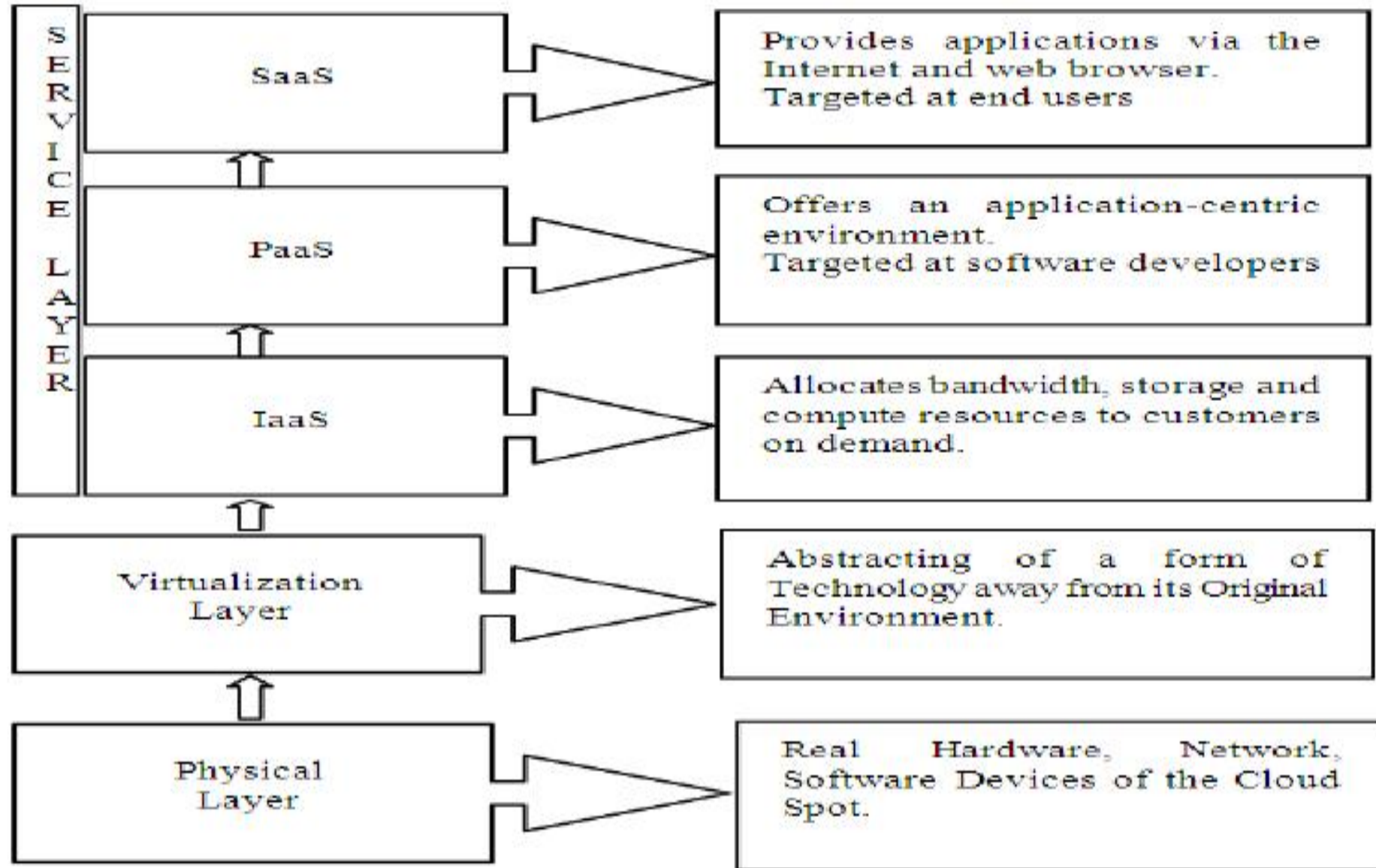# Cloud Computing UNIT 3

CLOUD ARCHITECTURE, SERVICES AND STORAGE

CONTENTS:

➢ Introduction

    ➢ Layered Architecture

    ➢ The National Institute of Standards and Technology **(NIST) Reference Architecture**

➢ Models for Cloud Computing

    ➢ Deployment Models

    ➢ Delivery Models

➢ Architectural Design Challenges

Cloud Architecture – LAYERED CLOUD ARCHITECTURE

SERVICE LAYER		
SaaS	→	Provides applications via the Internet and web browser. Targeted at end users
PaaS	→	Offers an application-centric environment. Targeted at software developers
IaaS	→	Allocates bandwidth, storage and compute resources to customers on demand.
Virtualization Layer	→	Abstracting of a form of Technology away from its Original Environment.
Physical Layer	→	Real Hardware, Network, Software Devices of the Cloud Spot.

Cloud Architecture – LAYERED CLOUD ARCHITECTURE

1) The Physical Layer:

- **The physical layer comprises compute, storage, and network resources, which are the fundamental physical computing resources that make up a cloud infrastructure.**

- This layer comprises of **physical servers, network and other aspects that can be physically managed and controlled.**

2) The Infrastructure Layer:

- The infrastructure layer that is developed on the virtualization technology where the service providers offer virtual machines as a service to the end-users.

- This includes storage facilities, **virtualized servers, and networking**. **Infrastructure as a Service** or IaaS points to delivery of services in hosted format.

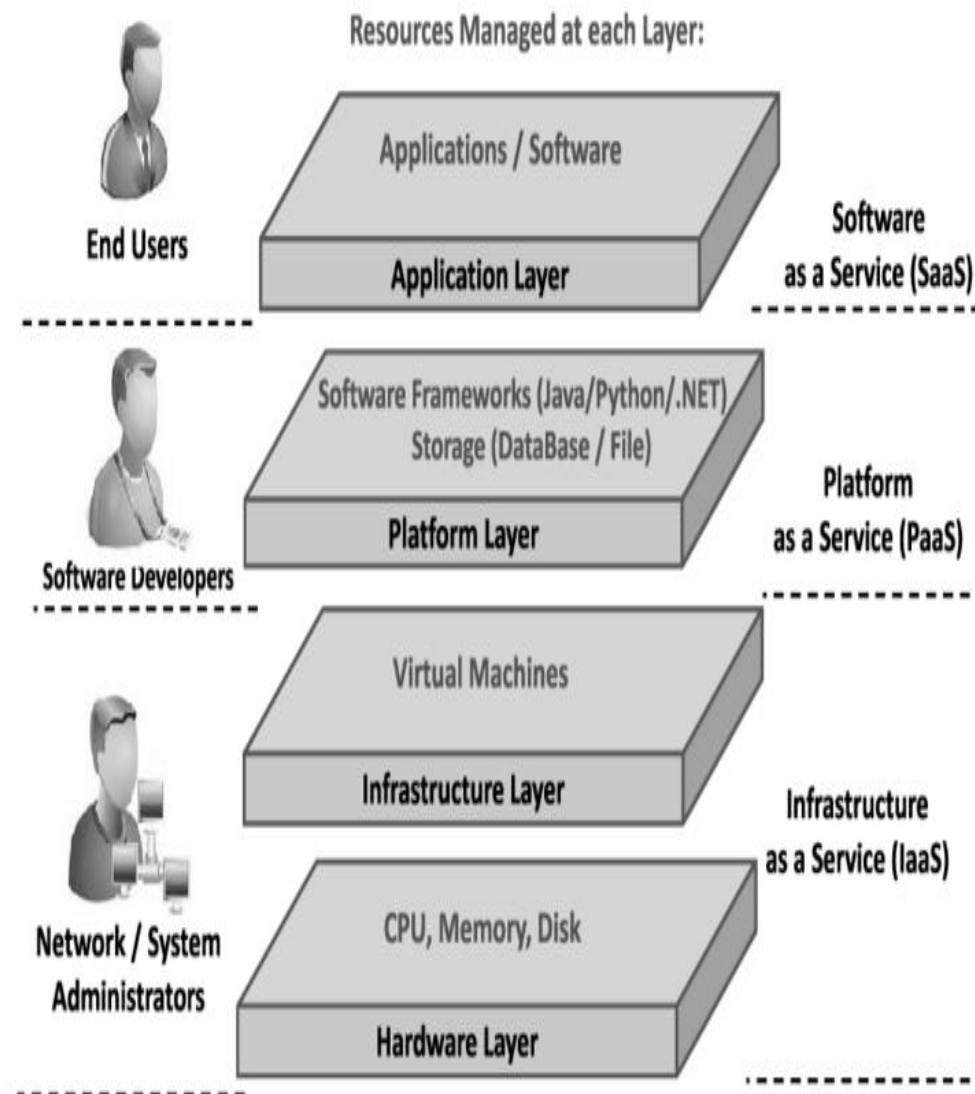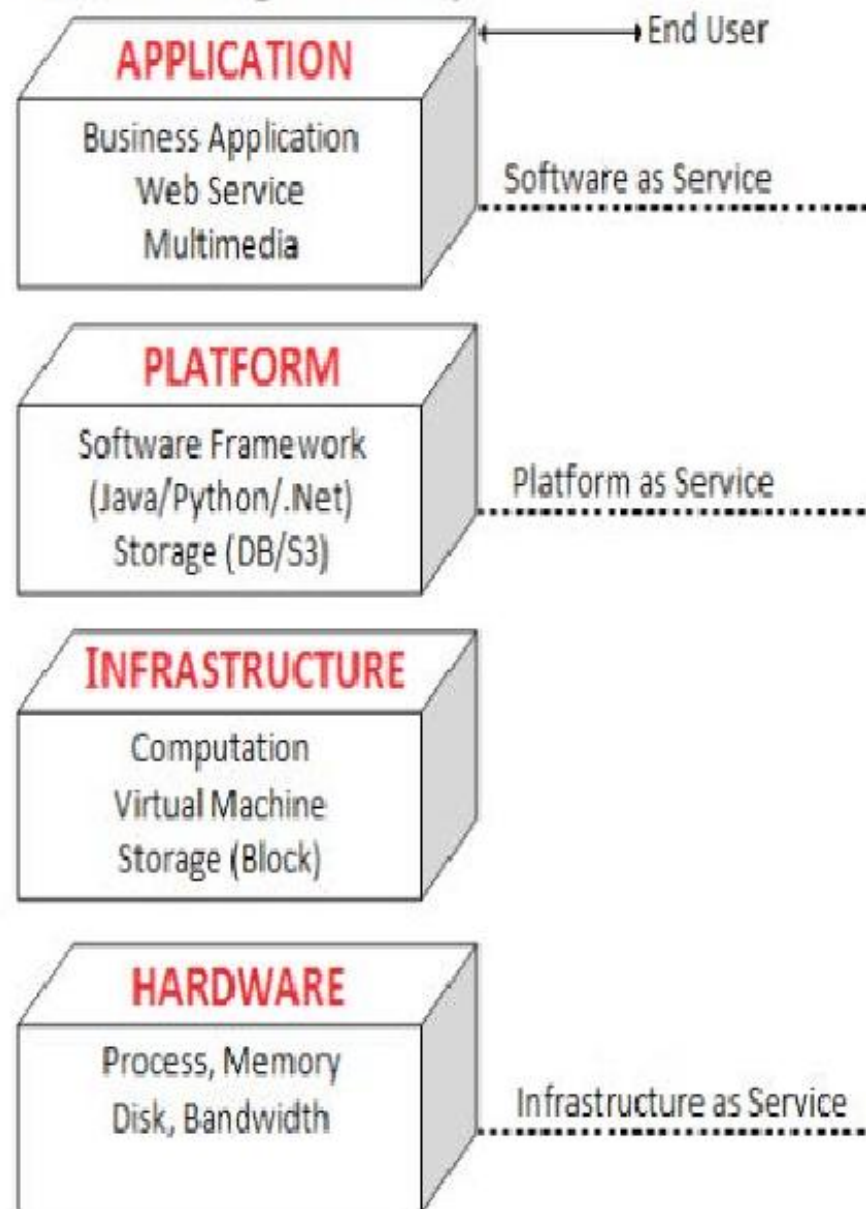# Cloud Architecture – LAYERED CLOUD ARCHITECTURE

3) Platform Layer:

- It serves as a **platform for development and deployment**. The Platform layer provides the right **platform for development and deployment of applications** vital for the cloud to run smoothly.
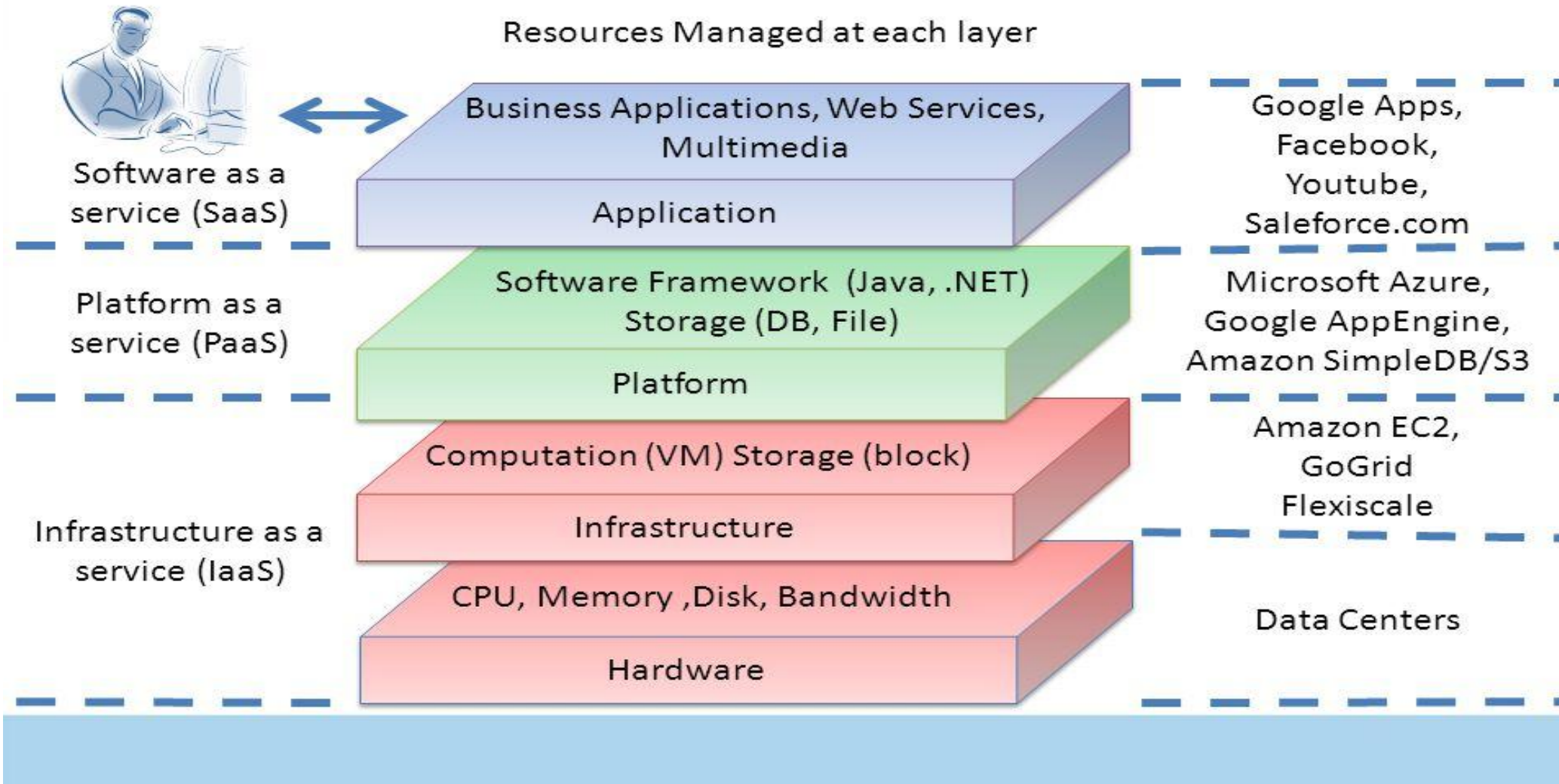
4) Application Layer:

- The Application Layer is the one that **end users interact with in a direct manner.** It mainly comprises of **software systems delivered as service. Examples are Gmail and Dropbox.**
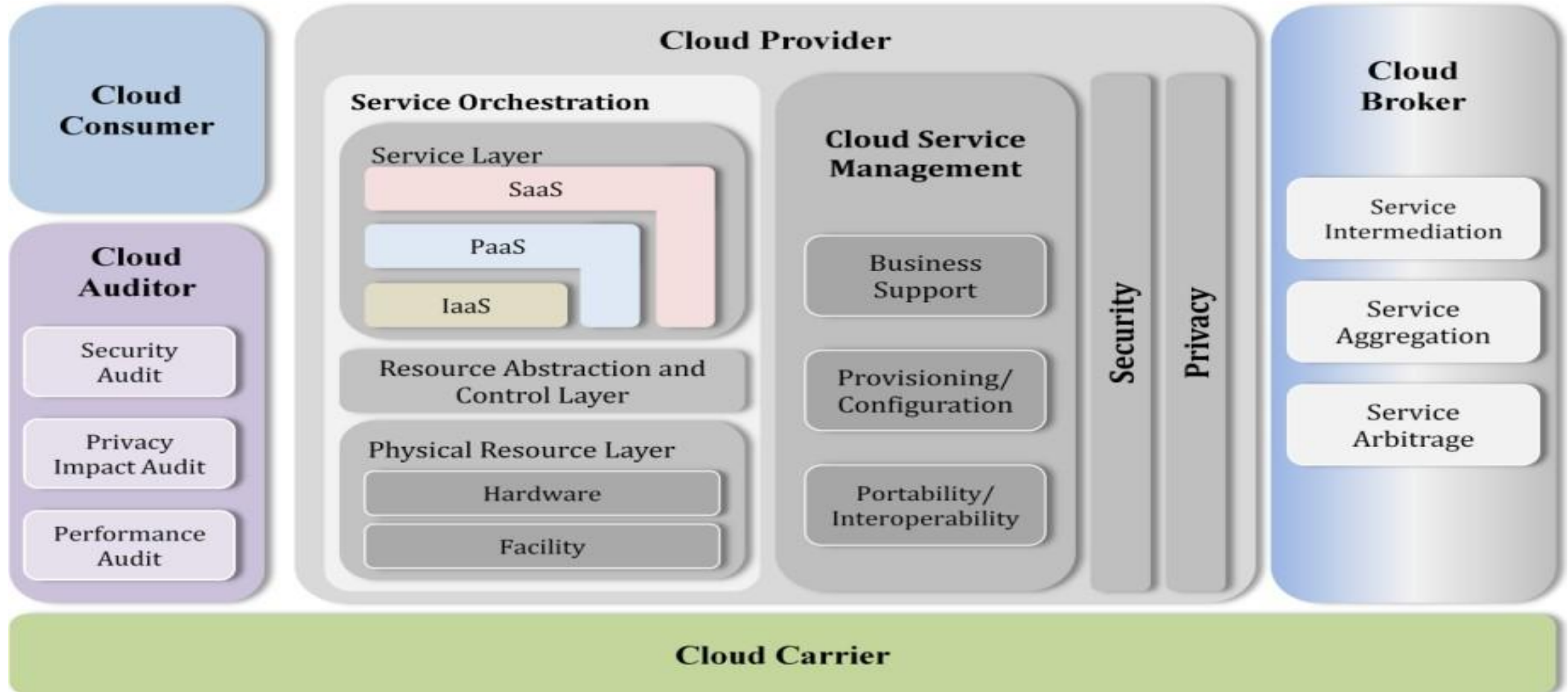
Cloud Computing Layers

Resources Managed at each layer

Software as a service (SaaS)

Business Applications, Web Services, Multimedia

Application

Google Apps, Facebook, Youtube, Saleforce.com

Platform as a service (PaaS)

Software Framework (Java, .NET) Storage (DB, File)

Platform

Microsoft Azure, Google AppEngine, Amazon SimpleDB/S3

Infrastructure as a service (IaaS)

Computation (VM) Storage (block)

Infrastructure

Amazon EC2, GoGrid Flexiscale

CPU, Memory ,Disk, Bandwidth

Hardware

Data Centers

	SaaS	PaaS	IaaS
Full Form	Software As a Service	Platform as a Service	Infrastructure as a Service
General Users	Business Users	Developers and Deployers	System managers
Services available	Email , Office automation , CRM , website testing , Virtual desktop	Service and application test , development , integration and deployment	Virtual machines, operating systems, network, storage, backup services.
Business Justification	To complete business tasks	Create and deploy service and applications for users	Create platform for service and application test, development.
Abstraction	Complete abstraction	Abstraction of underlying hardware, software and application services.	Abstraction of underlying hardware resources
Examples	Paypal , Salesforce.com	Azure Service platform, Force.com	Amazon EC2 , GoGrid
Control	Highest degree of control and flexibility	Good degree of control and flexibility	Minimal degree of control and flexibility
Operational cost	Minimal	Lower	Highest
Portability	No portability	Lower	Best
Risk of Vendor Interlock	Highest	Medium	Lowest
Security	Requires transparency in service provider's security policies to be able to determine the degree of sensitive corporate data.	Additional security is required to make sure rogue applications don't exploit vulnerabilities in software platform.	Should consider Virtual and physical servers security policy conformity.

Cloud Architecture – The National Institute of Standards and Technology **(NIST) CLOUD REFERENCE ARCHITECTURE**

# Cloud Architecture – NIST CLOUD REFERENCE ARCHITECTURE

➢ The NIST cloud computing reference architecture, identifies the major actors, their activities and functions in cloud computing.

➢ It depicts a generic high-level architecture - to facilitate the understanding of the requirements, uses, characteristics and standards of cloud computing.

➢ NIST cloud computing reference architecture defines five major actors:

➢ *cloud consumer,*

➢ *cloud provider,*

➢ *cloud carrier,*

➢ *cloud auditor* and

➢ *cloud broker*

Major Actors – NIST CLOUD REFERENCE ARCHITECTURE

Actor	Definition
Cloud Consumer	A person or organization that maintains a business relationship with, and uses service from, *Cloud Providers*.
Cloud Provider	A person, organization, or entity responsible for making a service available to interested parties.
Cloud Auditor	A party that can conduct independent assessment of cloud services, information system operations, performance and security of the cloud implementation.
Cloud Broker	An entity that manages the use, performance and delivery of cloud services, and negotiates relationships between *Cloud Providers* and *Cloud Consumers*.
Cloud Carrier	An intermediary that provides connectivity and transport of cloud services from *Cloud Providers* to *Cloud Consumers*.

Actors in Cloud Computing
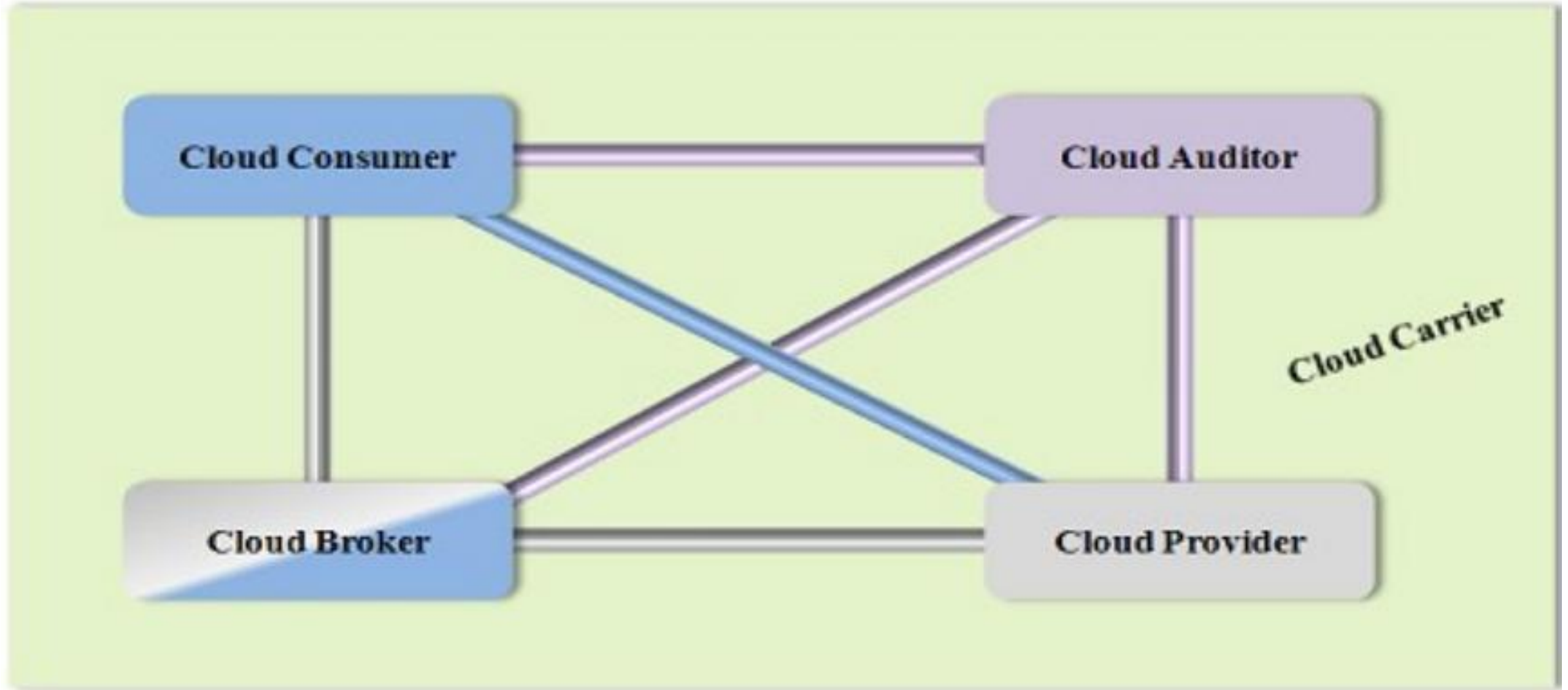
Cloud Consumer

Cloud consumer **browses & uses the service.**

Cloud consumer **sets up contracts with the cloud provider**.

Cloud consumers need **Service Level Agreements** (SLAs) to specify the technical performance requirements fulfilled by a cloud provider.

SLAs cover the quality of service, security, preparations for performance failures.

A cloud provider list some **Service Level Agreements (**SLAs) that limit and obligate the cloud consumers by must acceptance.

Cloud consumer can freely choose a cloud provider with better pricing with favorable conditions.

Pricing policy and SLAs are non-negotiable (**can not changed again and again**).

NIST Cloud Computing Reference Architecture

Cloud Consumer
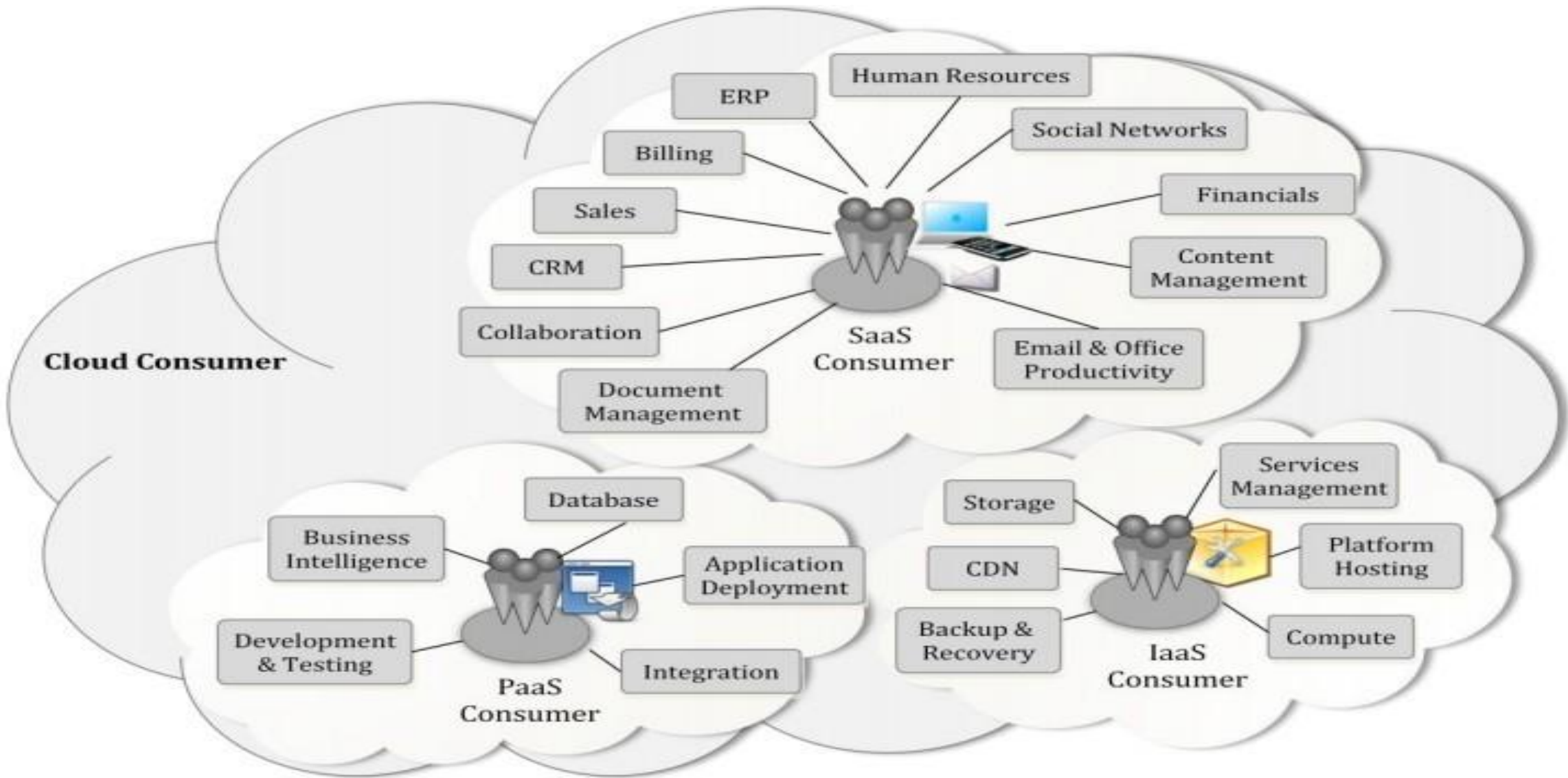
* CDNs- Content Delivery Networks

SaaS consumers

- **SaaS consumers can be organizations that provide their members** with access to software applications, end users who directly use software applications, or software application administrators who configure applications **for end users.**

- SaaS consumers can be **billed** based on the number of end users, the time of use, the network bandwidth consumed, the amount of data stored or duration of stored data.

NIST Cloud Computing Reference Architecture

PaaS consumers

PaaS consumers can be application developers or administrators

1. Software life cycle
2. who **design and implement application software**
3. application testers **who run and test applications**
4. who publish applications into the cloud
5. who configure and monitor application performance.

PaaS consumers can be **billed** according to, processing, database storage and network resources consumed by the PaaS application, and the duration of the platform usage.

NIST Cloud Computing Reference Architecture

IaaS consumer

IaaS consumer can be system developers, system administrators and IT managers who are interested in creating, installing, managing and monitoring services for **IT infrastructure operations**.

IaaS consumer can be billed according to the amount or duration of the resources consumed, such as **CPU hours** used by virtual computers, **volume and duration of data stored**, **network bandwidth consumed,** number of IP addresses used for certain intervals.

NIST Cloud Computing Reference Architecture

Cloud Provider

Cloud Provider **acquires and manages the computing infrastructure required for providing the services, runs the cloud software that provides the services, and makes arrangement to deliver the cloud services to the Cloud Consumers through network access.**

SaaS provider deploys, configures, maintains and updates the operation of the **software applications on a cloud infrastructure**. **SaaS provider maintains the expected service levels to cloud consumers.**

PaaS Provider manages the computing infrastructure for the platform and components (runtime software execution stack, databases, and other middleware).

IaaS Cloud Provider **provides physical hardware** and **cloud software** that makes the provisioning of these infrastructure services, for example, the **physical servers, network equipments, storage devices, host OS and hypervisors for virtualization.**

NIST Cloud Computing Reference Architecture

Cloud Broker

Integration of cloud services can be complex for consumers. Hence cloud broker, is needed.
Broker manages the use, performance and delivery of cloud services and **negotiates relationships between cloud providers and cloud consumers.**

In general, a **cloud broker can provide services in three categories**:

Service Intermediation: **Broker enhances a service by improving capability and providing value-added services to consumers**.The improvement can be managing access to cloud services, identity management, performance reporting, enhanced security, etc.

Service Aggregation: **Broker combines and integrates multiple services into one or more new services.**The broker provides data integration and ensures the secure data movement.

Service Arbitrage: It is similar to service aggregation with the flexibility to **choose services from multiple agencies**. **For example, broker can select service with the best response time.**

NIST Cloud Computing Reference Architecture

Scenarios in Cloud:1

1. Cloud consumer interacts with the cloud broker instead of contacting a cloud provider directly.

2. The cloud broker may create a new service (mash up) by combining multiple services or by enhancing an existing service.

3. Actual cloud providers are invisible to the cloud consumer.
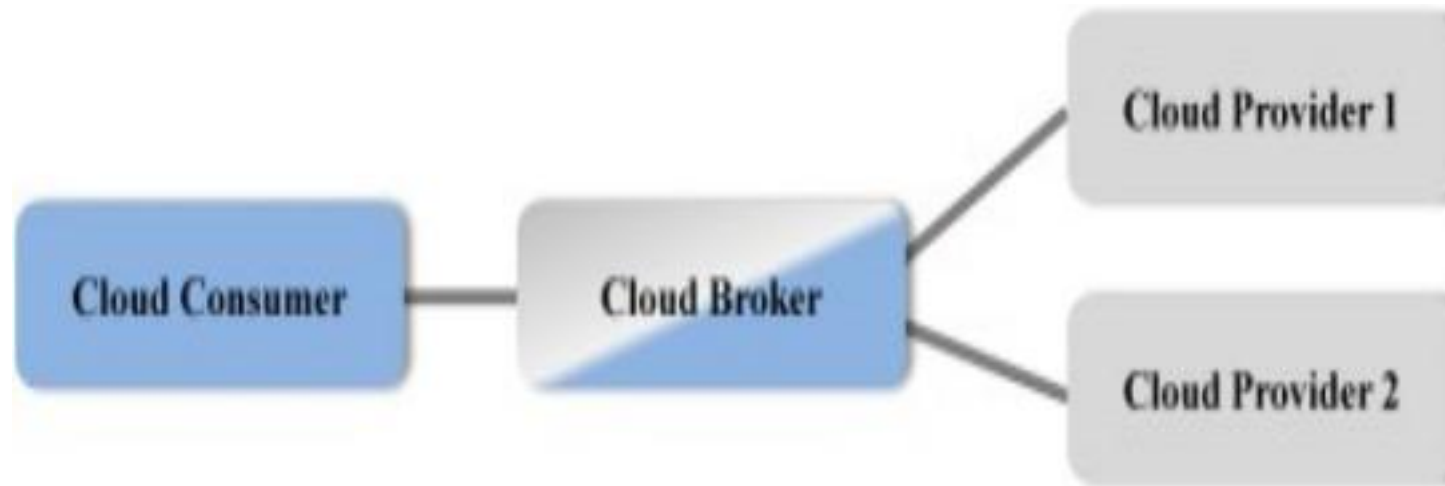
NIST Cloud Computing Reference Architecture

Cloud Carrier

Cloud carriers provide access to consumers through network, telecommunication and other access devices.

For example, cloud consumers can obtain cloud services through network access devices, such as computers, laptops, mobile phones, mobile internet devices (MIDs), etc.

The distribution of **cloud services is normally provided by network and telecommunication** carriers or a *transport agent,* where a transport agent refers to a business organization that provides physical transport of storage media such as high-capacity hard drives.

Cloud provider can set up Service Level Agreements (SLAs) **with a cloud carrier** to provide services consistent with the level of SLAs offered to **cloud consumers.**

NIST Cloud Computing Reference Architecture

Scenarios in Cloud:2

1. **Cloud carriers provide the connectivity and transport** of cloud services from cloud providers to cloud consumers.

2. **Cloud provider participates in and arranges for two unique service level agreements** (SLAs), one with a cloud carrier (e.g. SLA2) and one with a cloud consumer (e.g. SLA1).

3. A cloud provider may request cloud carrier to provide dedicated and encrypted connections to ensure the cloud services (SLA's).

NIST Cloud Computing Reference Architecture

Scenarios in Cloud:3

1. **Cloud auditor conducts independent assessments for the operation and security of the cloud service.**

2. **The audit may involve interactions with both the Cloud Consumer and the Cloud Provider.**
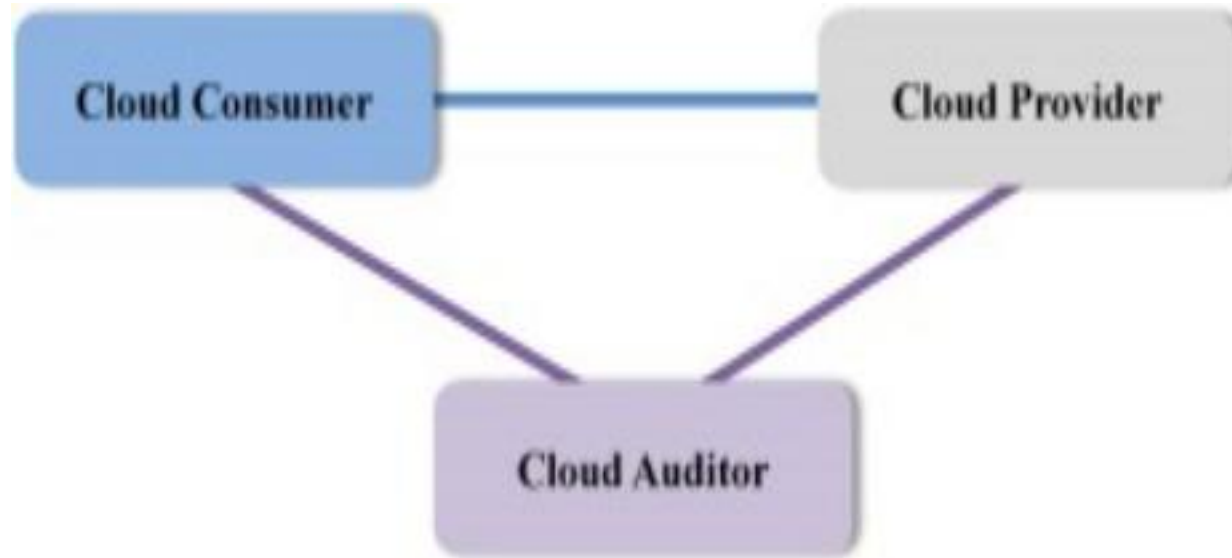
NIST Cloud Computing Reference Architecture

Cloud Computing Models

Deployment Models

Public Cloud

➢ A cloud platform in which the cloud resources are owned and operated by a third-party cloud service provider and delivered over the Internet.

➢ The hardware resources in public cloud are shared among similar users and accessible over a public network such as the internet.

➢ Often used by : Budget conscious startups, Small and medium-sized enterprises (SMEs) not keen on high level of security features looking to save money can opt for Public Cloud Computing.

Public Cloud
- Highly Flexible
- PAYG or Pay as you use
- Maintained and Monitored by others

CLOUD MODEL- Types:-

(i) PUBLIC CLOUD MODEL:- { Small fee, cost, free }

↳ Systems and Services are easily accessible to general public.

Eg:- → GOOGLE
→ AMAZON   } Internet.
→ MICROSOFT

User 1
User 2
User 3
:
:
User...n

Mail Services] Google
Appl^n Services] Microsoft
Storage Services] Dropbox.

Admin

Public cloud model.

Advantages:- → i) Reliability
→ ii) Flexibility
→ iii) Location independence
→ iv) High scalability
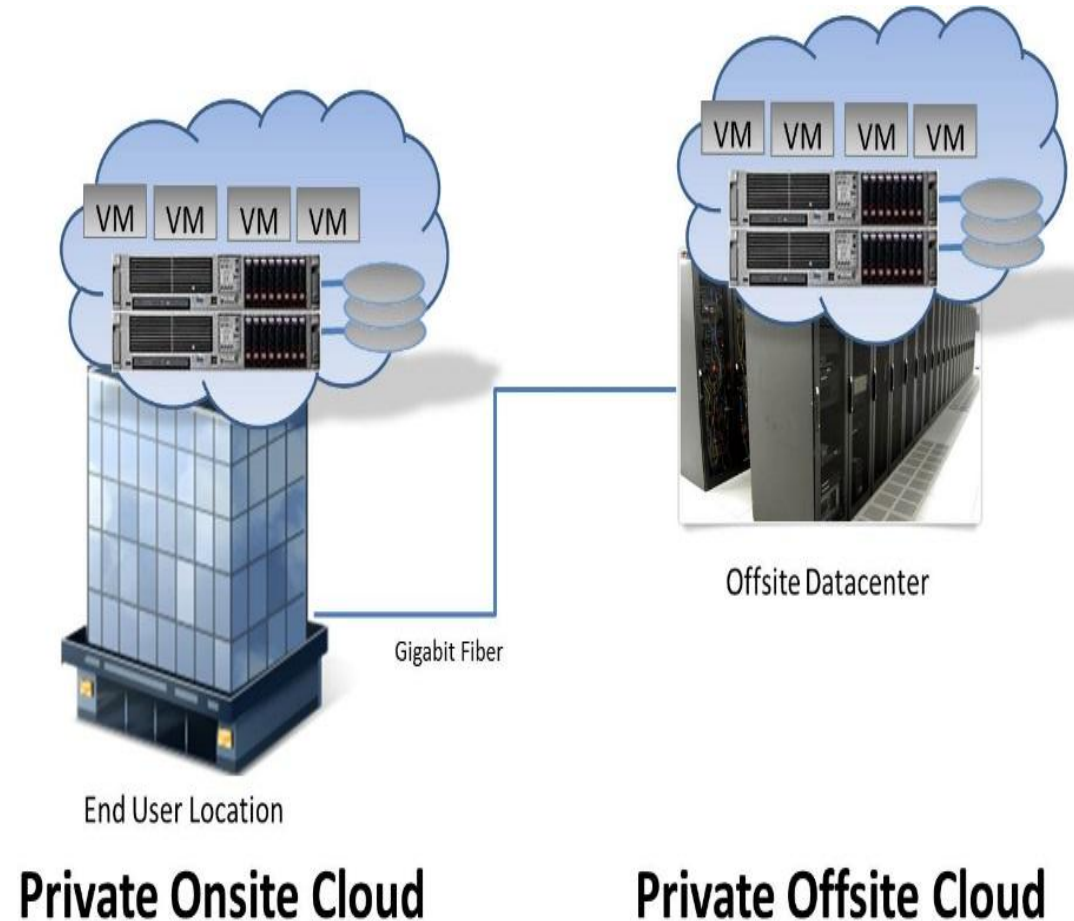→ v) Cost effective
→ vi) utility style costing.

Disadvantages:-

(i) Low Security
(ii) Less Customizable than private cloud.
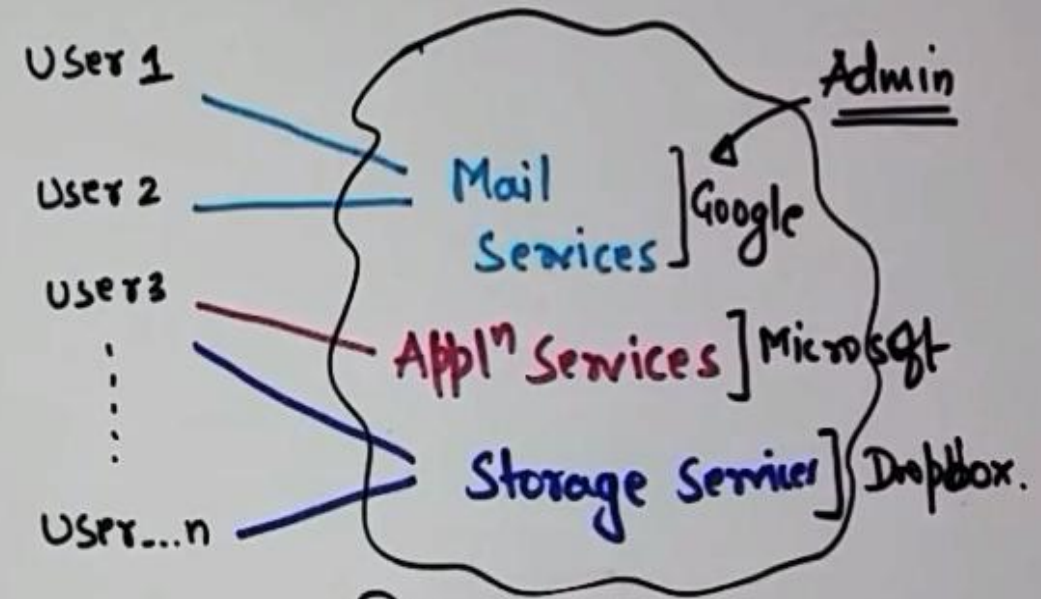
Free,
Gmail (15GB)
↓ >15GB
Fee

Private Cloud

➢ A private cloud consists of computing resources used exclusively by one business or organization.

➢ It can be physically located at your organization's on-site datacenter or it can be hosted by a third-party service provider.

➢ Makes it easier for an organization to customize its resources.

➢ Often used by government agencies, financial institutions, any other mid- to large-size organizations with **business-critical operations** seeking enhanced **control over their environment.**

VM VM VM VM

Gigabit Fiber

Offsite Datacenter

End User Location

Private Onsite Cloud

Private Offsite Cloud

(ii) PRIVATE CLOUD MODEL:- {managed by third-party also}.

↳ Systems and Services are accessible only within the organization.

[Microsoft, Vmware, Elastra-private cloud, ubuntu]
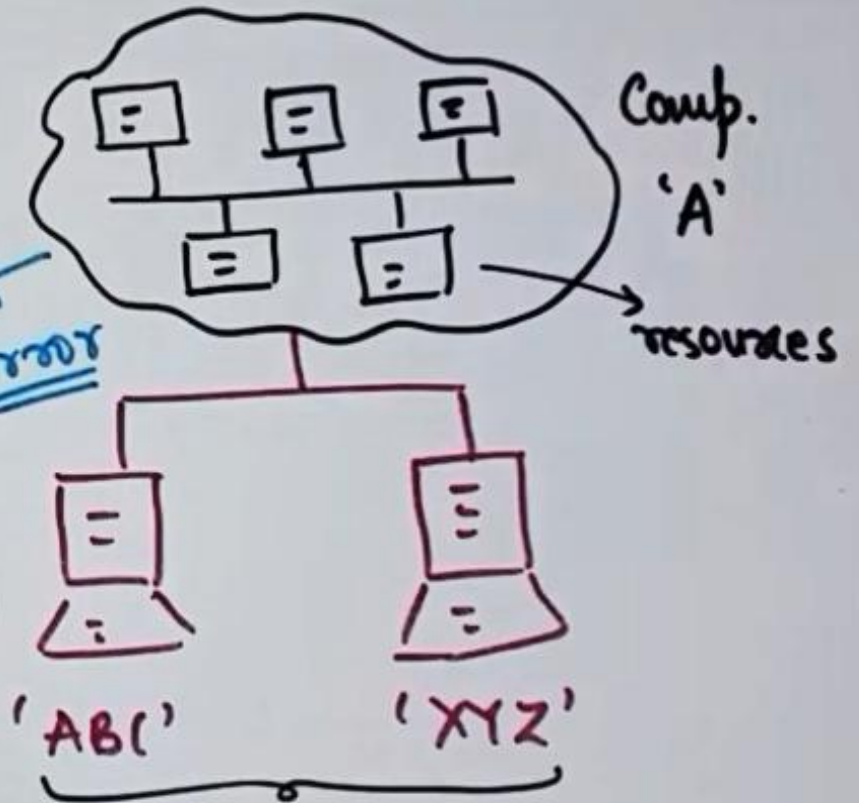
Ⓜ —✗ Error
User

Comp. 'A'

→ resources

Advantages:-

(i) High Security and privacy

(ii) More Control

(iii) Cost and Energy efficient

(iv) Improved Reliability

is used only by trusted people.

Disadvantages:-

↳ i) Area of opr" is limited

ii) Price is ↑.

iii) Scalability is limited

iv) Skilled people is required.

'ABC'   'XYZ'

Both the users should be member of Comp. 'A'

Hybrid Cloud

➢ Often called "the best of both worlds,"

➢ In a hybrid cloud, data and applications can move between private and public clouds for **greater flexibility** and more deployment options.

➢ In a hybrid cloud, "cloud bursting" is also an option. This is when an application or resource runs in the private cloud until there is a spike in demand at which point the organization can "burst through" to the public cloud to tap into additional computing resources.
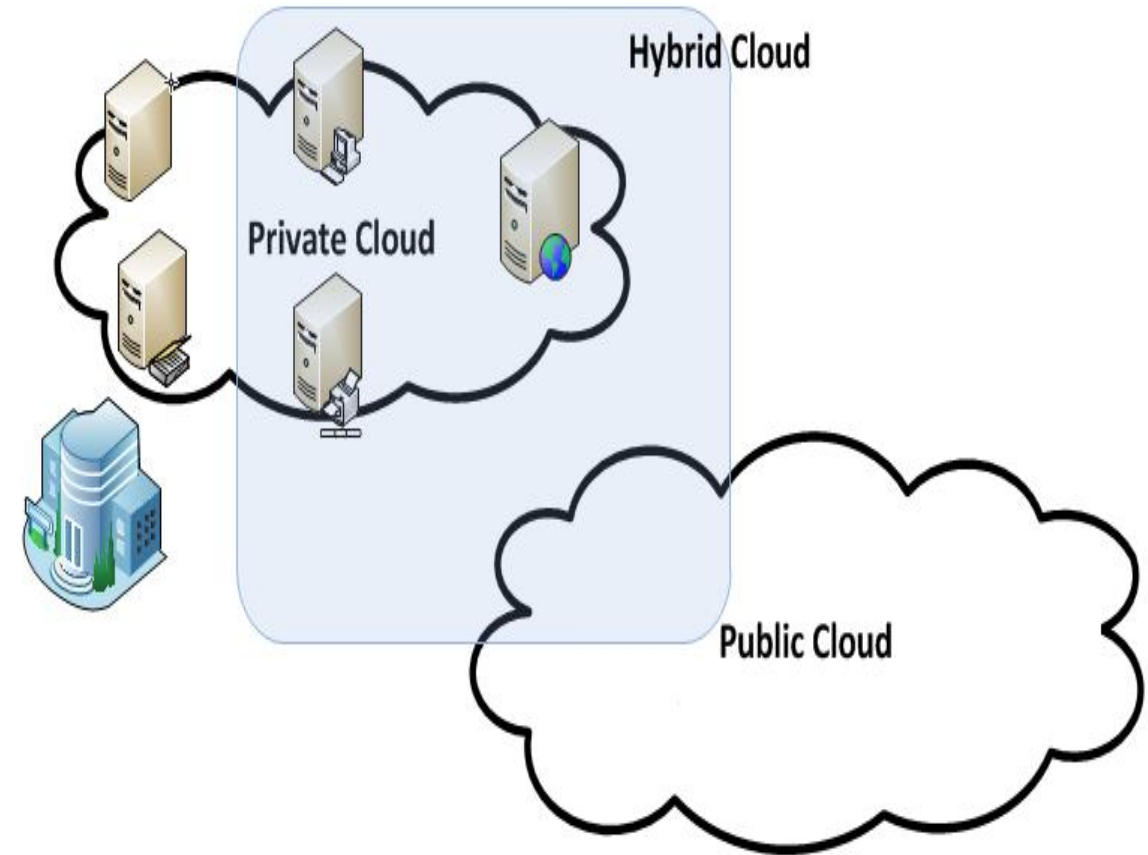
HYBRID CLOUD MODEL: → non-critical activities

↳ Combination of both PUBLIC and PRIVATE Cloud.
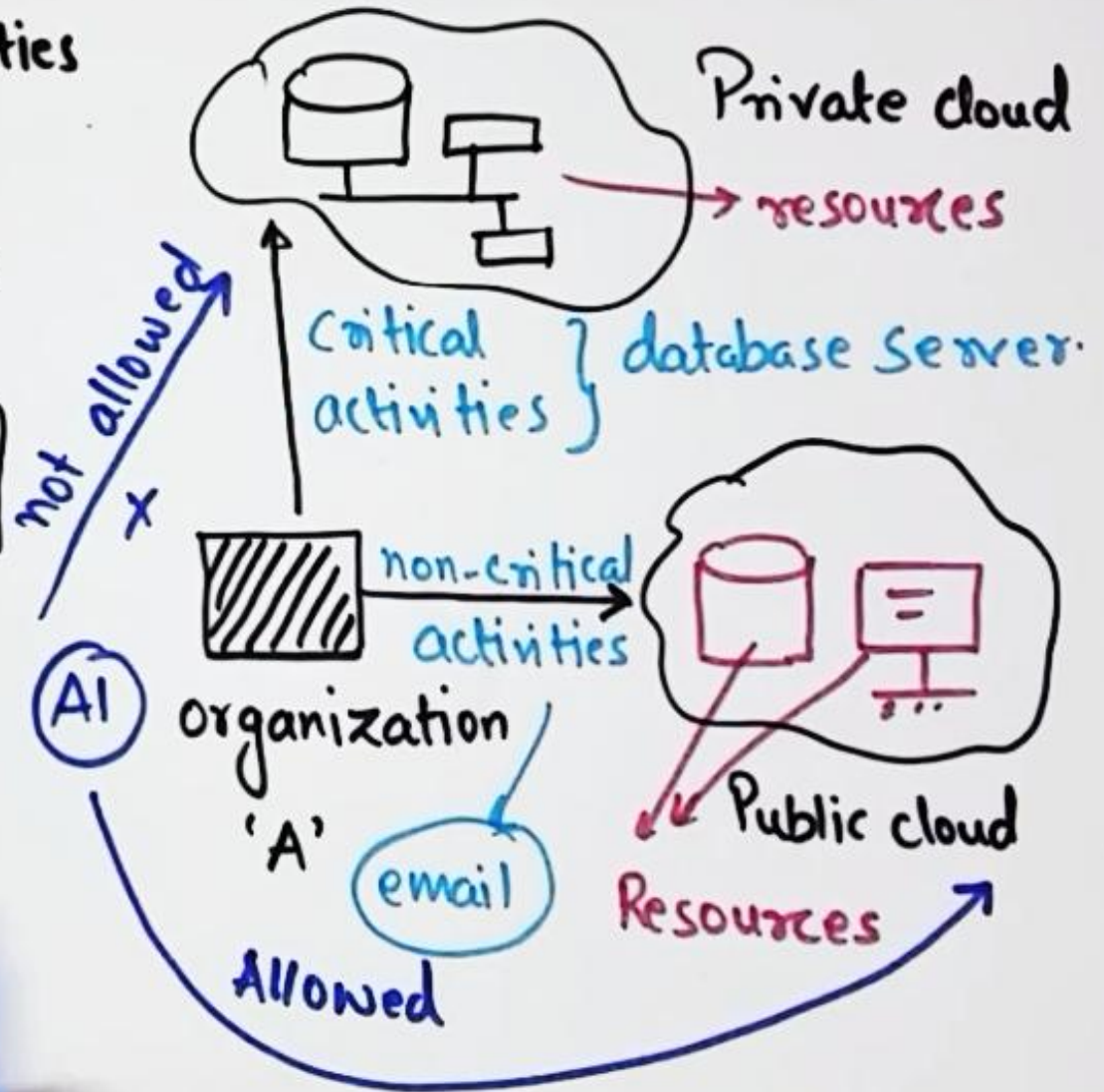
critical activities

Advantages:-
↳ i) Scalability
ii) Security
iii) Flexibility
iv) ↓ Cost

Disadvantages:
↳ i) N/w Issues [Complexity of both]
ii) Security Compliance
iii) Dependency on the Infrastructure.
Internal IT.

not allowed ✗

Critical activities } database server.

Private cloud → resources

non-critical activities

AI organization 'A' email Allowed

Public cloud Resources

Community cloud Model: falls b/w category of private and public cloud.

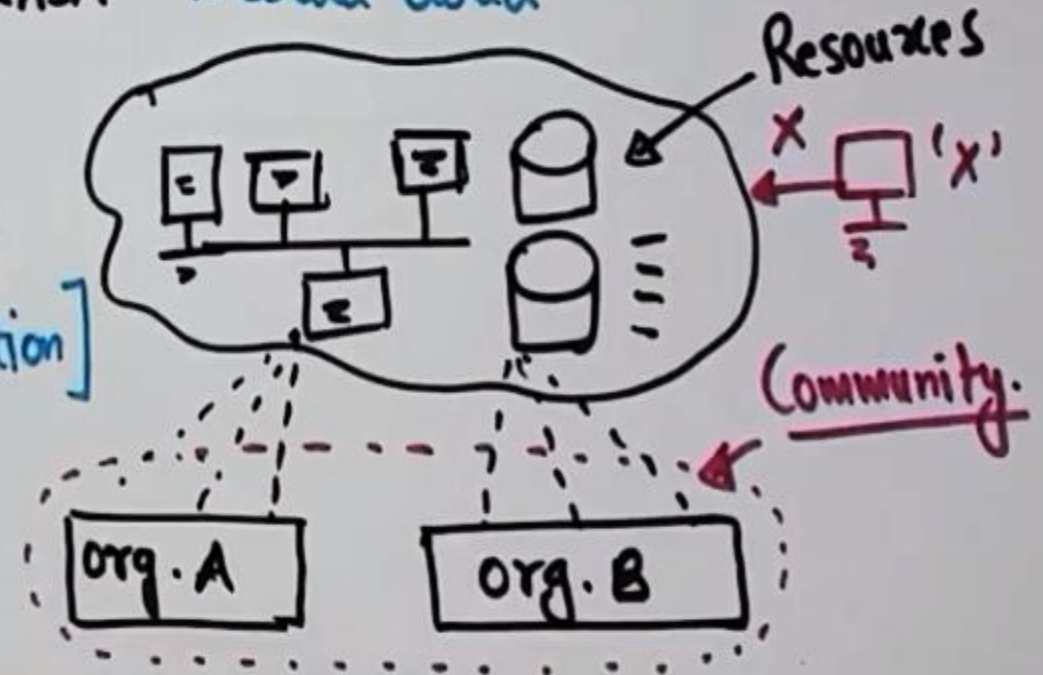↳ Allows Systems and Services to be accessible by group of organizations.

} COSTLY than public cloud.

→ Google 'Gov Cloud'
→ NASA 'Nebula cloud'

Advantages:

↳ i) Low Cost than private cloud.

ii) Sharing among org.

iii) Security [more Secure than public but less than private]

Disadvantages:

↳ i) we need to be careful in storing data [data Seggregation]
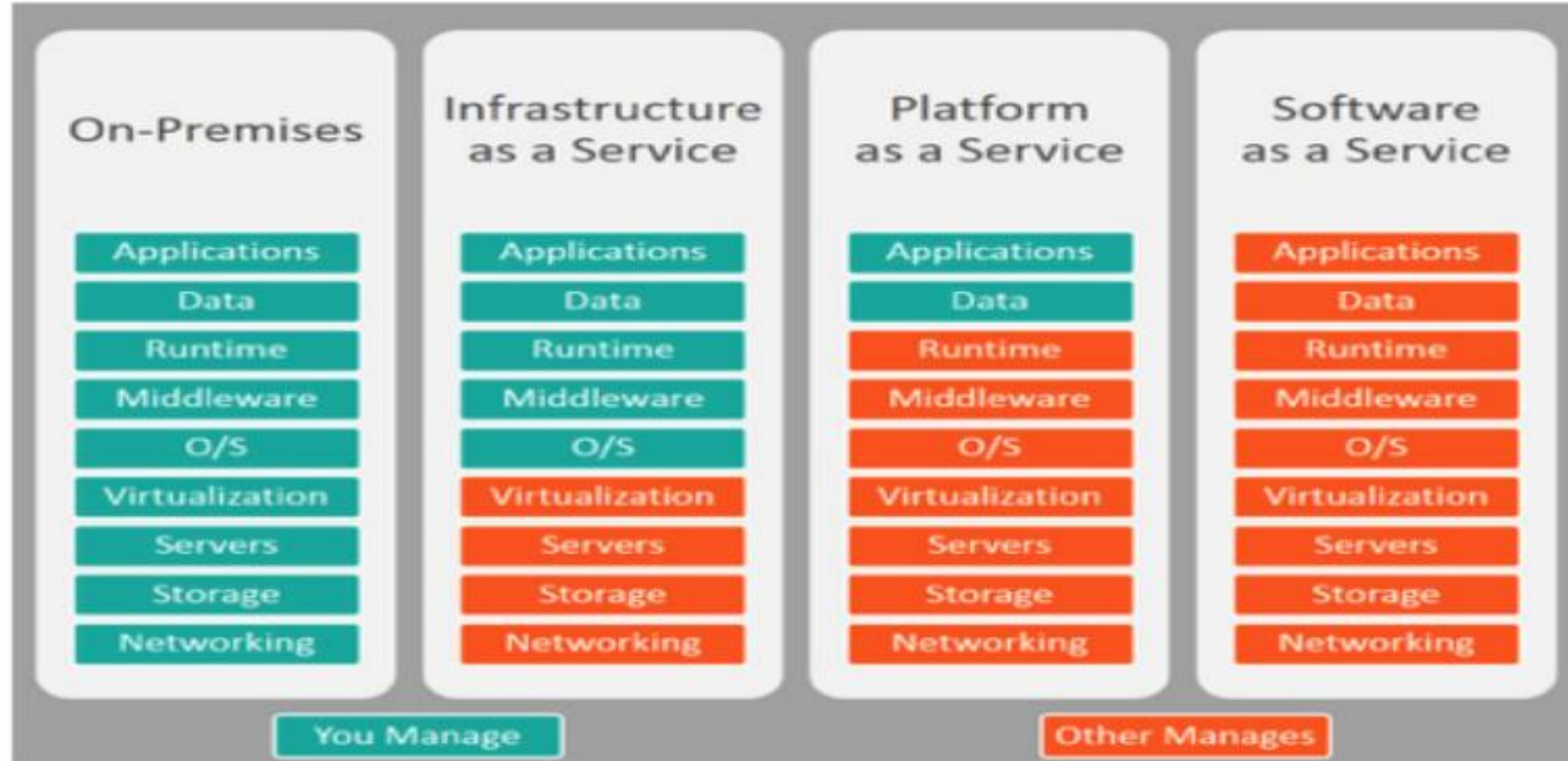
Responsibilities

Resources

Community.

org. A   org. B

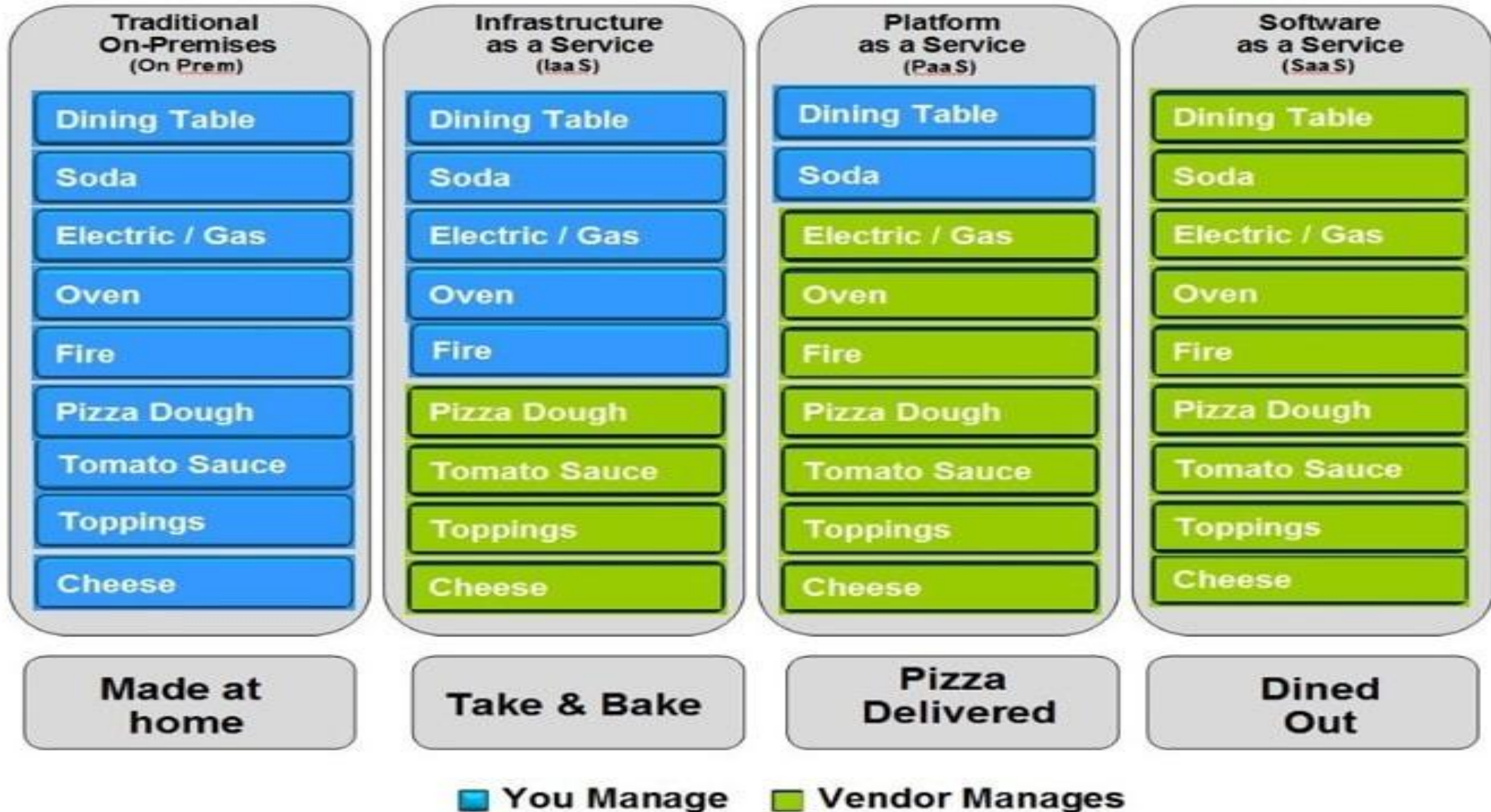| Difference	Private	Public	Hybrid
Tenancy	Single tenancy: there's only the data of a single organization stored in the cloud.	Multi-tenancy: the data of multiple organizations in stored in a shared environment.	The data stored in the public cloud is usually multi-tenant, which means the data from multiple organizations is stored in a shared environment. The data stored in private cloud is kept private by the organization.
Exposed to the Public	No: only the organization itself can use the private cloud services.	Yes: anyone can use the public cloud services.	The services running on a private cloud can be accessed only the organization's users, while the services running on public cloud can be accessed by anyone.
Data Center Location	Inside the organization's network.	Anywhere on the Internet where the cloud service provider's services are located.	Inside the organization's network for private cloud services as well as anywhere on the Internet for public cloud services.
Cloud Service Management	The organization must have their own administrators managing their private cloud services.	The cloud service provider manages the services, where the organization merely uses them.	The organization itself must manage the private cloud, while the public cloud is managed by the CSP.
Hardware Components	Must be provided by the organization itself, which has to buy physical servers to build the private cloud on.	The CSP provides all the hardware and ensures it's working at all times.	The organization must provide hardware for the private cloud, while the hardware of CSP is used for public cloud services.
Expenses	Can be quite expensive, since the hardware, applications and network have to be provided and managed by the organization itself.	The CSP has to provide the hardware, set-up the application and provide the network accessibility according to the SLA.	The private cloud services must be provided by the organization, including the hardware, applications and network, while the CSP manages the public cloud services.

Cloud Computing Models

Delivery Models

Delivery Models – IaaS, PaaS & SaaS

Pizza as a Service

Traditional On-Premises (On Prem)	Infrastructure as a Service (IaaS)	Platform as a Service (PaaS)	Software as a Service (SaaS)
Dining Table	Dining Table	Dining Table	Dining Table
Soda	Soda	Soda	Soda
Electric / Gas	Electric / Gas	Electric / Gas	Electric / Gas
Oven	Oven	Oven	Oven
Fire	Fire	Fire	Fire
Pizza Dough	Pizza Dough	Pizza Dough	Pizza Dough
Tomato Sauce	Tomato Sauce	Tomato Sauce	Tomato Sauce
Toppings	Toppings	Toppings	Toppings
Cheese	Cheese	Cheese	Cheese
Made at home	Take & Bake	Pizza Delivered	Dined Out

You Manage   Vendor Manages

Cloud Computing has various different service models such as Infrastructure as a Service (IAAS), Platform as a Service (PAAS), and Software as a Service (SAAS).

i. Infrastructure as a Service (IAAS)

Cloud consumers can directly use IT infrastructures (processing, storage, networks, and other fundamental computing resources) provided in the IaaS cloud. **IaaS cloud provides "Virtualization"** in order to integrate/decompose **physical resources in an ad-hoc manner to meet growing or shrinking resource demand from cloud consumers. An example of IaaS is** Amazon Elastic Compute Cloud (EC2).

ii. Platform as a Service (PAAS)

PaaS provides a development platform that **supports the full "Software Lifecycle" which allows cloud consumers to develop their cloud services and applications (e.g. SaaS) directly on the PaaS cloud.** The main difference between SaaS and PaaS is that SaaS only hosts completed cloud applications whereas **PaaS offers a development platform** that hosts both completed and in-progress cloud applications. **Example of PaaS is Google AppEngine.**

iii. Software as a Service (SAAS)

Cloud consumers can release their applications on a hosting environment, **which can be accessed through internet from various clients (e.g. web browser**, PDA, etc.) by application clients. Examples of SaaS are **SalesForce.com, Google Docs, and Google Mail.**

IaaS: Infrastructure as a Service

➢ Cloud infrastructure providers use virtualization technology to deliver scalable compute resources to their clients.

➢ Clients **don't have to buy personal hardware and manage its components.**

➢ Instead, they can deploy their platforms and applications within the provider's virtual machines

➢ An **IaaS provider is responsible for the entire infrastructure**, but users have total control over it.

➢ IaaS users can compare the cost and performance of different providers in order to choose the best option.

IAAS [Infrastructure-as-a Service]

cloud Service Models:

↳ Provides access to → Physical machines
→ Virtual machines] Operates by
→ Virtual Storage. } (Hypervisor)

↳ other things that

offers:
↳ i) Virtual LAN(VLANs)] N/w device
ii) IP addresses
iii) S/w bundles
iv) load balancers
v) Disk Storage
[AMAZON, Google Compute Engine]

(KVM or Xen)
(Physical resources)

Cloud provider

Virtual resource

(Saas) Email, Games, office etc.	Layer-3
(Paas) Database, web server, tools etc.	Layer-2
(Iaas) Storage, virtual w/c, N/w etc.	Layer-1

} Cloud Clients.
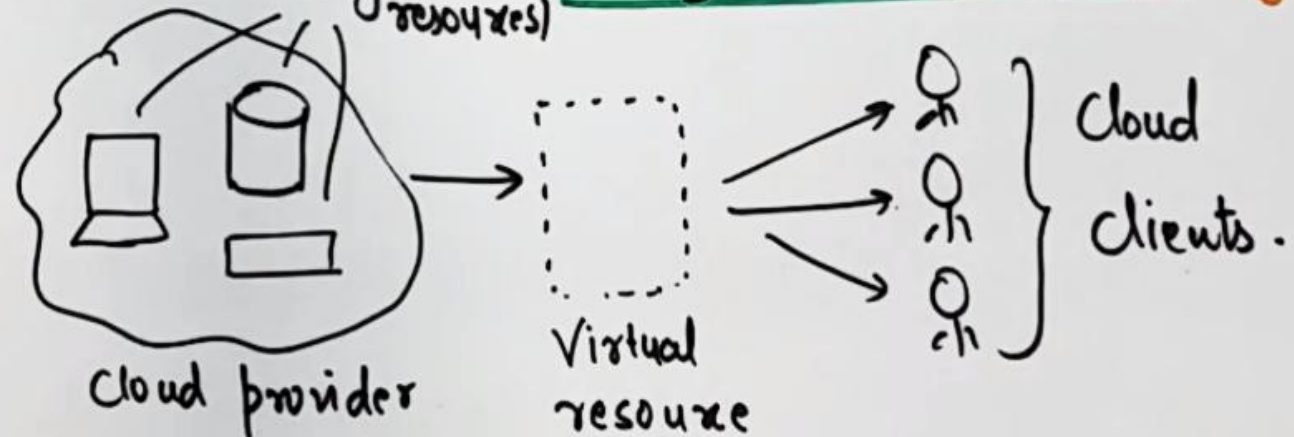
Benefits of IAAS: Using IAAS, cloud provider Can freely locate infrastructure over the internet in cost-effective manner.

↳ i) Global Accessibility

ii) Easy & Integration of devices

iii) Scalability is Easy

iv) Availability is high

v) Flexibility

vi) Full Control to Virtual m/c.

VM1 VM2 VM3 VM4

Virtual m/c

Hypervisor

Computer
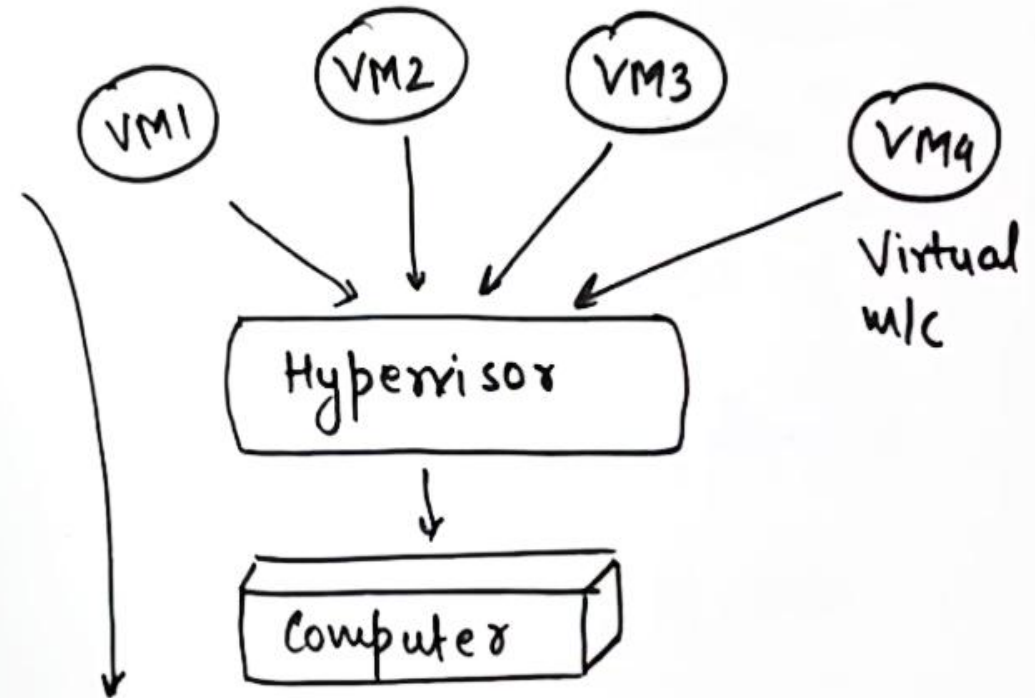
Services is being provided by virtual m/c through hypervisor.
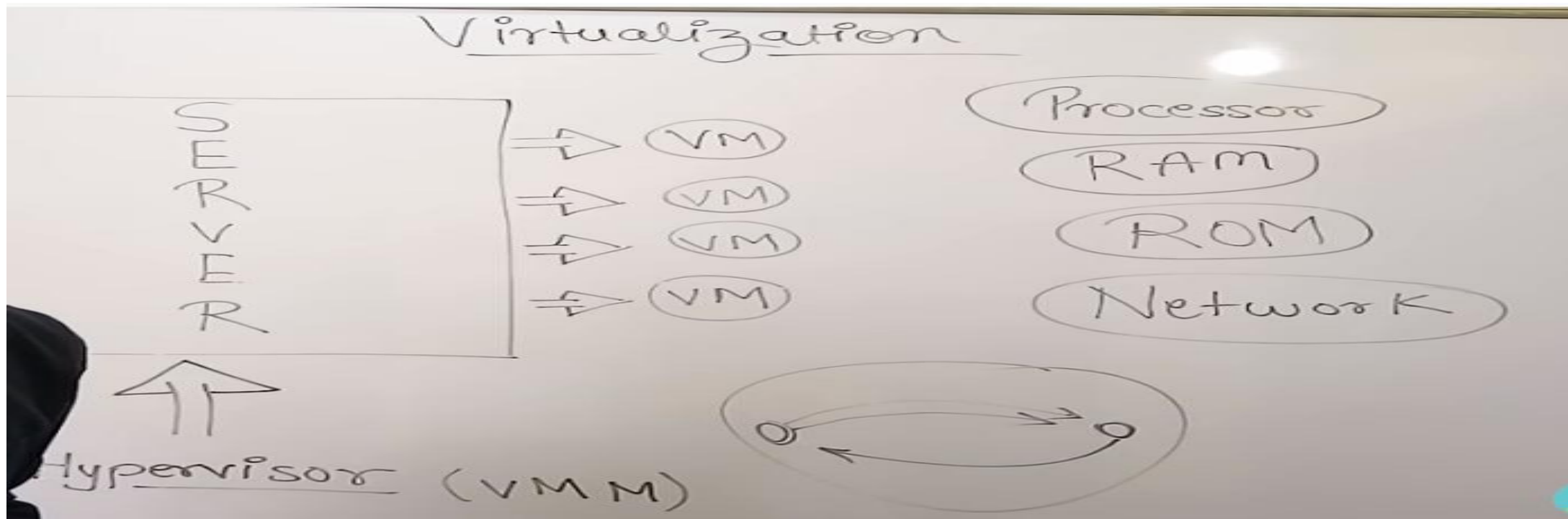
Virtual Machine Manager/Monitor (VMM): Also called a "**hypervisor,**" this is one of many hardware virtualization techniques that allow multiple operating systems, termed guests, to **run concurrently on a host computer. Hypervisors are installed on server hardware whose only task is to run guest** operating systems. **VMM is the primary software behind virtualization environments** and implementations. When installed over a **host machine**, VMM facilitates the creation of VMs, each with separate operating systems (OS) and applications. VMM manages the backend operation of these VMs by allocating the necessary computing, memory, storage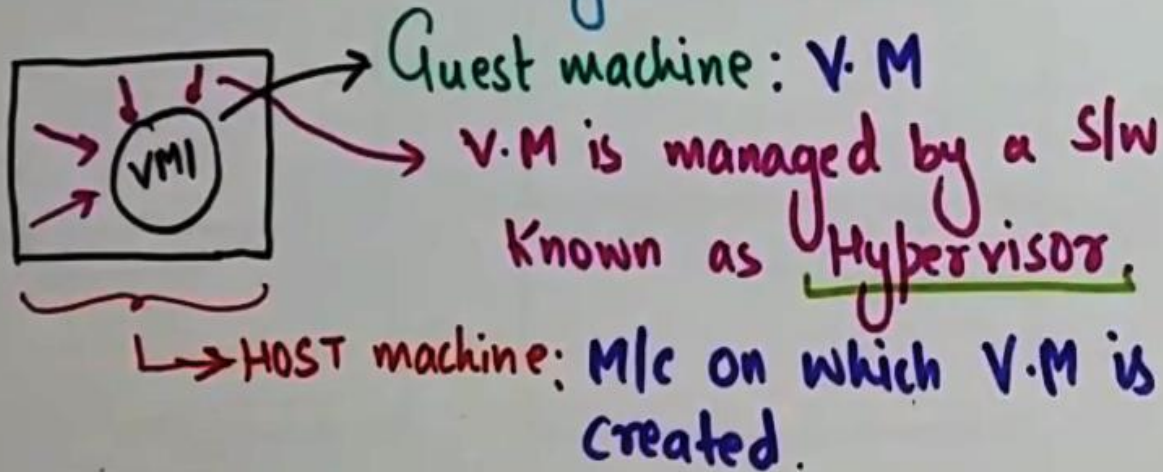 and other input/output (I/O) resources. Hardware Virtualization, Operating system Virtualization, Server Virtualization, Storage Virtualization.

CLOUD Computing Virtualization: → Physical resources available as Virtual resources.

Virtualization :- Allows to Share Single physical instance of an appl" or resource among multiple organizations.

S.D → SD1] → User1
→ SD2] → User2
→ SD3] → User3

Physical

Logical/Virtual instances
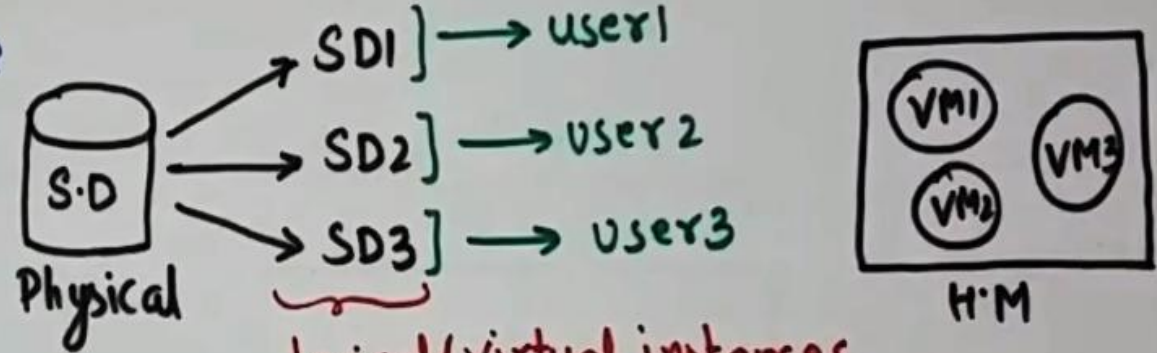
Hardware Virtualization: It means Creating Virtual machine over existing O.S and H/W.

→ Guest machine: V.M
→ V.M is managed by a S/w Known as Hypervisor.

→ HOST machine: M/c on which V.M is Created.

Characteristics:-
→① Partitioning: Separate diff. V.M on Single physical System.
② Isolation: Host and V.M should be isolated.
③ Encapsulation: V.M should be encapsulated in Single file.

IaaS Examples
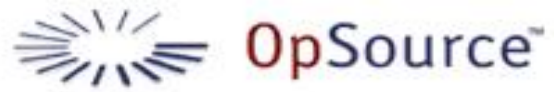
PaaS: Platform as a Service

- **Such solutions are especially profitable to developers who want to spend more time in coding, testing and deploying their applications.**

- **Multiple developers work on one project**

➤ PaaS in cloud computing is **a framework for software creation delivered over the internet**.

➤ **It offers a platform with built-in software components and tools, using which developers can create, customize, test and launch applications.**

➤ PaaS vendors manage servers, operating system updates, security patches and backups.

➤ Clients focus on app development and data without worrying about infrastructure, middleware and OS maintenance.

PAAS (Platform-as-a Service) Platform ⇒ Computing Platform [HIW, OS, Libraries]
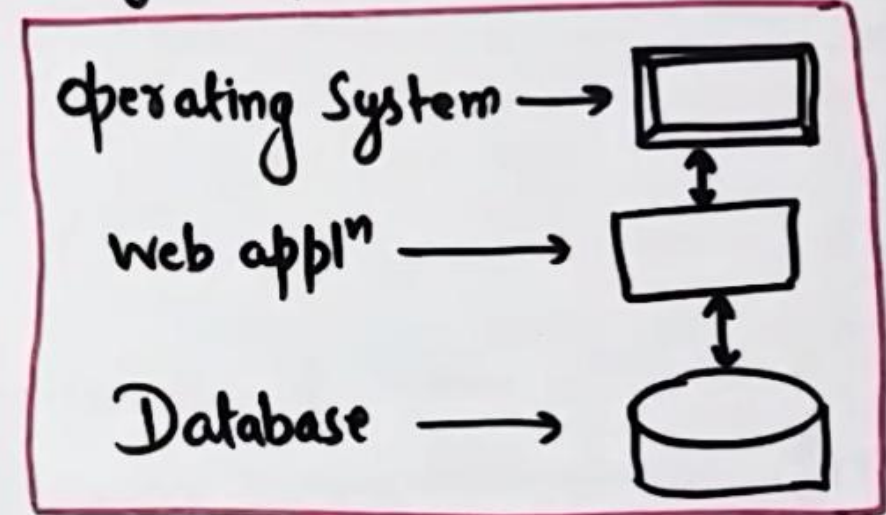
↳ It offers runtime environment for the applications.

↳ Basically provide platform to develop appl".

Eg:- Google App Engine
Force. Com
} Helping the user to create web appl" online. (LOG IN) Coding.

User

Operating System →
Web appl" →
Database →

PaaS (cloud provider)

PaaS Examples

SaaS: Software as a Service

➢ SaaS is the most common category of cloud computing. SaaS model allows to use software applications as a service to end users. Users get access to the vendor's cloud-based software.

➢ The SaaS provider manages everything from hardware stability to app functioning.

➢ Clients are not responsible for anything in this model; they only use programs to complete their tasks.

➢ In this case, the client software experience is fully dependent on the provider.

• **No need to download, install or upgrade software**

• **Apps are accessible from any connected device**

• **If your company needs to launch a ready-made software quickly**

• **The provider is responsible for everything**

• **The best-known SaaS solutions vendors are Google Apps, Dropbox, Gmail, Salesforce, Cisco WebEx, GoToMeeting, Office365.**

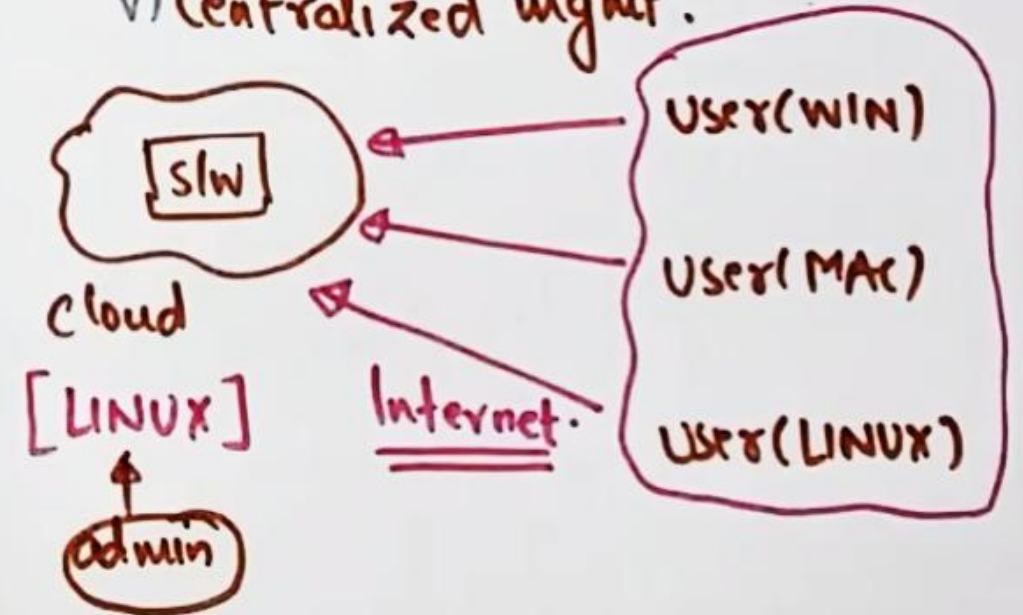➢ Using such apps, customers can collaborate on projects, as well as store and analyze data.

Characteristics of SAAS: → word, excel.

Availability of s/w over internet.
Maintenance of s/w by Vendor.] w/g radation
Subscription or Usage based license.
Cost effective   ] Pay as per use.
On-demand availability.] anywhere, anytime
Easily scalable as per need.
Works on shared model. (s/w) ← client 1
                                    2
                                    3
Automatic updation of s/w.
   → client will always gets to
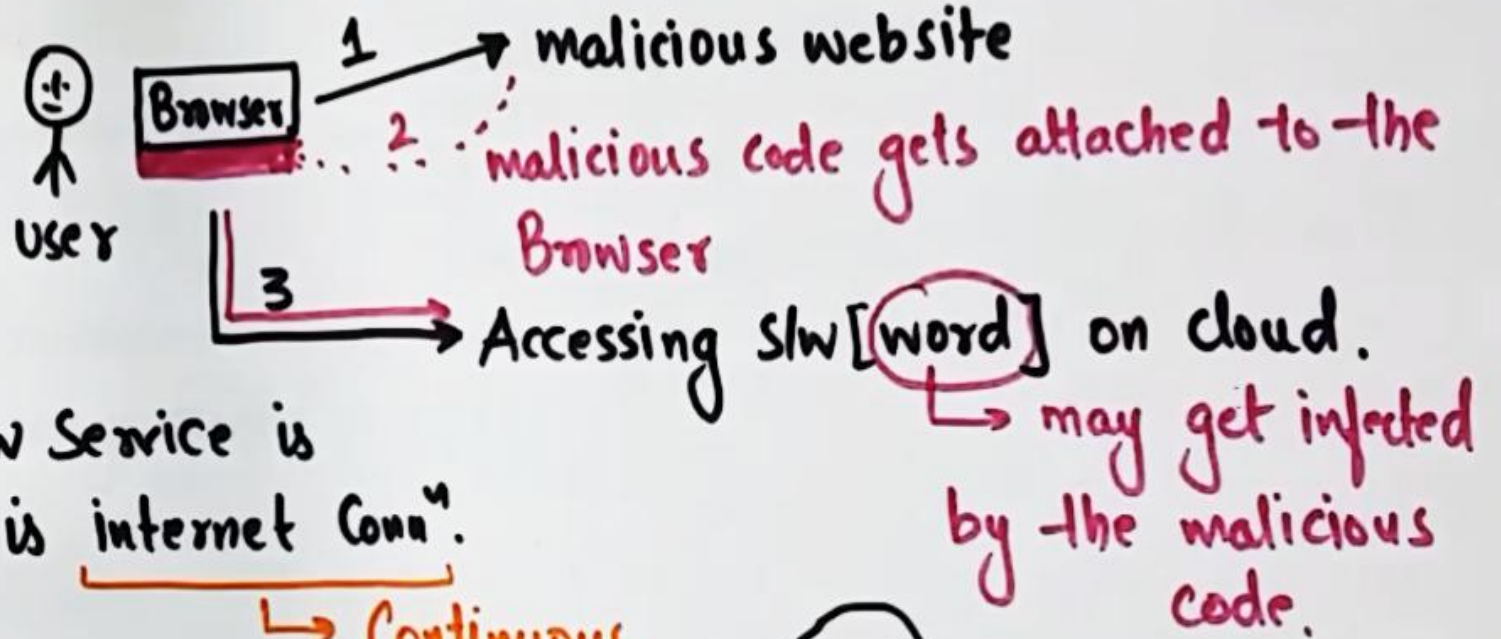   work on the latest version
     of the s/w.

Benefits of SAAS:

→ i) Modern s/w tools.
  ii) Platform independence to user.
 iii) Efficient use of s/w license.
  iv) Multitenant sa".
   v) Centralized mgmt.

cloud
[LINUX]
   ↑
(admin)

Internet.

User(WIN)

User(MAC)

User(LINUX)

SAAS ISSUES:-

↳ i) Browser based risks

User

Browser

1 → malicious website

2 ...malicious code gets attached to the Browser

3 → Accessing S/w [word] on cloud.
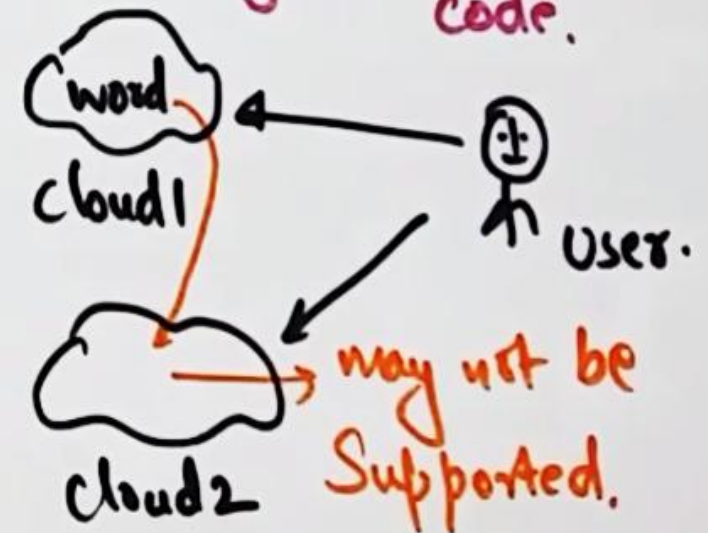↳ may get infected by the malicious code.

ii) N/w dependence :- S/w Service is available till there is internet Conn".
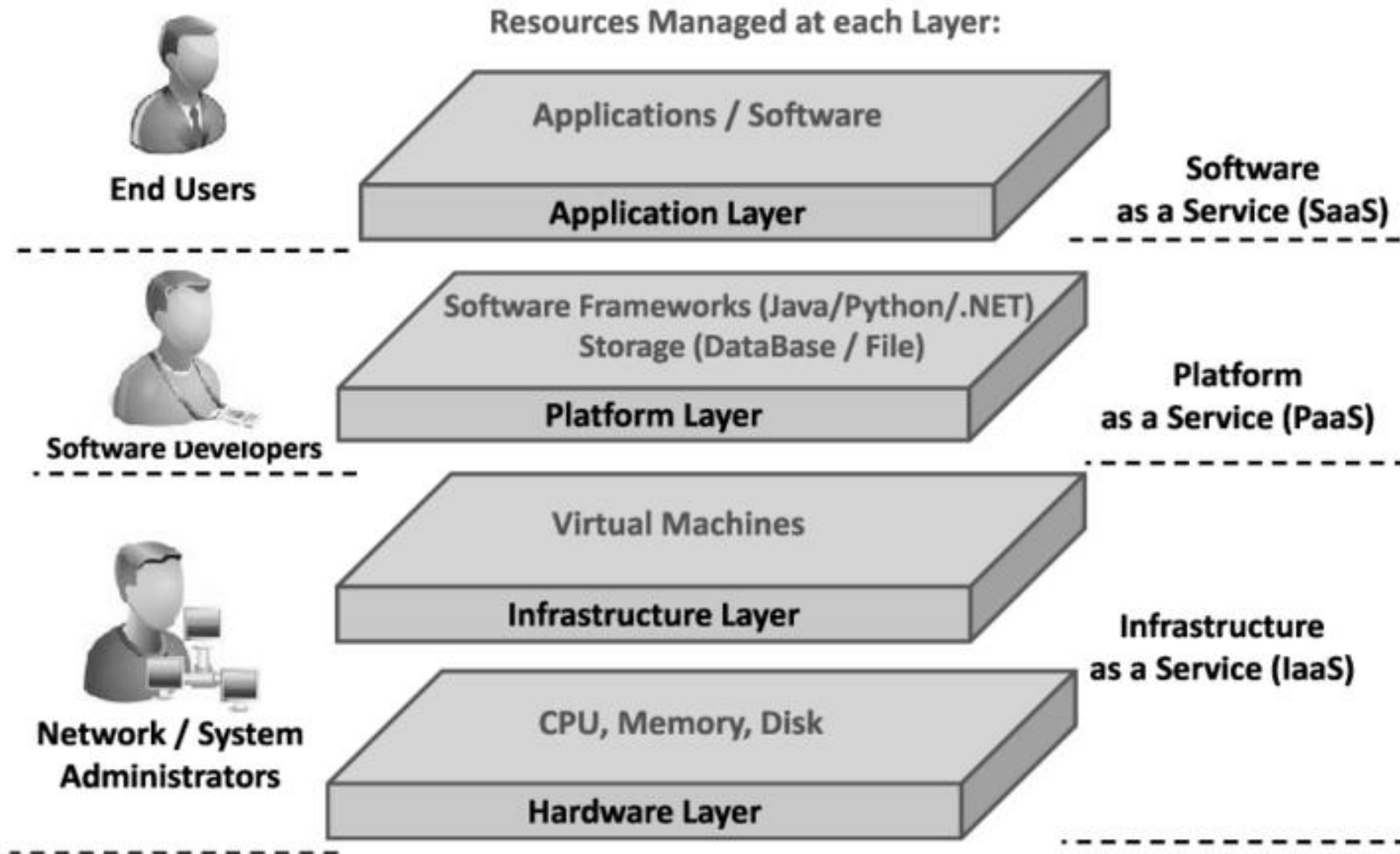↳ Continuous.

iii) Portability Issues.
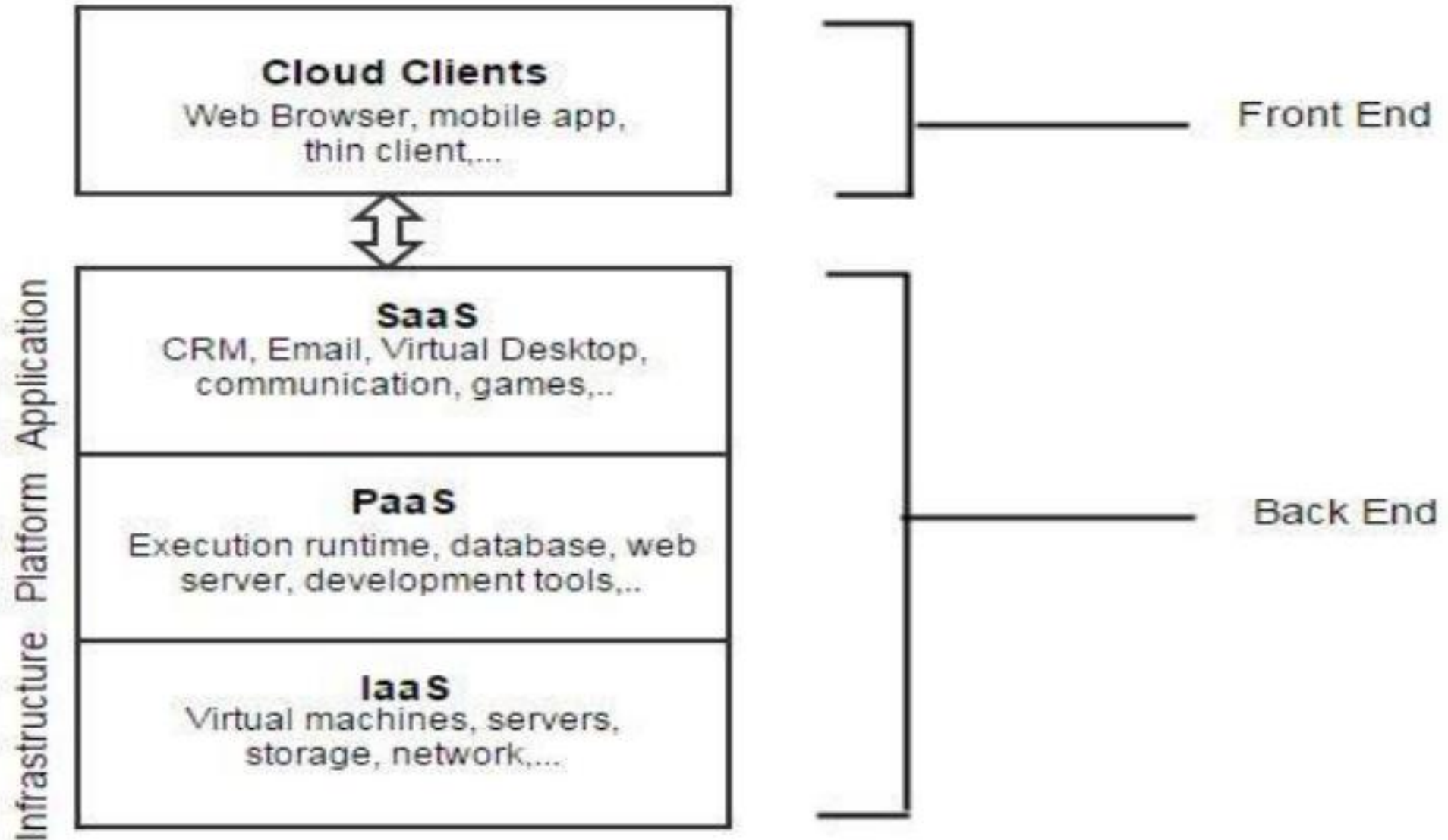↳ among diff. SaaS Clouds.

Eg:- NetSuite
AT&T
Intacct

word
cloud1

User
may not be Supported.

Cloud2

SaaS Examples

Cloud-computing Architecture

Architectural Design Challenges

1. Cost

- Cloud computing itself is affordable, **but tuning the platform according to the company's needs can be expensive.**

- Furthermore, the **expense of transferring the data** to public clouds can prove to be a problem **for short-lived and small-scale projects.**

2. Service Provider Reliability

- The capacity and capability of a technical service provider are as important as price. The **service provider must be available when you need them.**

- The main concern should be the service provider's sustainability and reputation.

Architectural Design Challenges

3. Downtime

- **Downtime is a significant shortcoming of cloud technology.**

- **No seller can promise a platform that is free of possible downtime.**

- **Companies with an untrustworthy internet connection probably want to think twice before adopting cloud computing.**

4. Password Security

- **Active password supervision** plays a vital role in cloud security. **However, the more people you have accessing your cloud account, the less secure it is.**

- **Businesses should employ multi-factor authentication and make sure that passwords are protected and altered regularly, particularly when staff members leave.**

Architectural Design Challenges

5. Data privacy

- **Sensitive and personal information that is kept in the cloud should be defined as being for internal use only, not to be shared with third parties.**

- Businesses must have a **plan to securely and efficiently manage the data** they gather.
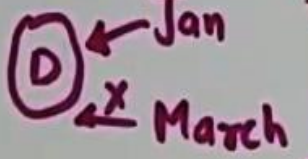
6. Vendor lock-in

- **Entering a cloud computing agreement is easier than leaving i**t. "Vendor lock-in" happens **when altering providers** is either excessively expensive or just not possible. It could be that the service is nonstandard or that there is no viable vendor substitute.

- It comes down to buyer carefulness. Guarantee the services you involve are typical and transportable to other providers, and above all, understand the requirements.

Architectural Design Challenges

CLOUD COMPUTING CHALLENGES:

Cloud Computing is used for enabling global access to mutual pool of resources such as Services, apps, data, servers and Computer Nlw.
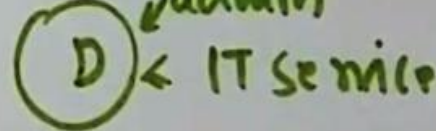
Challenges:

i) COST: Tuning the Platform, Data transfer, Maintenance, management] ↑ COST of cloud Computing.

ii) RELIABILITY: (D) ← Jan / ← March] Service must be available when need.

iii) DOWNTIME: To give better Service downtime should be as low as poss

iv) SECURITY: Is you data Secure.
↳ More Security in Passwords.
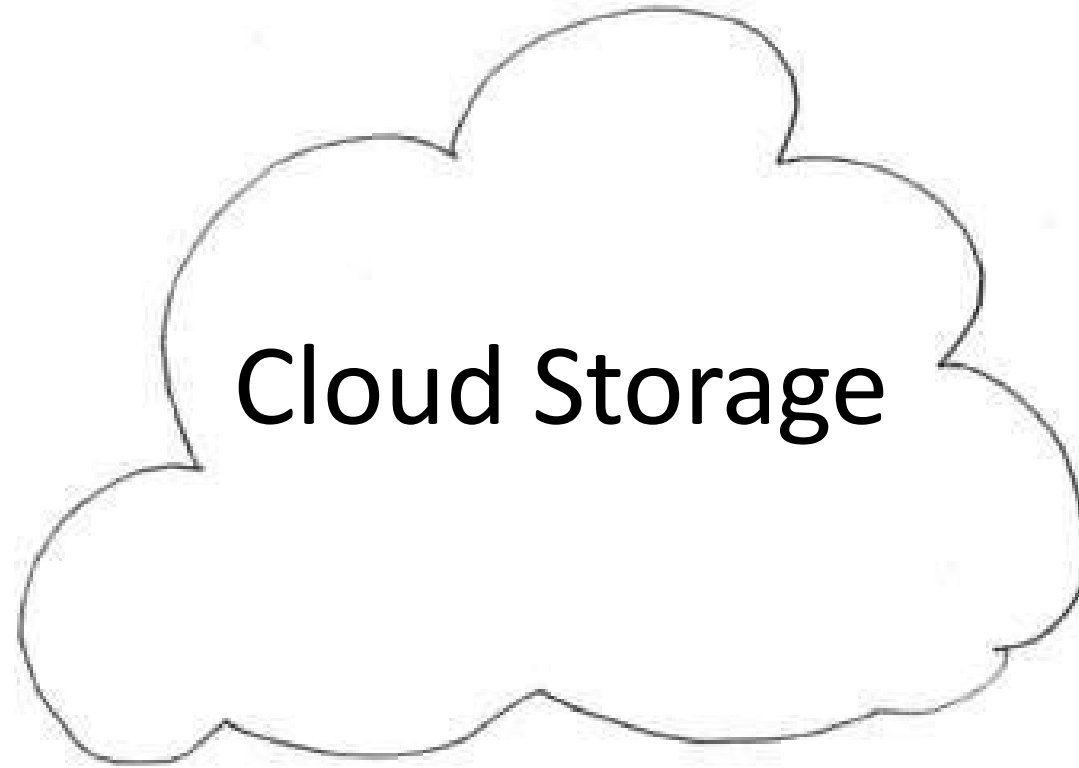↳ Access rights.

v) DATA PRIVACY: (D) ← admin / < IT service
All the info" related to Stored data must be kept private.

vi) LOCK-IN: Aggrement blw User and vendor.
↳ to make it Consumer friendly.

Cloud Storage

Cloud Storage

Contents

❑What is Cloud storage and introduction

❑Advantages of Cloud Storage

❑Storage as a service

❑Cloud Service Providers

❑Challenges in Cloud Storage

❑Disadvantages of Cloud Storage

❑Types of storage

What is cloud storage?

Data (or files) are said to be stored in the <u>cloud</u> when they are saved on a remote server, which is easily accessible from <u>anywhere with internet</u> <u>access</u>. This allows access to the data from any device connected to the internet, including computers, tablets and smartphones.

•**Refers to saving data to an off-site storage system maintained by a third party.**

•Instead of storing information to your computer's hard drive or other local storage device, **you save it to a remote database.**

• The Internet provides the connection between your computer and the database.

Cloud storage
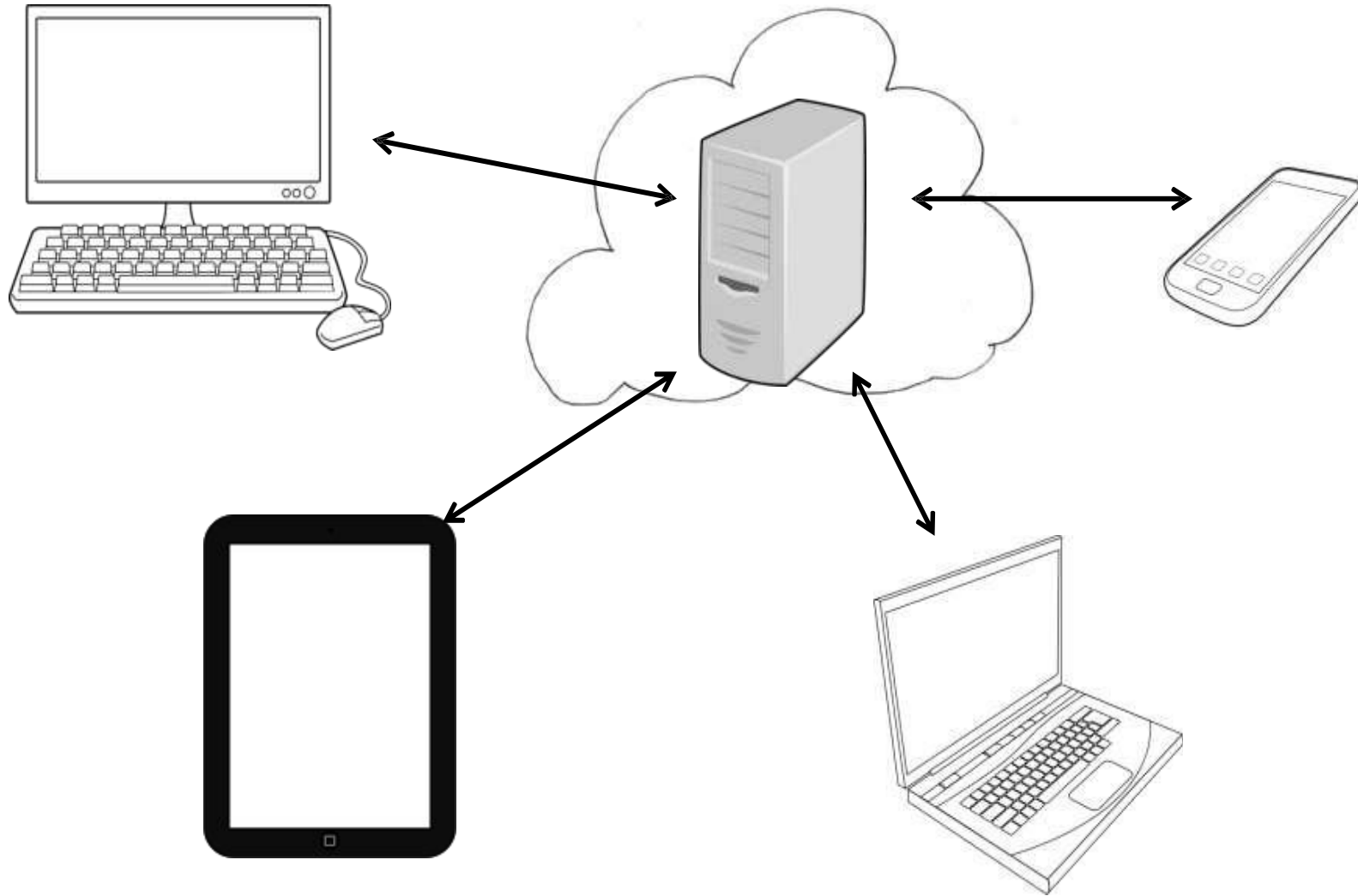
Cloud Storage - Business Benefits

- **With cloud storage, there's no need for CDs, external hard drives, or localized servers**

- **Data is quickly and automatically updated in the cloud and available for your retrieval whenever you need it**

- Should your office become the victim of a **robbery, fire, or natural disaster, your data is safe and secure in the cloud**, even if your physical assets are destroyed.

- With no need for physical, on-site storage space, **you can have a smaller workspace, less equipment to buy, and fewer IT employees to maintain your equipment and manage your data**

- IT staff's can spend more time to **focusing on other important tasks to help your business growth.**

Storage as a Service

- The term Storage as a Service means that **a third-party provider rents space on their storage to end users who lack the budget or capital budget to pay for it on their own.**

- Also ideal **when technical personnel are not available or have inadequate knowledge to implement and maintain that storage infrastructure.**

Commonly used platforms
(Examples of Storage as service (SaaS))

Google Drive

Google Drive

- This is a 'pure' cloud computing service, with **all the apps and storage found online. You can use it via desktop top computers, tablets like the iPad or on smartphones.   All of Google's services could be considered cloud computing really: Gmail, Google Calendar**, Google Reader, Google Voice, and so on.
- **Microsoft's OneDrive is very similar to Google Drive and offers much the same services.**

Dropbox

- Commonly used by boys and staff **to store their documents and images.**
- You might set your phone to automatically send **all pictures you take with it into your Dropbox account, so that even if you lose your phone, the pictures will still be available to you** up in space; you might use it to access your documents at home, and then save changes to it.
- Sugarsync is another example.

Apple iCloud

- Apple's cloud service is primarily **used by Apple users for online storage** and **synchronization** of their **mail**, **contacts**, **calendar**, and more. All the data you need is available to you on whichever device you seek to access it from, your iOS, Mac OS, or Windows device, and if you make a change to a document, say, on one of your devices, it will automatically update it so that when you next access it the amended version will be available to you on whatever device you use.

- **If you have loads of data up there (perhaps pictures or films you have made) then you will need to pay for extra storage – as indeed you do for all of these services.**

Amazon Cloud Drive

Storage at the big retailer is mainly for music – and they would certainly prefer it is music that you have bought from them!

Common Features

- A **three platforms** are third party services.
- All offer a basic amount of free storage:
  - **Dropbox**: 5 GB
  - **OneDrive** (linked to Microsoft live account): 7 GB
  - **Google Drive** (linked to Gmail account): 15 GB
- **After that, the user has to pay a yearly or monthly subscription fee.** E.g. Google Drive: 100 GB – $4.99/month; 200 GB – $9.99/month

Advantages of Cloud Storage

- Universal Access
- Collaboration
- Scalability
- Economical
- Reliability

Internet
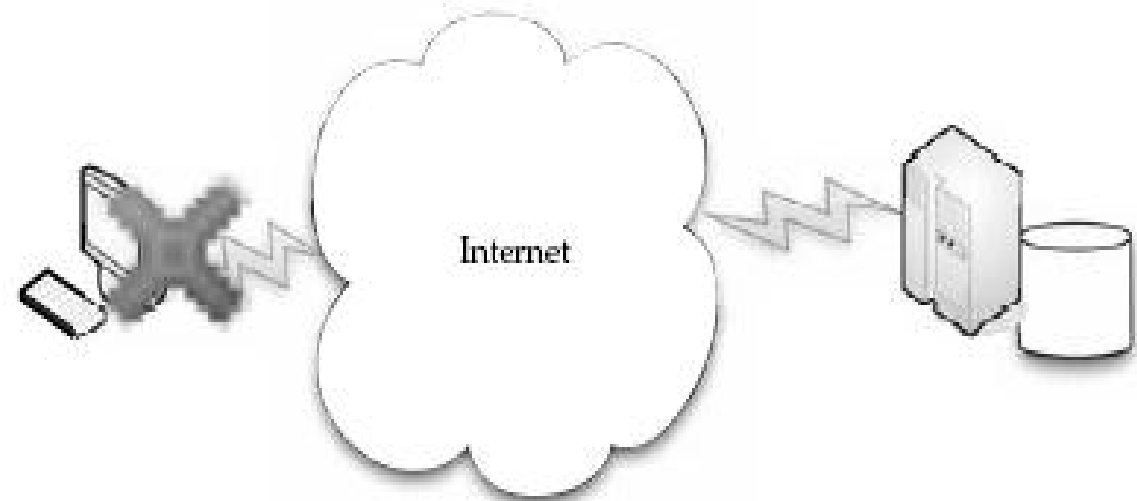
If there is a catastrophe at your organization, having your files backed up at a cloud storage provider means you won't have lost all your data.

Disadvantages of Cloud Storage

- Outsourcing increases attack surface area.
- Due to more locations, the **risk of unauthorized physical access** to the data increases.
- **Number of people** with access to data who could be compromised increases dramatically.
- Increases the networks over which the **data travels**.
- Access to other customers is also possible.

Challenges in Cloud Storage

- Security (Data Leakage): Stored as well as data in transit
- Security : -**Many companies may not want to hand over their data to an external organization to store, fearing that they may not have the right security software to protect the company's data.**
- Performance: There were several incidents that some **cloud-service providers temporarily went down or lost customer's data.**
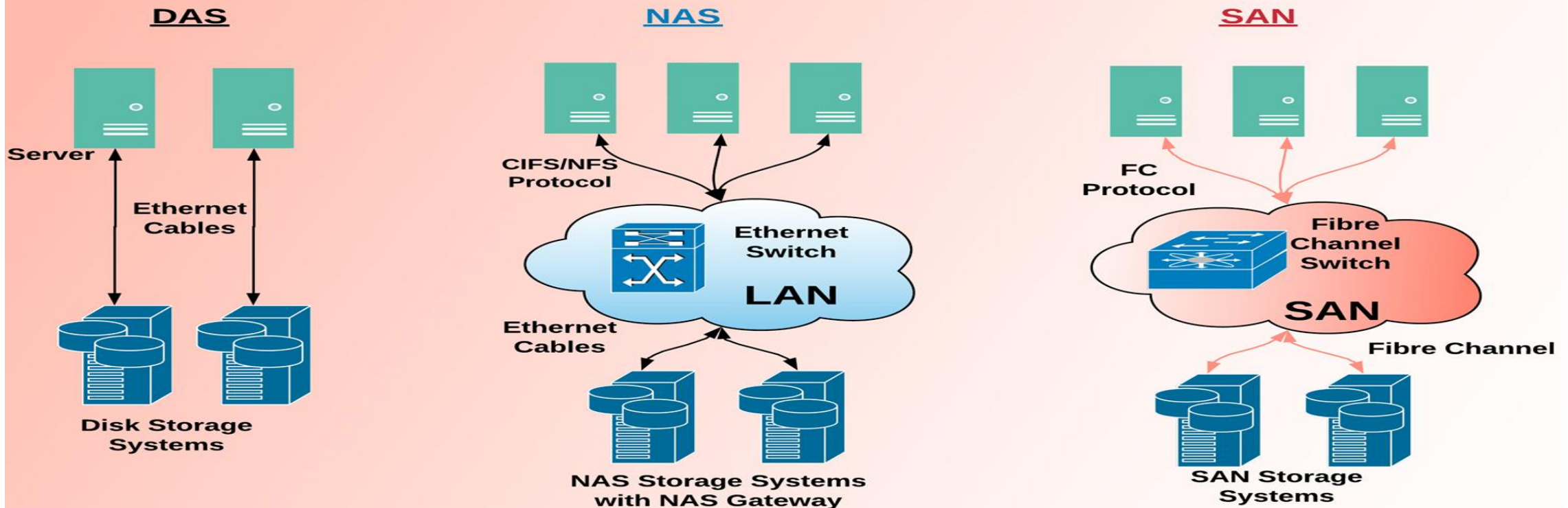
Security can be provided through using a combination of techniques:

- Encryption
- Authentication
- Authorization
- Reliability (Provided through Redundancy)

Types of Storage

- **Direct Attached Storage (DAS)**
- **Network Attached Storage (NAS)**
- **Storage Area Network (SAN)**


DAS vs NAS vs SAN Architecture

Direct Attached Storage (DAS)

- Direct-attached storage (DAS) refers to a **digital storage system directly attached to a server or workstation, without a storage network in between.**

- Examples of DAS include hard drives, optical disc drives, and storage on external drives.

- **Example is our local desktop, laptop etc. On Windows, the USB drive appears** and is made available as an unique partition. The USB drive is assigned its own unique letter, behaving much like an internal **hard drive would on Windows — appearing as (C:\), (D:\), (E:\), etc.**

- The main protocols used for DAS connections are ATA, SATA, eSATA, SCSI, SAS, USB, USB 3.

- DAS has been referred to as "Islands of Information". The disadvantages of DAS include **its inability to independently share data or unused resources with other servers.**

- SAN and NAS are specifically designed to be shared resources by multiple computers, whereas **DAS is designed to be used by (usually) a single computer.**

Direct Attached Storage (DAS)
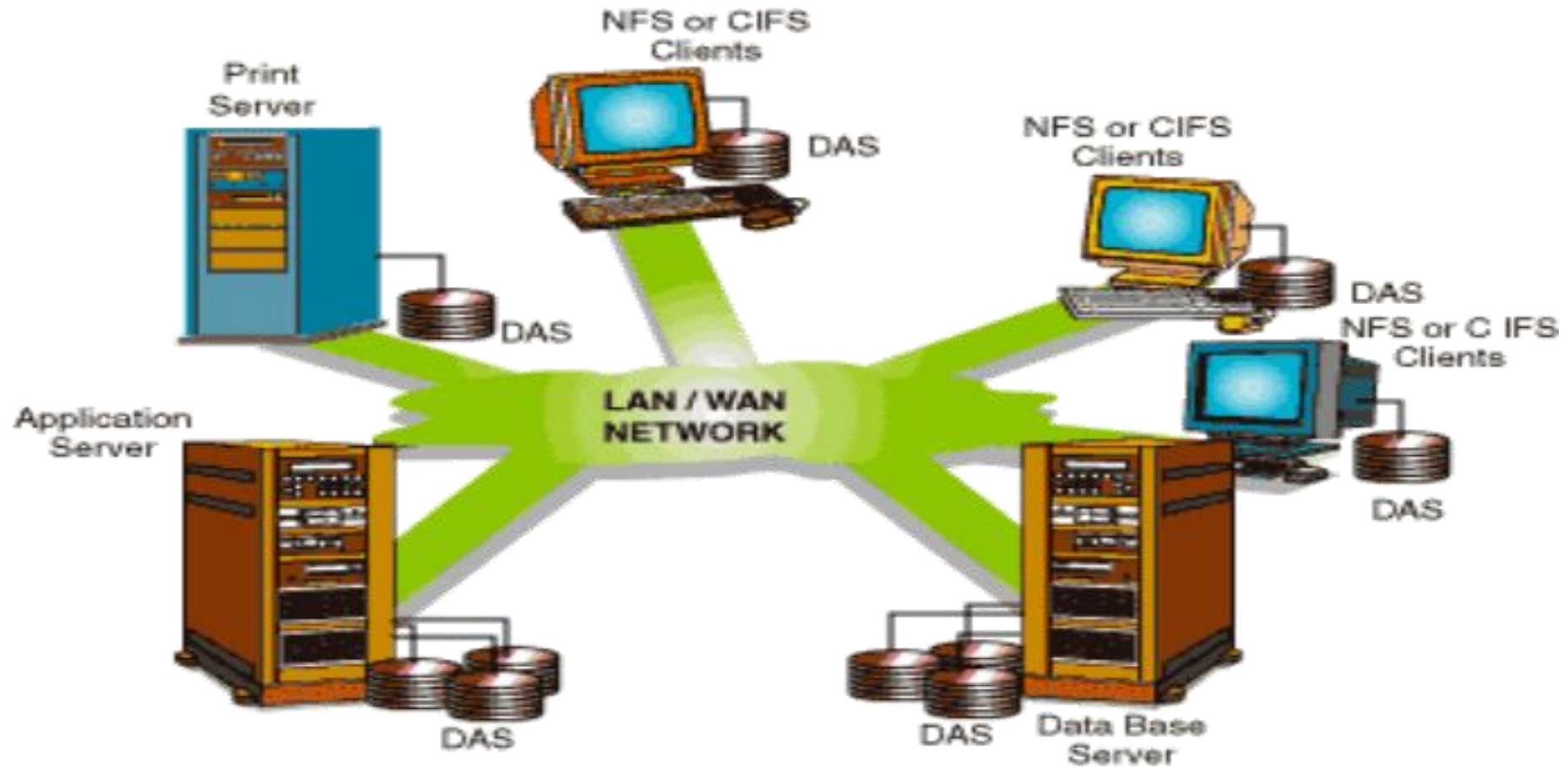
NFS used for Unix/ Linux systems and CIFS used for windows systems.

NFS, or Network File System.

"Common Internet File System." CIFS.

Direct Attached Storage (DAS)

- Best Use Case Scenario: DAS is ideal for **small businesses that only need to share data locally,** have a defined, non-growth budget to work with and have little to no IT support to maintain a complex system.

- Worst Use Case Scenario: **DAS is not a good choice for businesses that are growing quickly, need to scale quickly, need to share across distance and collaborate** or support a lot of system users and activity at once. **For cloud storage DAS is not a good choice. Only good for local storage, local company etc.**

Network Attached Storage (NAS)

- **Remember that a DAS functions as if it were "within" the computer it is connected to.**

- A NAS remains and functions as a separate computer that you will have to connect to with credentials (user and password).

- Once connected to a NAS, **you will see folders**, or more appropriately named "**Shares". Shares are just special folders that are accessible over the network. We could say "My Share" on "Super Desktop" is now shared over the network.**

- We could **even create multiple user logins and provide different levels of access here**. **Network attached storage devices are particularly good for sharing information and allowing for collaboration. Many businesses get a central file server (NAS)** setup fairly quickly, so they can **collaborate on files more easily across multiple computers.**

- **A NAS device is a shareable resource. Economical way to provide large storage to many persons or computers**

- **Several times easier to setup and configure versus SAN**

- **Allows users permissions, folder privileges, restricted access to documents, etc.**

- **On Windows**, you can find Shares provided by **NAS devices under the "Network" icon**. On Mac, you will see a "Shared" listing on the sidebar of Finder which is automatically populated.

Network Attached Storage (NAS)

- Network-attached storage (NAS) is **file-level computer data storage connected to a computer network providing data access to a heterogeneous group of clients.**

- NAS not only operates as a file server, but is specialized for this task either by its hardware, software, or configuration of those elements.

- Computer appliance – **a specialized computer built from the ground up for storing and serving files – rather than simply a general purpose computer** being used for the role.

- Provides access to files using network file sharing protocols such as NFS, SMB/CIFS (Server Message Block/Common Internet File System), or AFP(Apple Filing Protocol).

Network Attached Storage (NAS)

- Small Computer System Interface (SCSI) is a set of standards for physically connecting and transferring data between computers and peripheral devices.

- Common Internet File System." **CIFS** is a **standard file system designed for sharing files over the Internet**. It is **part of the SMB protocol**, which allows multiple types of **computers** to share data and peripherals over a network.
- **Server Message Block." SMB is a network protocol used by Windows-based computers.**

Network Attached Storage (NAS)

- Best Use Case Scenario: NAS is perfect for SMBs and organizations that need a minimal-maintenance, reliable and **flexible storage system that can quickly scale up as needed to accommodate new users or growing data.**

- Worst Use Case Scenario: Server-class devices at enterprise **organizations that need to transfer block-level data supported by a Fibre Channel connection may find that NAS can't deliver everything that's needed.** Maximum data transfer issues could be a problem with NAS.

NAS is also not good for cloud computing/cloud storage and for large scale organizations.

Storage Area Network (SAN)

- Remember what DAS is good at? Speed. Speed. SPEED.

- Remember what NAS is good at? Sharing. High Utilization. Flexibility.

- **Combining the best of DAS and NAS. So, use** Storage Area Network (SAN)

- SAN allows virtual environments, cloud computing, etc.
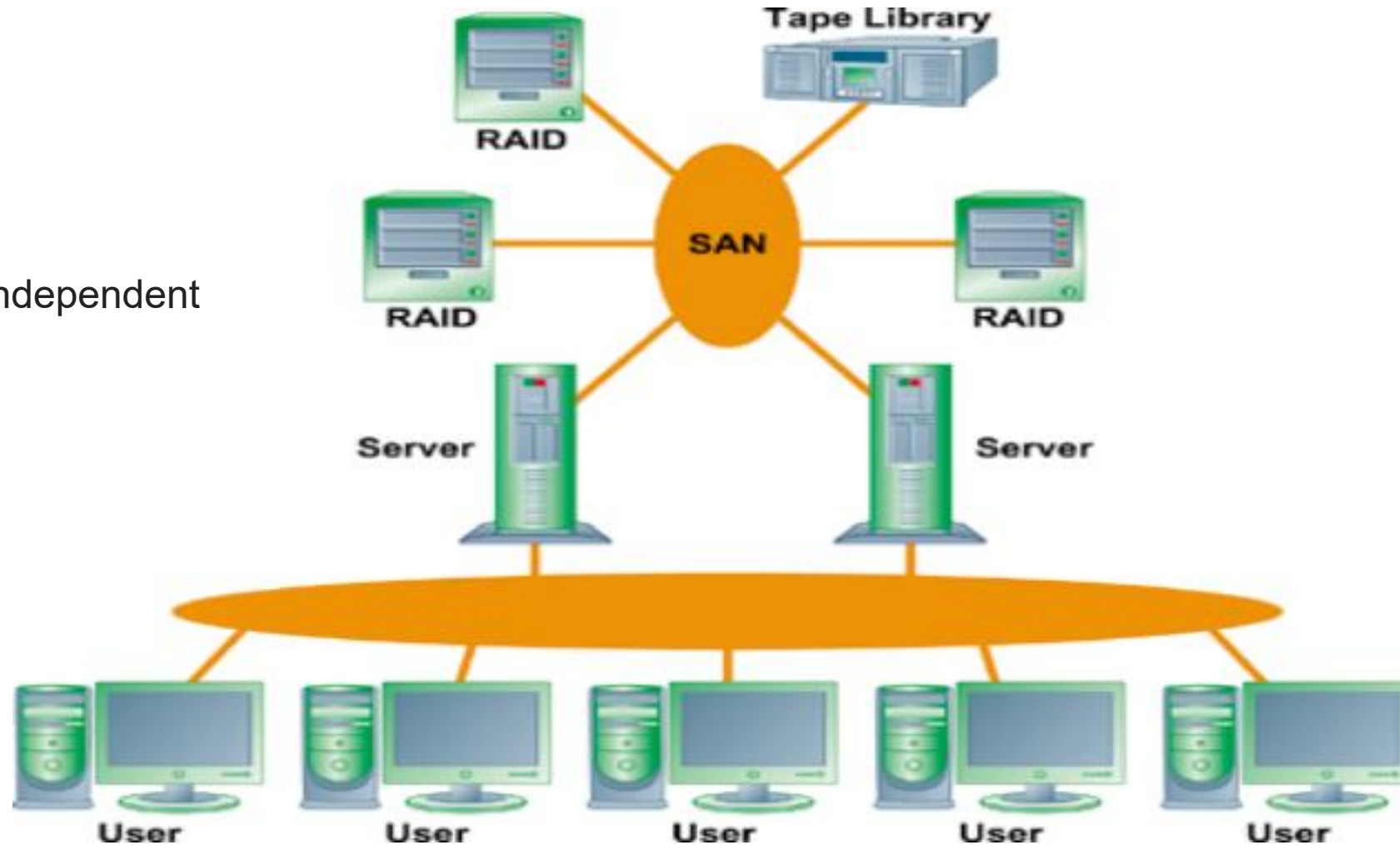
Storage Area Network (SAN)

- Used in cloud computing and **based on very high speed networks through fiber cables.**

- It is a collection of computers and storage devices, connected over a **high-speed optical network** and dedicated to the task of storing and protecting data.

- **High-speed network usually consists of optical fiber cables and switches** that use **light waves to transmit data** with a connection protocol known as Fiber Channel.

- **The act of using a network to create a shared pool of storage devices is what makes a SAN different.**

- **It provides a fast connection medium for data backup and restoration and data archiving and retrieval.**

- **Through the SAN different servers, servers to servers, storage to server, storage to storage can communicate each other using high speed networks.**

Storage Area Network (SAN)

- Historically data centers first created "islands" of SCSI disk arrays as direct-attached storage (DAS), each dedicated to an application.

- SAN consolidates such storage islands together using a high-speed network .

- **A typical SAN consists of a server, storage devices, and networking devices, and is used strictly for storage.**

- The SAN stores data on many different types of storage devices, providing data to the enterprise.

- **The SAN supports communication between any server and the storage unit as well as between different storage devices in the network.**

Storage Area Network (SAN)

Redundant Array of Independent Disks

Storage Area Network (SAN)

- It eliminates any restriction to the amount of data that a server can access, currently limited by the number of storage devices that are attached to the individual server.

- Instead, **a SAN introduces the flexibility of networking to enable one server or many heterogeneous servers to share a common storage utility.**

- **A network might include many storage devices, including disk, tape, and optical storage.**

- **Additionally, the storage utility might be located far from the servers that it uses.**

Data Communication in SAN

- **Server to storage:**
  - This is the traditional model of interaction with storage devices.
  - **The advantage is that the same storage device might be accessed serially or concurrently by multiple servers.**

- **Server to server: A SAN might be used for high-speed, high-volume communications between servers.**

- **Storage to storage:**
  - **Storage to Storage data transfer is also available via direct data transmission with minimal or no server intervention**
  - Therefore freeing up server processor cycles for other activities like application processing.
  - **Examples include a disk device that backs up its data to a tape device without server intervention.**

Benefits of using SAN

- **Greater performance: Fiber Channel SANs allow data retrieval speeds that exceed 5 Gbps.**

- **Centralized and Consolidated Storage:** Simpler management, scalability and flexibility.

- **Increased disk utilization:** SAN enables more than one server to access the same physical disk, which lets you allocate the free space on those disks more effectively.

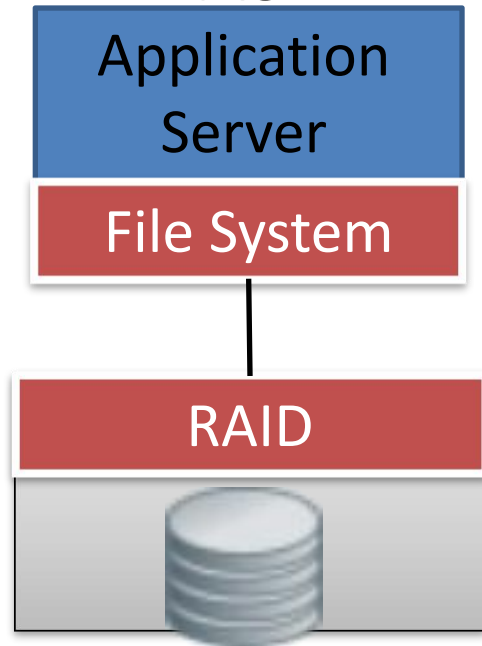- **Higher availability to storage by use of multiple access paths**

Benefits of using SAN

- **Deferred disk procurement:** Because you can use disk space more effectively, no space goes to waste, thus **you don't need to buy disks** as often as you used to.

- **Reduced data center rack/floor space:** Because you don't need to buy big servers with room for lots of disks, **you can buy fewer, smaller servers, which takes up less room.**

- **New disaster recovery capabilities:** SAN devices have the ability to **mirror the data on the disks to another location**. This can make your data safe if a disaster occurs.

- **Better staff utilization:** SANs enable **fewer people to manage much more data.**

	NAS	SAN
Fabric	Uses TCP/IP networks, most commonly Ethernet	Runs on high speed Fibre Channel networks
Data processing	Processes file-based data	Processes block data
Protocols	Connects directly to an Ethernet network Can use several protocols to connect with servers including NFS, SMB/CIFS, and HTTP	Uses SCSI protocol to communicate with servers
Performance	Generally has lower throughput and higher latency because of its slower file system layer	A higher performer for environments that need high-speed traffic
Scalability	Entry level and NAS devices are not highly scalable, High-end NAS systems scale to petabytes using clusters or scale-out nodes	Scalability is a major driver: its network architecture enables admins to scale performance and capacity in scale-up or scale-out configurations
Ease of management	Easier to manage: device easily plugs into the LAN and offers a simplified management interface	Requires more administration time than NAS
Price	In general NAS is less expensive to purchase and maintain, although a high-end NAS will cost more than an entry-level SAN	SANs are more complex to manage with FC SANs on top of the complexity heap

Storage Comparison

DAS

Application Server

File System

RAID

Just Like a local system,
local storage

NAS

Application Server

Application Server

Ethernet Switch

File System

RAID

SAN

Application Server

Application Server

File System

File System

Ethernet Switch

RAID
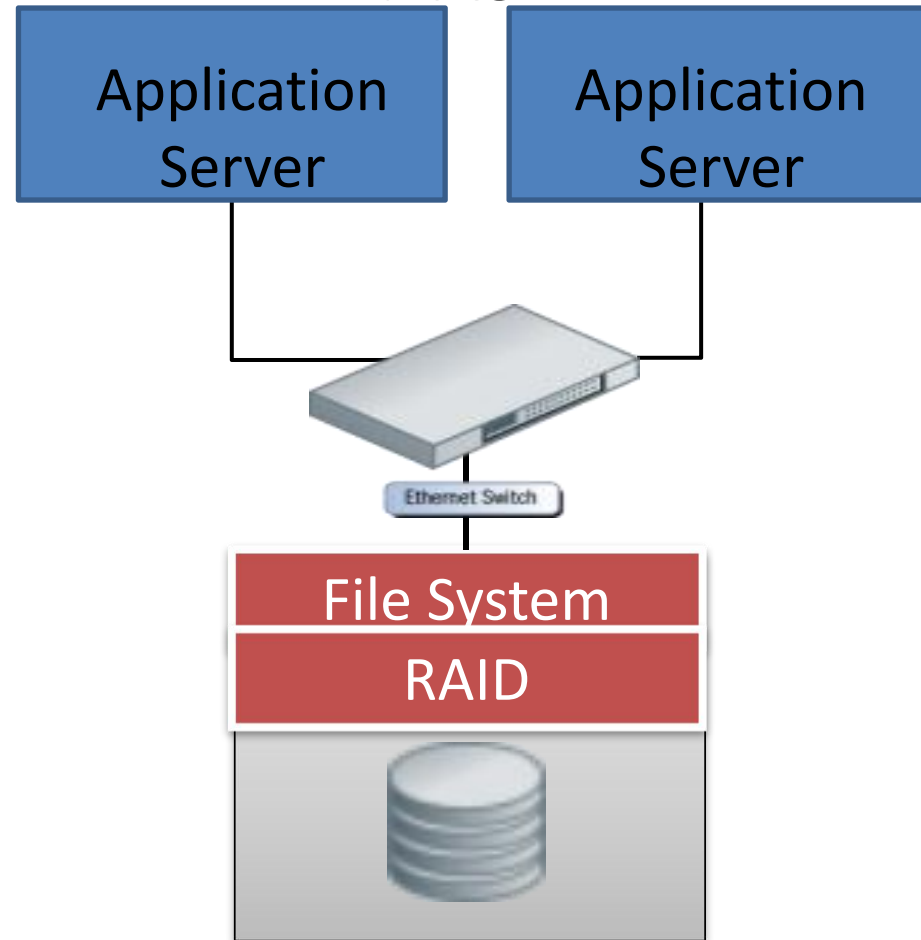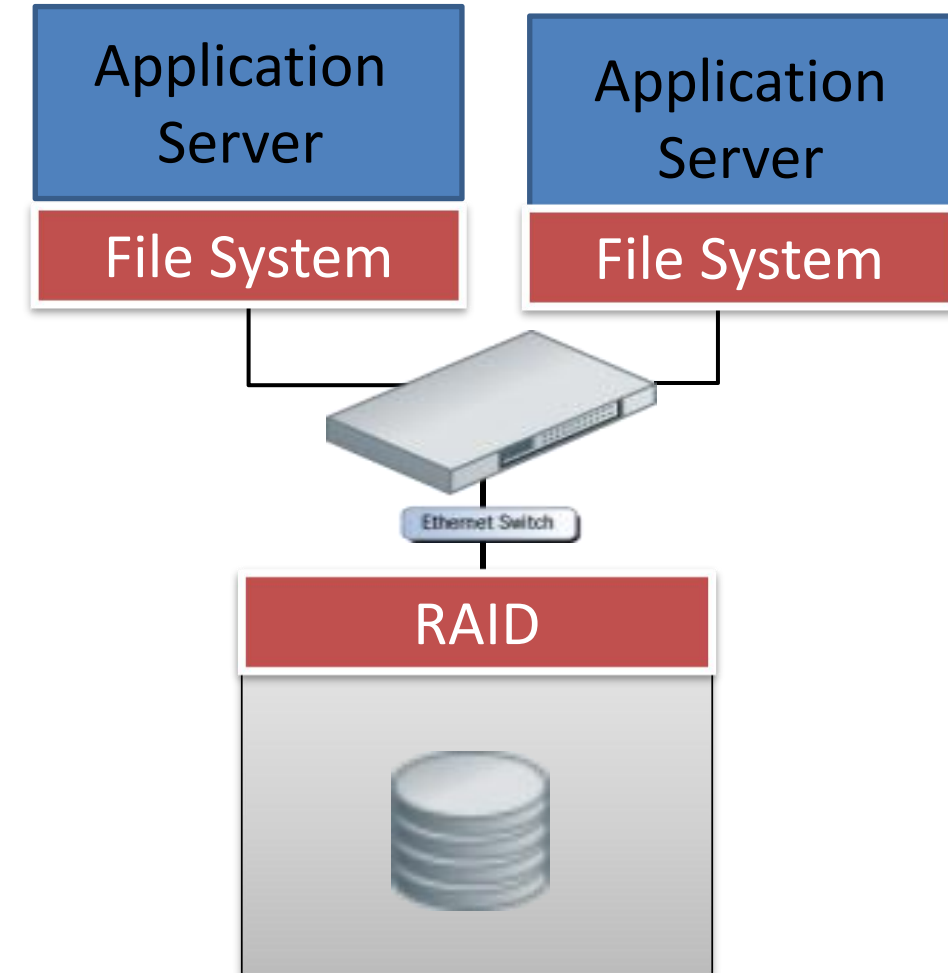
Cloud Service Providers

Contents

- What is Cloud Service Providers

- Amazon Elastic Compute Cloud(EC2)

- Amazon Simple Storage Service(S3)

- Microsoft Windows Azure

- Google App Engine

CLOUD COMPUTING PROVIDERS:

① Amazon Web Services (AWS):

   ↳ Provides services such as Computation power, Storage etc.

   ↳ flexible, reliable and scalable

   ↳ (Pay per usage.)

② Microsoft Azure: Used for building, testing, deploying and managing (appl".)

   ↳ uses Hypervisor } → Virtualization

③ Google Cloud: Basically used for Google Search and Youtube.

   ↳ Services offered: → Data Analysis → Machine Learning → Storage.

     ↳ Apps.

④ Salesforce.Com: Development Platform. [CRM]

   ↳ Customer rel" management

IBM, Adobe (Acrobat, flashplayer)

Saas

Cloud Service Providers

- Cloud service providers (CSP) **are companies that offer network services, infrastructure, or business applications in the cloud. The cloud services are hosted in a data center that can be accessed by companies or individuals using network connectivity.**

1. Amazon- **Elastic Compute** Cloud (EC2)-IaaS
2. Amazon Simple **Storage Service**(S3)
3. Microsoft- Windows Azure (PaaS)
4. Google- Google App Engine (PaaS)
5. Salesforce.com (SaaS)

Features	AWS	Microsoft Azure	Google Cloud
Maximum Processors in VM	128	128	96
Maximum Memory in VM (GiB)	3904	3800	1433
SLA Availability	Amazon EC2: 99.95% annual uptime in service year Amazon S3: Monthly uptime of at least 99.9% for any billing cycle	99.9% Uptime	99.95% Monthly Uptime
Operating Systems Supported	Windows, SLES, CentOS, CoreOS, OpenSUSE, RHEL, CloudLinux, Debian, FreeBSD, Ubuntu, Oracle Linux	Windows, SLES, CentOS, CoreOS, OpenSUSE, RHEL, Debian, FreeBSD, Ubuntu, Oracle Linux	Windows, SLES, CentOS, CoreOS, OpenSUSE, RHEL, Debian, FreeBSD, Ubuntu,
Marketplace	AWS Marketplace	Azure Marketplace	G Suite Marketplace

AMAZON ELASTIC COMPUTE CLOUD (EC2)

Elastic Compute Cloud

→ Provide Secure and reseizable Compute Capacity in Cloud. (developer ease)

① Scaling. (Instances Scaled up or down)

② Integrated with other services. (S3, RDS)

③ Pay for what you use

④ Instances can be launched in one or more Regions and AZs.

⑤ Support for different OS.

⑥ Works with Amazon VPC to provide Secure network to resources.
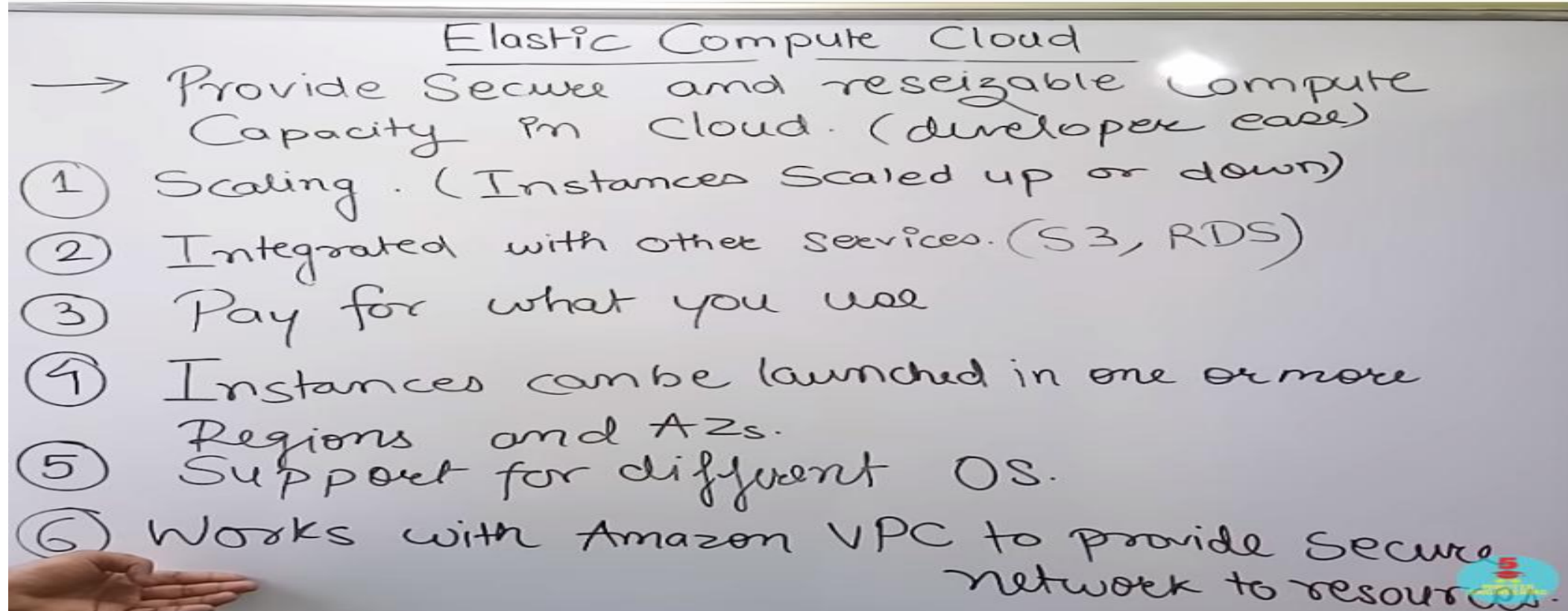
- Open the Amazon Elastic Cloud Compute (Amazon EC2) console. From the navigation bar, view the options in the Region selector. On the navigation pane, choose **EC2 Dashboard**. In the Service Health section, view the list of Availability Zones under **Availability Zone** Status.
- **Virtual private cloud (VPC)**
- **Amazon Relational Database Service** (Amazon **RDS**) is a web service that makes it easier to set up, operate, and scale a relational database in the AWS **Cloud**.

Amazon **Elastic Compute** Cloud

- Amazon Elastic Compute Cloud (Amazon EC2) is a web service that provides **resizable compute capacity in the cloud**.

- **An Amazon Machine Image (AMI) is a special type of pre-configured operating system and virtual application software which is used to create a virtual machine within the Amazon Elastic Compute Cloud (EC2).**

- It serves as the basic unit of deployment for services delivered using EC2.

Service Highlights

Elastic

- **Capacity can be increased or decreased** within minutes, not hours or days.

- You can order/demand one, hundreds or even thousands of **server instances simultaneously.**

Completely Controlled and Flexible

- **You have the choice of multiple instance types, operating systems, and software packages.**

Designed for use with other Amazon Web Services

Reliable

- The Amazon EC2 **Service Level Agreement** commitment is 99.95% availability for each Amazon EC2 Region.

Secure

- When launching Amazon EC2 resources within Amazon Virtual Private Cloud (Amazon VPC), you can isolate your compute instances by specifying the IP range you wish to use, and connect to your existing IT infrastructure using industry-standard encrypted IPsec VPN.

Amazon **Simple Storage Service**(S3)

- **Online Storage Web Service** offered by Amazon Web Services. Launched in 2006.

- S3's design aims to provide scalability, high availability, and low latency at commodity costs.

- S3 is designed to provide 99.999999999% durability and 99.99% availability of objects over a given year, however there is no Service Level Agreement (SLA) for durability.

# Amazon Simple Storage Service(S3)

Simple Storage Service

→ Provides object storage which is built for storing and recovering any amount of data from anywhere over the INTERNET.

→ Durability : 99.999999999 %

→ Availability : 99.99 %

→ Cost effective.

→ Scalability.

→ Security

→ Object consist of Data + metadata

→ Bucket stores objects.

→ Data Encryption : To protect data when its being Transmitted and also when at rest.

Features

- **Write, read, and delete <u>objects</u> containing from 1 byte to 5 gigabytes of data each.**

- **The number of objects that can be stored is unlimited.**

- Each **<u>object is stored and retrieved via a unique developer-assigned key.</u>**

- **Objects can be made <u>private or public, and rights can be assigned</u> to specific users.**

How S3 works?

- S3 stores arbitrary **objects** at up to 5GB in size, and each is accompanied by up to 2KB of metadata.

- <u>Objects are organized by</u> **buckets**. **Each bucket is owned by an AWS account and the buckets are identified by a unique, user-assigned key.**
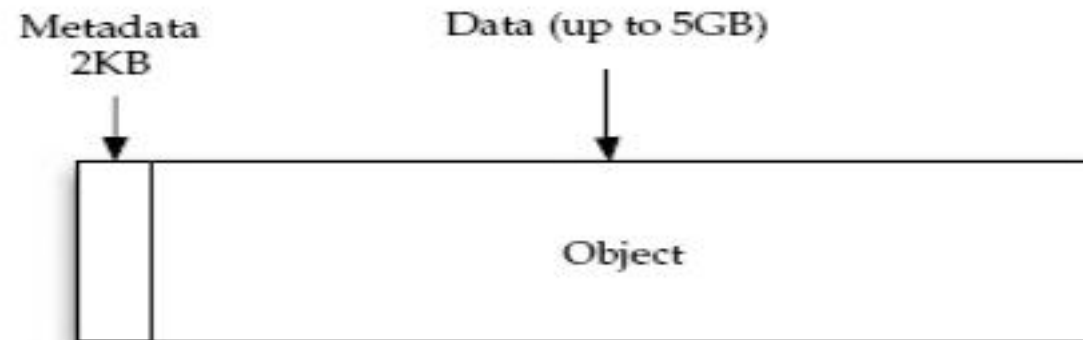
How S3 works?

- **An access control list restricts who can access the data in each bucket.**

- **Bucket names and keys are formulated so that they can be accessed using HTTP.**

- Requests are authorized using an access control list associated with each bucket and object, for instance:

  http://s3.amazonaws.com/examplebucket/examplekey

  http://examplebucket.s3.amazonaws.com/examplekey

The Amazon AWS Authentication tools allow the bucket owner to create an authenticated URL with a set amount of time that the URL will be valid. That is, someone can construct a URL that can be handed off to a third-party for access for a period such as the next 30 minutes, or the next 24 hours.

Amazon S3

Storage classes available with Amazon S3 are –
1. *Amazon S3 standard*
2. *Amazon S3 standard-infrequent Access*
3. *Amazon Glacier*

- **Amazon S3 Standard** for **general-purpose storage** of **frequently accessed data**

- **Amazon S3 Standard – Infrequent Access (Standard – IA)** for long-lived, but **less frequently accessed** data

- **Amazon Glacier** for long-term archive.

Life Cycle Management

- Amazon S3 also offers <u>configurable lifecycle policies for managing your data throughout its lifecycle.</u>

- <u>Once a policy is set, your data will automatically migrate to the most appropriate storage class</u> without any changes to your applications.

AWS Free Usage Tier

- As part of the AWS Free Usage Tier, you can get started with Amazon S3 for free.

- Upon sign-up, new AWS customers receive 5 GB of Amazon S3 standard storage, 20,000 Get Requests, 2,000 Put Requests, and 15GB of data transfer out each month for one year.

S3 Applications

- Photo hosting service SmugMug has used S3 since April 2006.

- **DropBox, StoreGrid and SyncBlaze are some of the many online backup and synchronization services that use S3 as their storage and transfer facility.**

- The science team at the University of California Berkeley responsible for NASA's

  "Stardust@Home" project   (http://stardustathome.ssl.berkeley.edu/) **is using Amazon S3 to store and deliver the 60 million images** that represent the data collected from their dust particle aerogel experiment.

Microsoft- Windows Azure (PaaS)

- **Microsoft cloud computing platform.**

- **Window Azure is worked as PaaS**

- **Used to build, deploy and manage applications through a global network of Microsoft-managed datacenters.**

- **Allows for applications to be built using many different languages, tools or frameworks (PHP, Java, .NET)**
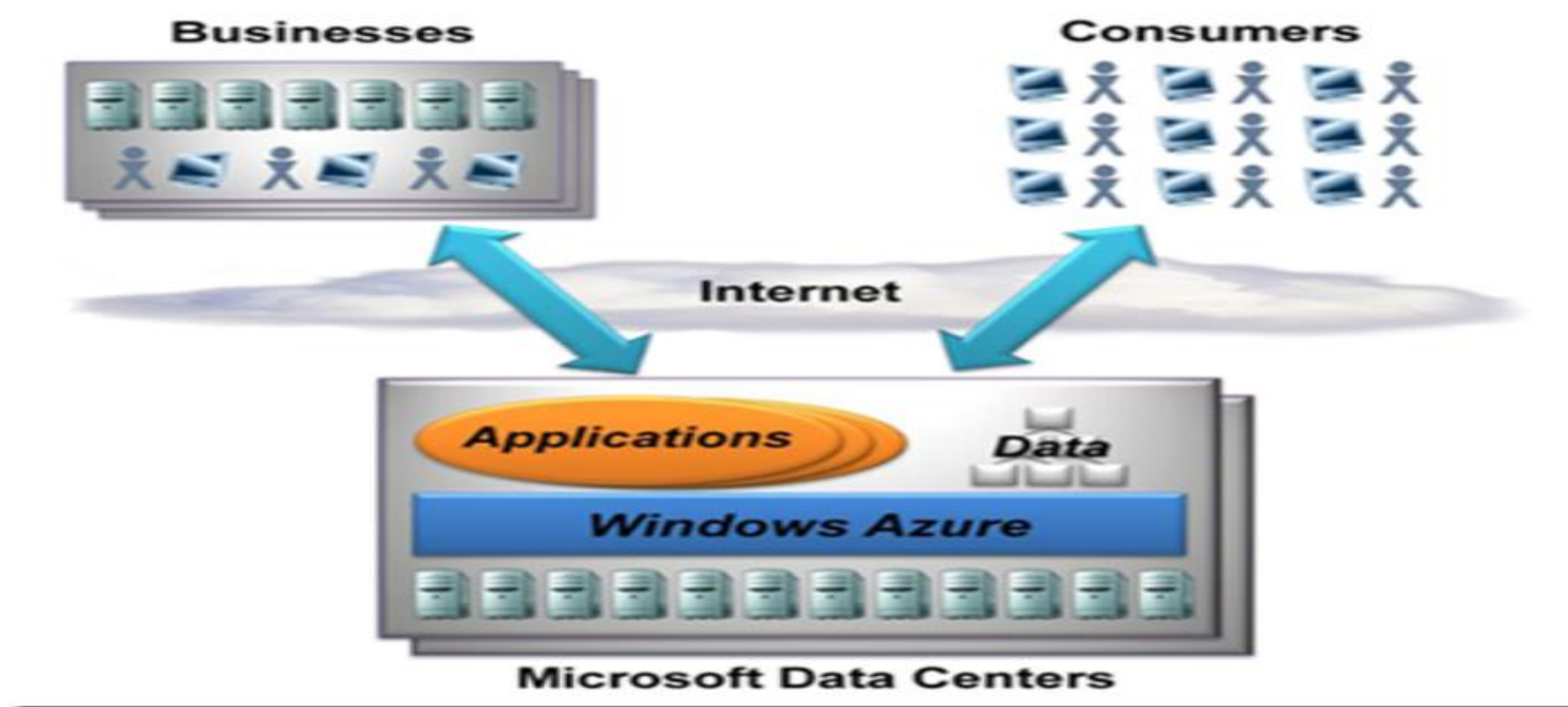
Windows Azure

Figure shows the Microsoft Data Centers in which Window Azure is worked as PaaS, different application can run on this platform and used by end user .

Windows Azure has three core components:
1. The Compute service
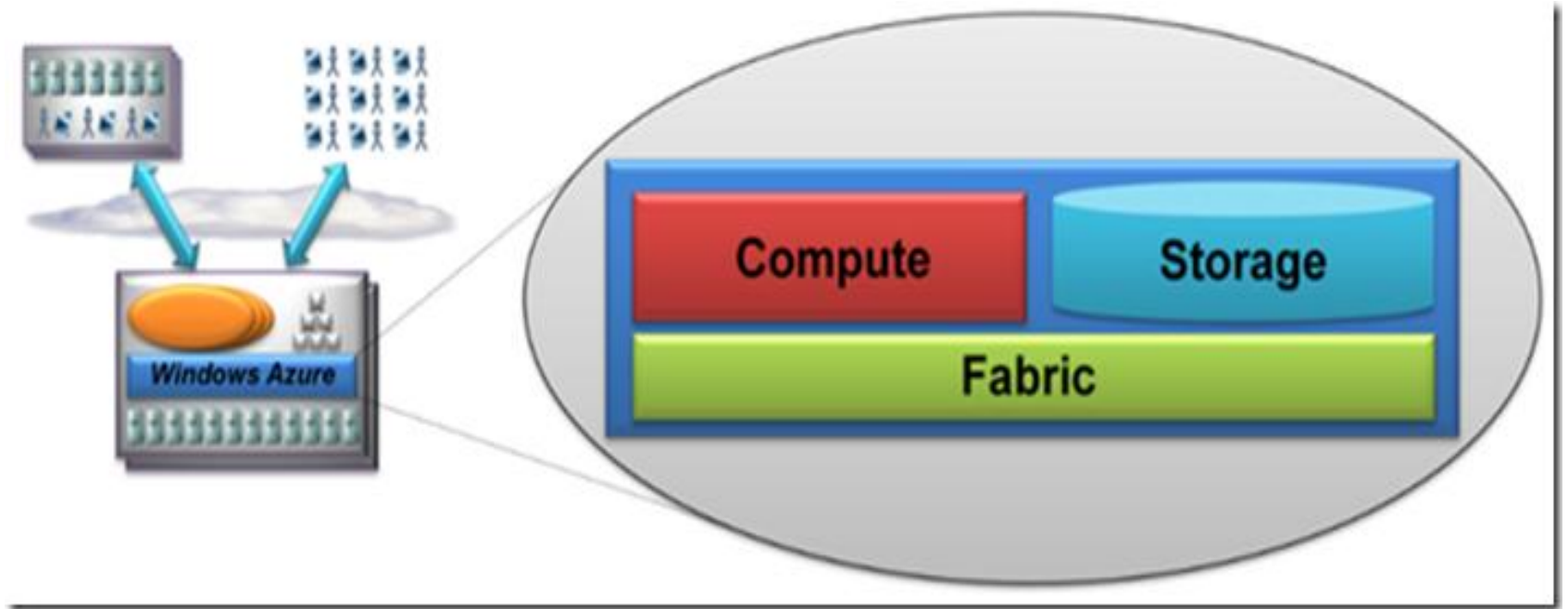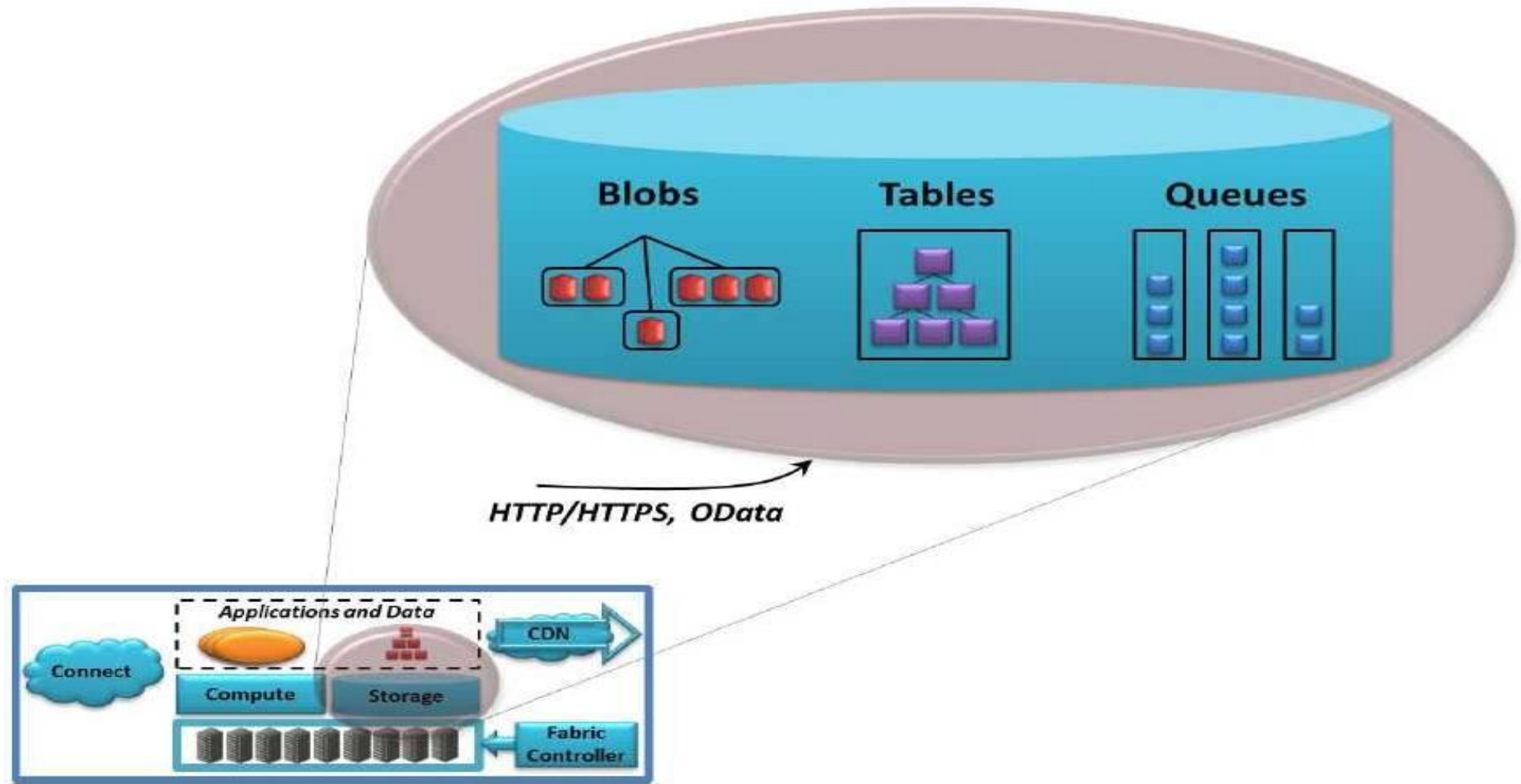**2. Storage service**
3. Fabric.

Figure shows the core components of Windows Azure
- **Compute : Runs applications**
- **Storage : Stores the data**
- **Fabric : Provides a common way** *to manage and monitor applications* **that use this cloud platform.**

Compute Service

- The Windows Azure **Compute service can run many different kinds of applications**.

- A primary goal of this platform is to **support applications that have a very large number of simultaneous users.**

- **To allow this, a Windows Azure application can have multiple instances, each executing in its own virtual machine (VM).**

- **To run an application, a developer accesses the Windows Azure portal through her Web browser, signing in with a Windows Live ID.**

- **She then chooses whether to create a hosting account for running applications, a storage account for storing data, or both.**

- Once the developer has a hosting account, she can upload her application, specifying how many instances the application needs. Windows Azure then creates the necessary VMs and runs the application.

Storage Service

Storage Service

- **BLOBS**
  - **Binary Large Objects** – Fundamental storage in Azure
  - Store binary data
  - Can be as big as **50 GB each**
 - May have associated metadata
- **TABLES**
  - To let applications work with data in a more fine-grained way, **Windows Azure storage provides tables.**
  - These aren't relational tables. In fact, even though they're called "tables", the data they hold is actually stored in a **simple hierarchy of entities that contain properties.**

Storage Service

- **Binary Large Objects (Blobs) and tables are both focused on storing and accessing data.**

- **The third option in Windows Azure storage, queues, has a quite different purpose.**

- A primary function of queues is to **provide a way for Web role instances to communicate with Worker role instances.**

- **All information held in Windows Azure storage is replicated three times.**

Fabric
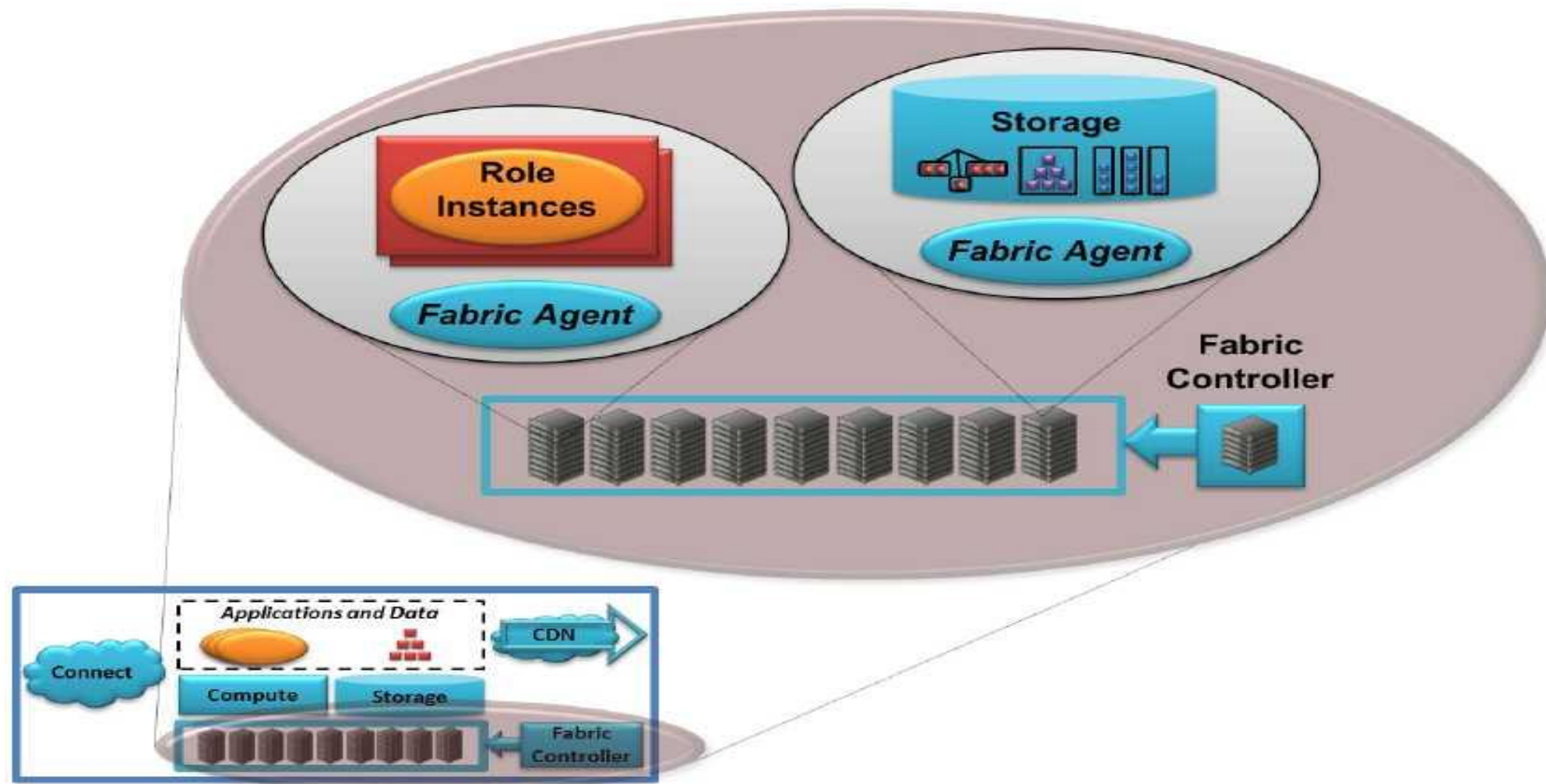
Fabric

- The Windows Azure Fabric consists of a (large) **group of machines, all of which are managed by software called the fabric controller.**

- The **fabric controller** is replicated across a group of five to seven machines, and it **maintains all of the resources** in the fabric: computers, switches, load balancers, and more.

- Because it can communicate with a fabric agent on every computer, it's also aware of every Windows Azure application in this fabric.

Fabric Controller

- **It monitors all running applications**, for example, giving it an up-to-the-minute picture of what's happening in the fabric.

- **It manages operating systems**, taking care of things like patching the version of Windows Server 2008 that runs in Windows Azure VMs.

- **It also decides where new applications should run**, choosing physical servers to optimize hardware utilization.

Google App Engine..(Contd..)

- Google App Engine (often referred to as **GAE** or simply App Engine) is **a platform as a service (PaaS) cloud computing platform for developing and hosting web applications** in Google-managed data centers.
- **App Engine offers automatic scaling for web applications—as the number of requests increases for an application.**
- **Automatically allocates more resources for the web application to handle the additional demand.**
- **If you want to get an app on the cloud, the Google App Engine is the perfect tool to use to make this dream become reality. In crux, you write a bit of code in Python, change some HTML code, and then you've got your app built, and it only takes a few minutes.**

Google App Engine

Easy to build.

Easy to maintain.

Easy to scale as the traffic and storage needs grow.

- Tools you know and love: Python, Java, PHP, Go and Cloud SQL.
- Used by millions: Snapchat, Rovio, and Khan Academy run on App Engine.
- Build and deploy: No worrying about DBAs, servers and load balancers.
- Scale: Auto scale to 7 billion requests per day.
- Type: Web development

Google App Engine..(Contd)

Strengths

Don't have to worry about buying servers or load balancers, Google handles all heavy lifting for you

Automatically allocates more resources for the web application to handle the additional demand.

App Engine is best for simple applications that plan on staying simple.

Weakness

App Engine is like a data store. It won't do the complex things that Oracle will allow

Does not support 'naked' domains (without www) like http://example.com

Your app has to be pretty efficient, because App Engine will kill any thread that takes too long to run.

Google says it reserves the right to "pre-screen, review, flag, filter, modify, refuse or remove any or all Content from the Service."

Some Commercial-Oriented Cloud platforms/technologies

System Property	Amazon EC2 & S3	Google App Engine	Microsoft Azure	Manjrasoft Aneka
Focus	IaaS	IaaS/PaaS	IaaS/PaaS	PaaS
Service Type	Compute (EC2), Storage (S3)	Web apps	Web and non-web apps	Compute/Data
Virtualisation	OS Level: Xen	Apps container	OS level/Hyper-V	Resource Manager and Scheduler
Dynamic Negotiation of QoS	None	None	None	SLA-oriented/ Resource Reservation
User Access Interface	EC2 Command-line Tools	Web-based Administration Console	Windows Azure portal	Workbench, Tools
Web APIs	Yes	Yes	Yes	Yes
Value-added Service Providers	Yes	No	Yes	No
Programming Framework	Amazon Machine Image (AMI)	Python	.NET framework	Multiple App models in.NET languages

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