CS 4037
Introduction to Cloud Computing
Lecture 4

Danyal Farhat

FAST School of Computing

NUCES Lahore

Fundamental Concepts and Models

Lecture's Agenda

- **Roles and Boundaries**

- Cloud Characteristics

- Cloud Service / Delivery Models

- Cloud Deployment Models

Roles

Cloud Provider:

- **Cloud Provider is the organization that provides cloud-based IT resources.**

- **Cloud providers own the IT resources that are made available for lease by cloud consumers.**

- **Some cloud providers also "resell" IT resources leased from other cloud providers.**
  - Example: MS Azure Stack deployed on PTCL servers.

Roles (Cont.)

Cloud Consumer:

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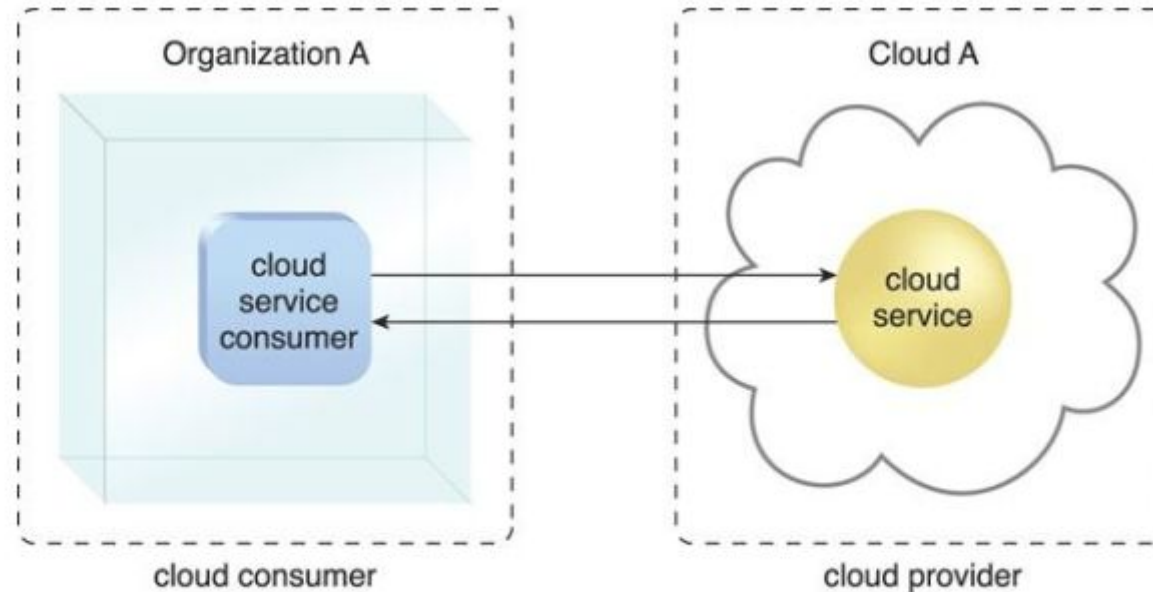

Figure 4.1. A cloud consumer (Organization A) interacts with a cloud service from a cloud provider (that owns Cloud A). Within Organization A, the cloud service consumer is being used to access the cloud service.

Roles (Cont.)

Cloud Service Owner:

- The person 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.

- For example, either the cloud consumer of Cloud X or the cloud provider of Cloud X could **own** Cloud Service A.

- A cloud service owner is **not called a cloud resource owner** because the cloud service owner role only applies to cloud services (which are externally accessible IT resources that reside in a cloud).

Roles (Cont.)

Cloud Service Owner:

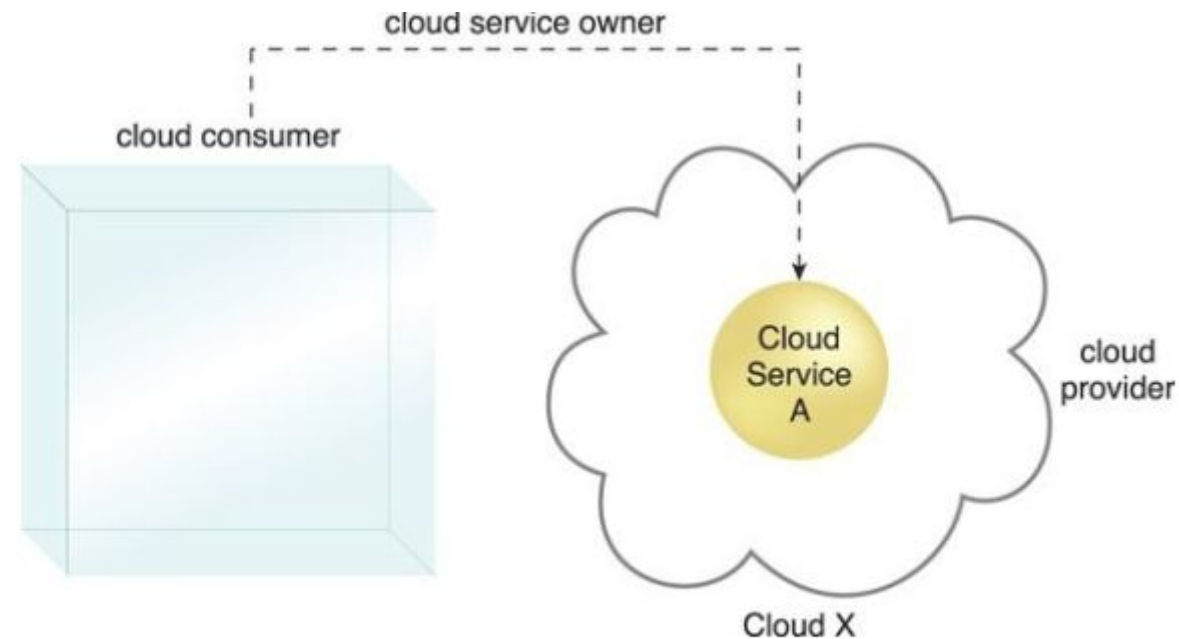- **Tower technologies web server deployed in a VM that resides in PTCL cloud.**

Figure 4.2. A cloud consumer can be a cloud service owner when it deploys its own service in a cloud.

Roles (Cont.)

Cloud Service Owner:

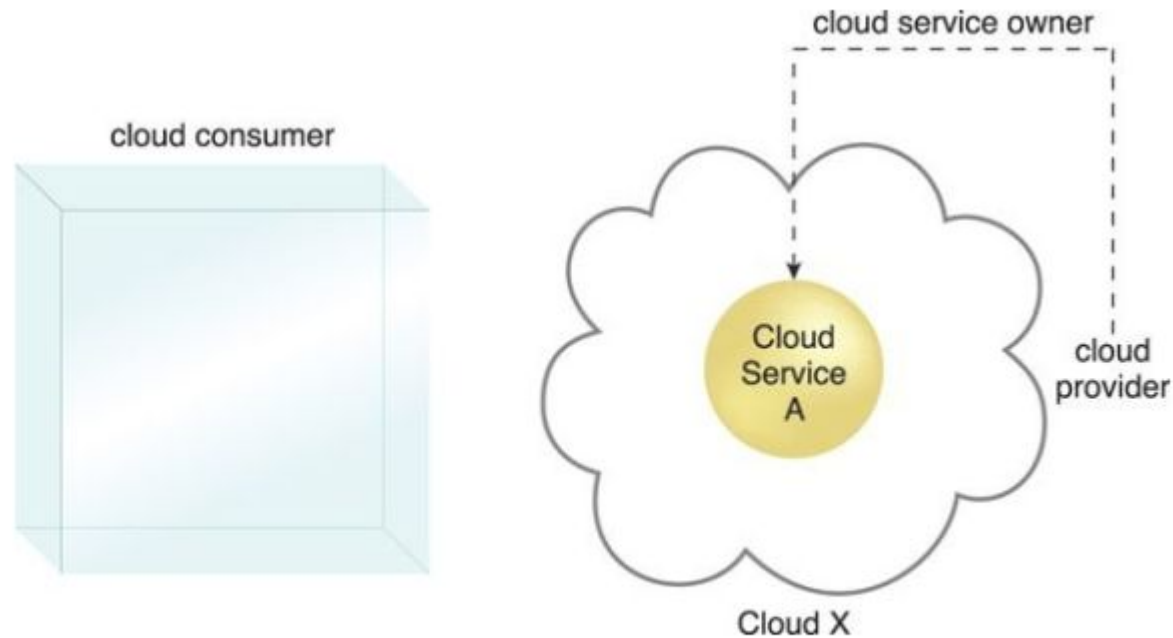- **AWS EC2 Instance available as a service in AWS cloud for the consumers.**

Figure 4.3. A cloud provider becomes a cloud service owner if it deploys its own cloud service, typically for other cloud consumers to use.

Roles (Cont.)

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 belong to **consumer or provider** of the cloud within which the cloud service resides.

- The cloud resource administrator can also belong to a **third-party organization** contracted to administer the cloud based IT resource.
  - Example: NUCES is using an AWS service administered by Systems Limited.

Roles (Cont.)

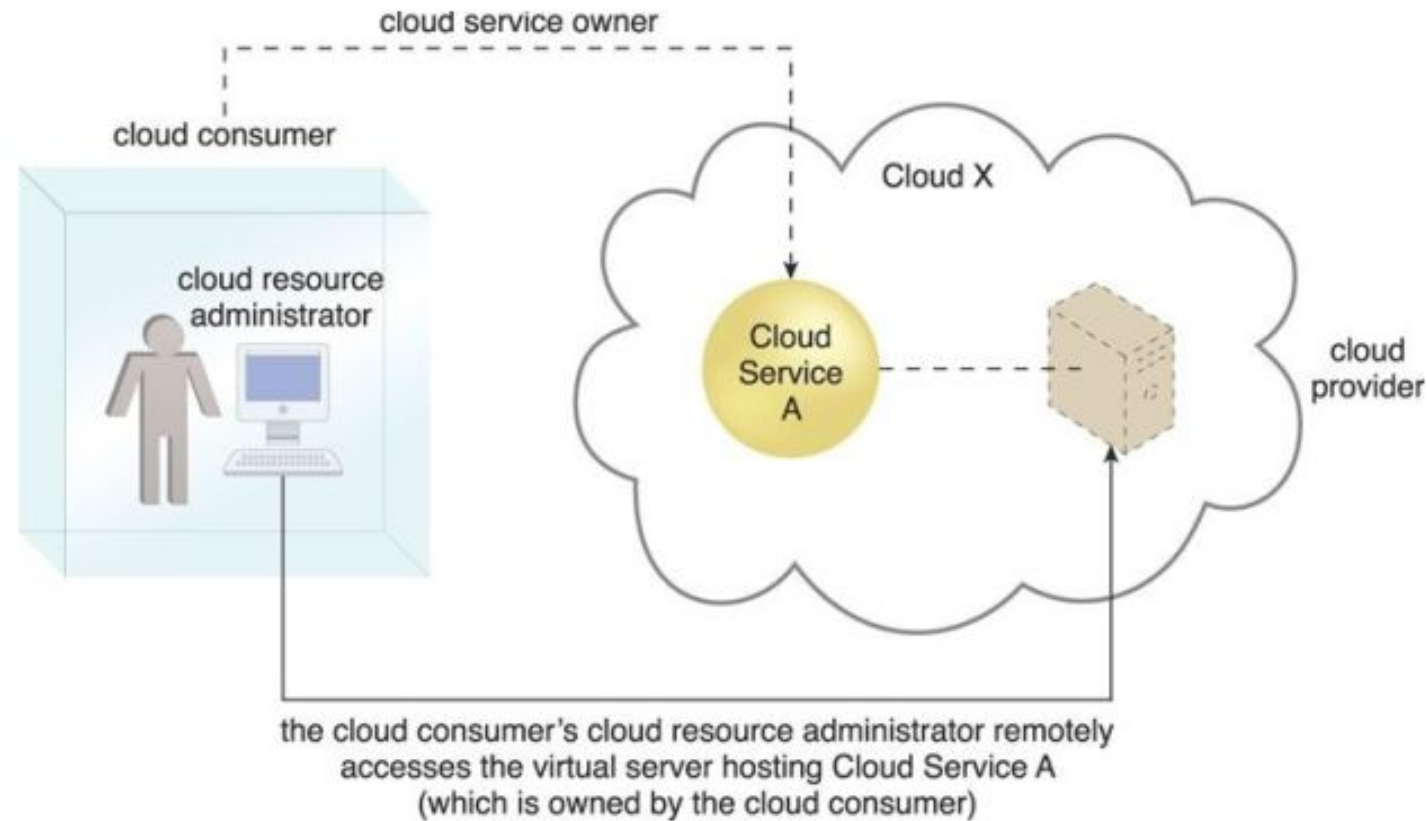## Cloud Resource Administrator:

Figure 4.4. A cloud resource administrator can be with a cloud consumer organization and administer remotely accessible IT resources that belong to the cloud consumer.

Roles (Cont.)

Cloud Resource Administrator:

cloud service owner

cloud consumer

Cloud X

Cloud Service A

cloud provider

cloud resource administrator

the cloud provider's cloud resource administrator accesses the virtual server that's hosting Cloud Service A (which is owned by the cloud provider)
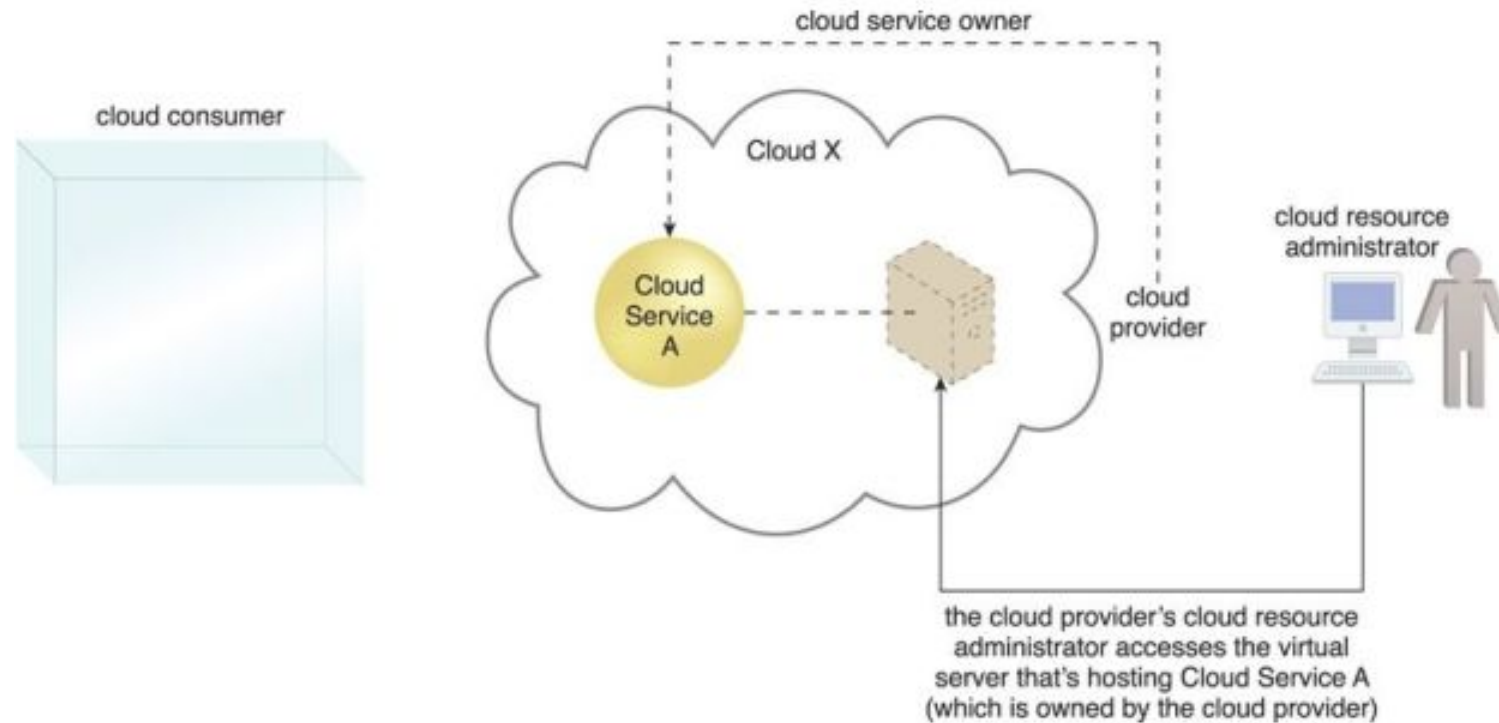
Figure 4.5. A cloud resource administrator can be with a cloud provider organization for which it can administer the cloud provider's internally and externally available IT resources.

Roles (Cont.)

Cloud Auditor:

- A third-party (often accredited) that **conducts independent assessments** of cloud environments assumes the role of the cloud auditor.

- The **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 endorsement) of a cloud environment to help strengthen the trust relationship between cloud consumers and cloud providers.

Roles (Cont.)

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, and arbitrage.

- Can be a person from cloud provider's marketing or business department.

- Can be a third party organization providing consulting services.

Roles (Cont.)

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 normally assumed by network and telecommunication providers.**

- **Example: VU using PTCL cloud using two communication links.**
  - **Communication link from OneLink**
  - **Communication link from PTCL**

Boundaries

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.

- Clouds have their own organizational boundary.

Boundaries (Cont.)
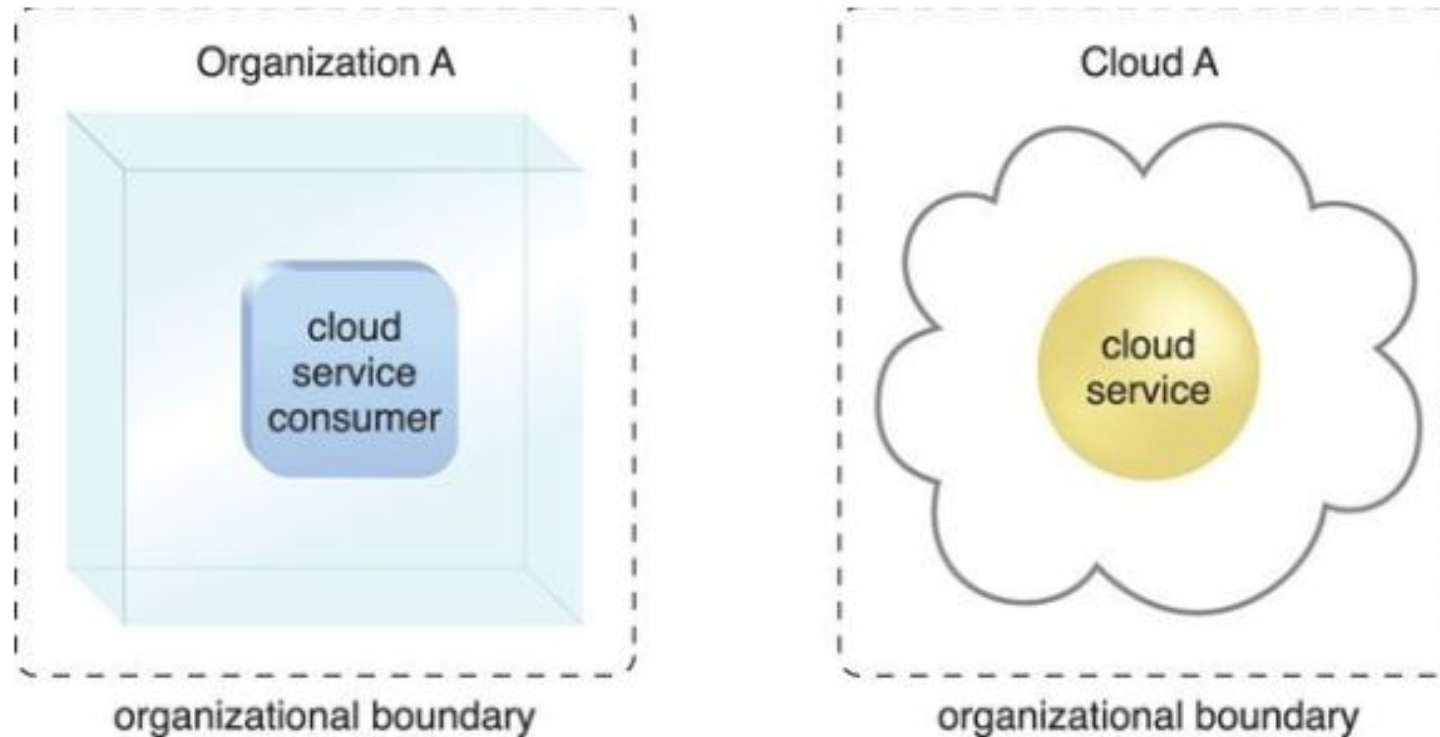
Organizational Boundary:

Figure 4.6. Organizational boundaries of a cloud consumer (left), and a cloud provider (right), represented by a broken line notation.

Boundaries (Cont.)

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 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.
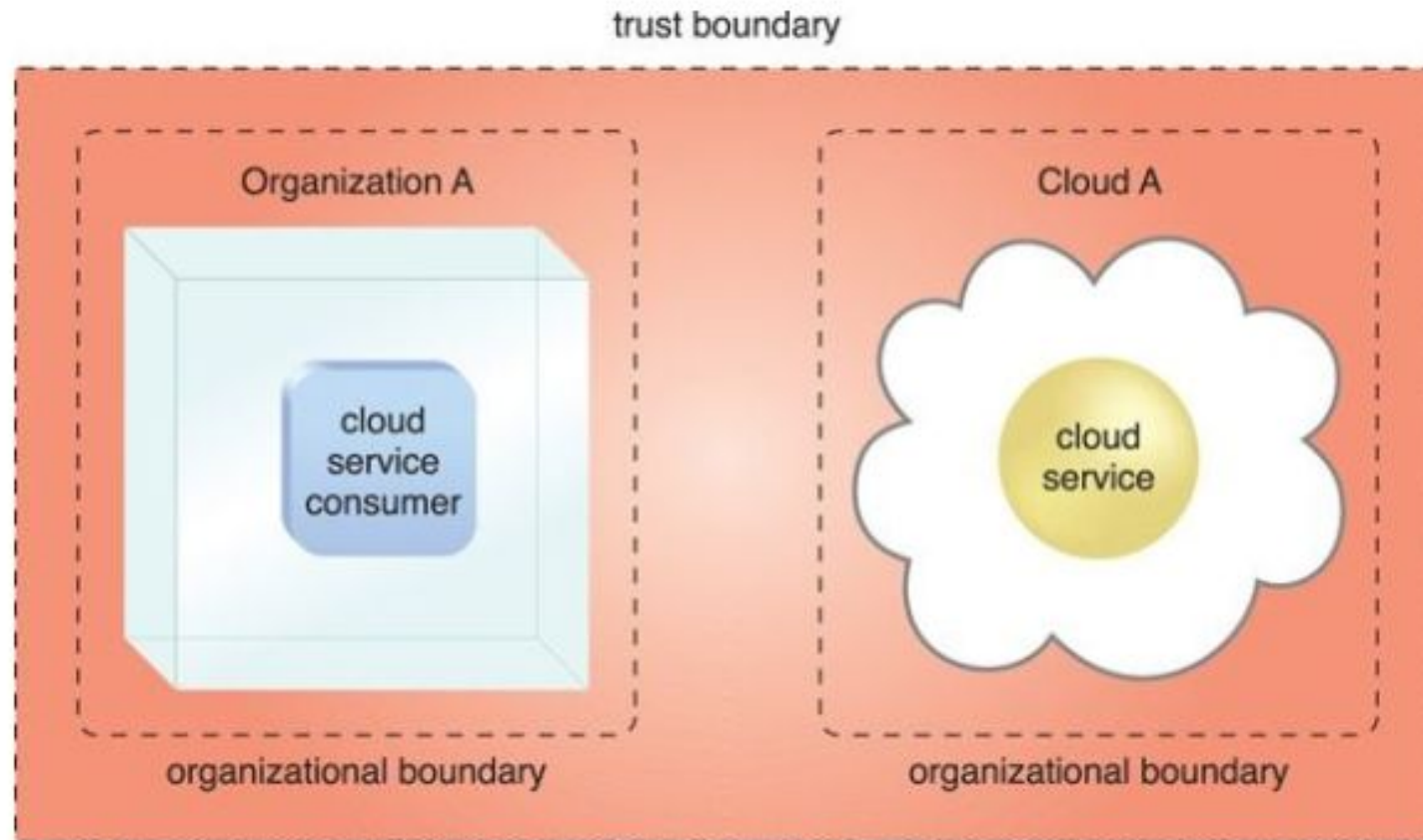
Boundaries (Cont.)

Trust Boundary:

Figure 4.7. An extended trust boundary encompasses the organizational boundaries of the cloud provider and the cloud consumer.

Roles and Boundaries – Key Points

- **Common roles associated with cloud-based interaction and relationships include the cloud provider, cloud consumer, cloud service owner, and cloud resource administrator.**

- **An organizational boundary represents the physical scope of IT resources owned and governed by an organization.**

- **A trust boundary is the logical perimeter that encompasses the IT resources trusted by an organization.**

Lecture's Agenda

- Roles and Boundaries

- **Cloud Characteristics**

- Cloud Service / Delivery Models

- Cloud Deployment Models

Cloud Characteristics

- **On-demand usage**

- **Ubiquitous access**

- **Multitenancy (and resource pooling)**

- **Elasticity**

- **Measured usage**

- **Resiliency (not included in NIST's definition)**

Cloud Characteristics (Cont.)

On-demand Usage:

- A cloud consumer can **unilaterally access** cloud-based IT resources giving the cloud consumer the freedom to self-provision 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.

Cloud Characteristics (Cont.)

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, and security technologies.

- To enable this level of access, cloud service architecture must be tailored to the particular needs of different cloud service consumers.

Cloud Characteristics (Cont.)

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.**

Cloud Characteristics (Cont.)

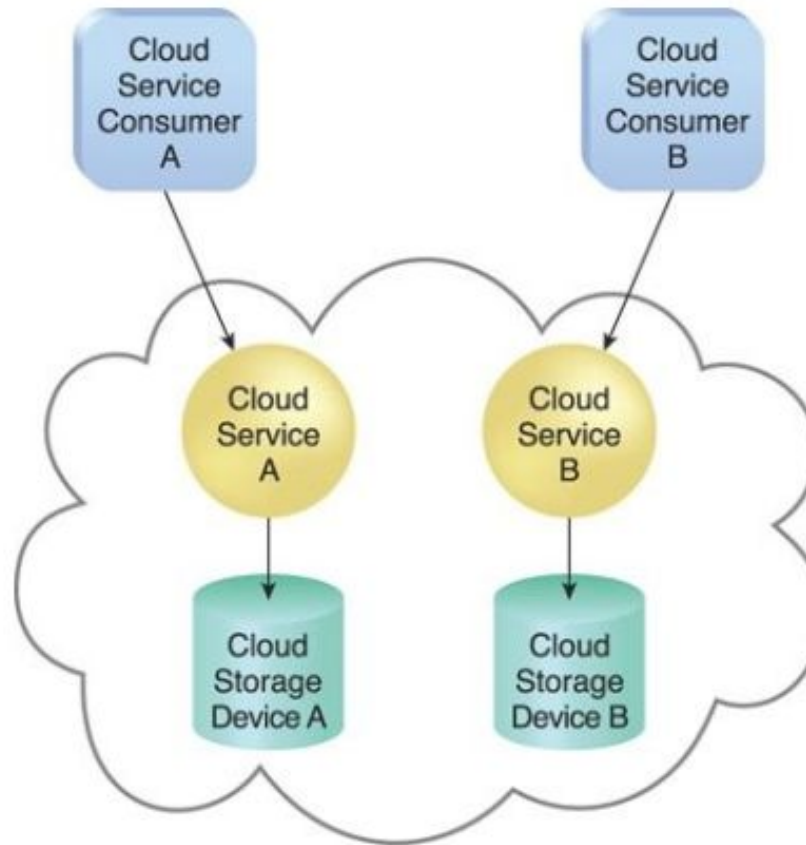## Multitenancy (and Resource Pooling):

Figure 4.8. In a single-tenant environment, each cloud consumer has a separate IT resource instance.

Cloud Characteristics (Cont.)
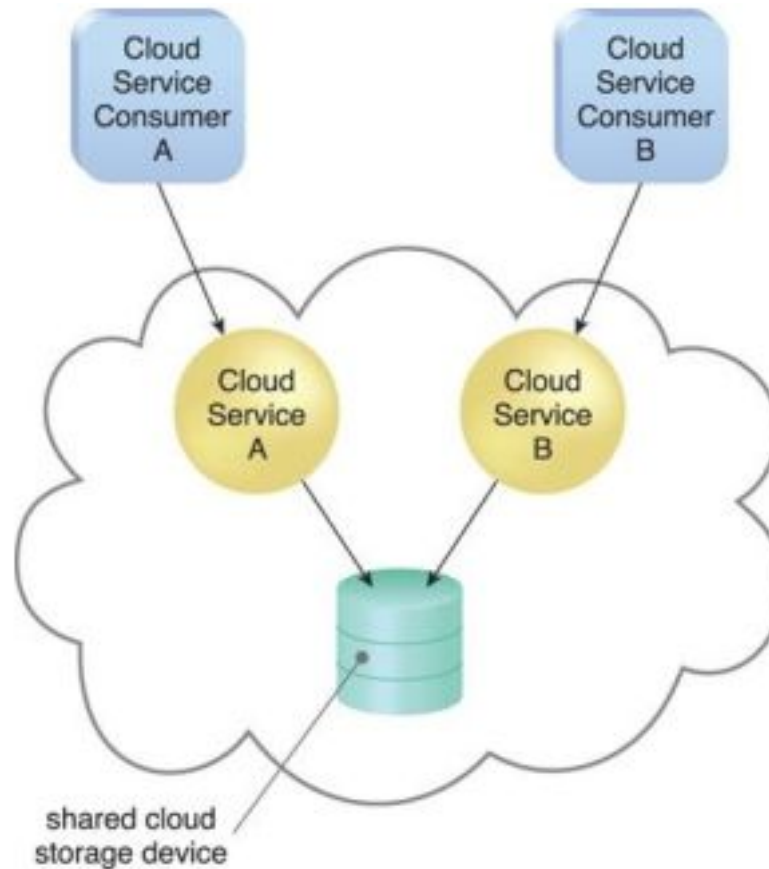
Multitenancy (and Resource Pooling):

Figure 4.9. In a multitenant environment, a single instance of an IT resource, such as a cloud storage device, serves multiple consumers.

Cloud Characteristics (Cont.)

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 considered a core justification for the adoption of cloud computing.**

- **Cloud providers with vast IT resources can offer the greatest range of elasticity.**

Cloud Characteristics (Cont.)

Measured Usage:

- The measured usage characteristic represents the ability of a cloud platform to keep track of the usage of its IT resources, primarily by cloud consumers.

- Based on what is measured, the cloud provider can charge a cloud consumer only for the IT resources actually used and/or for the timeframe during which access to the IT resources was granted.

Cloud Characteristics (Cont.)

Resiliency:

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

- **IT resources can be pre-configured so that if one becomes deficient, processing is automatically handed over to another redundant implementation.**

- **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.**

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

Cloud Characteristics (Cont.)
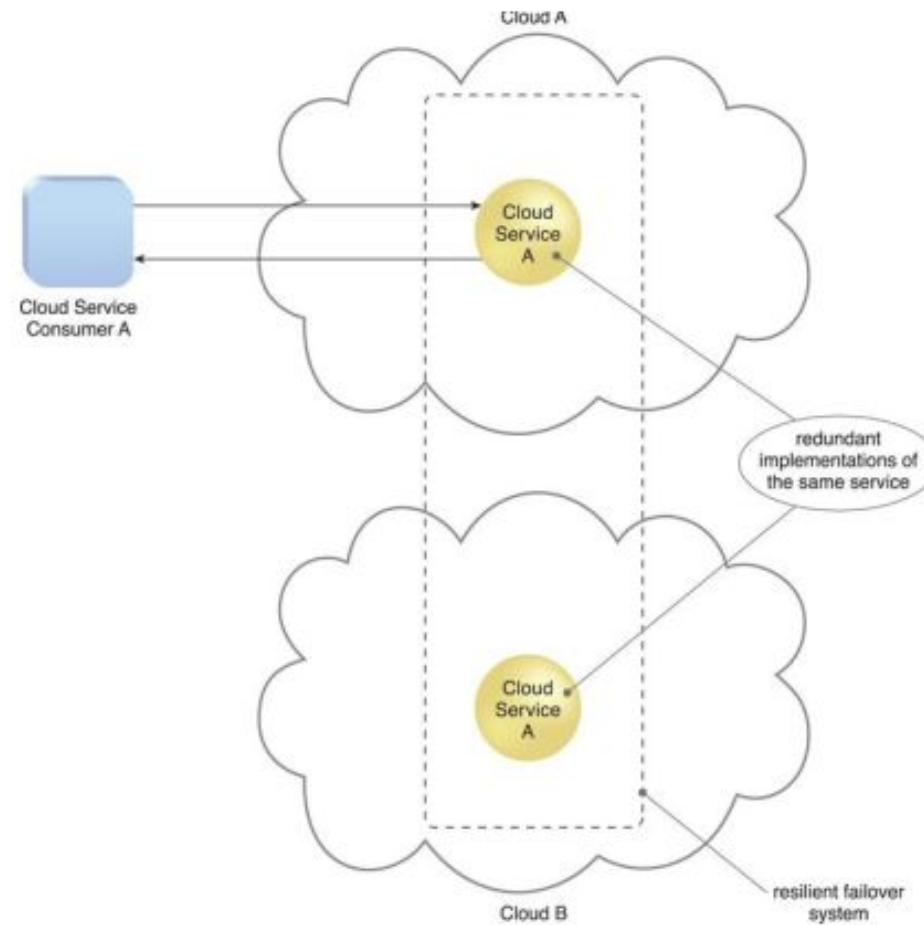
Resiliency:

Figure 4.10. 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 Characteristics – Key Points

- **On-demand usage is the ability of a cloud consumer to self-provision and use necessary cloud-based services without requiring cloud provider interaction.**

- **On-demand usage is related to measured usage, which represents the ability of a cloud to measure the usage of its IT resources.**

- **Ubiquitous access allows cloud-based services to be accessed by diverse cloud service consumers.**

Cloud Characteristics – Key Points (Cont.)

- **Multitenancy is the ability of a single instance of an IT resource to transparently serve multiple cloud consumers simultaneously.**

- **The elasticity represents the ability of a cloud to transparently and automatically scale IT resources out or in.**

- **Resiliency pertains to a cloud's inherent failover features of availability and reliability.**

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- Cloud Deployment Models

Cloud Delivery Models

- A cloud delivery model represents a specific, pre-packaged combination of IT resources offered by a cloud provider.

- 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)

- These models are interrelated in how the scope of one can encompass the scope of another.

Cloud Delivery Models (Cont.)

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

Infrastructure-as-a-Service (IaaS)

- 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.

- 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.

- A central and primary IT resource within a IaaS environment is the **virtual server**.

- Virtual servers are leased by specifying **server hardware requirements** (processor capacity, memory, and local storage space) etc.
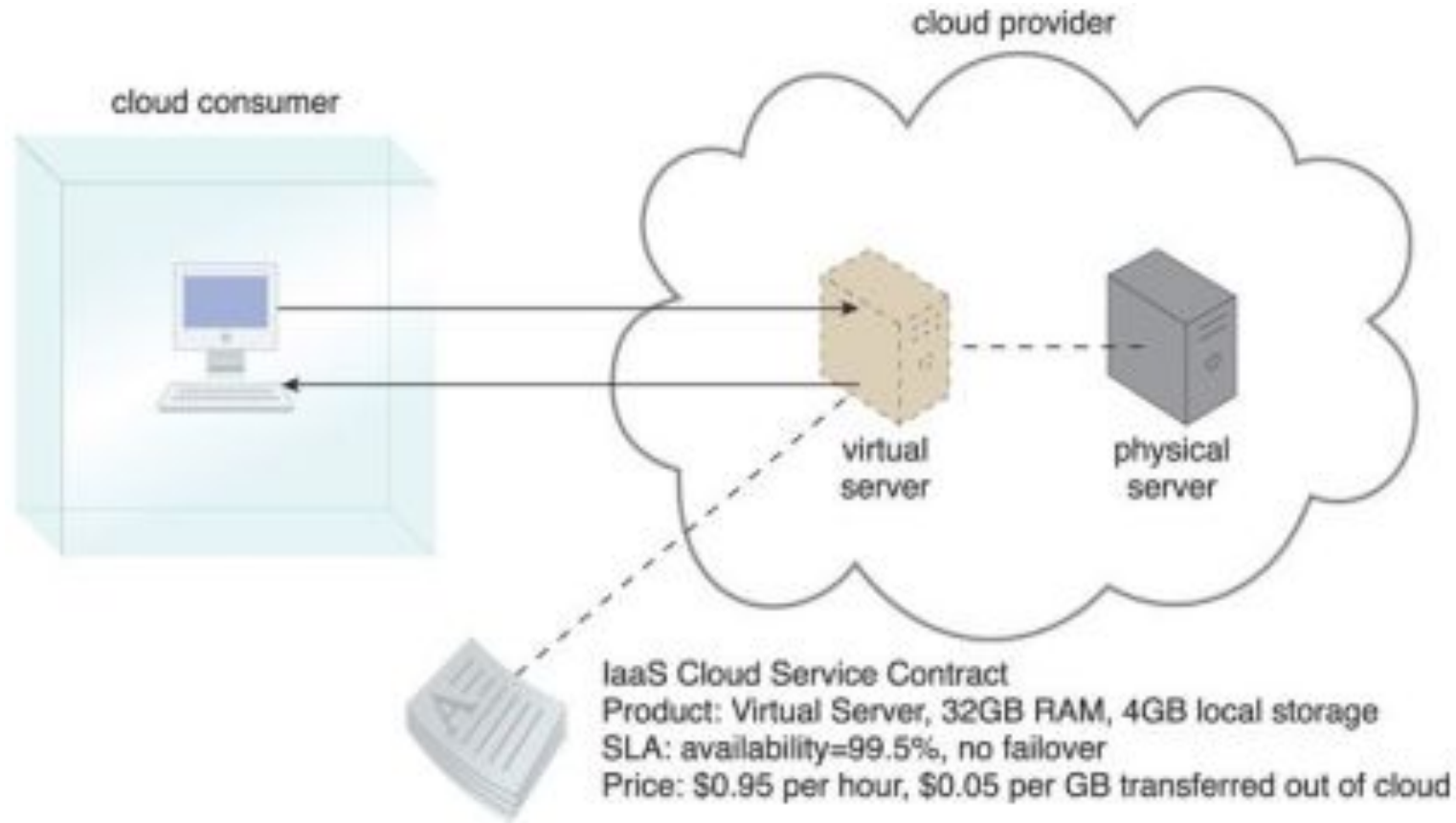
Infrastructure-as-a-Service (Cont.)

Figure 4.11. 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.

IaaS Examples

Example services managed by the customer

Amazon EC2

Amazon Elastic Block Store (Amazon EBS)

Amazon Virtual Private Cloud (Amazon VPC)

Platform-as-a-Service (PaaS)

- **Represents a pre-defined "ready-to-use" environment comprised of already deployed and configured IT resources.**

- **PaaS relies on (and is primarily defined by) the usage of a readymade environment that establishes a set of pre-packaged products and tools used to support the entire delivery lifecycle of custom applications.**

- **By working within a ready-made platform, the cloud consumer is spared the administrative burden of setting up and maintaining the bare infrastructure IT resources provided via the IaaS model.**

- **However, the cloud consumer is granted a lower level of control over the underlying IT resources that host and provision the platform.**

Platform-as-a-Service (Cont.)

ready-made environment

cloud consumer

virtual server

cloud provider

PaaS Cloud Service Contract
Product: application server + DMBS platforms
SLA: availability=99.5%, auto-scaling
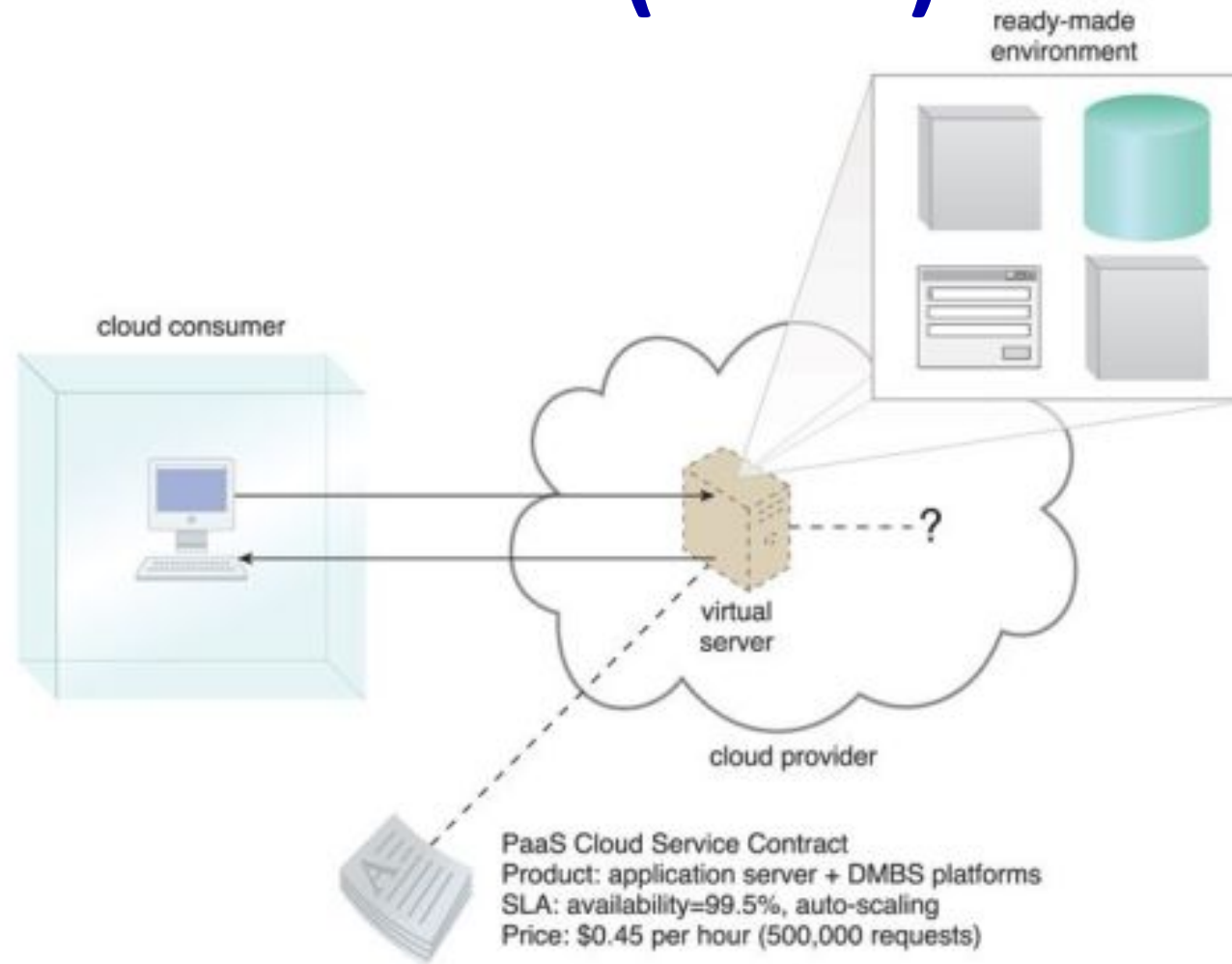Price: $0.45 per hour (500,000 requests)

Figure 4.12. A cloud consumer is accessing a ready-made PaaS environment. The question mark indicates that the cloud consumer is intentionally shielded from the implementation details of the platform.

PaaS Examples

Example services managed by AWS

AWS
Lambda

Amazon
Relational Database
Service (Amazon RDS)

AWS Elastic
Beanstalk

Software-as-a-Service (SaaS)

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

- SaaS is used to make a reusable cloud service widely available to a range of cloud consumers.

- An entire marketplace exists around SaaS products that can be leased and used for different purposes and via different terms.

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

- Examples: Google Classes, MS Teams, Netflix etc.
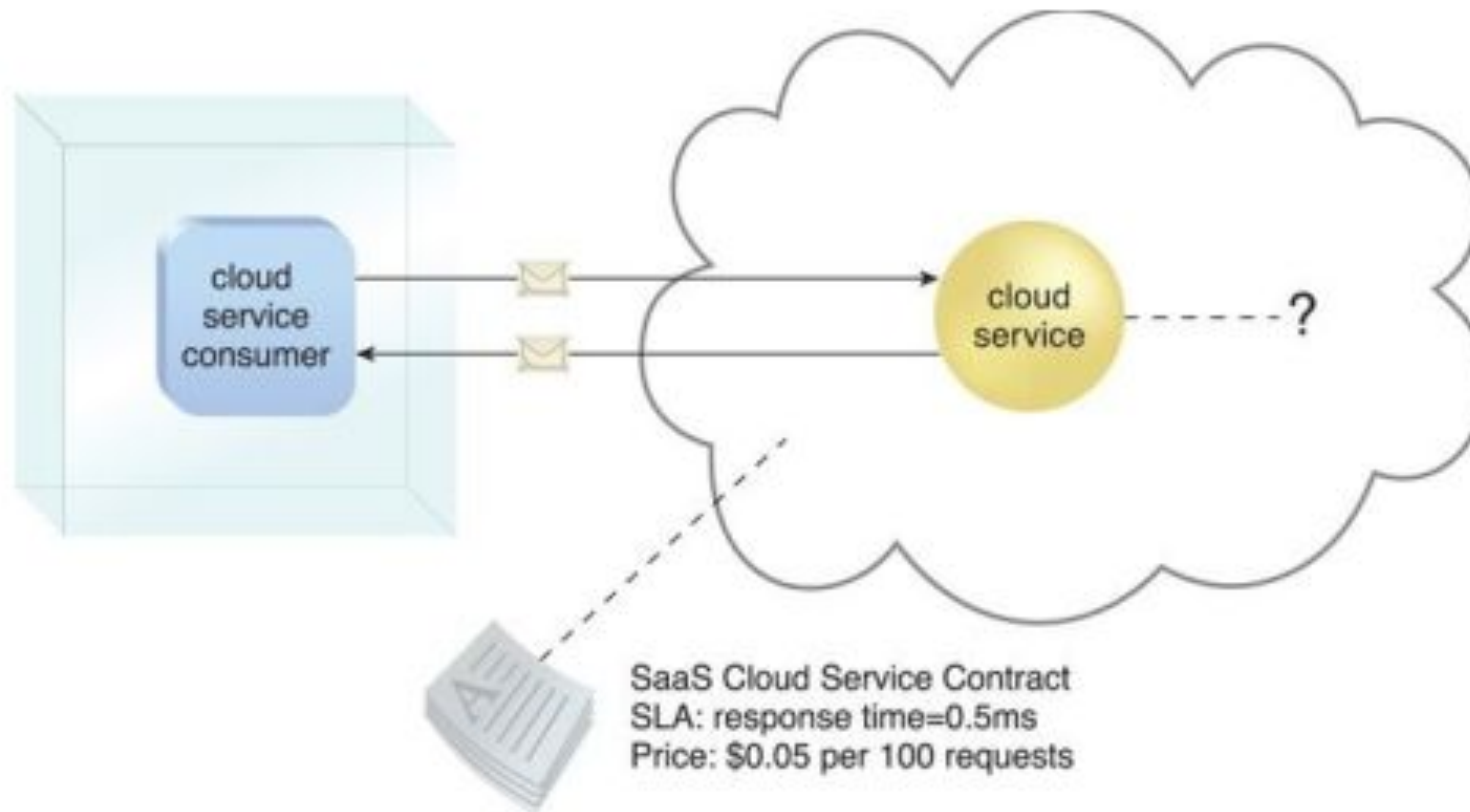
Software-as-a-Service (Cont.)

SaaS Cloud Service Contract
SLA: response time=0.5ms
Price: $0.05 per 100 requests

Figure 4.13. The cloud service consumer is given access the cloud service contract, but not to any underlying IT resources or implementation details.

SaaS Examples

SaaS examples

AWS Trusted Advisor

AWS Shield

Amazon Chime

Comparing Cloud Delivery Models

Layer	Infrastructure as a Service (IaaS)	Platform as a Service (PaaS)	Software as a Service (SaaS)
Data	Customer responsibility	Customer responsibility	Customer responsibility
Application	Customer responsibility	Customer responsibility	Cloud provider responsibility
Operating system	Customer responsibility	Cloud provider responsibility	Cloud provider responsibility
Virtualization	Cloud provider responsibility	Cloud provider responsibility	Cloud provider responsibility
Servers	Cloud provider responsibility	Cloud provider responsibility	Cloud provider responsibility
Storage	Cloud provider responsibility	Cloud provider responsibility	Cloud provider responsibility
Network	Cloud provider responsibility	Cloud provider responsibility	Cloud provider responsibility
Physical	Cloud provider responsibility	Cloud provider responsibility	Cloud provider responsibility

Comparing Cloud Delivery Models (Cont.)

Table 4.1. 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 (Cont.)

Table 4.2. Typical activities carried out by cloud consumers and cloud providers in relation to the cloud delivery models.

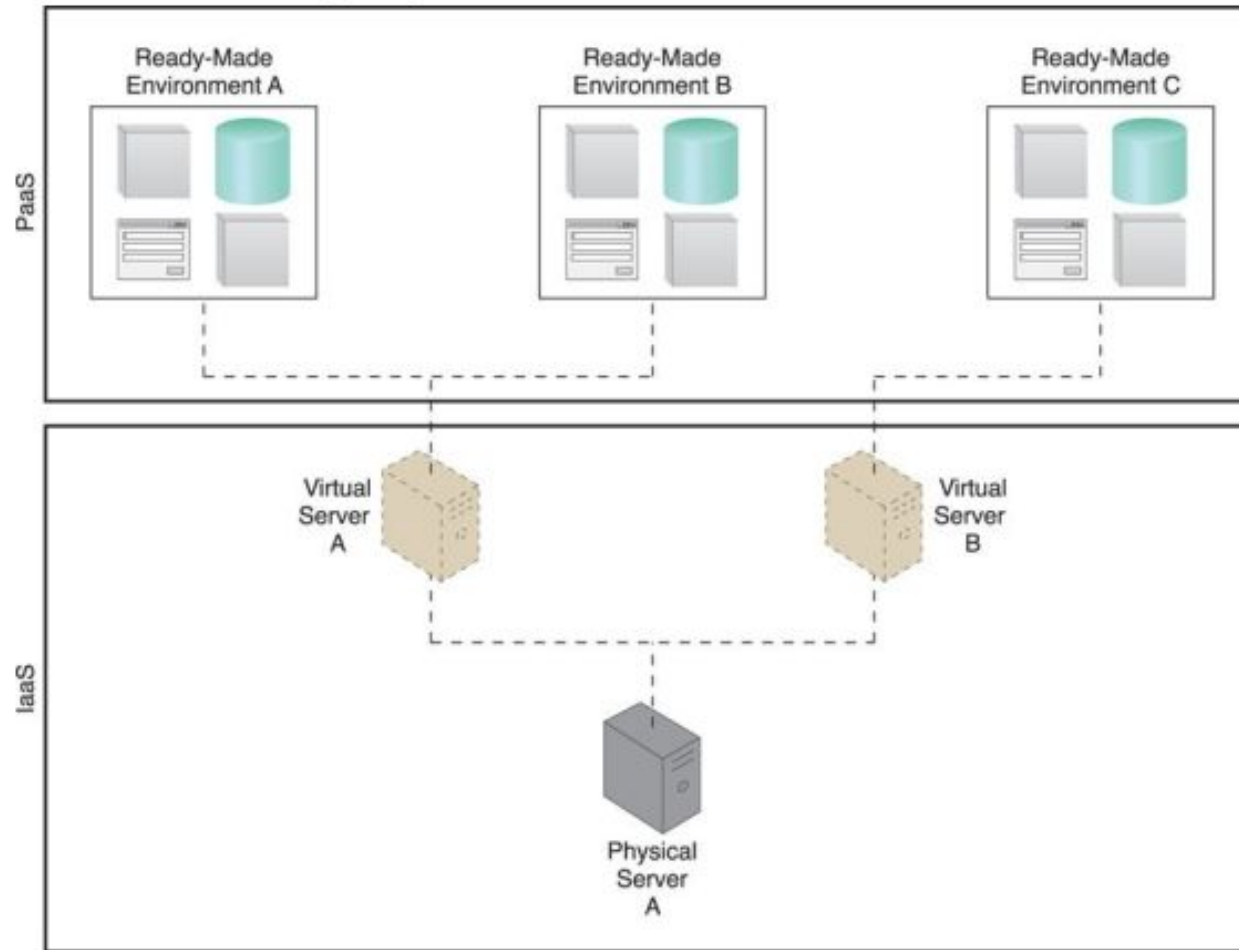| Cloud Delivery Model	Common Cloud Consumer Activities	Common Cloud Provider Activities
SaaS	uses and configures cloud service	implements, manages, and maintains cloud service monitors usage by cloud consumers
PaaS	develops, tests, deploys, and manages cloud services and cloud-based solutions	pre-configures 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

Figure 4.14. A PaaS environment based on the IT resources provided by an underlying IaaS environment.

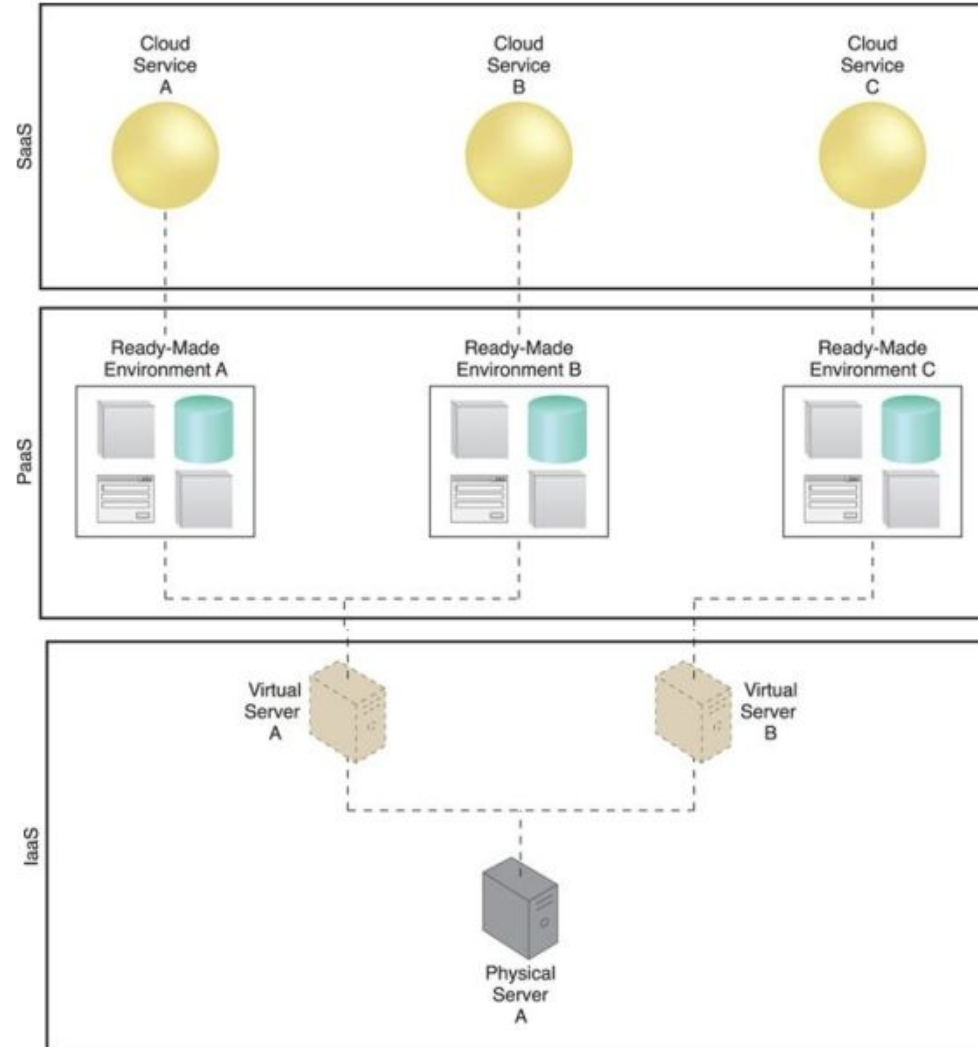# Combining Cloud Delivery Models (Cont.)

Figure 4.16. A simple layered view of an architecture comprised of IaaS and PaaS environments hosting three SaaS cloud service implementations.

Cloud Delivery Models – Key Points

- IaaS offers cloud consumers a high level of administrative control over "raw" infrastructure-based IT resources.

- PaaS enables a cloud provider to offer a pre-configured environment that cloud consumers can use to build and deploy cloud services and solutions, though with decreased administrative control.

- SaaS is a cloud delivery model for shared cloud services that can be positioned as commercialized products hosted by clouds.

- Different combinations of IaaS, PaaS, and SaaS are possible, depending on how cloud consumers and cloud providers choose to leverage the natural hierarchy established by these base cloud delivery models.

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- Roles and Boundaries

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- **Cloud Deployment Models**

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**

Public Cloud

- A public cloud is a **publicly accessible cloud** environment owned by a third-party cloud provider.

- The IT resources on public clouds are **provisioned** via cloud delivery models and are offered to cloud consumers at a pay-per-use cost.

- The cloud provider is **responsible** for the creation and on-going maintenance of the public cloud and its IT resources.
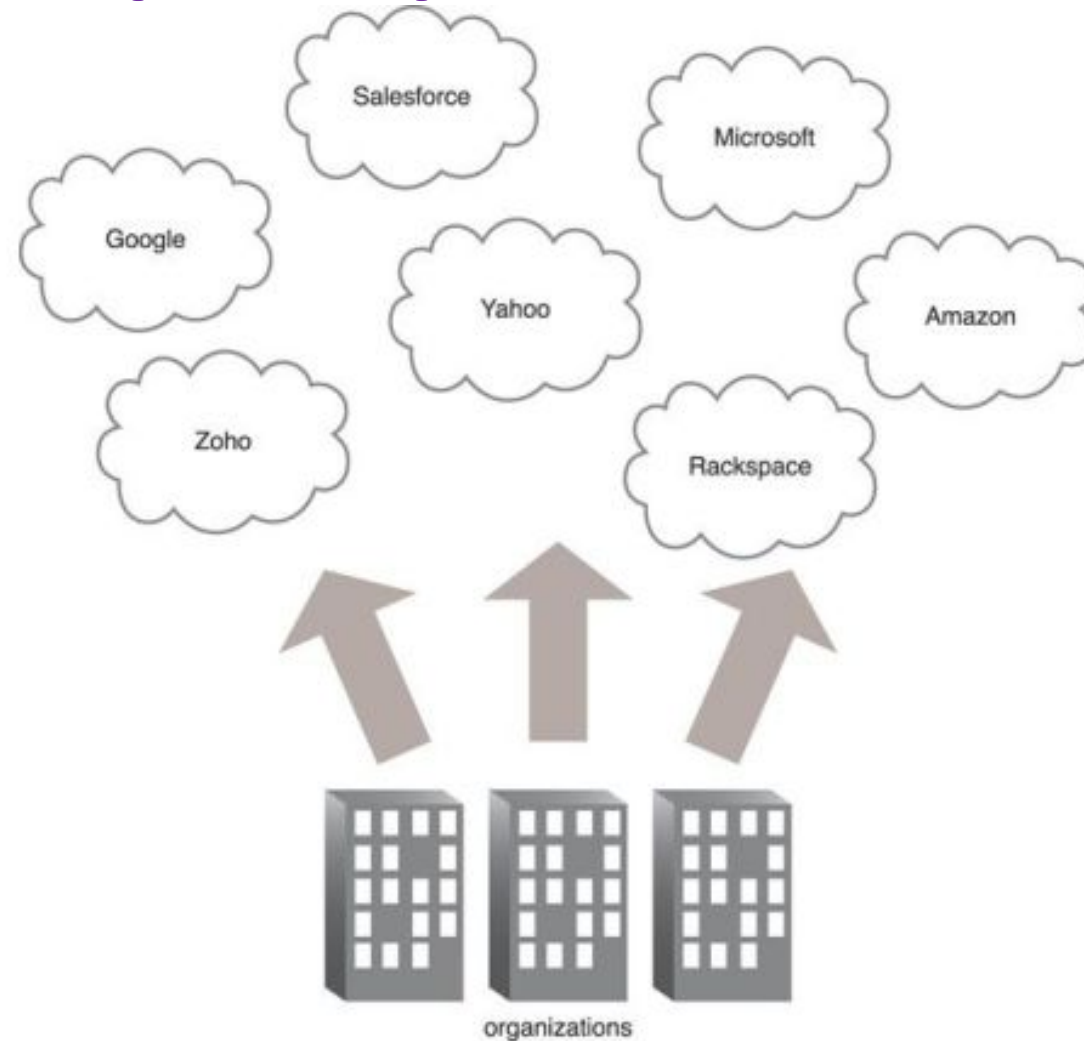
Public Cloud (Cont.)

Figure 4.17. Organizations act as cloud consumers when accessing cloud services and IT resources made available by different cloud providers.

Community Cloud

- 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 **share the responsibility** for defining and evolving the community cloud.
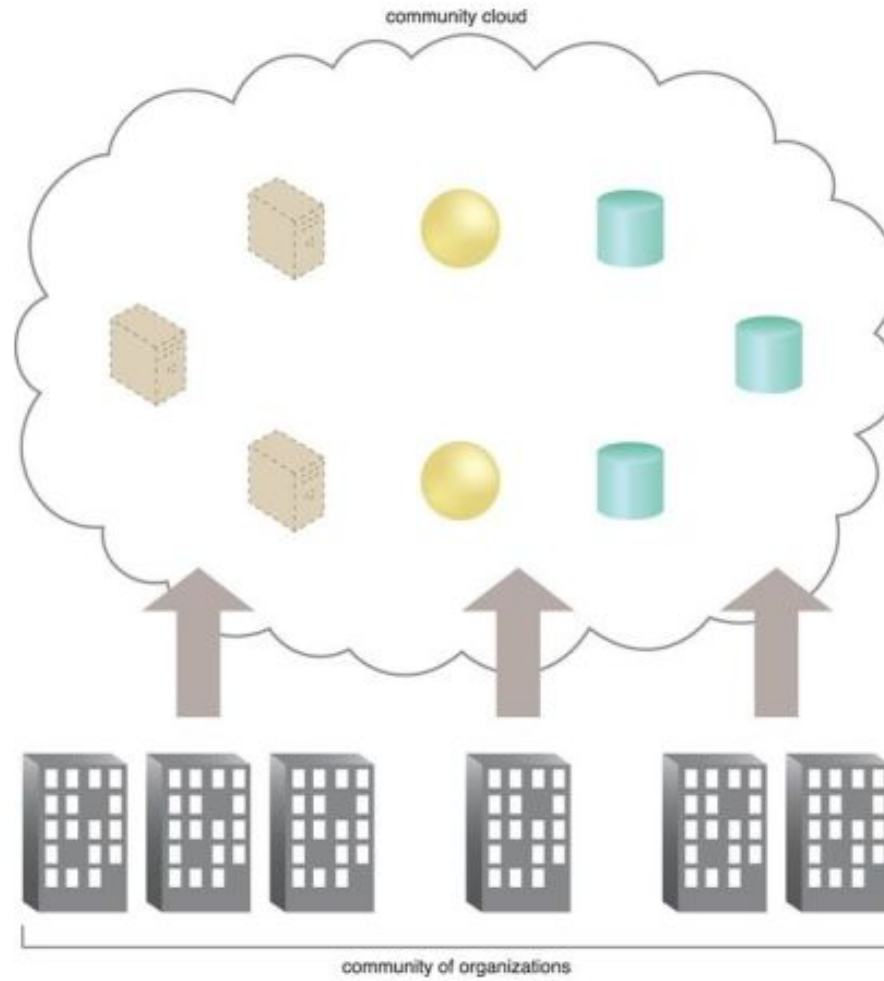
Community Cloud (Cont.)

community cloud

community of organizations

Figure 4.18. An example of a "community" of organizations accessing IT resources from a community cloud.

Private Cloud

- 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 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**
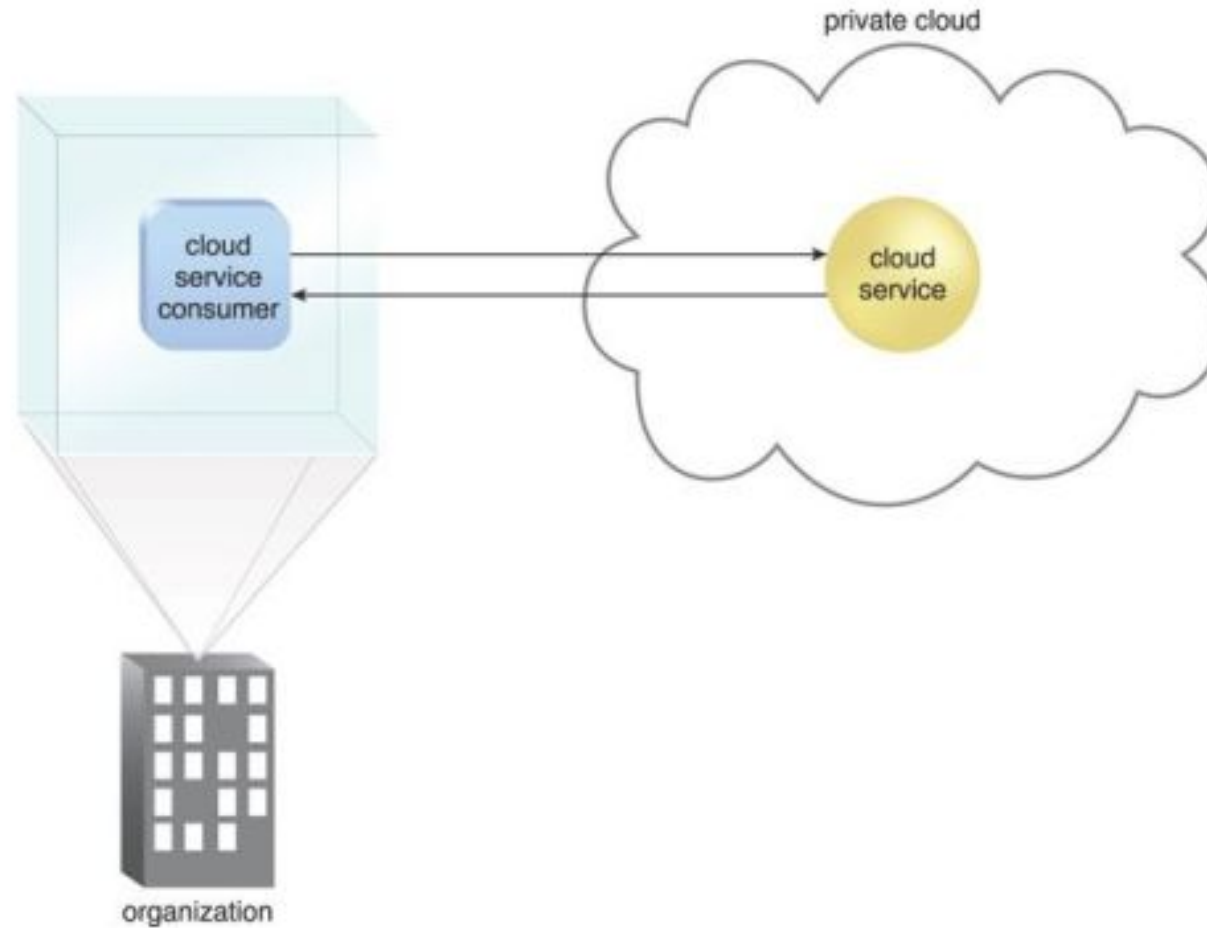
Private Cloud (Cont.)

Figure 4.19. 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.

Hybrid Cloud

- A hybrid cloud is comprised of two or more different cloud deployment models.

- A cloud consumer may choose to deploy cloud services processing sensitive data to a private cloud and less sensitive cloud services to a public cloud, the result of this combination is a hybrid deployment model.
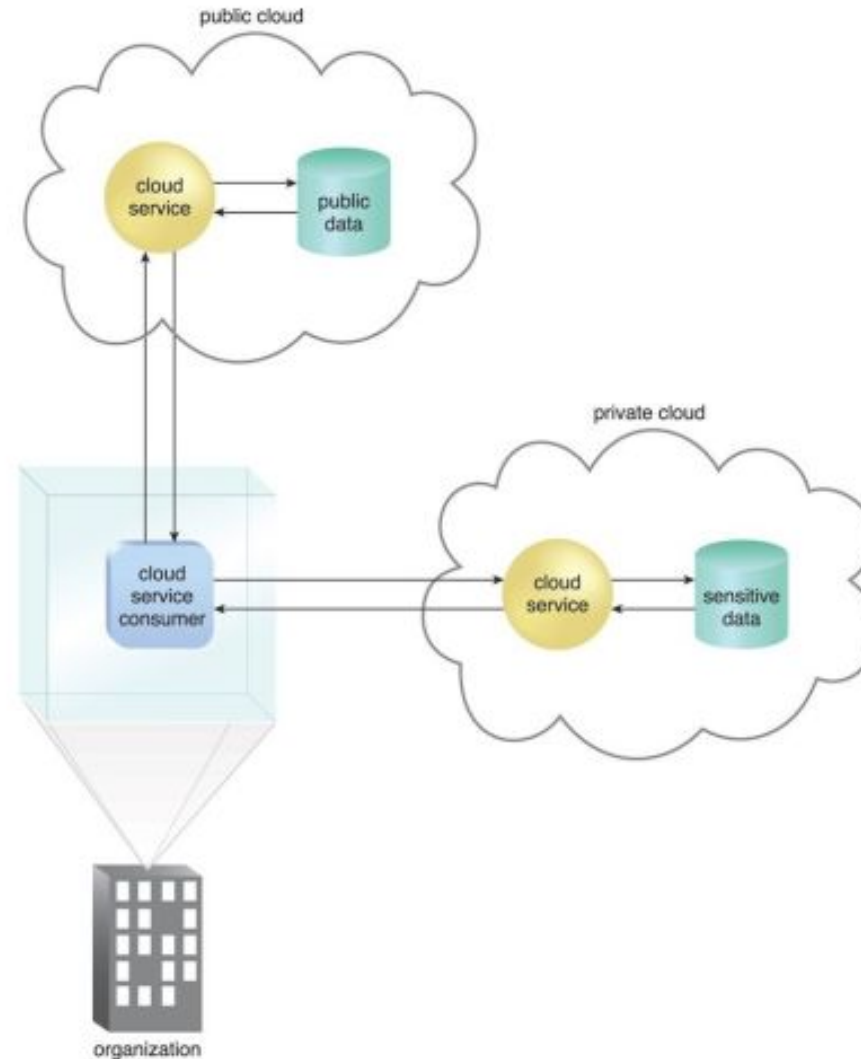
Hybrid Cloud (Cont.)

Figure 4.20. An organization using a hybrid cloud architecture that utilizes both a private and public cloud.

Cloud Deployment Models – Key Points

- A **public cloud** is owned by a third party and offers commercialized cloud services and IT resources to cloud consumer organizations.

- A **private cloud** is owned by an individual organization and resides within the organization's premises.

- A **community cloud** is limited for access by a group of cloud consumers that may also share responsibility in its ownership.

- A **hybrid cloud** is a combination of two or more cloud deployment models.

Organization Creation Steps in Cloud

1. Create a virtual organization
2. Create organizational virtual datacenter
3. Create edge service gateway – Public IPs Range
4. Create organization VDC network – Private IPs Range
5. Create and configure virtual machine
6. Private to Public IP NAT [SNAT / DNAT]
7. Access virtual machine using public IP via SSH / RDP

Additional Resources

- **Cloud Computing – Concepts, Technology, and Architecture** by Thomas Erl, Zaigham Mahmood, and Ricardo Puttini

   Chapter 4: Fundamental Concepts and Models

Questions?