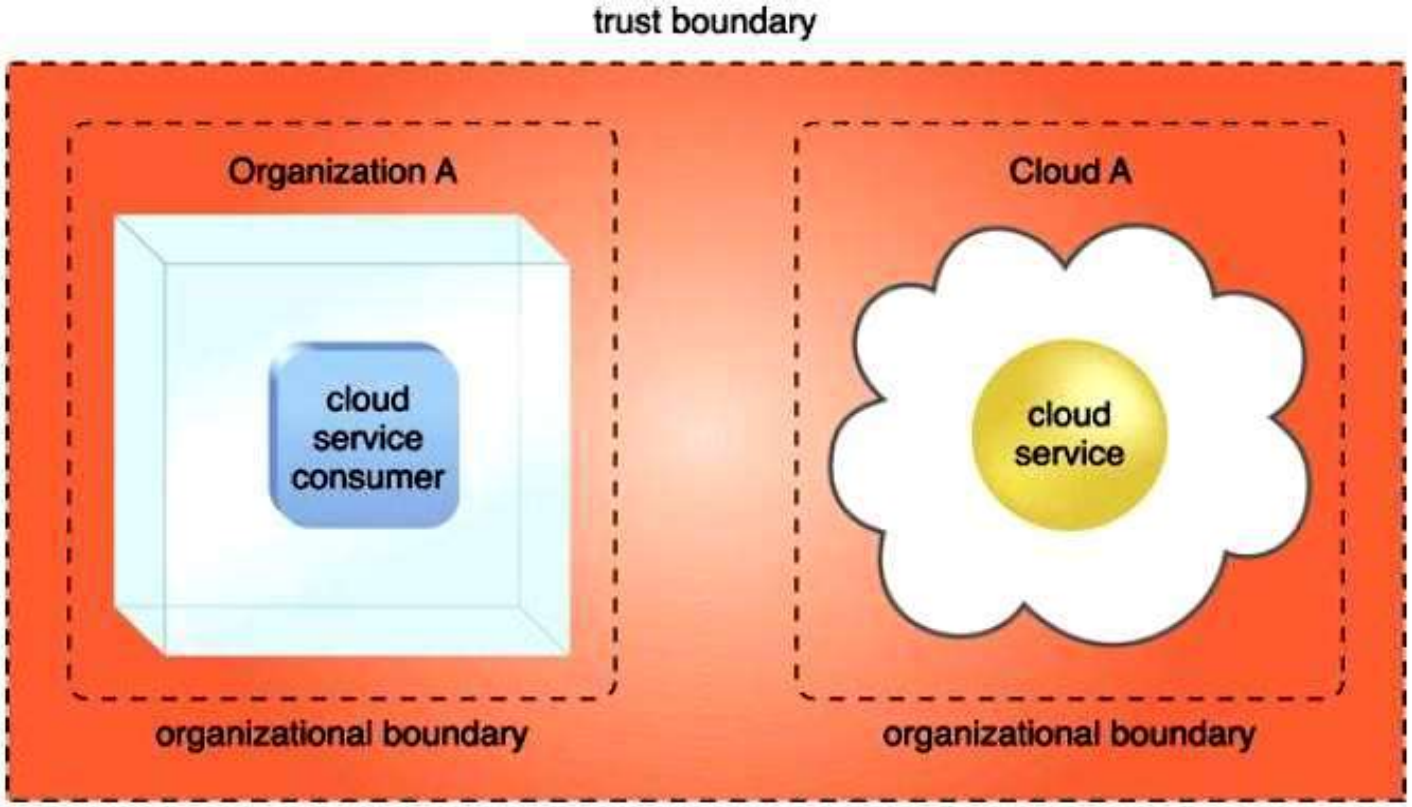
Trust Boundary:

- When an organization **assumes the role of cloud consumer** to access **cloud-based IT resources**, it needs to **extend its trust** beyond the **physical boundary** of the organization **to include parts of the cloud environment**.

- A *trust boundary* is a **logical perimeter** that typically spans **beyond physical boundaries** to represent the **extent** to which **IT resources are trusted**.

- When analyzing cloud environments, the trust boundary is **most frequently associated with** the **trust issued by the organization** acting as the **cloud consumer**.

Roles and Boundaries (Contd..)



An **extended trust boundary** encompasses the organizational boundaries of the cloud provider and the cloud consumer.

Cloud Characteristics

- An IT environment requires a **specific set of characteristics** to **enable** the **remote provisioning of scalable and measured IT resources** in **an effective manner**.
- The following **six specific characteristics** are common to the majority of cloud environments:
  - On-Demand Usage
  - Ubiquitous Access
  - Multitenancy (and Resource Pooling)
  - Elasticity
  - Measured Usage
  - Resiliency (or Resilient Computing)

Cloud Characteristics (Contd..)

On-Demand Usage:

- A cloud consumer can **individually access** cloud-based IT resources giving the cloud consumer the **freedom to self-provision** these IT resources.
- Once configured, **usage of the self-provisioned IT resources** can be **automated**, requiring **no further human involvement** by the cloud consumer or cloud provider.

  – This results in an *on-demand usage environment*.
- Also known as **"on-demand self-service usage,"** this characteristic enables the service-based and usage-driven features found in conventional clouds.

Ubiquitous Access:

- *Ubiquitous access* represents the ability for a cloud service to be **widely accessible**.
- Establishing ubiquitous access for a cloud service can require support for a **range of devices, transport protocols, interfaces, & security methods**.

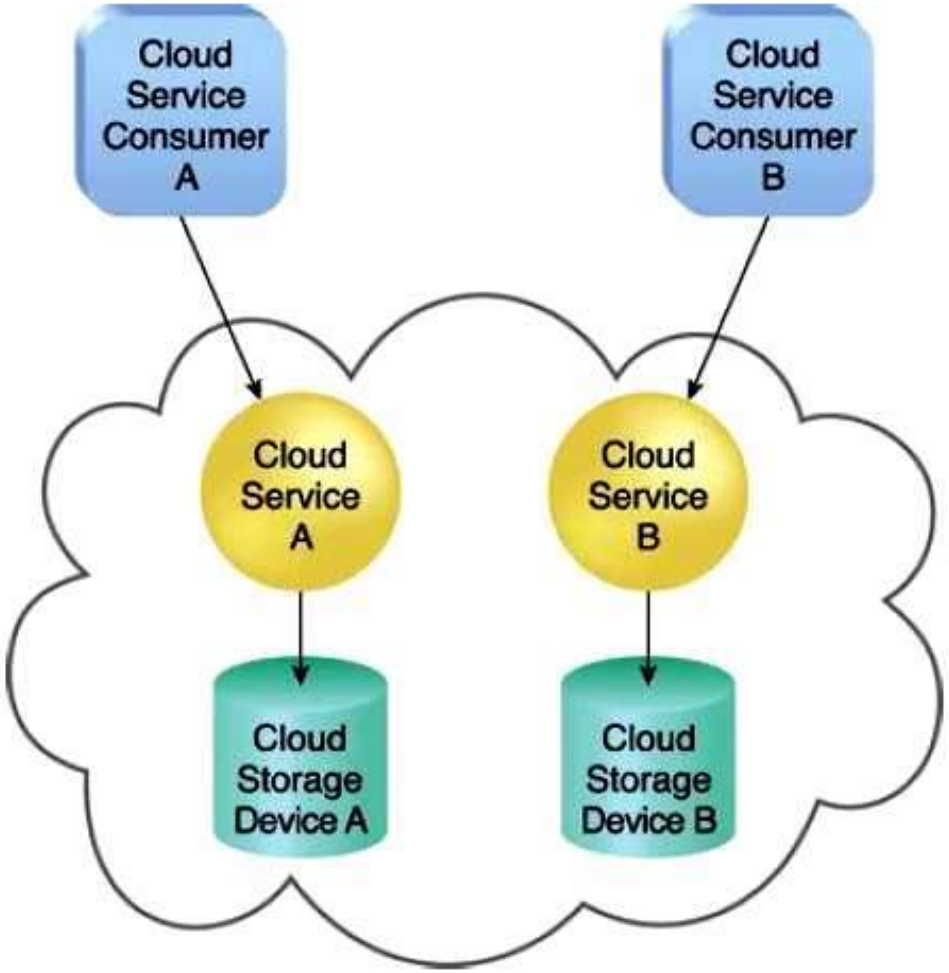
Cloud Characteristics (Contd..)

Multitenancy (and Resource Pooling):

- The **characteristic of a software program** that **enables an instance of the program** to **serve different consumers (tenants)** whereby each is **isolated from the other**, is referred to as *multitenancy*.
- A cloud provider **pools its IT resources** to **serve multiple cloud service consumers** by using **multitenancy models** that frequently rely on the use of **virtualization technologies**.
- Through the use of multitenancy technology, IT resources can be **dynamically assigned and reassigned**, according to **cloud service consumer demands**.

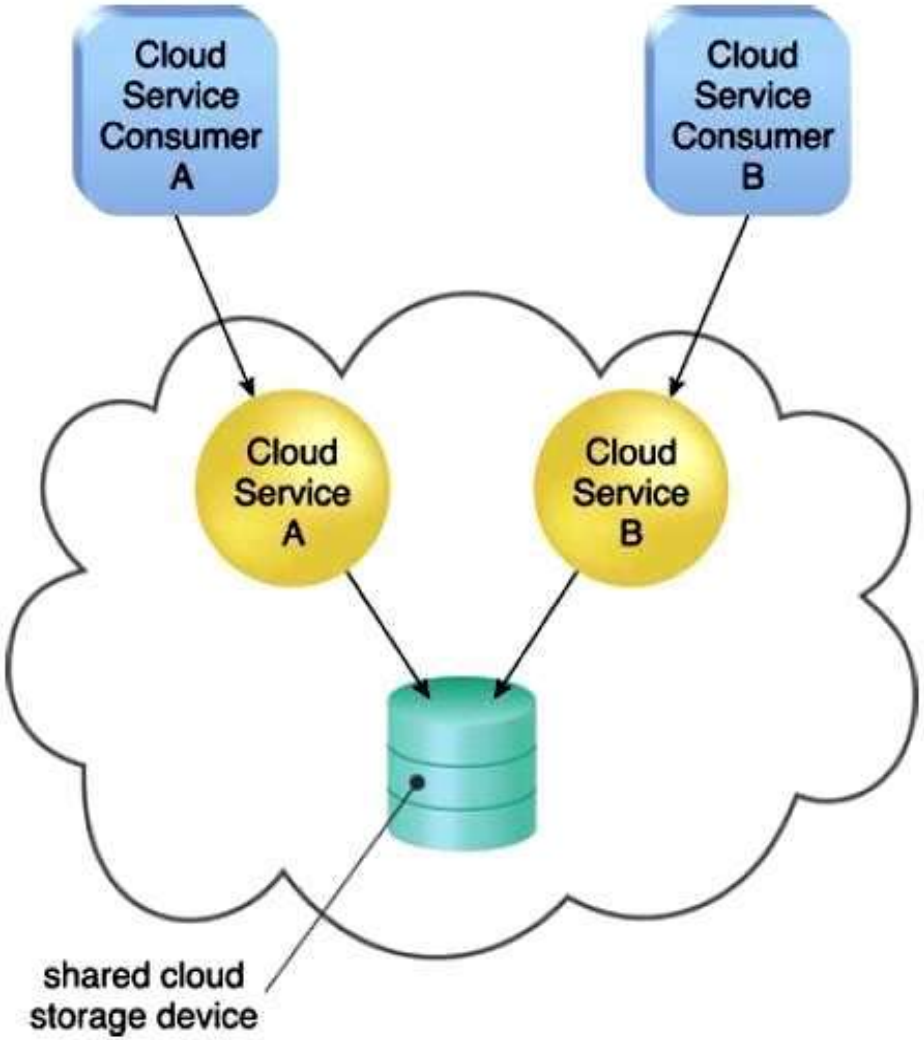
- **Resource Pooling** allows cloud providers to pool large-scale IT resources to serve multiple cloud consumers.

Cloud Characteristics (Contd..)



In a **single-tenant environment**, each cloud consumer has a **separate IT resource instance**.

Cloud Characteristics (Contd..)



In a **multitenant environment**, a **single instance of an IT resource**, such as a **cloud storage device**, serves **multiple consumers**.

Cloud Characteristics (Contd..)

Elasticity:

- *Elasticity* is the **automated ability** of a cloud to transparently scale IT resources, as required in response to **runtime conditions** or as **pre-determined** by the cloud consumer or cloud provider.
- Elasticity is often considered a **core justification** for the adoption of cloud computing, primarily due to the fact that it is **closely associated with** the **Reduced Investment and Proportional Costs** benefit.
- Cloud providers with **enormous IT resources** can offer the **greatest range of elasticity**.

Measured Usage:

- Represents the **ability of a cloud platform** to keep track of the **usage** of its **IT resources**, primarily by **cloud consumers**.

Cloud Characteristics (Contd..)

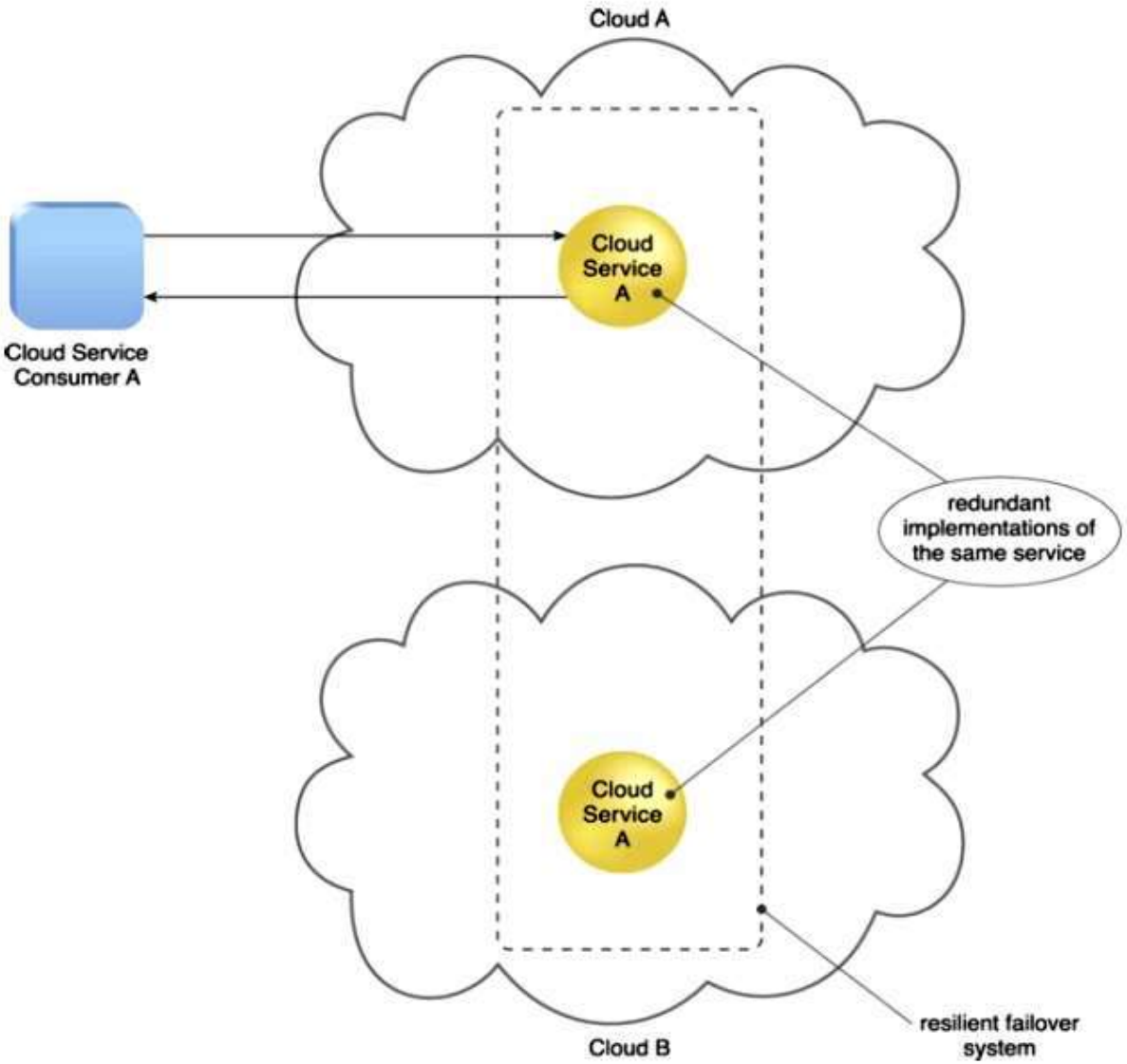
Resiliency:

- Within cloud computing, the characteristic of *resiliency* can refer to **redundant IT resources within the same cloud** (but in **different physical locations**) or **across multiple clouds**.

- **Resilient Computing** is a form of **failover** that distributes redundant implementations of IT resources across physical locations.

- Cloud consumers can increase both the **reliability and availability** of their applications by utilizing the resiliency of cloud-based IT resources.

Cloud Characteristics (Contd..)



A resilient system in which **Cloud B** hosts a **redundant implementation** of **Cloud Service A** to provide **failover** in case **Cloud Service A** on **Cloud A becomes unavailable**.

Cloud Delivery Models

- A *cloud delivery model* represents a **specific**, **pre-packaged** combination of IT resources offered by a cloud provider.
- Also known as *cloud service model* / *cloud utilization model*.
- Three common cloud delivery models have become widely established and formalized:
  - **Infrastructure-as-a-Service (IaaS)**
  - **Platform-as-a-Service (PaaS)**
  - **Software-as-a-Service (SaaS)**

NOTE:

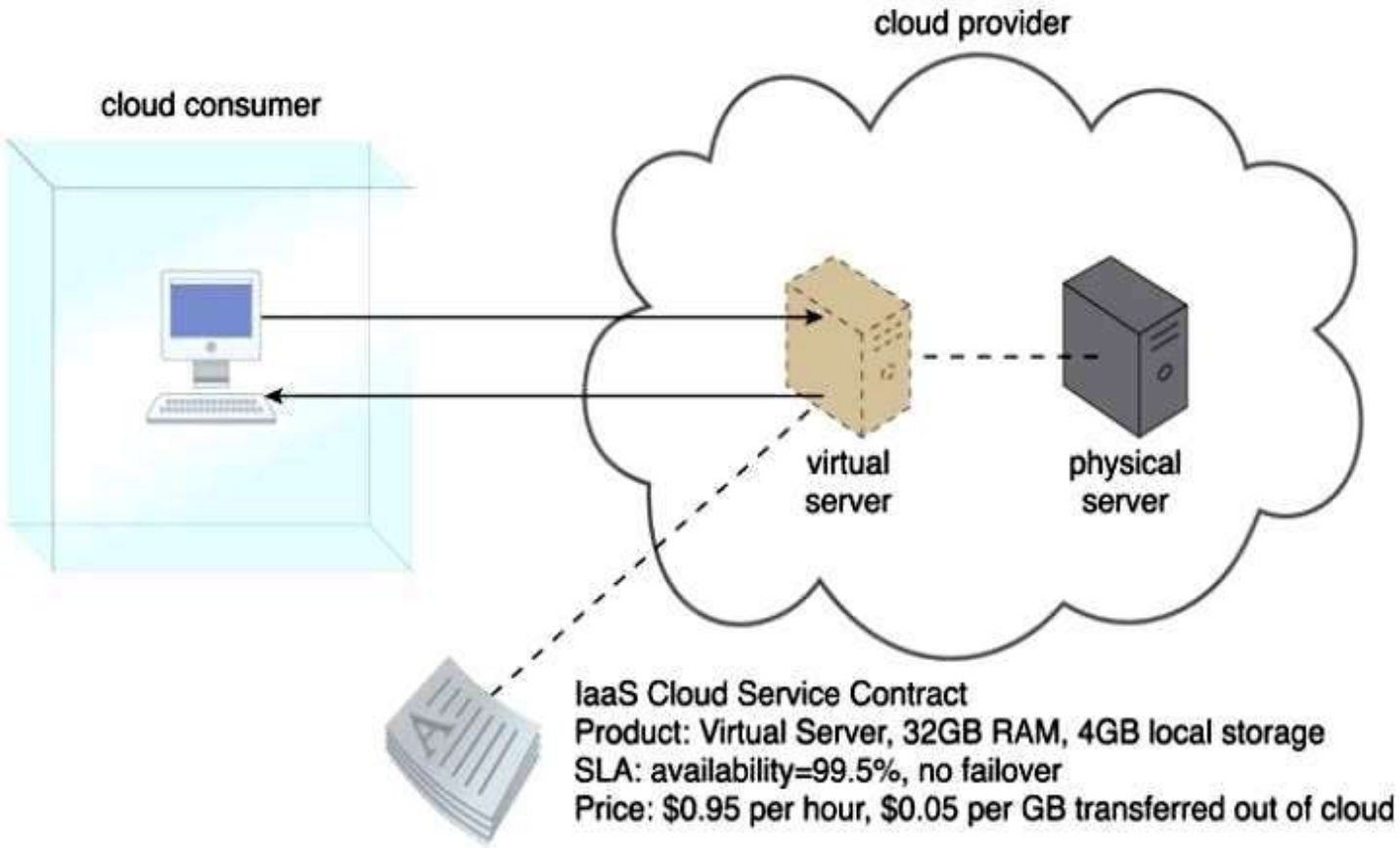
- Many specialized variations of the three base cloud delivery models have emerged, each comprised of a distinct combination of IT resources.
- Some examples include: Storage-as-a-Service, Database-as-a-Service, Security-as-a-Service, Communication-as-a-Service, Integration-as-a-Service, Testing-as-a-Service, Process-as-a-Service.

Cloud Delivery Models (Contd..)

Infrastructure-as-a-Service (IaaS)

- The *IaaS delivery model* represents a **self-contained IT environment** comprised of **infrastructure-centric IT resources** that can be accessed and managed via **cloud service-based interfaces and tools**.
- This environment can include hardware, network, connectivity, operating systems, and other **"raw"** IT resources.
- The general purpose of an *IaaS environment* is to provide cloud consumers with a **high level of control** and **responsibility** over its **configuration** and **utilization**.
- The IT resources provided by IaaS are generally **not pre-configured**, placing the **administrative responsibility** directly upon the cloud consumer.
- This model is therefore used by cloud consumers that require a high level of control over the cloud-based environment they intend to create.

Cloud Delivery Models (Contd..)



A cloud consumer is using a **virtual server** within an IaaS environment. Cloud consumers are provided with a range of contractual guarantees by the cloud provider, pertaining to characteristics such as **capacity**, **performance**, and **availability**.

Cloud Delivery Models (Contd..)

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IaaS Examples

Cloud Delivery Models (Contd..)

Platform-as-a-Service (PaaS)

- The *PaaS delivery model* represents a **pre-defined "ready-to-use"** environment typically comprised of **already deployed** and **configured IT resources**.
- *PaaS* relies on (and is primarily defined by) the usage of a **ready-made environment** that establishes a **set of pre-packaged products** and **tools** used to support the entire delivery lifecycle of custom applications.
- Common reasons a cloud consumer would use and invest in a PaaS environment include:
  - The cloud consumer wants to extend on-premise environments into the cloud for scalability and economic purposes.
  - The cloud consumer uses the ready-made environment to entirely substitute an on-premise environment.

Cloud Delivery Models (Contd..)

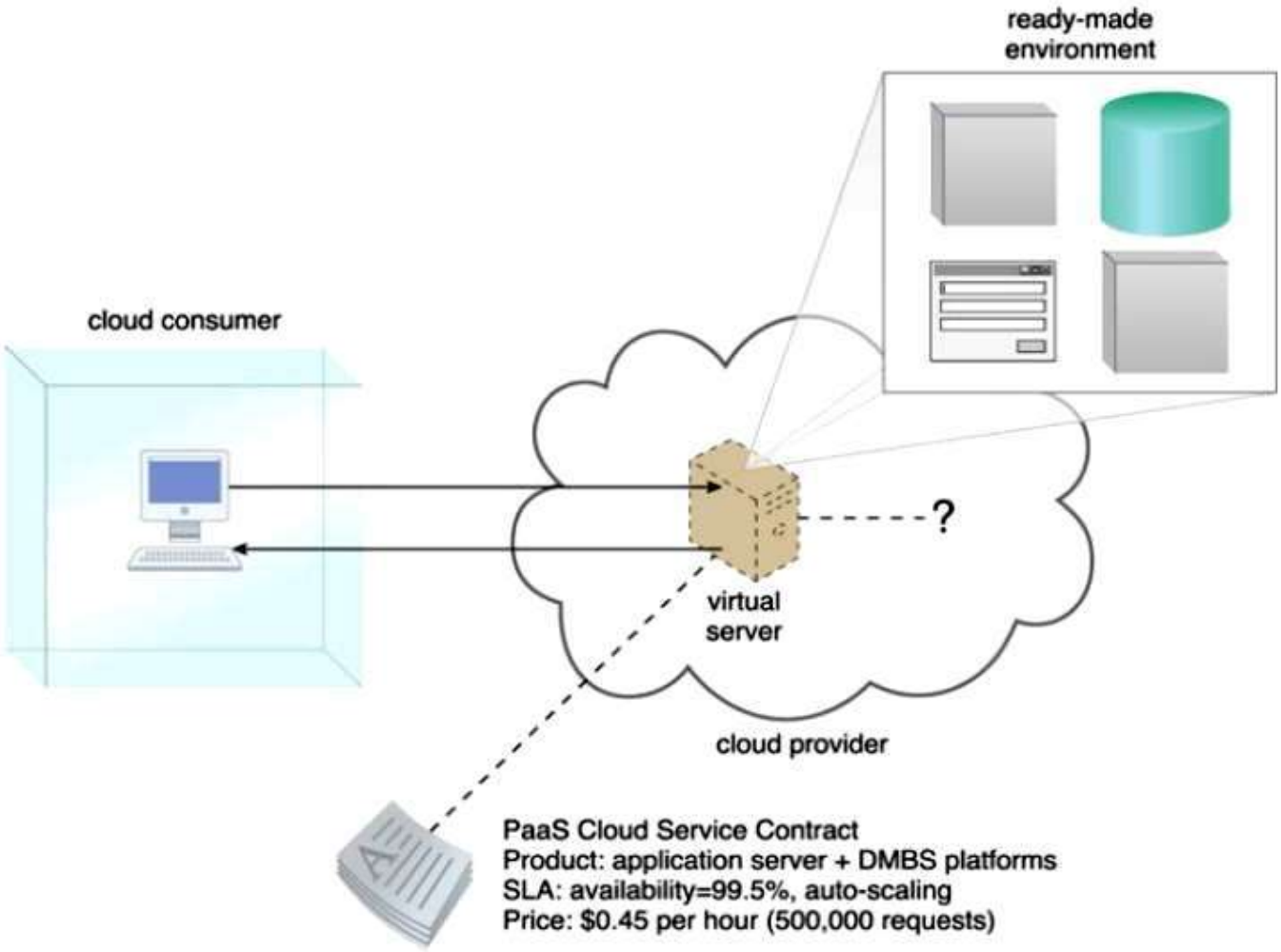
- The cloud consumer wants to become a cloud provider and deploys its own cloud services to be made available to other external cloud consumers.

- The cloud consumer **not requires administrative burden** of setting up and maintaining the bare infrastructure IT resources provided via the IaaS model.

Ready-Made Environment:

- 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**.
- PaaS products are available with different development stacks.
- For example, **Google App Engine** offers a **Java** and **Python**-based environment.

Cloud Delivery Models (Contd..)



A cloud consumer is accessing a **ready-made PaaS** environment.

Cloud Delivery Models (Contd..)

PaaS Examples

Cloud Delivery Models (Contd..)

Software-as-a-Service (SaaS)

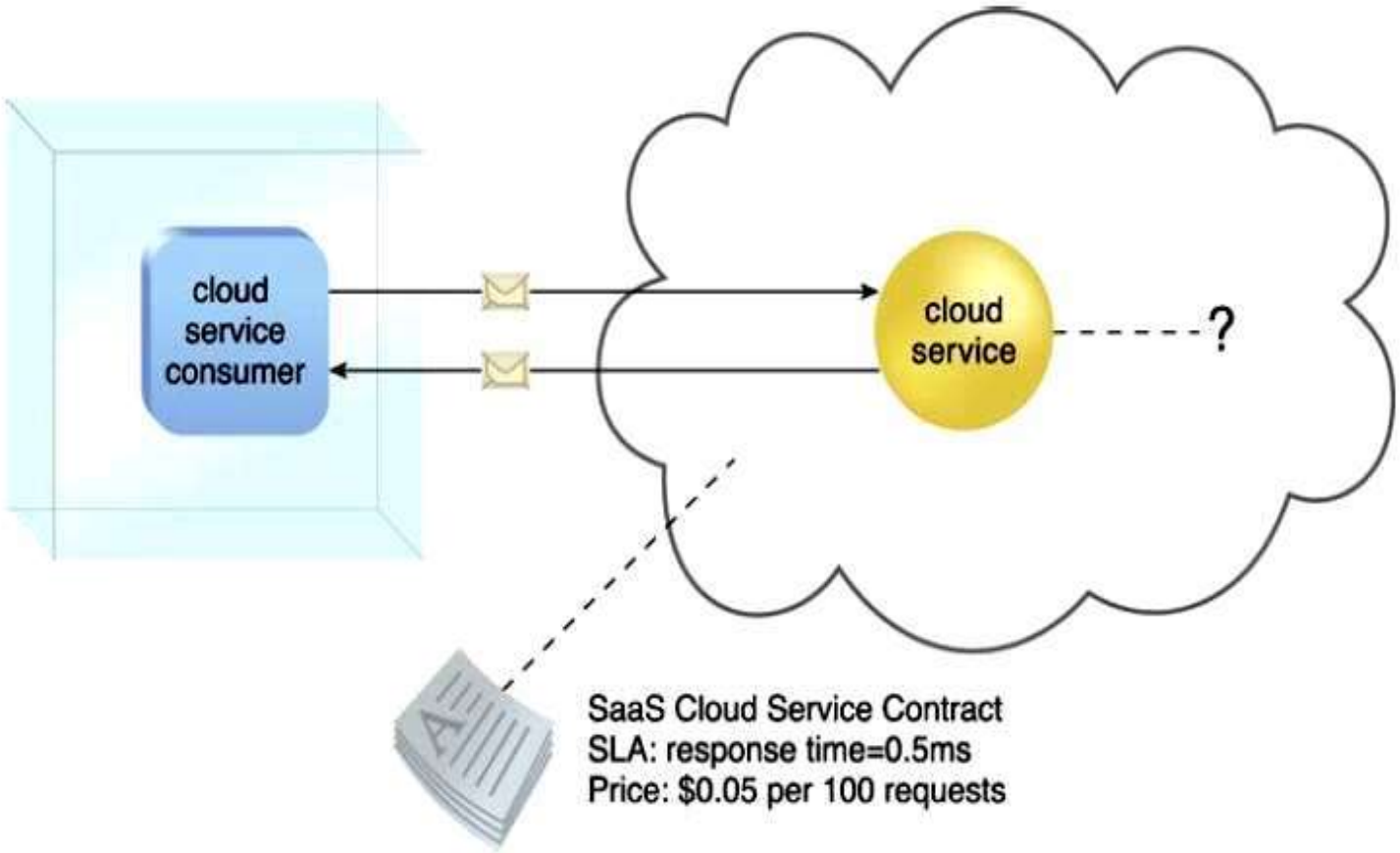
- A **software program** positioned as a **shared cloud service** and made available as a **"product"** or **generic utility** represents the typical profile of a *SaaS* offering.

- The *SaaS delivery model* is typically used to make a **reusable cloud service** widely available (often commercially) to a range of cloud consumers.

- A cloud consumer is generally granted **very limited administrative control** over a SaaS implementation.

- It is **most often** provisioned by the cloud provider, but it can be **legally owned** by whichever entity assumes the **cloud service owner** role.

Cloud Delivery Models (Contd..)



The cloud service consumer is given access the **cloud service contract**, but **not to any underlying IT resources** or **implementation** details.

Cloud Delivery Models (Contd..)

SaaS Examples

Platform Type	Common Examples
SaaS	Google Workspace, Dropbox, Salesforce, Cisco WebEx, Concur, GoToMeeting
PaaS	AWS Elastic Beanstalk, Windows Azure, Heroku, Force.com, Google App Engine, Apache Stratos, OpenShift
IaaS	DigitalOcean, Linode, Rackspace, Amazon Web Services (AWS), Cisco Metapod, Microsoft Azure, Google Compute Engine (GCE)

- 1. build a new house(IaaS)(fully control, but it is hard)
- 2. buy an empty house(PaaS)(customize some part of your house, but never change the original architecture)
- 3. live in an hotel(SaaS)(living in it)

Comparing Cloud Delivery Models

A comparison of typical cloud delivery model control levels.

Cloud Delivery Model	Typical Level of Control Granted to Cloud Consumer	Typical Functionality Made Available to Cloud Consumer
SaaS	usage and usage-related configuration	access to front-end user-interface
PaaS	limited administrative	moderate level of administrative control over IT resources relevant to cloud consumer's usage of platform
IaaS	full administrative	full access to virtualized infra-structure-related IT resources and, possibly, to underlying physical IT resources

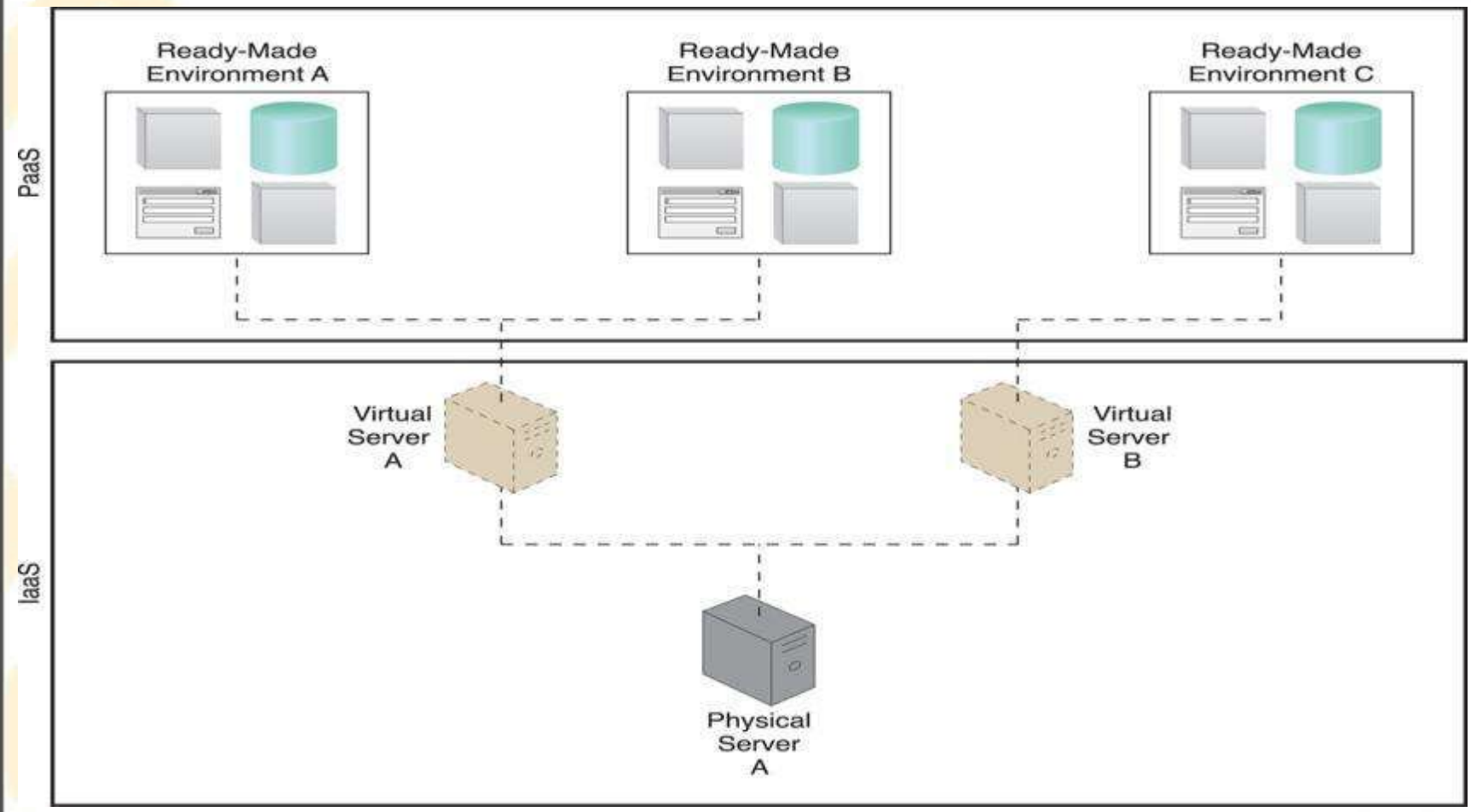
Comparing Cloud Delivery Models
(Contd..)

Typical activities carried out by cloud consumers and cloud providers in relation to the cloud delivery models.

Cloud Delivery Model	Common Cloud Consumer Activities	Common Cloud Provider Activities
SaaS	uses and configures cloud service	implements, manages, and maintains cloud service monitors usage by cloud consumers
PaaS	develops, tests, deploys, and manages cloud services and cloud-based solutions	pre-configures platform and provisions underlying infrastructure, middleware, and other needed IT resources, as necessary monitors usage by cloud consumers
IaaS	sets up and configures bare infrastructure, and installs, manages, and monitors any needed software	provisions and manages the physical processing, storage, networking, and hosting required monitors usage by cloud consumers

Combining Cloud Delivery Models

IaaS + PaaS

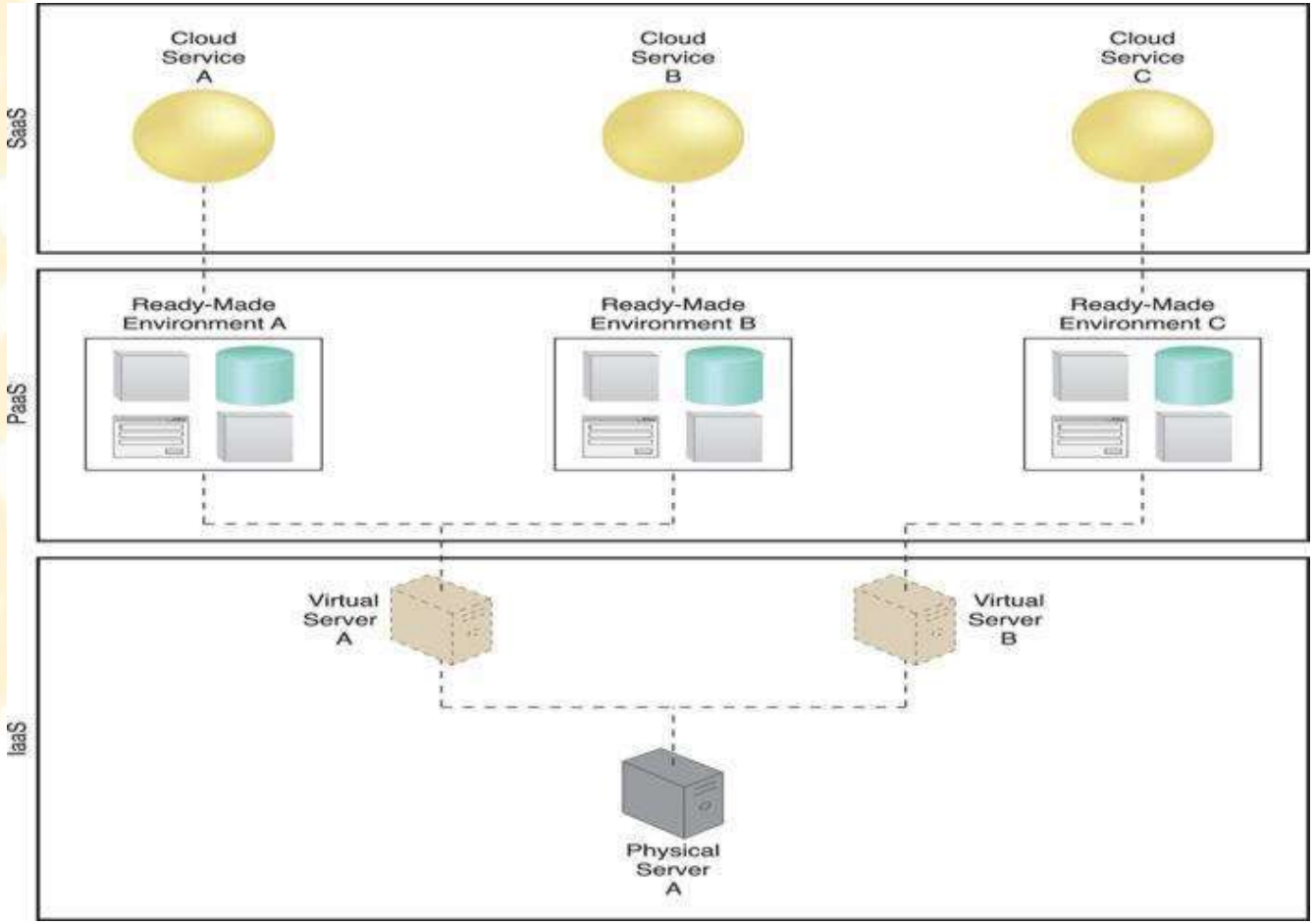


A PaaS environment based on the IT resources provided by an underlying IaaS environment.

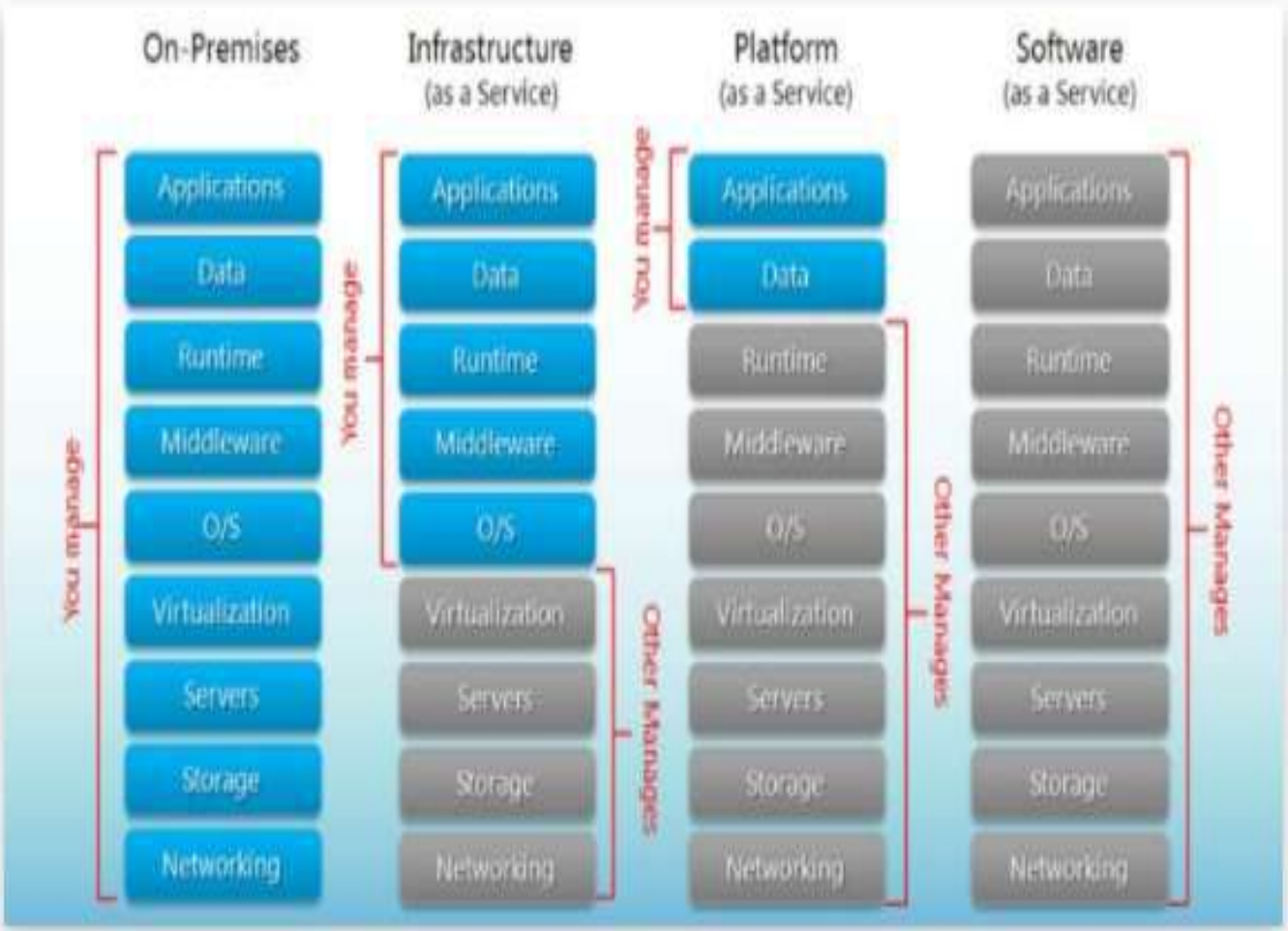
Combining Cloud Delivery Models

(Contd..)

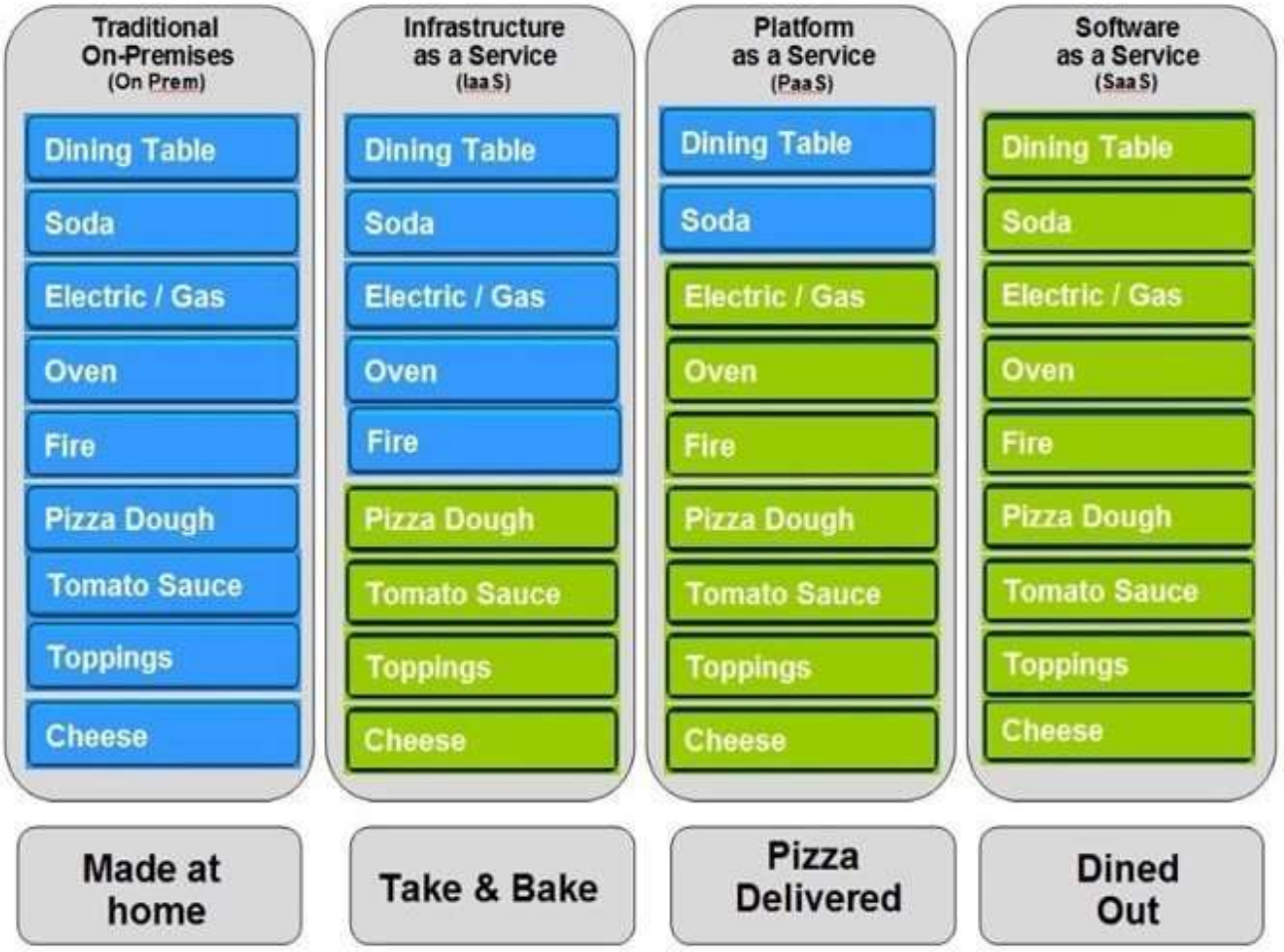
IaaS + PaaS + SaaS

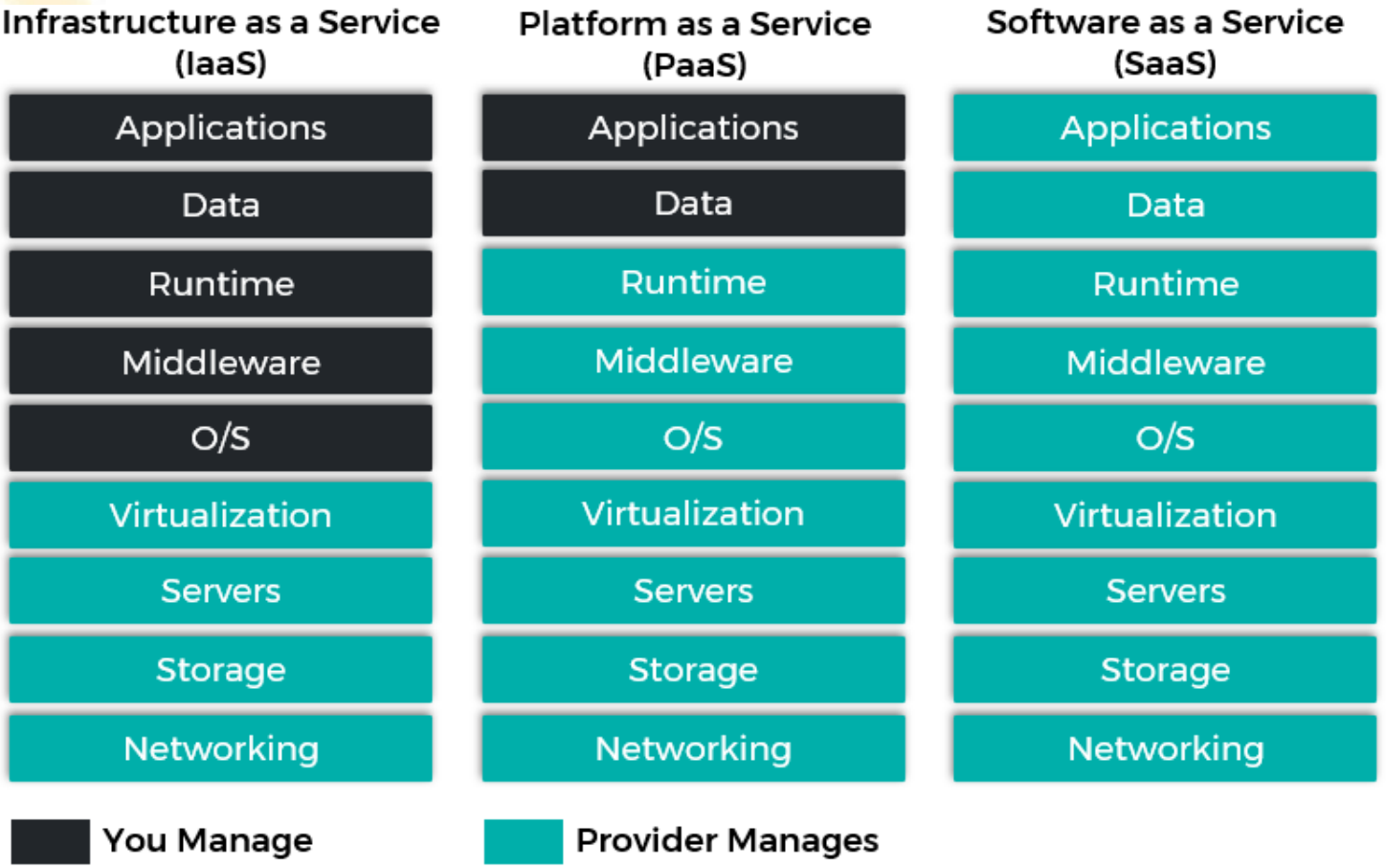


A simple layered view of an architecture comprised of IaaS and PaaS environments hosting three SaaS cloud service implementations.


On-Premises
Infrastructure (as a Service)
Platform (as a Service)
Software (as a Service)
Applications
Data
Runtime
Middleware
O/S
Virtualization
Servers
Storage
Networking
You manage
You manage
You manage
Other Manages
Other Manages
Other Manages

Pizza as a Service




Infrastructure as a Service (IaaS)
Applications
Data
Runtime
Middleware
O/S
Virtualization
Servers
Storage
Networking
Platform as a Service (PaaS)
Applications
Data
Runtime
Middleware
O/S
Virtualization
Servers
Storage
Networking
Software as a Service (SaaS)
Applications
Data
Runtime
Middleware
O/S
Virtualization
Servers
Storage
Networking
You Manage
Provider Manages

Cloud Deployment Models

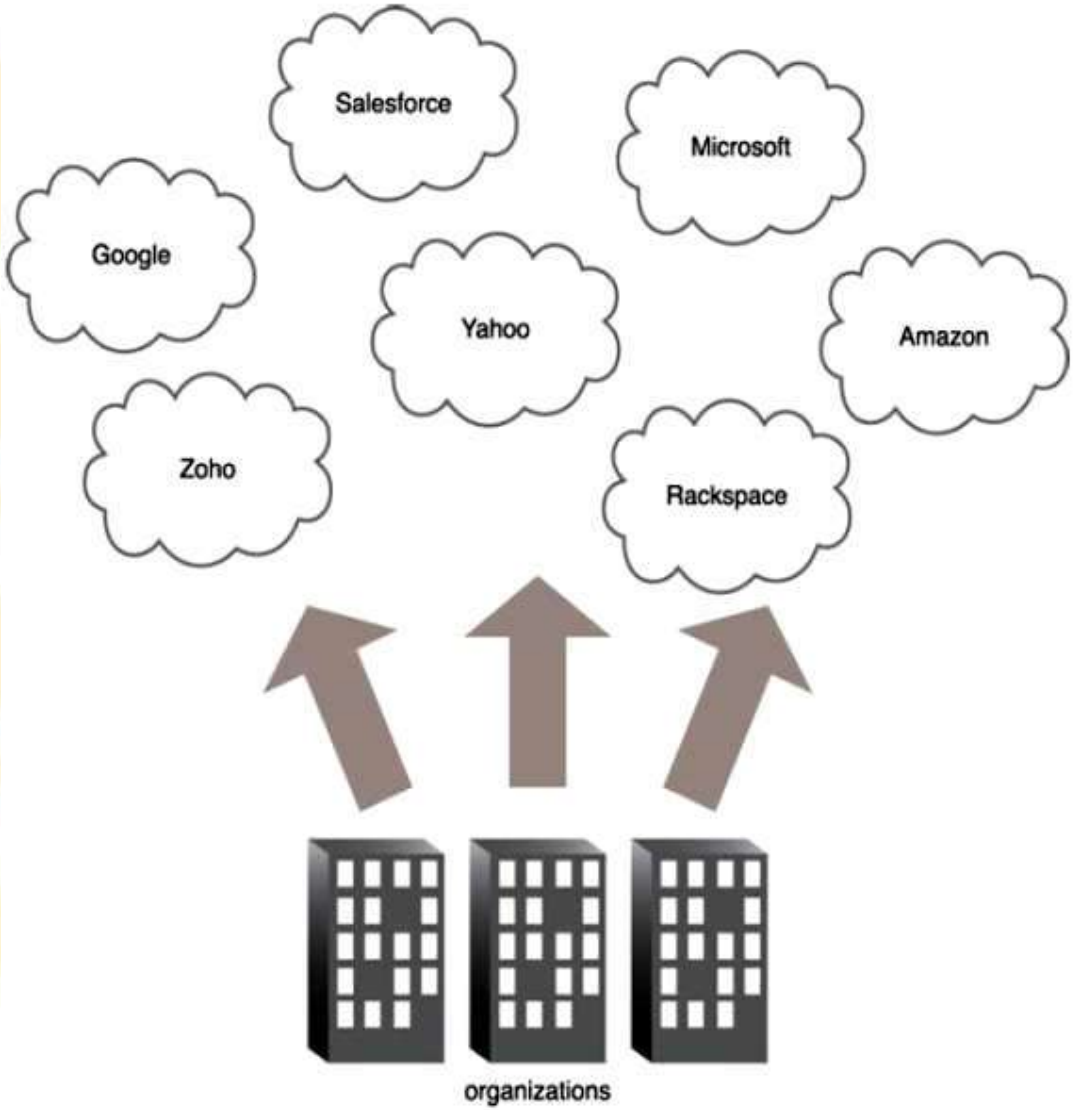
- A cloud deployment model represents a specific type of cloud environment, primarily distinguished by **ownership**, **size**, and **access**.
- There are four common cloud deployment models:
  - **Public Cloud**
  - **Community Cloud**
  - **Private Cloud**
  - **Hybrid Cloud**

Cloud Deployment Models (Contd..)

Public Clouds

- A *public cloud* is a **publicly accessible** cloud environment owned by a third-party cloud provider.
- IT resources on public clouds are usually provisioned via the previously described **cloud delivery models** and are generally offered to cloud consumers at a cost or are commercialized via other avenues (such as advertisement).
- The **cloud provider** is responsible for the **creation** and on-going **maintenance** of the public cloud and its IT resources.

Cloud Deployment Models (Contd..)



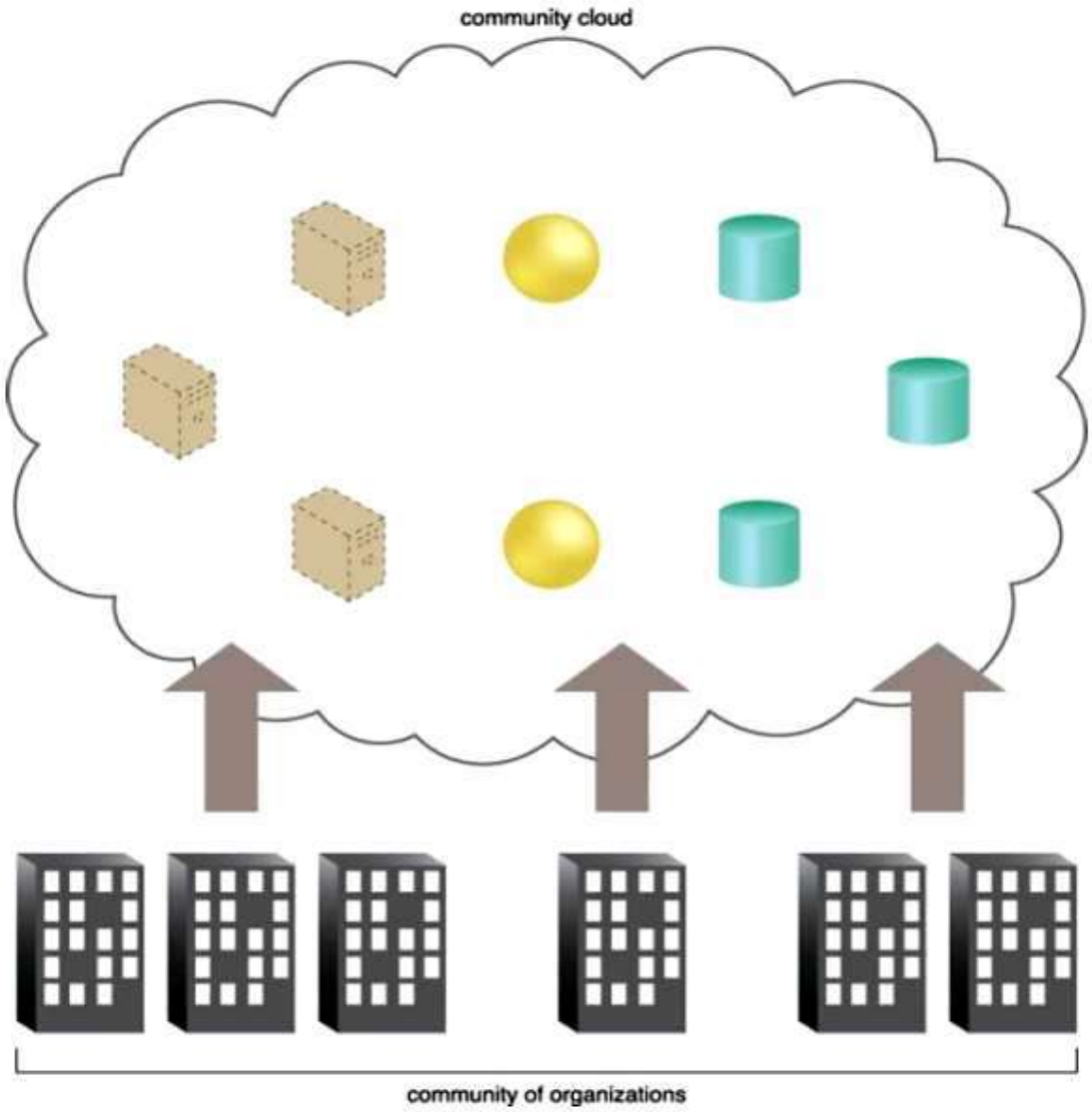
Organizations act as cloud consumers when accessing cloud services and IT resources made available by different cloud providers.

Cloud Deployment Models (Contd..)

Community Clouds

- A *community cloud* is similar to a public cloud except that its **access is limited** to a **specific community** of cloud consumers.
- The community cloud **may be jointly owned** by the community members or **by a third-party cloud provider** that provisions a public cloud with **limited access**.
- The member cloud consumers of the community typically **share the responsibility** for defining and evolving the community cloud.

Cloud Deployment Models (Contd..)



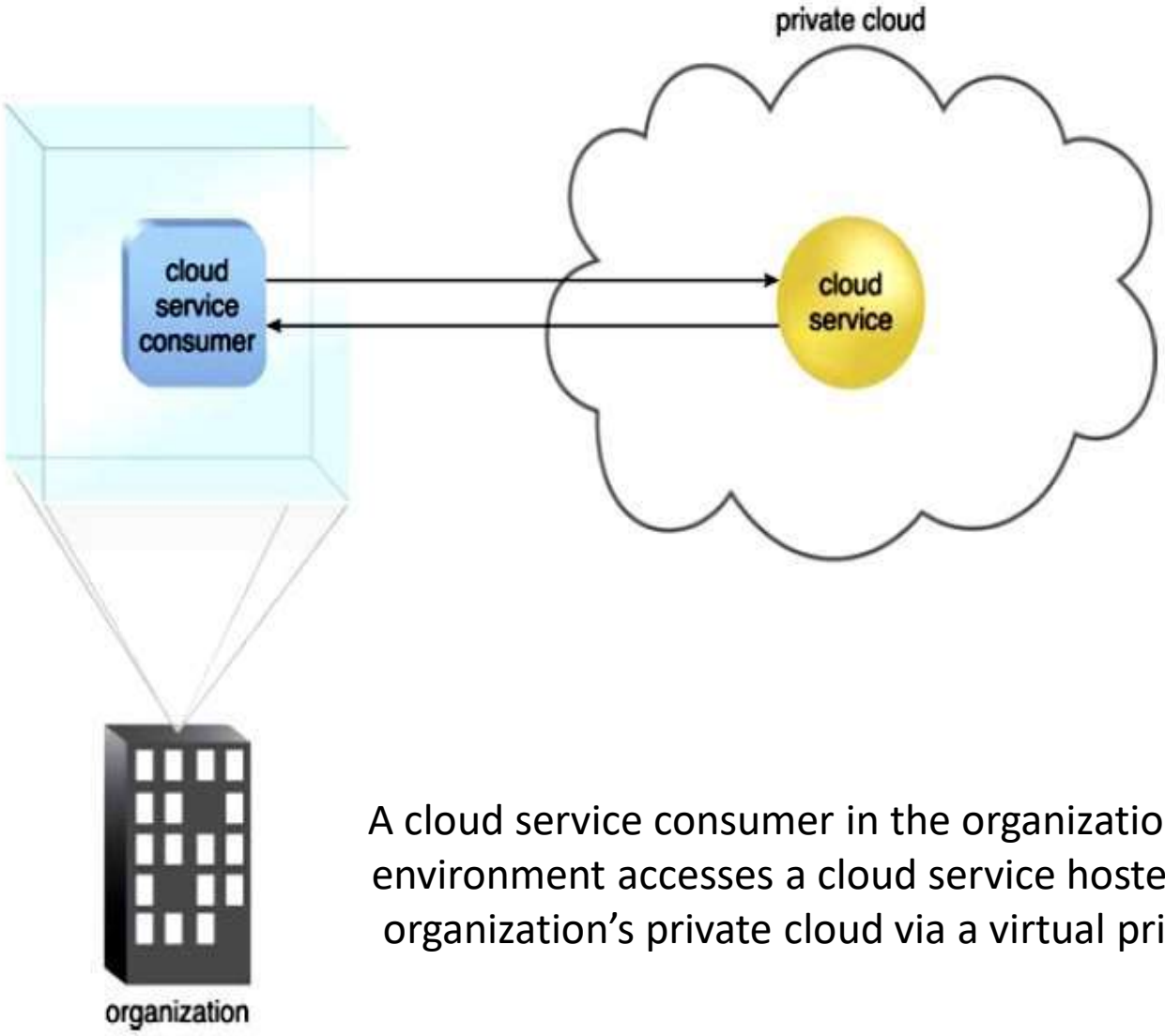
An example of a **"community"** of organizations accessing IT resources from a community cloud.

Cloud Deployment Models (Contd..)

Private Clouds

- A *private cloud* is **owned** by a single organization.
- Private clouds **enable an organization** to use **cloud computing technology** as a means of **centralizing access** to IT resources by different parts, locations, or departments of the organization.
- The **actual administration** of a private cloud environment may be carried out by **internal** or **outsourced staff**.
- With a private cloud, the same organization is technically both the cloud consumer and cloud provider. In order to differentiate these roles:
  - a separate organizational department typically assumes the responsibility for provisioning the cloud (and therefore assumes the cloud provider role).
  - departments requiring access to the private cloud assume the cloud consumer role.

Cloud Deployment Models (Contd..)



A cloud service consumer in the organization's on-premise environment accesses a cloud service hosted on the same organization's private cloud via a virtual private network.

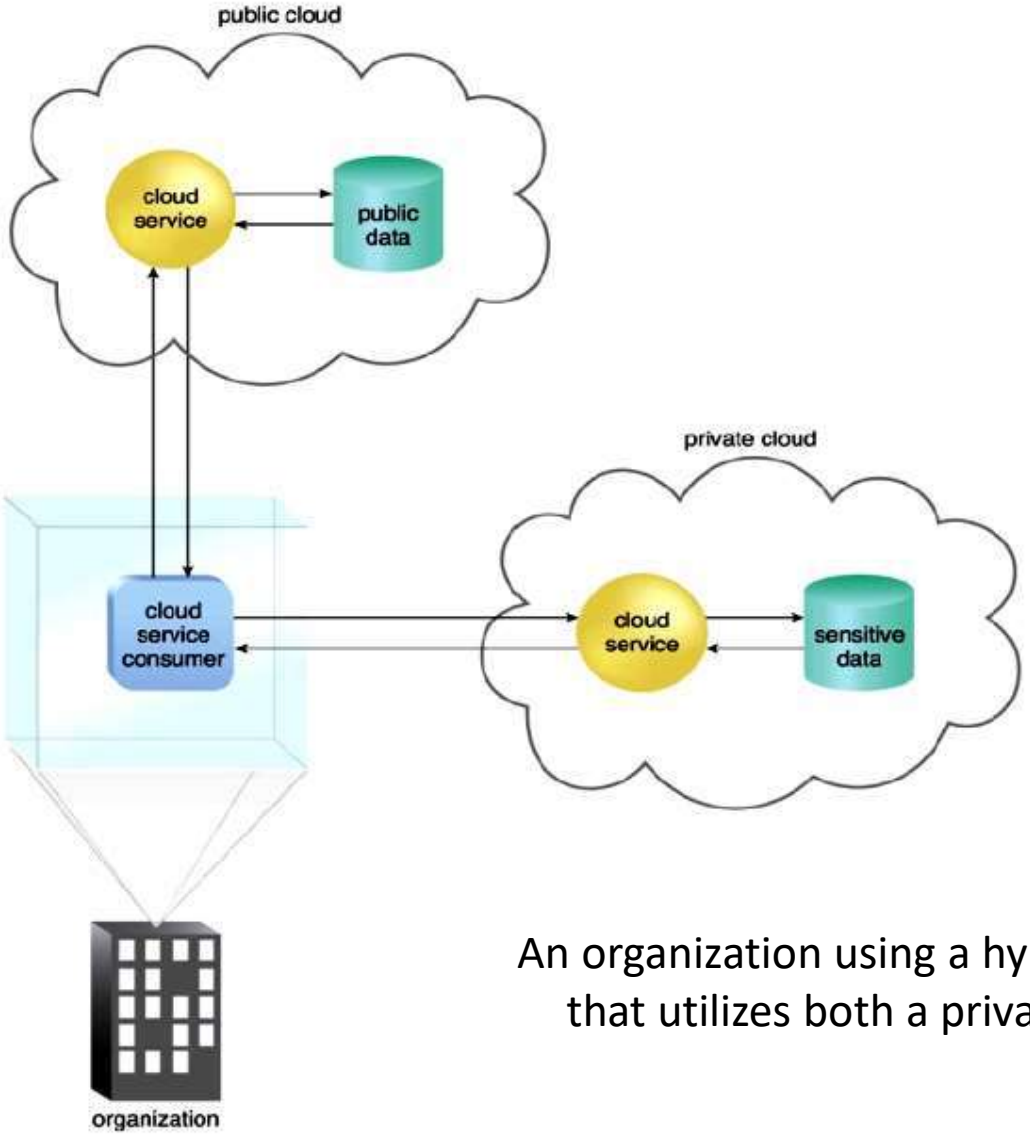
Cloud Deployment Models (Contd..)

Hybrid Clouds

- A *hybrid cloud* is a cloud environment comprised of **two or more** different cloud deployment models.
- For example, a cloud consumer may choose to deploy cloud services processing **sensitive data to a private cloud** and other, **less sensitive** cloud services to a public cloud.
  - The result of this combination is a hybrid deployment model.

- Hybrid deployment architectures can be complex and challenging to create and maintain
  - due to the potential discrepancy in cloud environments and
  - the fact that management responsibilities are typically split between the private cloud provider organization and the public cloud provider.

Cloud Deployment Models (Contd..)



An organization using a hybrid cloud architecture that utilizes both a private and public cloud.

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