# Cloud Computing Fundamentals


## Prepared By:
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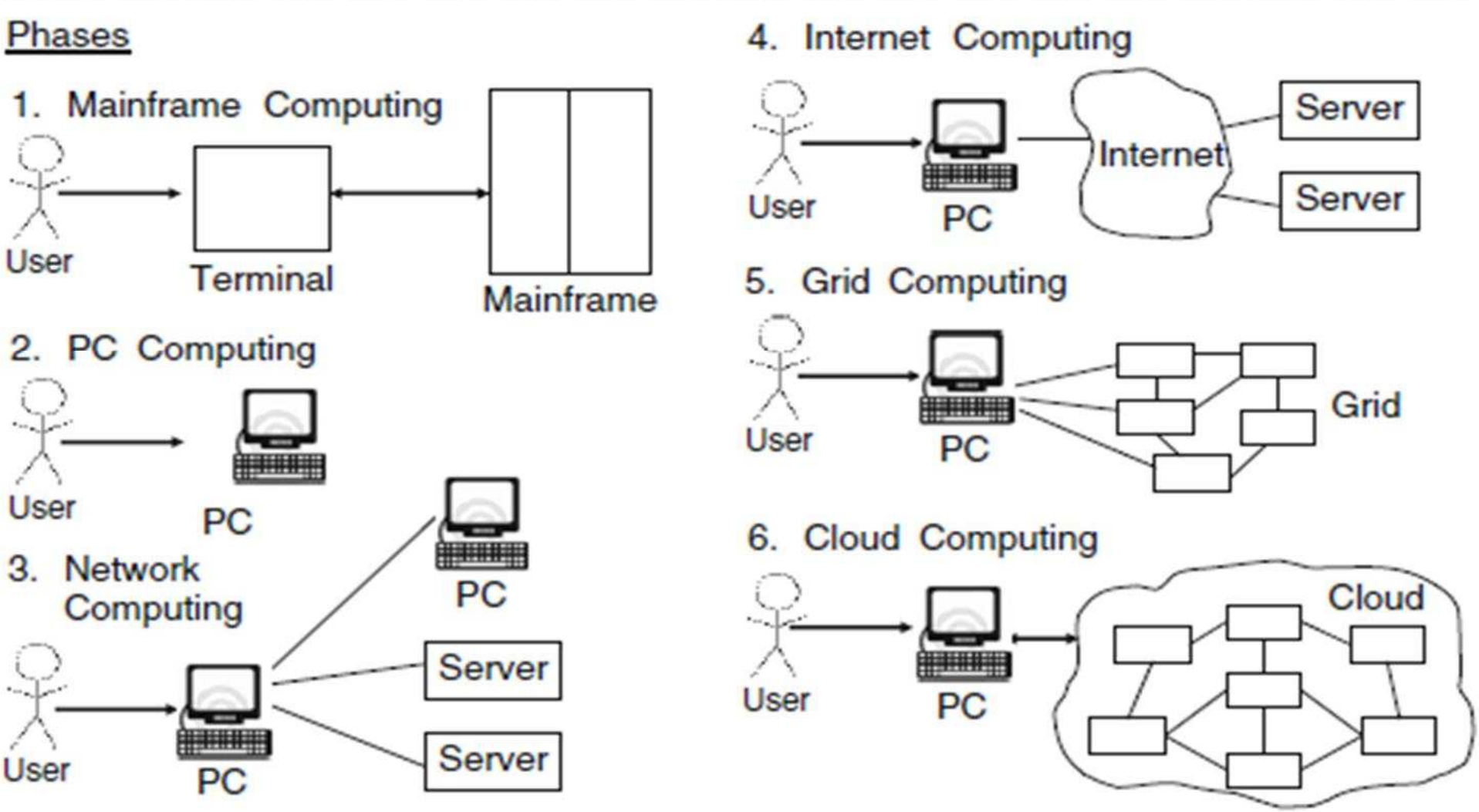
## Books:

Hand-Book of Cloud: Chapters 1-3

CLOUD COMPUTING Principles and Paradigms: Chapter 1

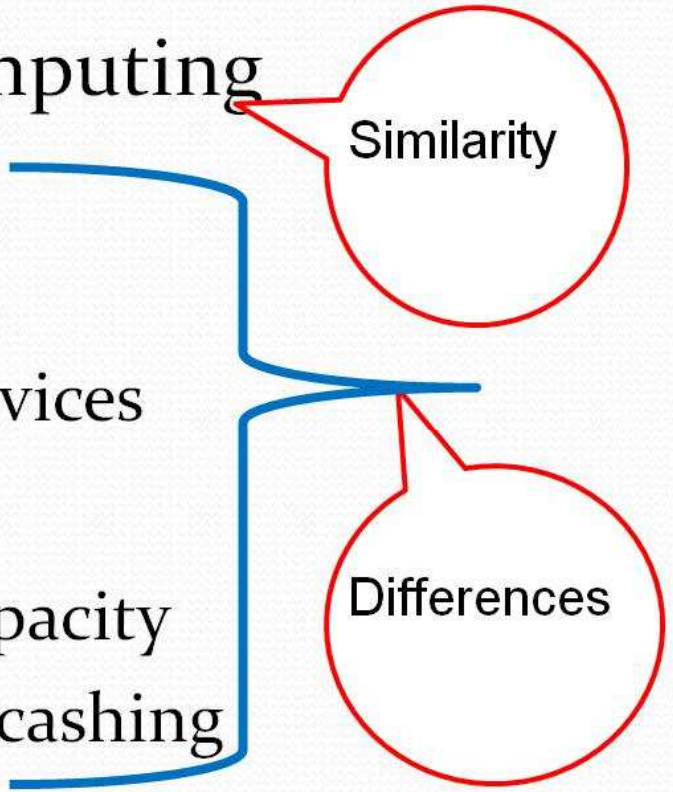
Other Materials

# Computing Generations



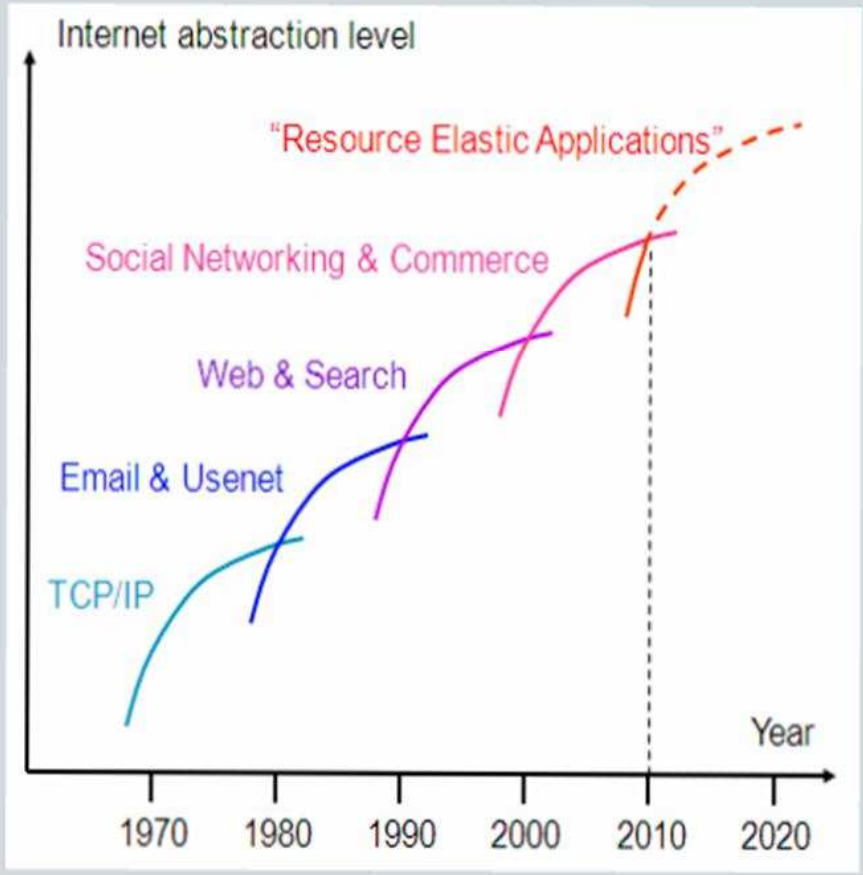
# Mainframe Vs. Cloud Computing

- Cloud is a return to mainframe computing
- **Mainframe**
  - Offers finite computing power
  - Dummy terminals as user interface devices
- **Cloud**
  - Provides almost infinite power and capacity
  - PCs can provide local computing and cashing



# History of The Internet Revolution

- The Internet has gone through ***four revolution*** since its inception
- Every revolution takes about ***ten years*** to be internalized
- ***Cloud Computing*** is a major part of the ***fifth revolution***



# Technologies Created Storm of Cloud Computing

- Broadband Internet
- Web services
- Computing systems
- Application software.

- Network
  - Center of the cloud delivery and consumption.
  - The linkage between end users and provider's data centers.
- Data center network
  - Connects thousands of compute and storage nodes.

# Cloud Computing Definition

- It is a ***computational environment*** that provides ***transparent access*** to a ***shared pool*** of ***computing resources matching*** the ***user's needs***.
- e.g.:
  - *Processing power, Storage, Applications, and Components*

**[Egypt's Cloud Computing Strategic Plan-2011]**

# Cloud Computing Definition

## The NIST Definition of Cloud Computing

- Cloud computing is a ***Computing model*** for ***enabling everywhere***, ***convenient***, ***on-demand network access*** to a ***shared pool*** of ***configurable computing resources*** (e.g., networks, servers, storage, applications, and services) that can be ***rapidly provisioned*** and ***released*** with ***minimal management effort*** or ***service provider interaction***.

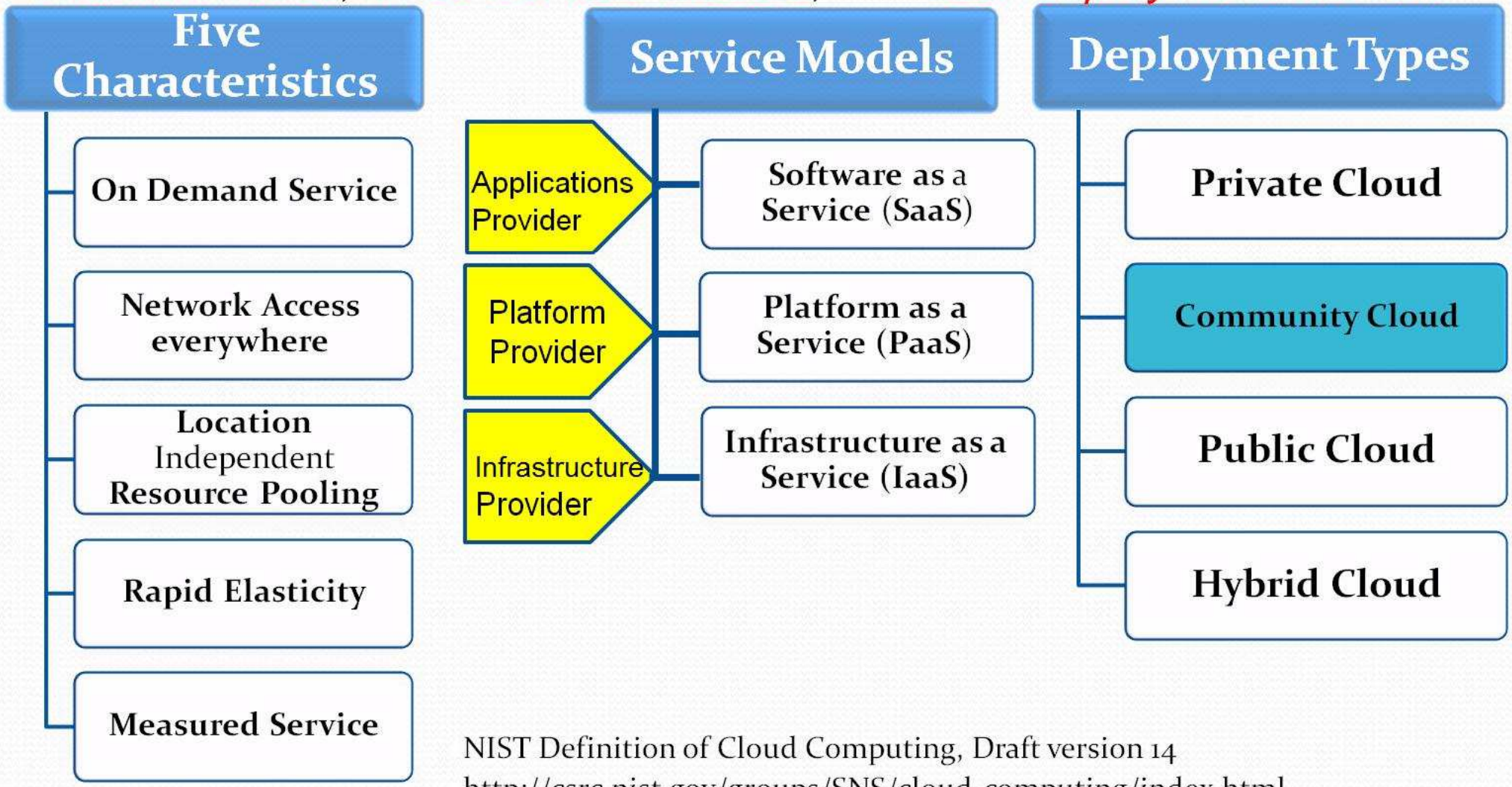
*NIST: National Institute of Standards and Technology*

***http://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication800-145.pdf***

# Cloud Computing Definition

***NIST definition:***

*cloud model promotes availability and is composed of five essential characteristics, three service models, and four deployment models.*




NIST Definition of Cloud Computing, Draft version 14
http://csrc.nist.gov/groups/SNS/cloud-computing/index.html

# Essential Characteristics:

## On-demand Self-Service

*A consumer* can *provision computing capabilities* (e.g., server time , network, and storage) as *needed automatically without* requiring *human interaction with* each *service provider*.

## Broad Network Access

Capabilities available over network and accessed through standard mechanisms using heterogeneous client platforms (e.g., mobile phones, tablets, laptops, and workstations).

## Resource Pooling

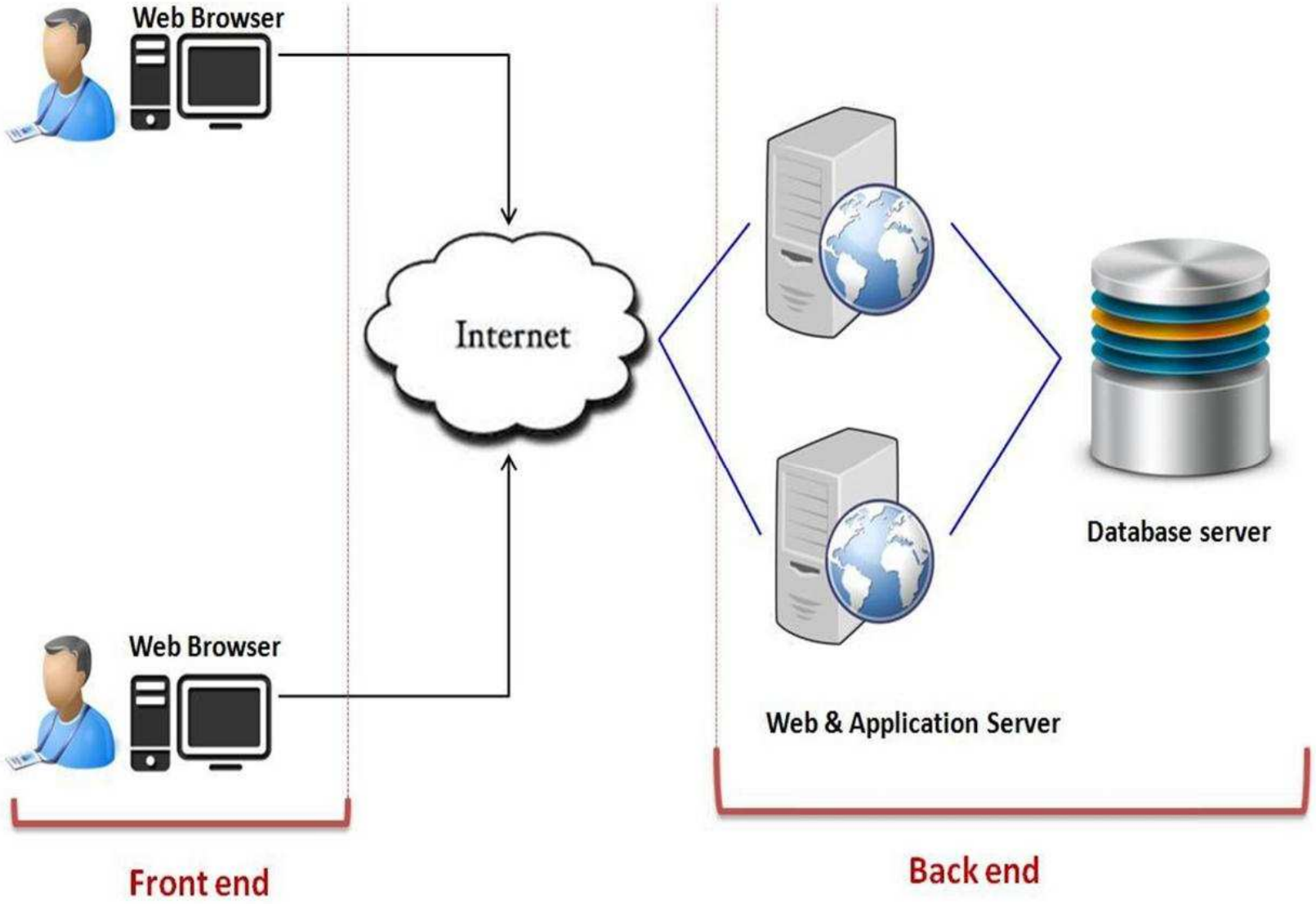
Computing resources are pooled to serve multiple consumers according to their demand.

## Rapid Elasticity

*Capabilities* can *elastically provisioned and released*, in some cases automatically, to scale up and down according to consuming rate.

## Measured Service

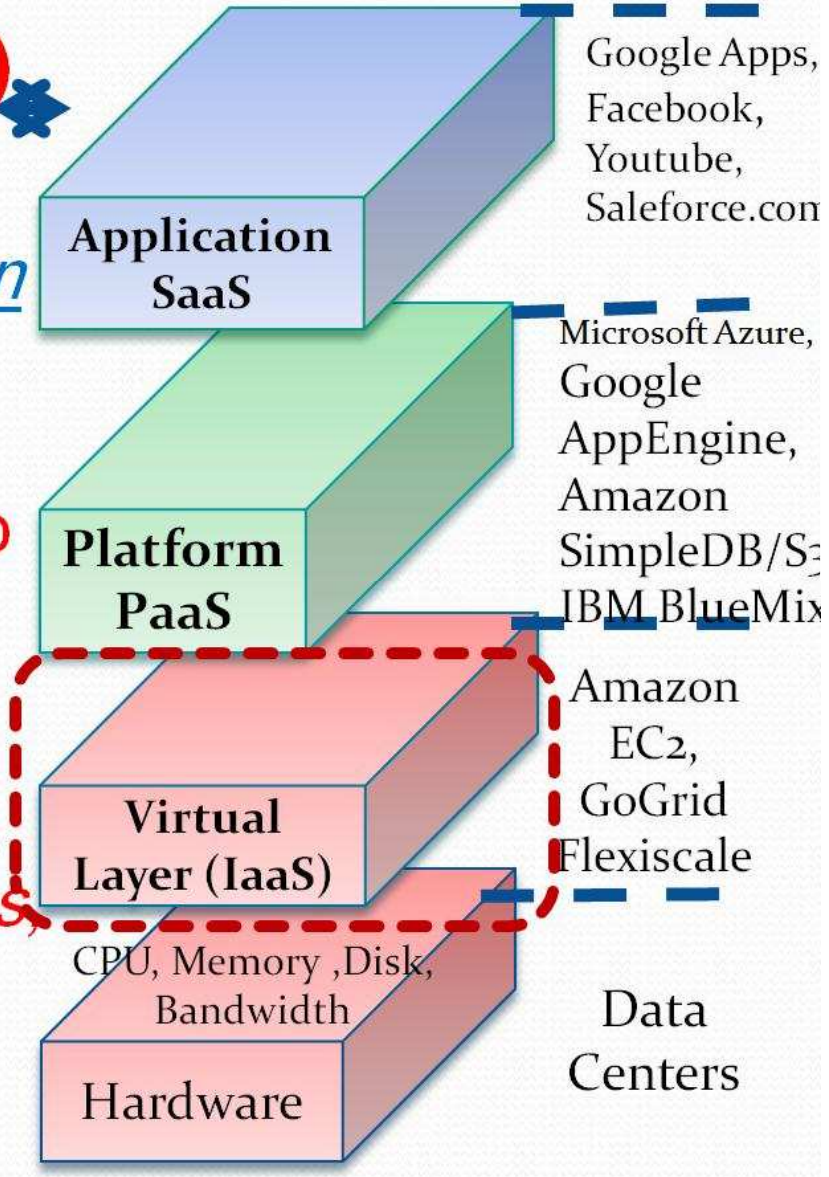
Resource usage can monitor, control, and report, providing transparency for both provider and consumer of the utilized service.


Web Browser
Internet
Database server
Web Browser
Web & Application Server
Front end
Back end

# Service Models

## Infrastructure as a Service (IaaS)

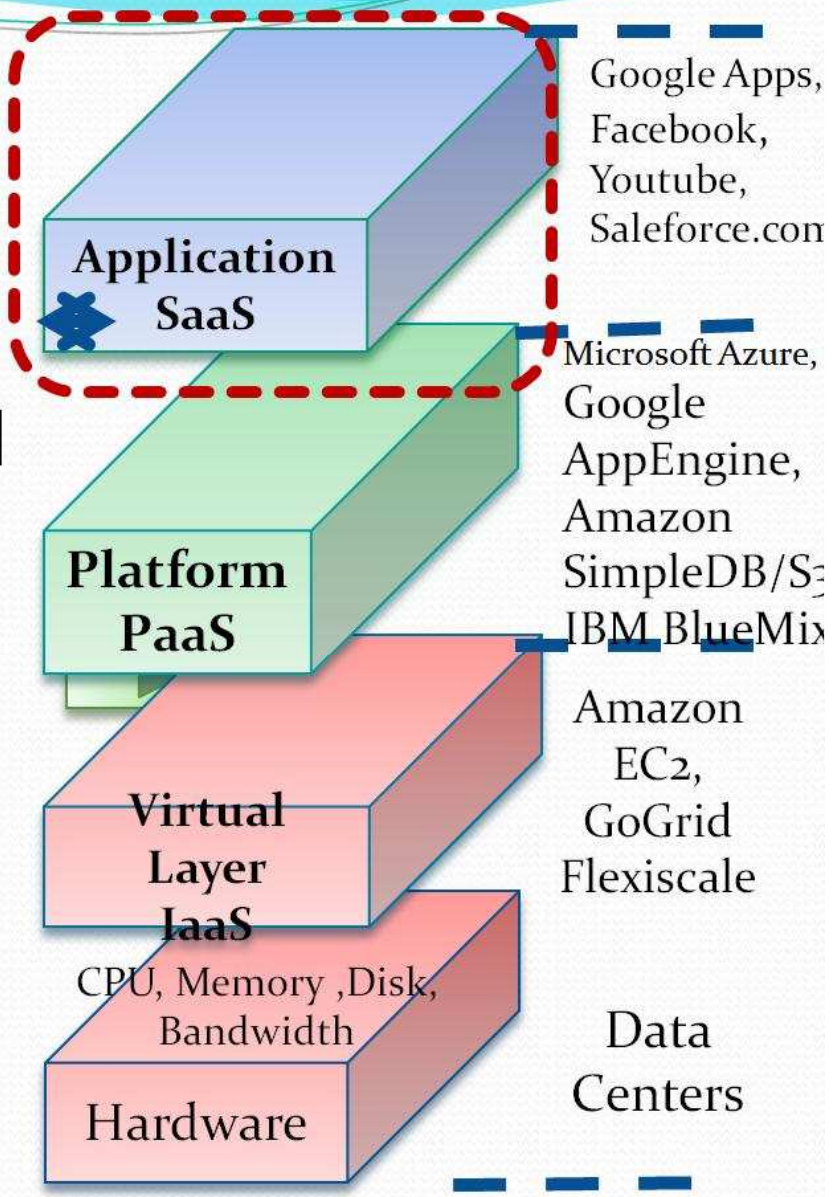
- The capability provided to the consumer (***organizations***) to *provision* processing, storage, networks, and other fundamental computing resources where the consumer able to ***deploy*** and ***run*** arbitrary software.
- The *consumer* does not manage or control underlying cloud infrastructure, but has *control over operating systems, storage, and deployed applications; and possibly limited control of select networking components* (e.g., host firewalls).



# Service Models

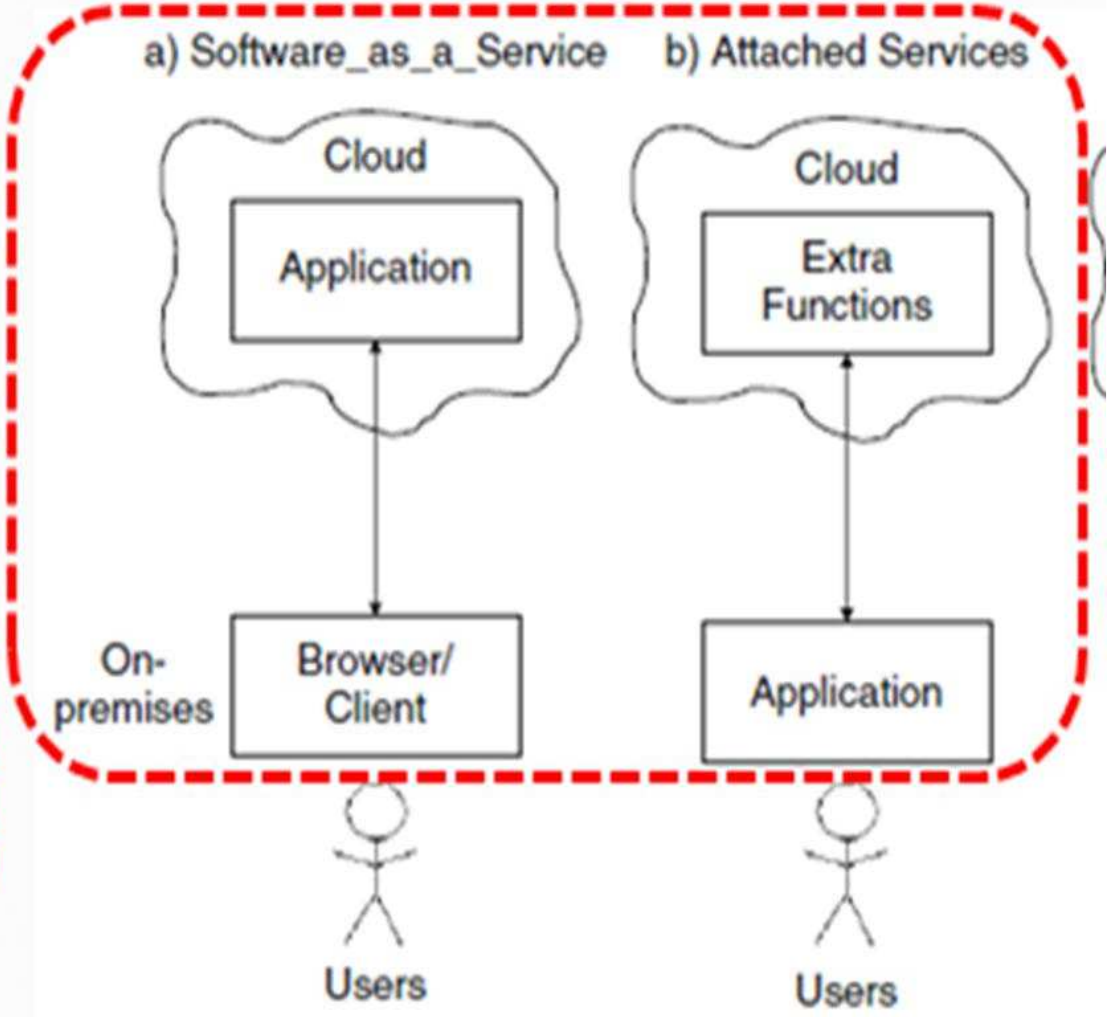
## Software as a Service (SaaS)

- The computing capability Provided to consumer (***External user***) with provider's applications running on a cloud infrastructure.
- The applications are accessible from various client devices through web browser
  - (e.g., web-based email), or a program interface.



# Software as a Service (SaaS)-Cont..

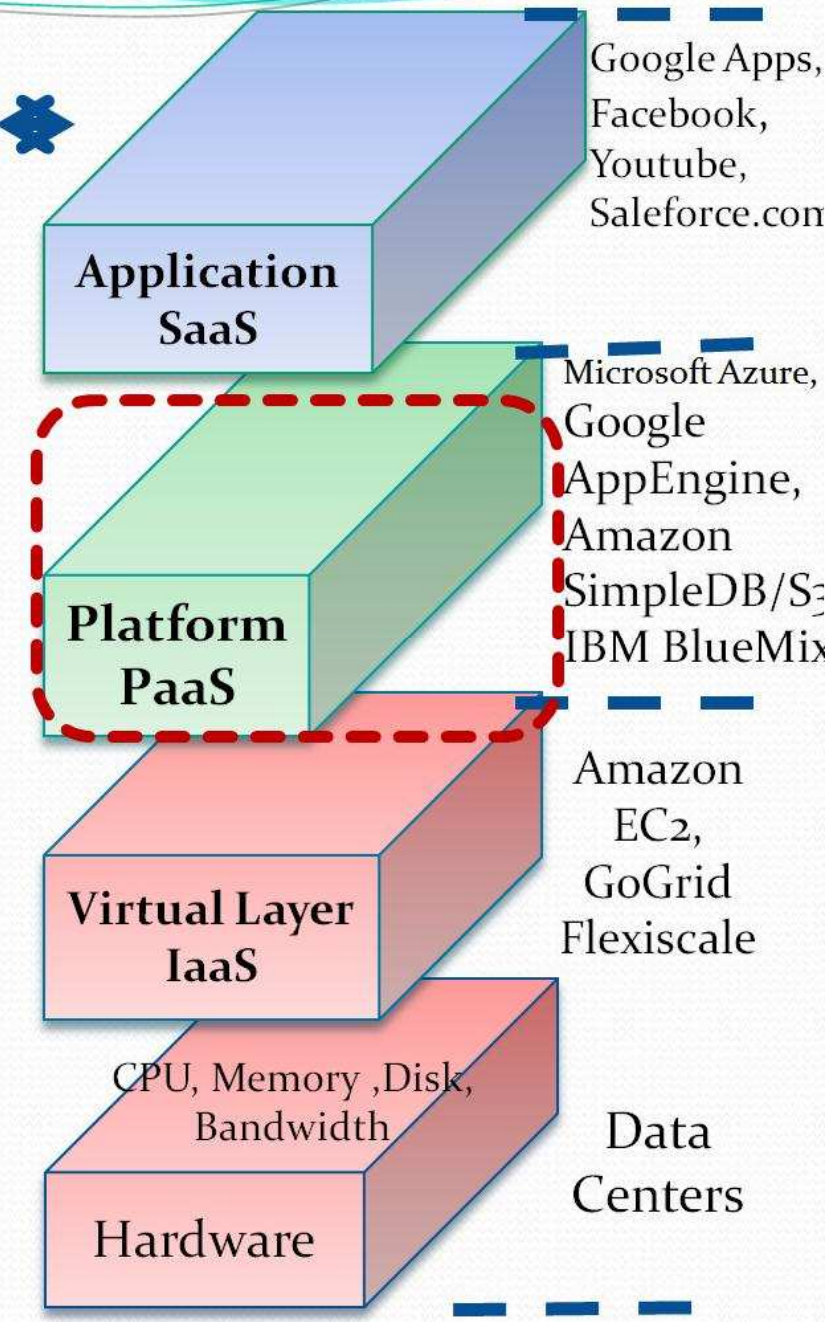
- SaaS
  - Entire application is running in the cloud
  - Client contains a browser to access application
  - **Example**: salesforce.com
- Attached services
  - Application runs on the client premises
  - Accesses functions and services provided in cloud
  - **Example:** Apple's iTunes



# Service Models

## Platform as a Service (PaaS)

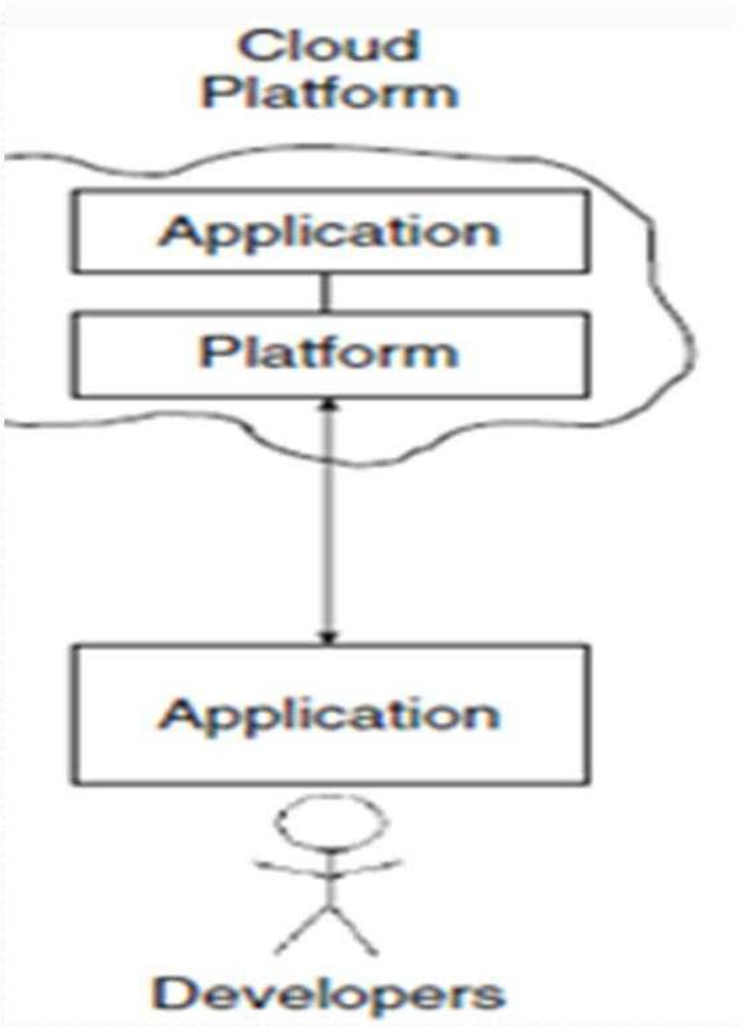
- The capability provided to the consumer (***developer***) by needed platform environment to develop his application using *programming languages*, *libraries*, *services*, and *tools* supported by the provider.
- The consumer **does not manage** or **control** underlying cloud infrastructure, but has control over deployed applications and possibly configuration settings for the application-hosting environment.



# Platform as a Service (PaaS)

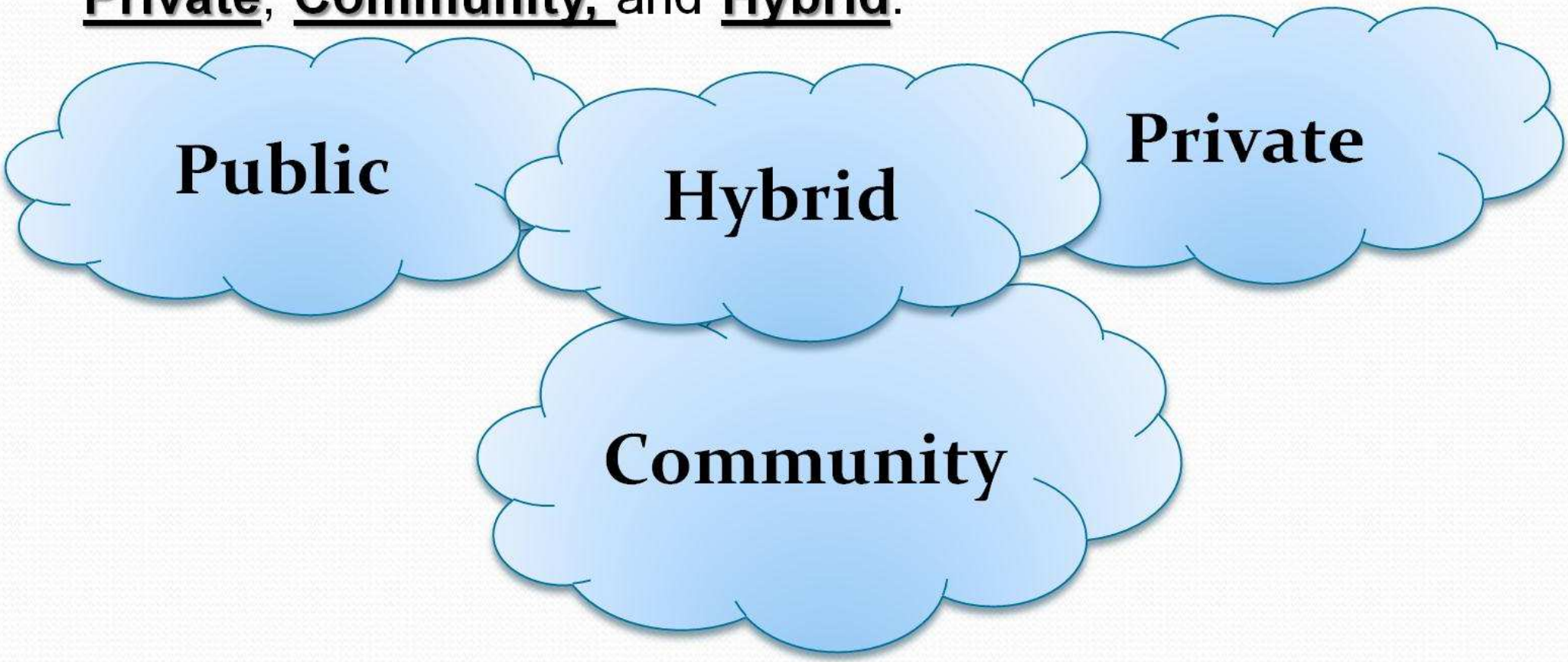
**Cloud Platform**

- Used by developers for creating a SaaS applications



# Deployment Types

- Deployment models define the type of access to the cloud, i.e., how the ***cloud is located***?
- Cloud can have any of the four types of access: **Public**, **Private**, **Community,** and **Hybrid**.



# Private Cloud

- Cloud infrastructure provisioned for exclusive use by ***a single organization*** comprising ***multiple consumers*** (e.g., business units).
- It may be *owned*, *managed*, and *operated* by the *organization*, a *third party*, or some combination of them, and
- it may exist on or off premises.

# Public Cloud

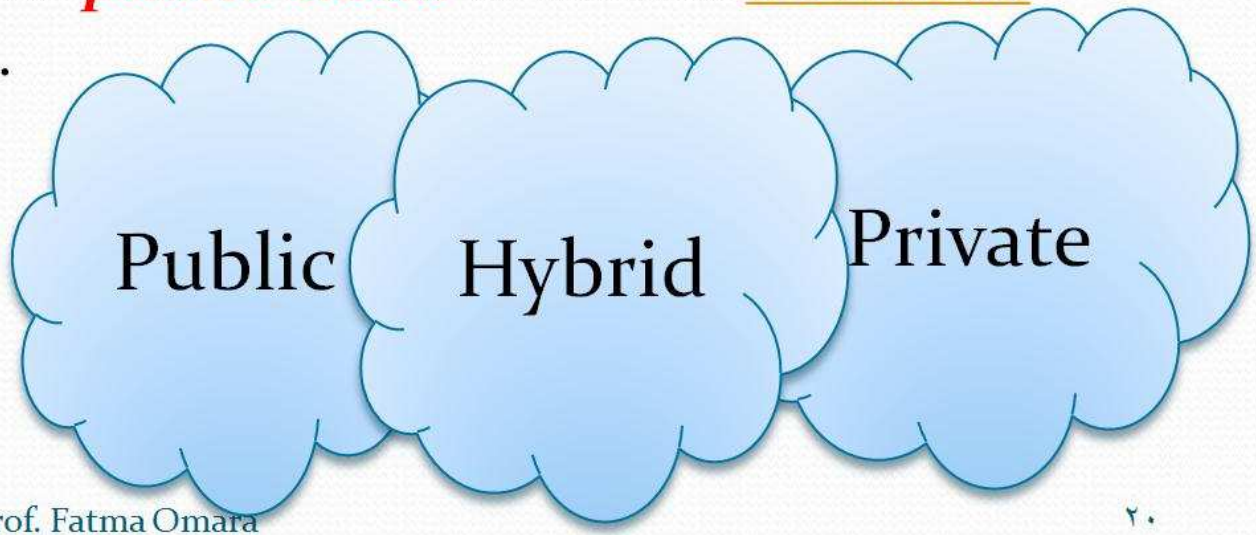
- Cloud infrastructure is provisioned for ***open use by the general public***.
- It may be *owned*, *managed*, and *operated* by a *business*, *academic*, or *government organization*, or some combination of them.
- It exists *on the premises* of the cloud provider (i.e., Data Centers).

# Community Cloud

- Cloud infrastructure is provisioned for exclusive use by ***a specific community of consumers from organizations*** that have ***shared concerns***
  - (e.g., mission, security requirements, policy, and other considerations).
- It may be owned, managed, and operated by one or more of the organizations in the community, a third party, or some combination of them, and
- it may exist *on* or *off* premises.

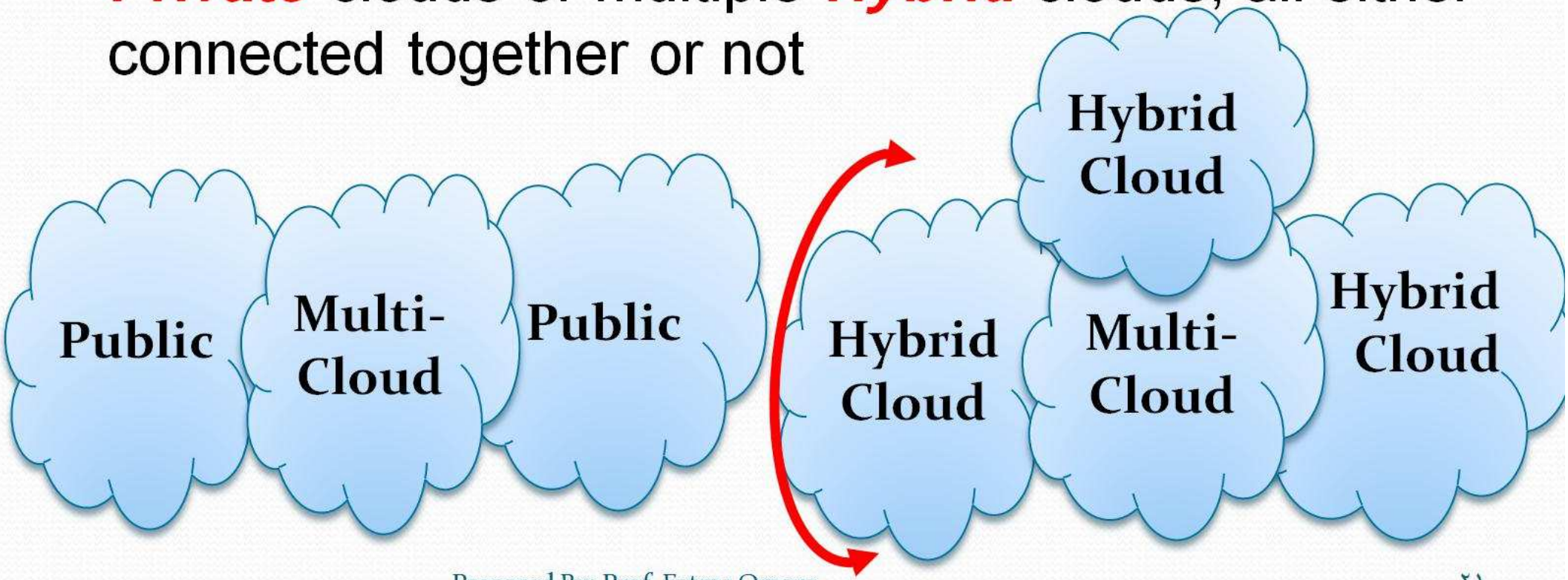
# Hybrid Cloud

- Cloud infrastructure is a composition ***of two or more distinct cloud infrastructures*** (private, community, or public) ***bound together by standardized*** ***or*** ***proprietary*** {p(r)əˈprīəˌterē}***technology*** that enables ***data and application portability*** (e.g., **cloud bursting** for load balancing between clouds).
- A cloud computing environment uses a mix of on-premises, **private cloud** and third-party, **public cloud** services with orchestration between their platforms
- Companies can run ***critical workloads or sensitive*** applications on the ***private cloud*** and use the ***public cloud*** to handle ***workload bursts*** or spikes in demand.



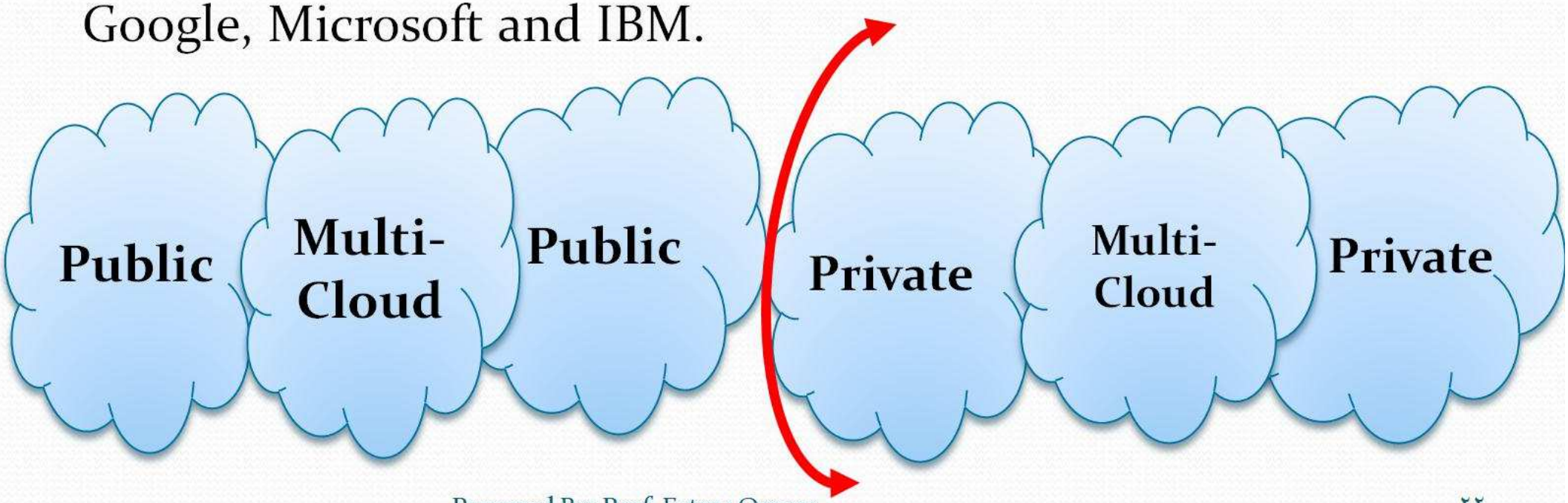
# Multi-Cloud

- A multi-Cloud strategy is an approach that operates any combination of ***Private***, ***Public***, and ***Hybrid*** clouds sourced from ***different vendors***. .
- An organization may have multiple ***Public*** and ***Private*** clouds or multiple ***Hybrid*** clouds, all either connected together or not



# Multi-Cloud

- It refers to the presence of ***more than one cloud deployment of the same type*** (**public** or **private** **or** **Hybrid**), sourced from ***different vendors***.
- There is ***no single multi-cloud infrastructure vendor***. Instead, ***a multi-cloud strategy involves a mix*** of the major **public cloud providers**, such as Amazon Web Services (AWS), Google, Microsoft and IBM.



# Multi-Cloud Challenges

- Clouds must have **compatible interfaces** to **migrate workloads** between them
- Clouds with **different APIs** can not able to talk to each other.
- Using cloud **storage services** in one cloud might not be available in another, which can make it impossible to move workloads easily between clouds.
- You might find yourself working from several **different management windows**, which increases chances of **getting lost** while configuring the environment.
- Every cloud comes with its own **monitoring tools**. It is difficult to monitor the output of different monitoring tools.
- Managing every cloud as a separate entity, it's difficult to avoid application ***stretch using services from different cloud***.
- When building a multi-cloud environment, it should make sure the clouds are highly compatible to simplify **interoperability**.

# Approaches helps multi-cloud environment to run smoothly

1. **Standardize as much as possible**
   - A standardized approach makes multi-cloud environments run smoother. At least, it ensures workloads can be easily migrated among different clouds.
2. ***Consolidate* Management**
   - A **single multi-cloud management tool** can solve challenges ranging from multiple management tools and multiple management portals to dealing with application and VM stretching over different clouds.
   - Providing a single interface to manage the multi-cloud environment and make it look as working with one cloud.
3. **Monitor the results**
   - An **independent monitoring tool** can be helpful.

# Multi-Cloud vs. Hybrid Cloud

| Hybrid Cloud | Multi-Cloud |
| --- | --- |
| ▪ An amalgamation of a private cloud with one or more public cloud.<br>▪ It can be any **combination** of SaaS, IaaS, PaaS and any other as-a-service<br>▪ It is a **singular entity** (i.e., the cloud components are integrated to form singular entity)<br>▪ a hybrid cloud could be part of a multi-cloud deployment. | ▪ An amalgamation of two or more public/hybride cloud under centralized management<br>▪ A multi-cloud strategy offers the **ability to select different cloud services** from **different providers**<br>▪ It **isn't single entity** "individual clouds may not be integrated together"<br>▪ Enables organizations to locate IT resources closely to end users to achieve **optimal performance** and **minimal latency**. |

Multi-cloud and hybrid cloud computing are similar, but different IT infrastructure models

# Cloud Benefits

1) No up-front investment (**Cap**ital **Ex**pense (**CapEx**))
   - Pay-as you-go pricing model.
   - No need to invest in the infrastructure.
   - Resources are rented according to needs.
2) Lowering operating cost (**Op**erational **Ex**pense (**OpEx**))
   - Resources are allocated and de-allocated on demand.
   - No need to provide capacities according to peak load.
   - Resources can be released to save on operating costs when service demand is low.

# Cloud Benefits (Cont.)

## 3) Highly scalable

- ***Infrastructure providers*** provide pool large amount of resources from data centers and make them easily accessible.
- ***Service providers*** can easily expand its service to large scales to handle rapid increase in service demands

## 4) Easy access

- Services hosted in the cloud are generally web-based.
- Accessible through devices with Internet connections.
  - **Devices:** desktop, laptop, cell phones and PDAs.

# Cloud Benefits (Cont.)

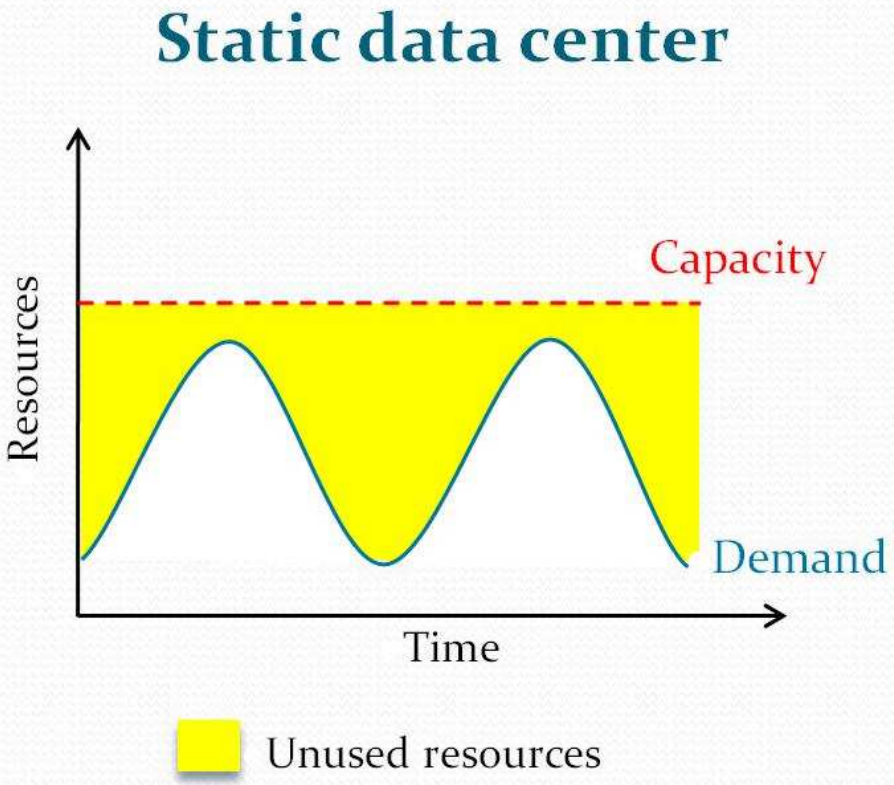
5) **Reducing business risks and maintenance expenses (OpEx)**

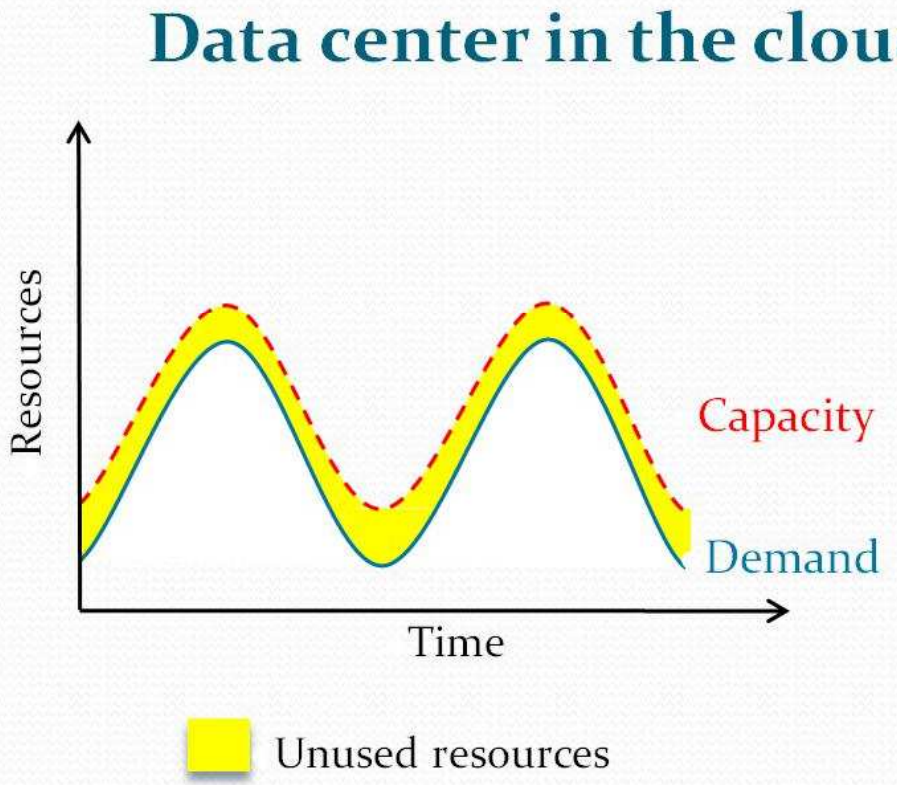
- Outsource the service infrastructure to the cloud
- **Service providers** shift business risks (such as hardware failures) to **infrastructure providers**
- A **service provider** can cut down the hardware maintenance and the staff training costs.
- **Infrastructure providers** often have better expertise and are better equipped for managing these risks.

# Cloud Benefits (Cont.)

## Pay by use instead of provisioning for peak

## (Elasticity)




Slide Credits: Berkeley RAD Lab

# Cloud Benefits (Cont..)

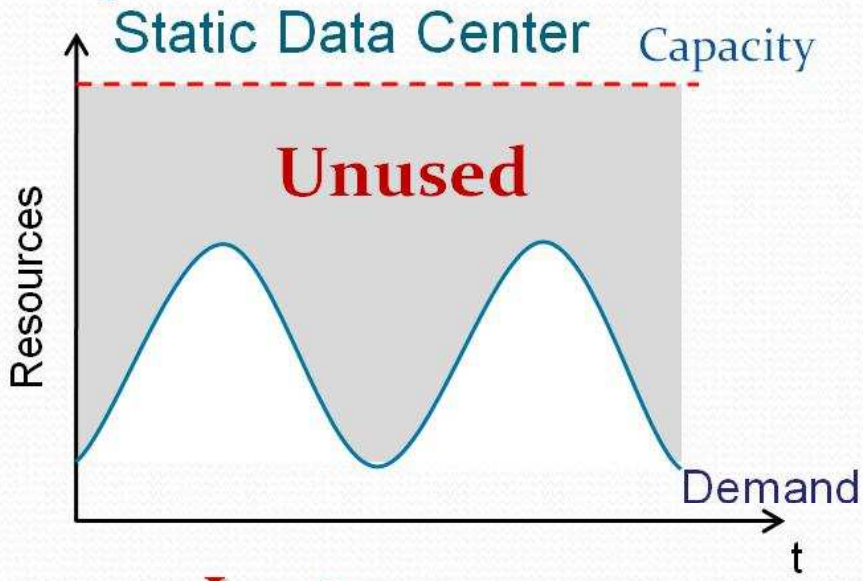
## 6) Elasticity

- ***Degree to which a system is able to adapt to workload changes by provisioning and de-provisioning resources in an autonomic manner***,
  - ❖ such that ***at each point in time*** the available resources match the current demand as closely as possible to:
  - **Avoid**
    - ***Over- or Under-Provisioning***.

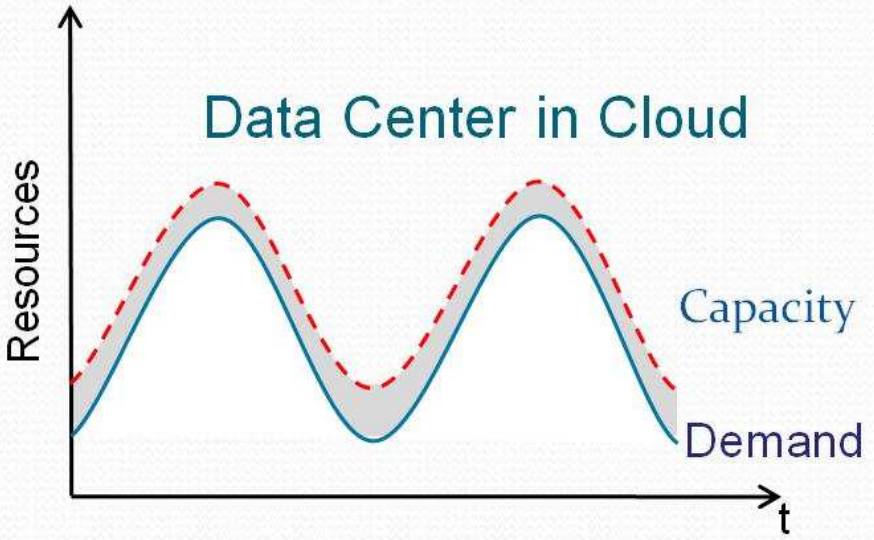
# Cloud Benefits (Cont.)

## Over-Provisioning

- Allocating more resources than required
- It should be avoided as the service provider often has to pay for the resources that are allocated to the service (**Lost revenue**)



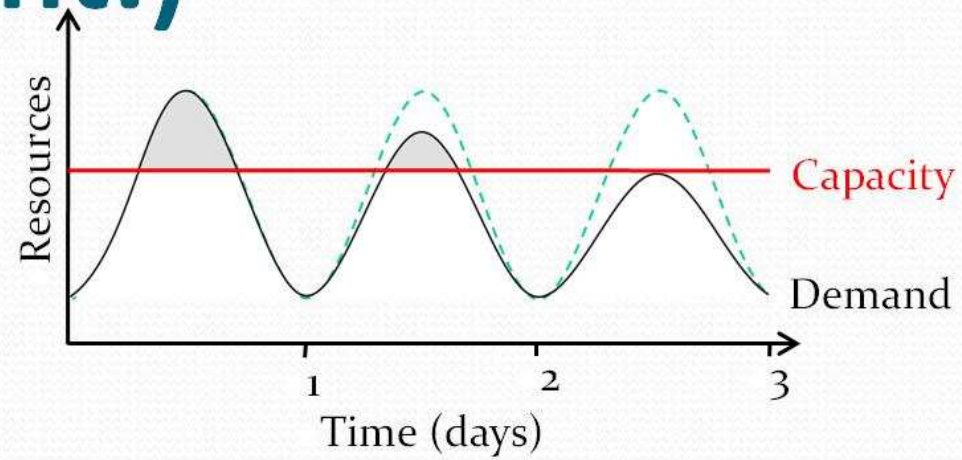

**Lost revenue**



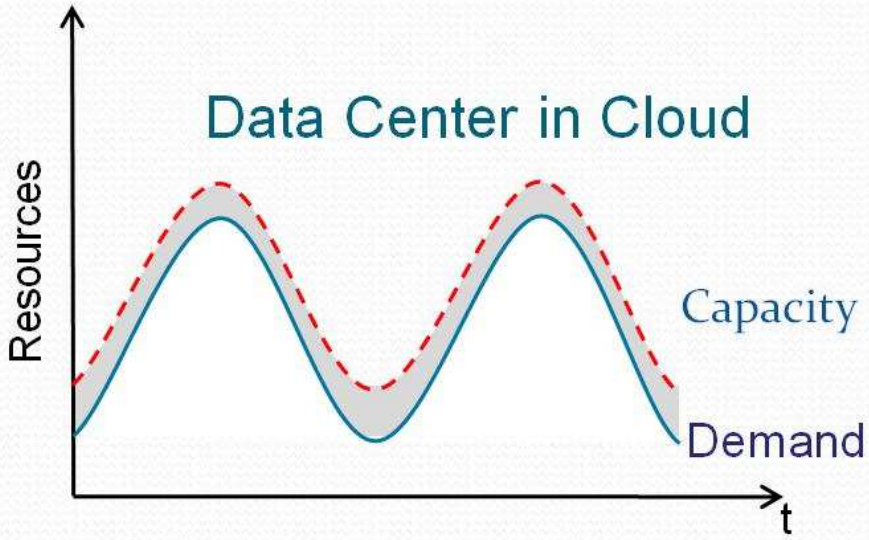
# Cloud Benefits (Cont.)

## Under-Provisioning

- Allocating fewer resources than required due to:
  - People don't understand how virtualization works
  - They don't realize how much of a computing resource they're really buying
- This must be avoided; otherwise the service cannot serve its users with a good service (**Lost Users**).



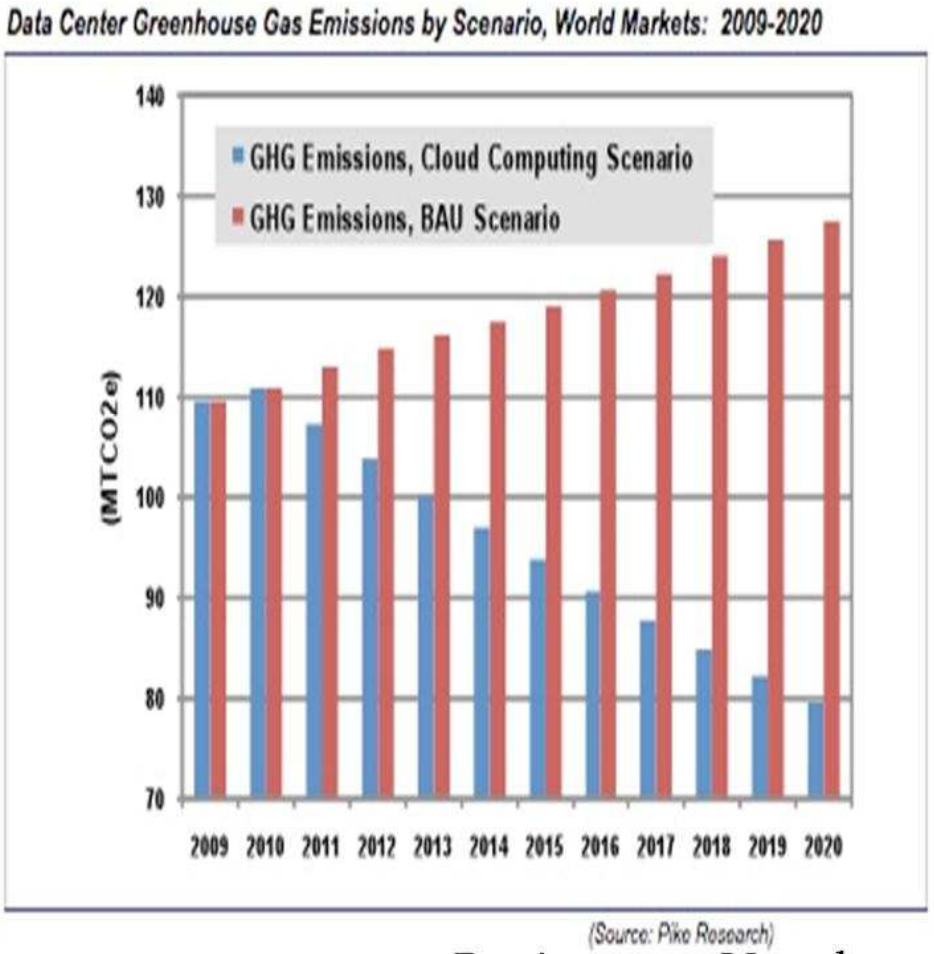

**Lost users**



# Cloud Benefits (Cont.)

## 7) Energy Savings

- "Energy efficiency benefits of cloud computing are substantial, and growth in the market will have important implications for both ***energy consumption*** and ***Green House Gas (GHG) Emissions***".
- The adoption of cloud computing leads to a ***38% reduction*** in worldwide data center energy expenditures by ***2020***.
- Total data center energy expenditures down from ***$23.3 billion*** in ***2010*** to ***$16.0 billion*** in ***2020***.




BAU: Business as Usual

[http://cloudnumbers.com/energy-savings-by-cloud-computing, September 8th, 2011]

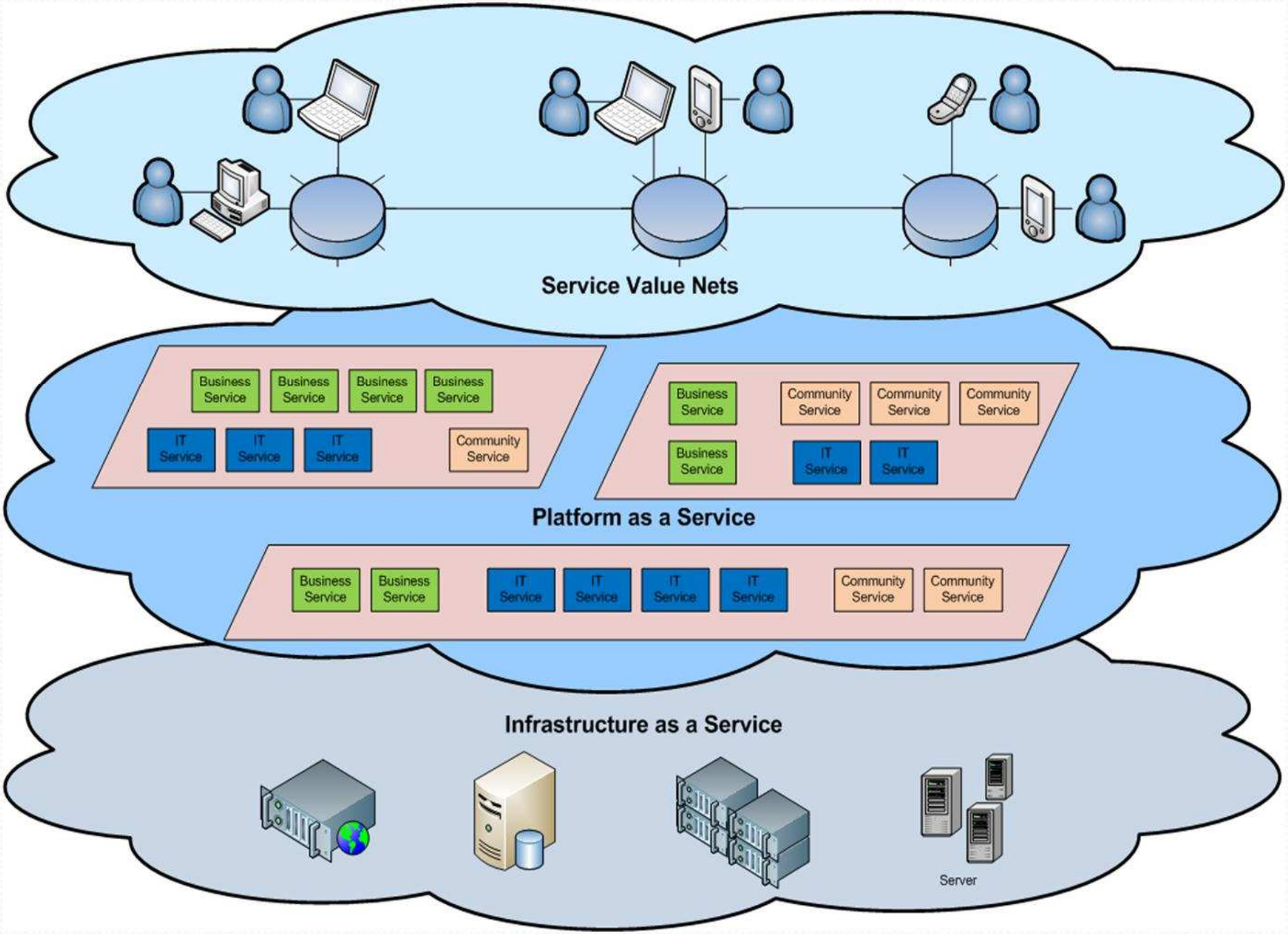
# Advantages of Cloud

- Lower computer costs
- Improved performance
- Reduced software costs
- Instant software updates
- Unlimited storage capacity
- Increased data reliability
- Universal document access
- Latest version availability
- Easier group collaboration
- Device independence

# Disadvantages of Cloud

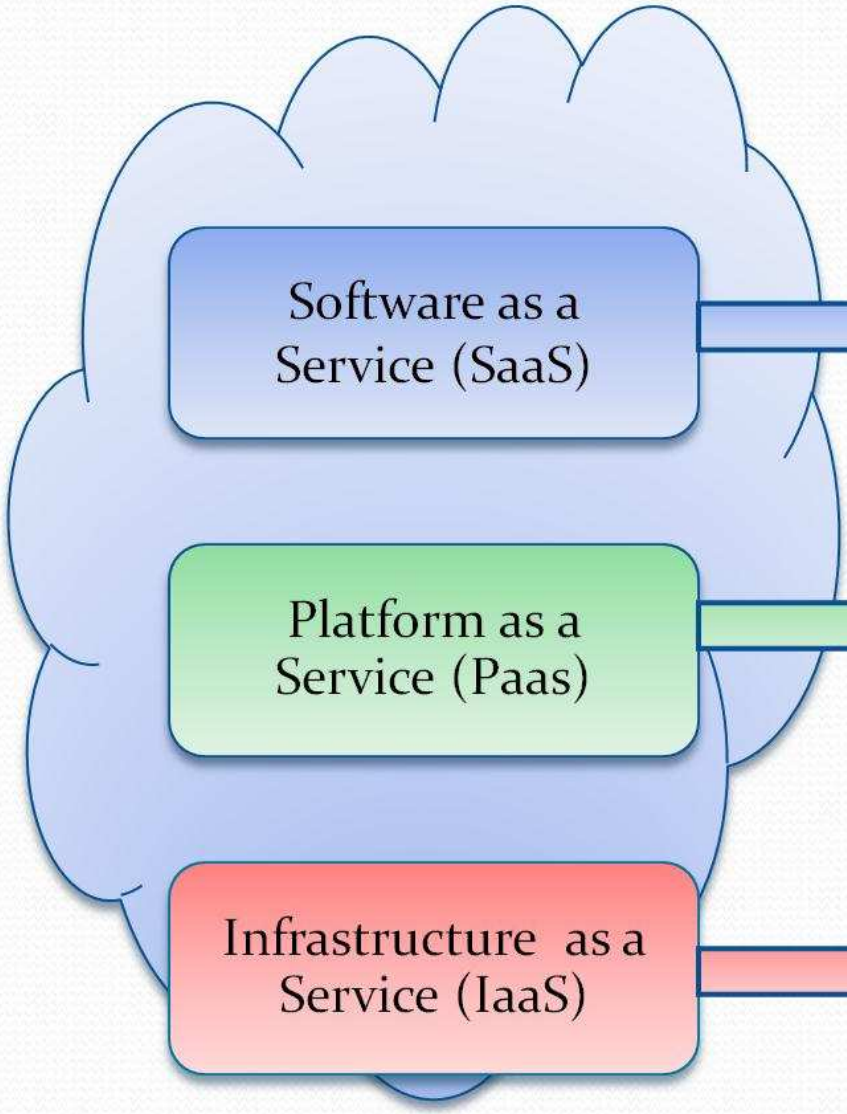
- Requires ***a constant Internet connection***
  - Does not work well with low-speed connections
- **Features might be limited**
  - **Can be slow**
  - **Stored data** can be **lost**
  - **Stored data** might not be **secure**
- **Large Latency Time**

# Cloud Architecture



# Cloud Computing Services

(CRM): Customer Relationship Management




| Who Uses It | What Services are available | Why use it? |
|---|---|---|
| Business Users | E-Mail, Office Automation, CRM, Website Testing, Wiki, Blog, Virtual Desktop ... | To complete business tasks |
| Developers and Deployers | Service and application test, development, integration and deployment environment | Create or deploy applications and services for users |
| System Managers | Virtual machines, operating systems, message queues, networks, storage, CPU, memory, backup services | Create platforms for service and application test, development, integration and deployment |

# Cloud Computing Hierarchy

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 IBM BlueMix

Infrastructure as a service (IaaS)

Computation (VM) Storage (block)

Infrastructure

Amazon EC2, GoGrid Flexiscale

Virtualization Layer

CPU, Memory ,Disk, Bandwidth

Hardware

Data Centers

# Application Layer

Software as a service (SaaS)


Google Apps, Facebook, Youtube, Saleforce.com

- Highest level of the hierarchy
- Consists of the actual cloud applications
- Cloud applications can better effect the automatic-scaling feature to achieve ***better performance***, ***availability*** and ***lower operating cost***.

# SaaS Examples

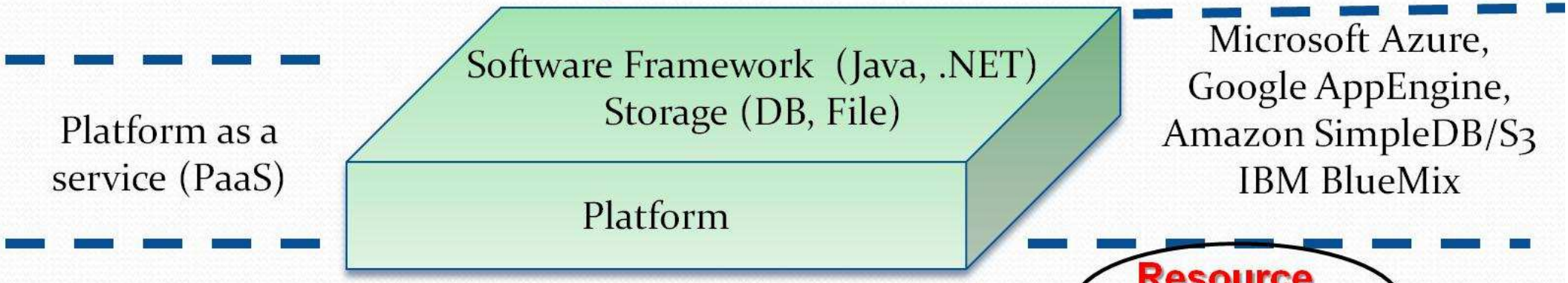
salesforce.com
Success On Demand.

NETSUITE
ONE SYSTEM. NO LIMITS.


postini


facebook

# Platform Layer




- Built on top of the infrastructure layer.
- Consists of OSs and application frameworks by ***providing Virtual Machines with specific configuration***.
- Minimize the burden of deploying applications directly into VM containers.
- E.g. Google App Engine provides API support for implementing storage, database, and business logic.

# PaaS Examples

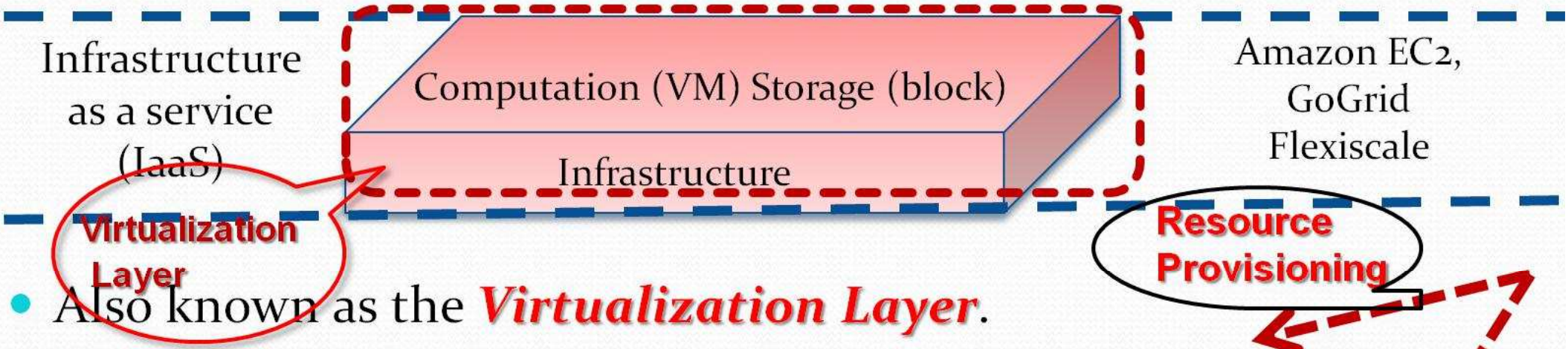






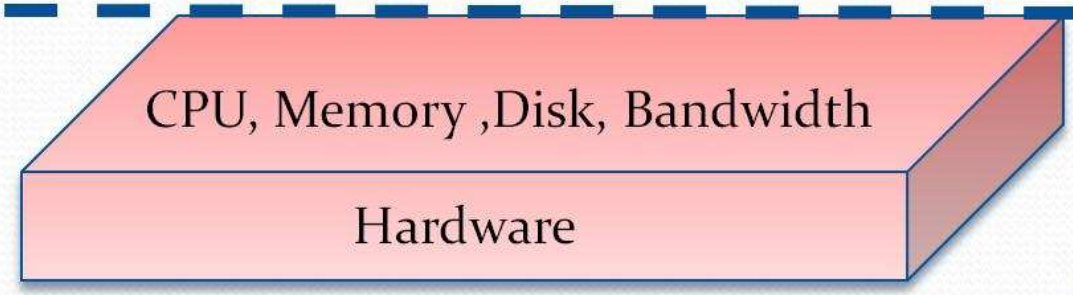

Resource Provisioning Vrs. Resource Allocation

# Infrastructure Layer




- Also known as the ***Virtualization Layer***.
- ***Creates a pool of storage and computing resources by partitioning the physical resources into instants using virtualization technologies*** such as Xen, KVM, and VMware.
- An essential component of cloud computing, since many key features, such as ***dynamic resource assignment***, are only made available through virtualization technologies.

# Hardware Layer




**Data Centers**

- Typically implemented in data centers
- Responsible for ***managing physical resources of the cloud***:
  - Physical servers, routers, switches, power cooling systems.
- Typical issues at hardware layer include:
  - Hardware configuration,
  - Fault tolerance,
  - Traffic management,
  - Power and cooling, resource management.

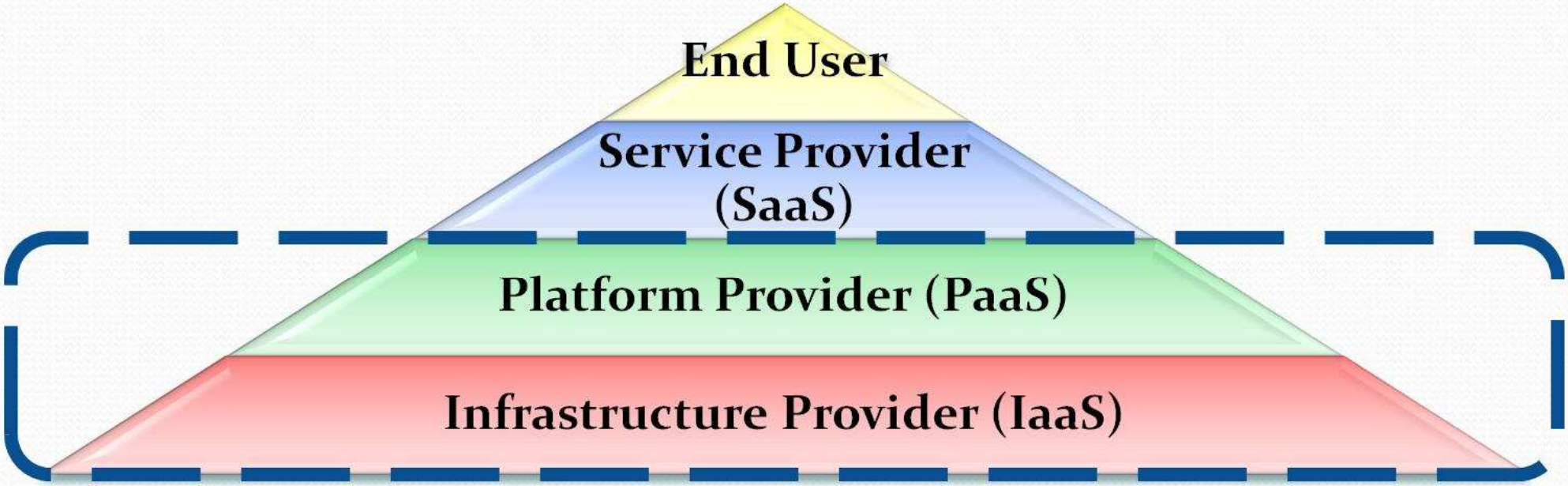
# IaaS Examples






# Do you Use the Cloud?

# Cloud Computing Providers

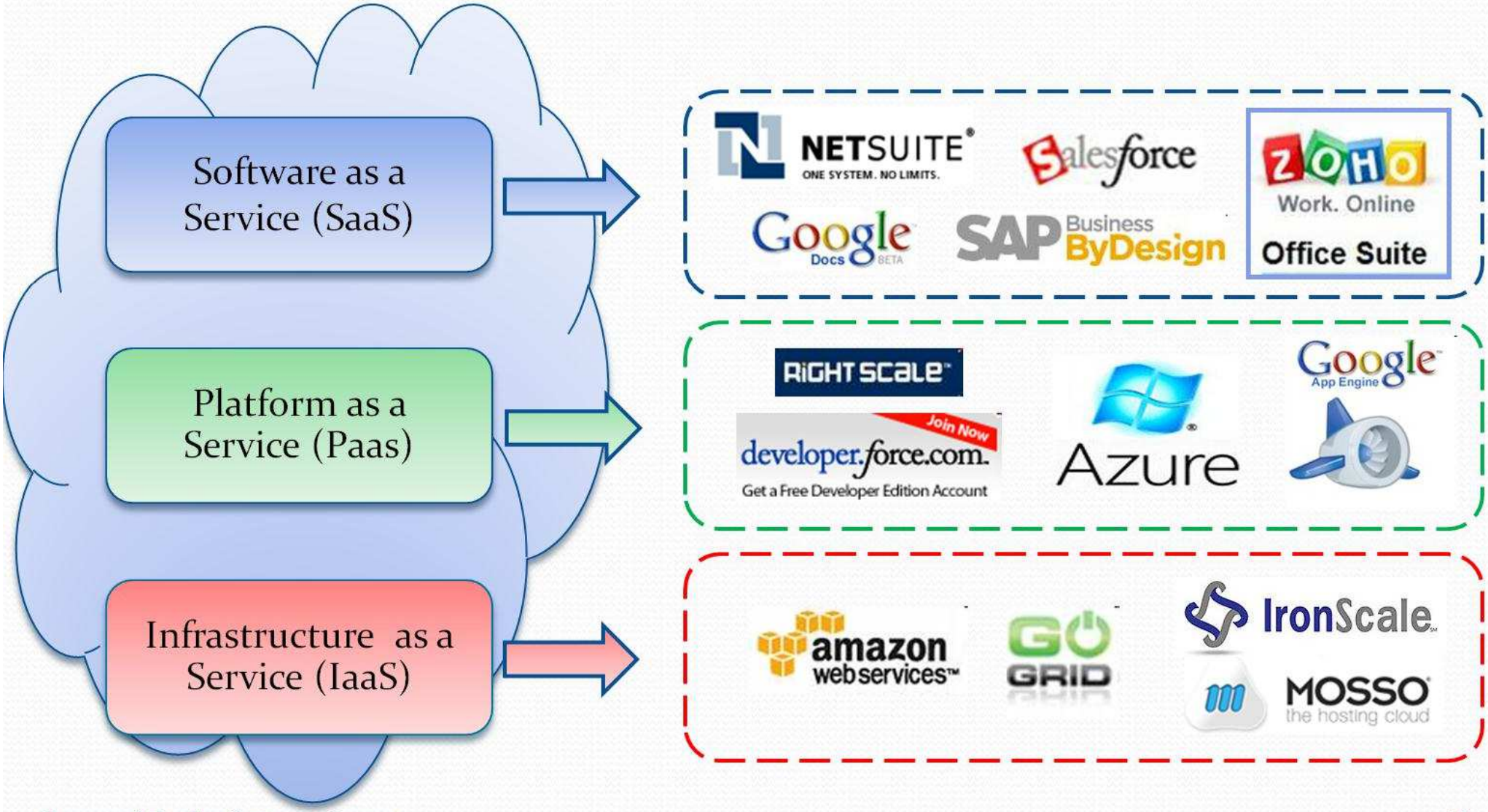



- IaaS and PaaS providers are often parts of the same organization (e.g. Google, Salesforce).
- PaaS and IaaS providers are often called the ***infrastructure providers*** or ***cloud providers***

# THE BOTTOM LINE

Cloud computing is a simple idea, but it can have a huge impact on the business.

# Market Overview



# Some Commercial Clouds


- **Windows Azure (PaaS)**
  - Hosting service for .NET applications and SQL databases
- **Google AppEngine (PaaS)**
  - Automatic scaling and reliability at the price of a highly constrained application structure (3-tier Web application)
- **BlueMix (PaaS)**
  - **Provides a dashboard** to *create*, *view*, and *manage applications* and *services*, as well as, *monitor application's resource usage*.
- **Amazon Web Services (IaaS)**
  - Includes Scalable Storage Service (S3), Elastic Computing Cloud (EC2), Elastic Block Store (EBS)
  - Comes with many secondary tools: e-commerce, Content-Distribution Network (CDN), etc.

# Service Level Agreement (SLA)

- Cloud places a strong emphasis on ***service management***.
- ***IaaS, PaaS and SaaS providers offer service according to Service Level Agreement (SLA) with customers.***
- **SLA** assurance is a critical objective of every provider.
- **SLAs** suppose to keep customers and providers happy, but writing one for the cloud means setting boundaries to account for more players and possibilities.

# Service Level Agreement (SLA)-Cont..

- **User needs:**
  - ***Guarantee*** the resources ***availability, reliability***, and ***QoS***.
- **Provider needs:**
  - ***Guarantee*** the resource ***utilization*** and ***revenue***
- This guarantee provided through a ***negotiation*** with some criteria called ***Service Level Agreements (SLAs).***

**The SLA:**

- ***A contract*** between the ***user*** and the ***Provider***.
- SLA contains ***terms and conditions to ensure the rights of the users, as well as, the providers.***
- Its role is ***identifying the users' needs and creates a relationship between the user and the service provider.***

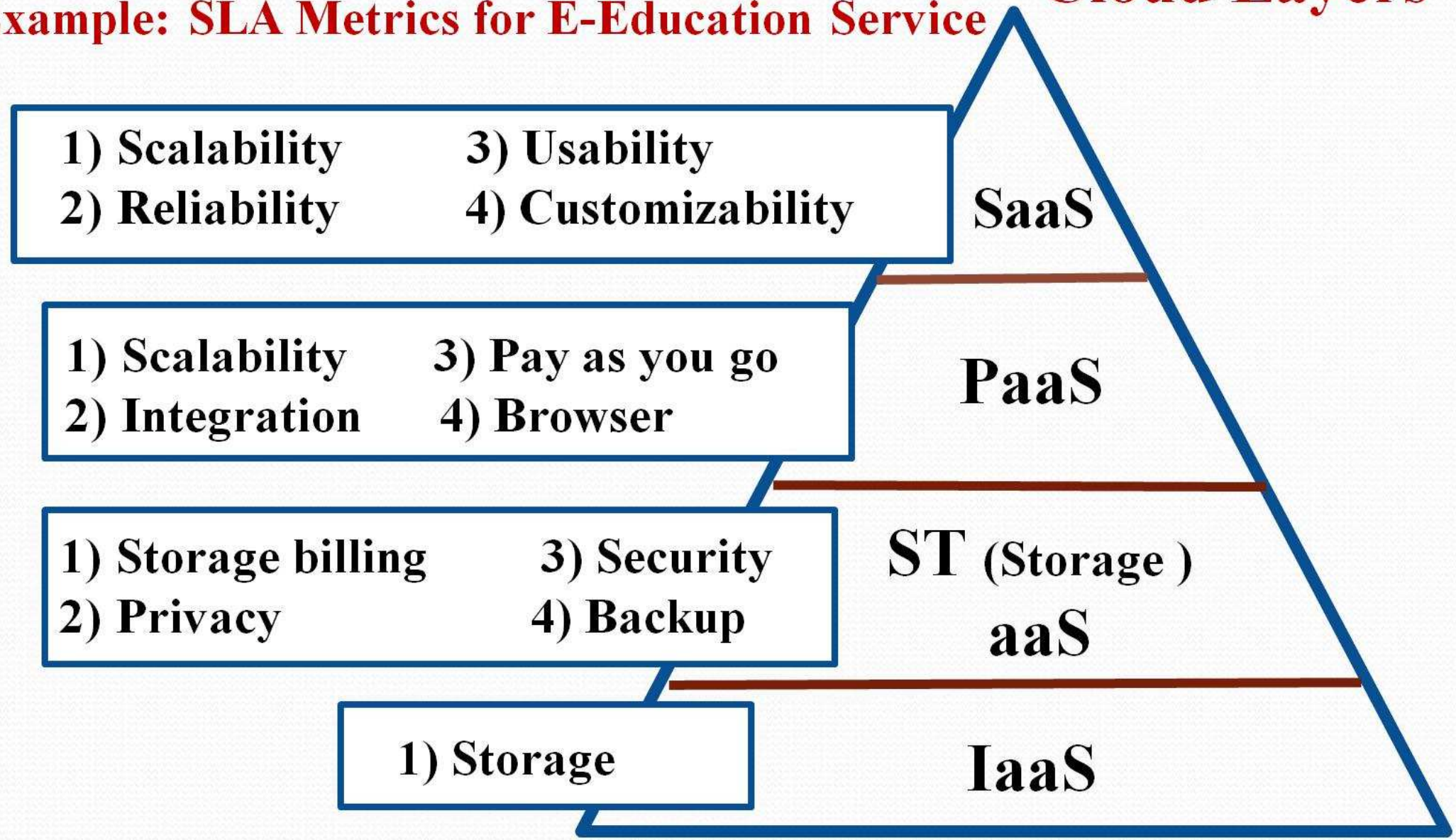
# Service Level Agreement (SLA)-Cont..

- SLA describes a set of ***non-functional requirements*** of the service the customer is rending.
- SLA usually ***contains penalties when the requirements are not met***.
- **If *one or more conditions are met*, then *appropriate actions are triggered***.

PARAMETER

# Cloud Layers

## Example: SLA Metrics for E-Education Service



# Service Level Agreement (SLA)- Cont..

A number of requirements that service users should consider for SLAs are:

| Component | Description |
|---|---|
| Responsibilities | Cloud service users should be responsible for limits on system usage and restrictions on the type of data that can be stored |
| Business continuity and disaster recovery | Cloud service users should ensure their cloud providers have adequate protection in case of a disaster. |
| System redundancy | Cloud service users moving data and applications that must be constantly available should consider the redundancy of their provider's systems. |
| Maintenance | Cloud service users should understand how and when their providers will do maintenance tasks |
| Location of Data | Cloud service users must be able to audit the provider to prove that regulations are being followed if a cloud service provider promises to enforce data location regulations, |
| Security | Cloud service users must understand their security requirements and what controls and federation patterns are necessary to meet those requirements. |
| Transparency | Cloud service users bear the burden of proving that the provider failed to live up to the terms of the SLA under the SLAs of some cloud providers. |
| Certification | Cloud service users might have the certification requirement that their cloud provider be ISO 27001 certified. |

# Service Level Agreement (SLA)- Cont..

a number of requirements providers should consider for SLAs are:

| Component | Description |
|---|---|
| Security | Provider must understand what they must deliver to the service users to enable the appropriate controls and federation patterns. |
| Data Encryption | The details of the encryption algorithms and access control policies should be specified in the SLA. |
| Privacy | An SLA should make it clear how the cloud provider isolates data and applications in a multi-tenant environment. |
| Data Retention and Deletion | Cloud providers must be able to keep data for a certain period of time and delete data after a certain period of time. |
| Hardware Erasure and Destruction | Cloud providers should offer the added protection of zeroing out memory space after a consumer powers off a VM. |
| Regulatory Compliance | Cloud providers must be able to prove their compliance if regulations must be enforced. |
| Transparency | Cloud providers must be proactive in notifying consumers when the terms of the SLA are breached for critical data and applications. |
| Certification | Cloud provider would be responsible for proving their certification and keeping it up-to-date. |

# Cloud Computing Transparency

- The cloud transparency shields complexities related to utility computing and Software as a Service (SaaS) from both ***developers*** and ***end-users***.
- Clouds transparency addressed eight aspects:
  - ***Access***, ***location***, ***concurrency***, ***replication***, ***failure***, ***mobility***, ***performance***, and ***scaling***.

[Egypt's Cloud Computing Strategic Plan-2011]

# Cloud Computing Challenges

- **Performance**
  - **Data-intensive** applications
  - **Latency** and **delays** for users far from cloud providers
- **Security and Privacy**
  - Companies are still concerned about **security**
  - Customers are worried about **vulnerability** to attacks
- **Control**
  - Providers have control of platforms
  - No platforms for specific users & their business practices

# Cloud Computing Challenges

- **Bandwidth Costs**
  - Low for smaller Internet-based applications
  - Significantly grow for data-intensive applications
- **Reliability**
  - Not always offer round-the-clock reliability
  - **HP Labs**, **Intel**, and **Yahoo** ***launched the distributed Cloud Research Test Bad to develop innovations including cloud computing specific chips***
  - **IBM** has launched the ***Research Computing Cloud***, which is an ***on-demand, globally accessible set of computing resources*** that support business processes