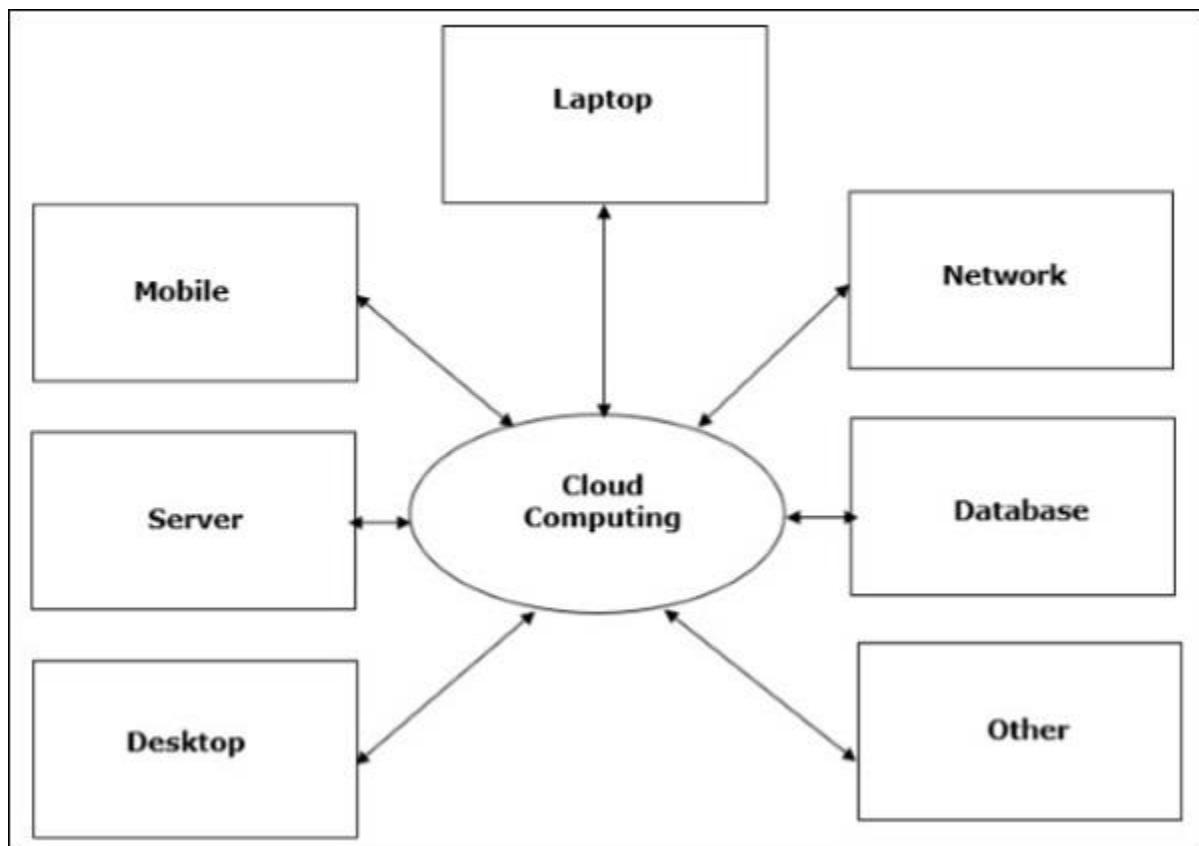


INTRODUCTION TO CLOUD COMPUTING

The popular trend in today's technology driven world is 'Cloud Computing'. Cloud computing can be referred to as the storing and accessing of data over the internet rather than your computer's hard drive. This means you don't access the data from either your computer's hard drive or over a dedicated computer network (home or office network). Cloud computing means data is stored at a remote place and is synchronized with other web information.

One prominent example of cloud computing is Office 365 which allows users to store, access, edit their MS Office documents online (in browser) without installing the actual program on their device.



Architecture of Cloud Computing

The architecture of cloud computing comprises of the following components –

- Front-end device

- Back-end platform
- Cloud-based delivery
- Network

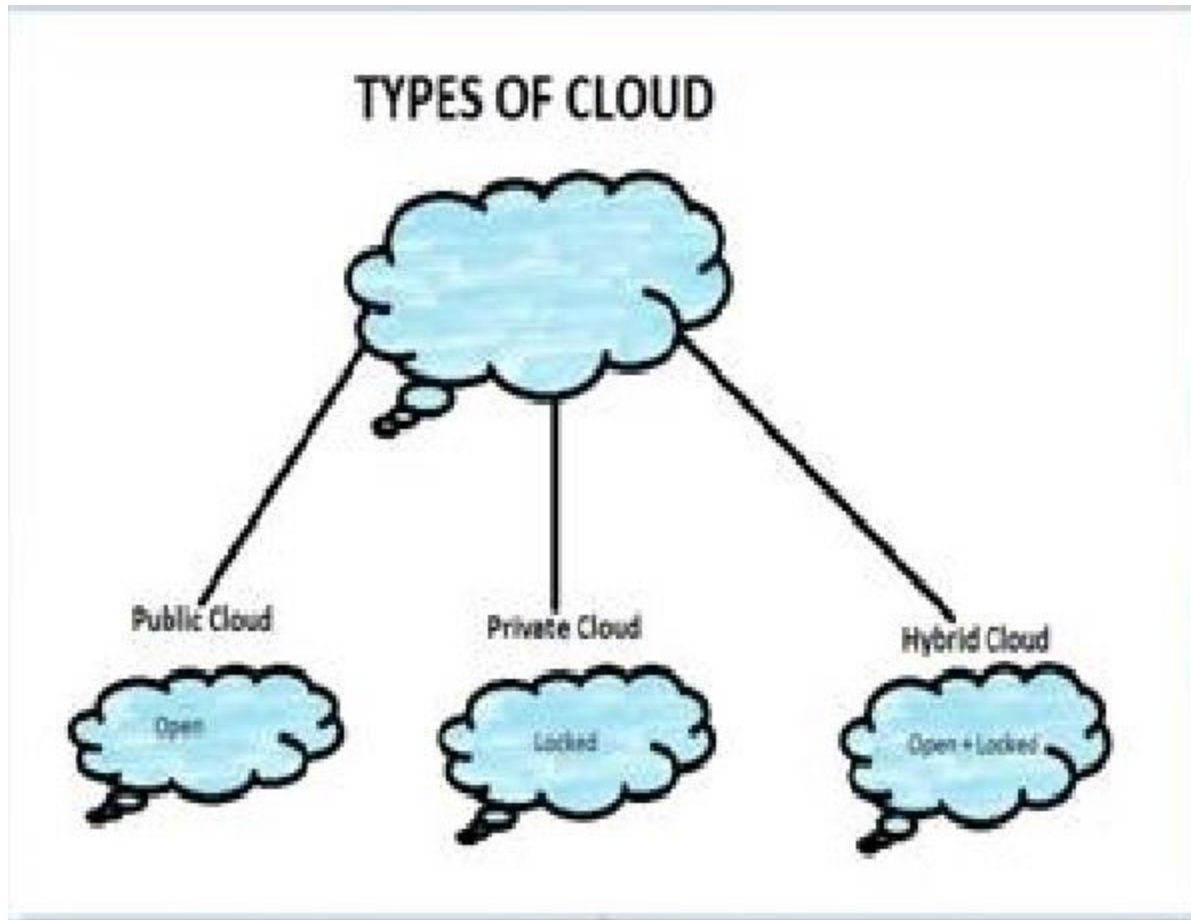
Front-end Devices – These are basically the devices that are used by clients to access the data or program using the browser or special applications.

Back-end Platform – There are various computers, servers, virtual machines, etc. that combine to become a back-end platform.

Types of Cloud

The storage options on cloud is in 3 forms –

- Public
- Private
- Hybrid



Public Cloud – A service provider makes the clouds available to the general public which is termed as a public cloud. These clouds are accessed through internet by users. These are open to public and their infrastructure is owned and operated by service providers as in case of Google and Microsoft.

Private Cloud – These clouds are dedicated to a particular organization. That particular organization can use the cloud for storing the company's data, hosting business application, etc. The data stored on private cloud can't be shared with other organizations. The cloud is managed either by the organization itself or by the third party.

Hybrid Cloud – When two or more clouds are bound together to offer the advantage of both public and private clouds, they are termed as Hybrid Cloud. Organizations can use private clouds for sensitive application, while public clouds for non-sensitive applications. The hybrid clouds provide flexible, scalable and cost-effective solutions to the organizations.

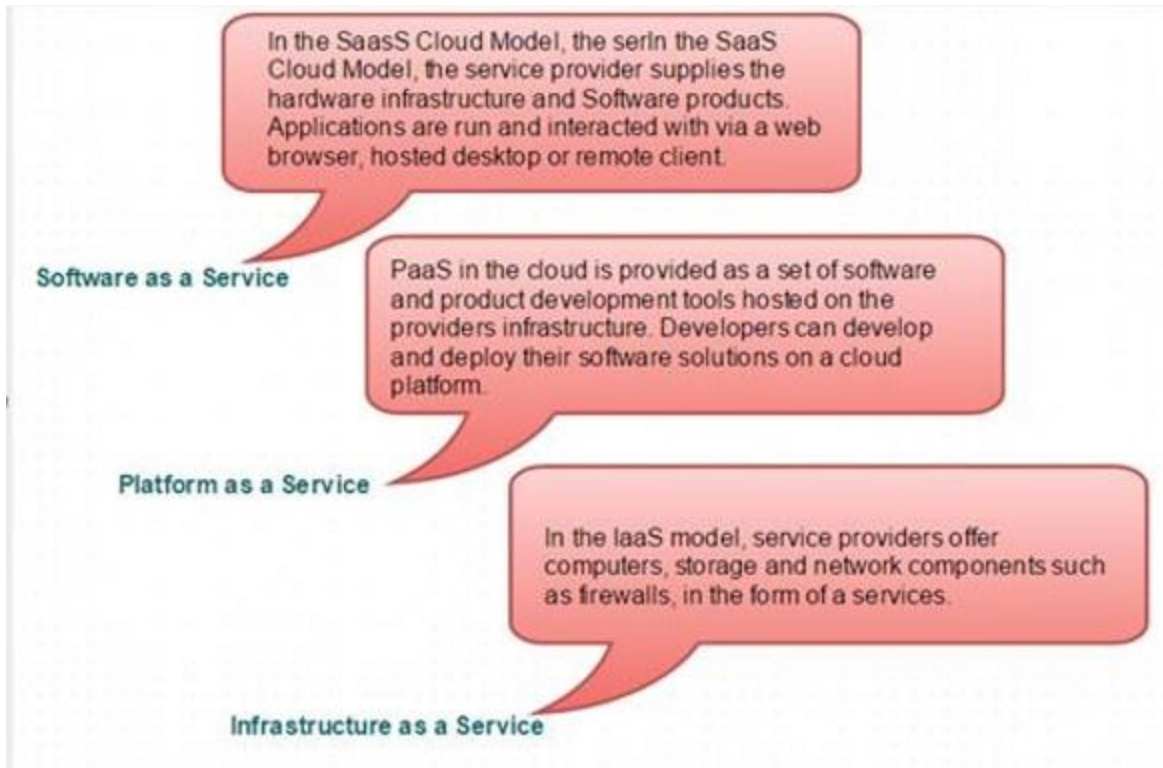
Benefits of Cloud

There are many benefits of clouds. Some of them are listed below.

- Cloud service offers scalability. Allocation and de-allocation of resources is dynamically as per demand.
- It saves on cost by reducing capital infrastructure.
- It allows the user to access the application independent of their location and hardware configuration.
- It simplifies the network and lets the client access the application without buying license for individual machine.
- Storing data on clouds is more reliable as it is not lost easily.

SPI

Next comes how cloud services are categorized. S stand for Software, P stands for Platform and I for Infrastructure in SPI. SaaS is Software as a service; PaaS is Platform as a service and IaaS is Infrastructure as a Service.



Following are the live examples of these models.

- **SAAS Model** – E-mail (Gmail, Yahoo, etc.)
- **PAAS Model** – Microsoft Azure
- **IAAS Model** – Amazon S3

Definition

Cloud computing is the delivery of different services through the Internet. These resources include tools and applications like data storage, servers, databases, networking, and software. ... As long as an electronic device has access to the web, it has access to the data and the software programs to run it.

Difference between Cloud Computing and Grid Computing

Cloud Computing

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

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

Grid Computing

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

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

Let's understand the difference between cloud computing and grid computing.

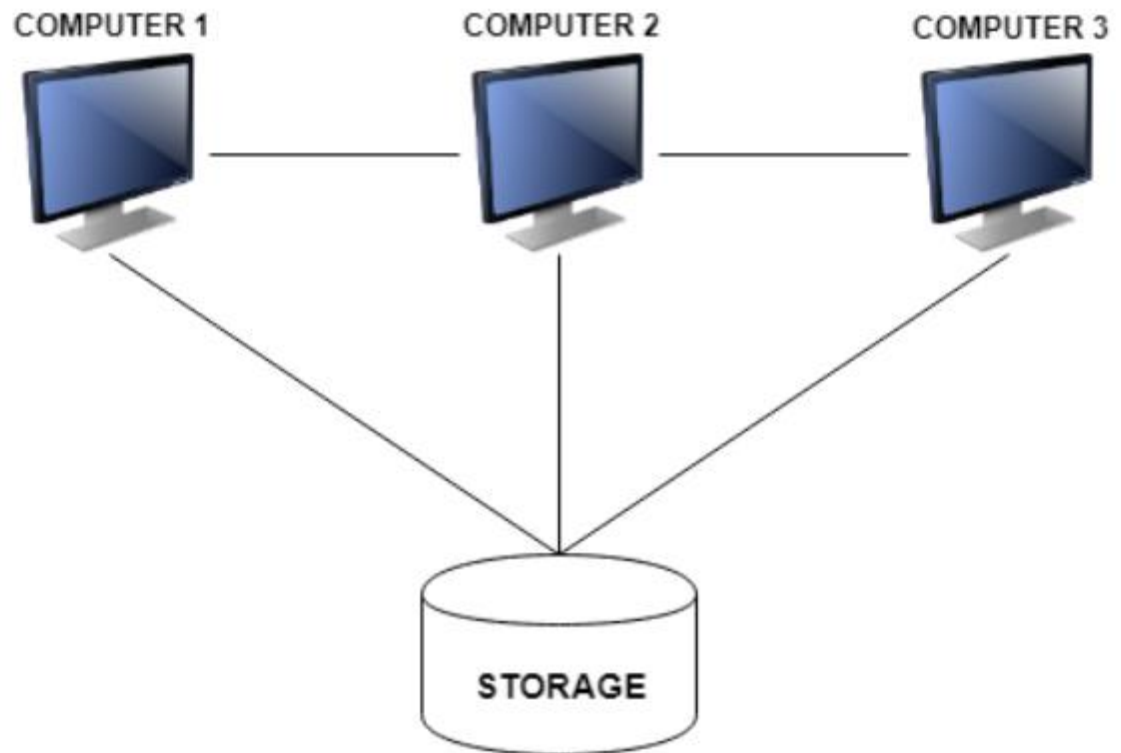
Cloud Computing	Grid Computing
Cloud Computing follows client-server computing architecture.	Grid computing follows a distributed computing architecture.
Scalability is high.	Scalability is normal.

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

CLUSTER COMPUTING

Clustered systems are similar to parallel systems as they both have multiple CPUs. However a major difference is that clustered systems are created by two or more individual computer systems merged together. Basically, they have independent computer systems with a common storage and the systems work together.

A diagram to better illustrate this is –



The clustered systems are a combination of hardware clusters and software clusters. The hardware clusters help in sharing of high performance disks between the systems. The software clusters makes all the systems work together .

Each node in the clustered systems contains the cluster software. This software monitors the cluster system and makes sure it is working as required. If any one of the nodes in the clustered system fail, then the rest of the nodes take control of its storage and resources and try to restart.

Types of Clustered Systems

There are primarily two types of clustered systems i.e. asymmetric clustering system and symmetric clustering system. Details about these are given as follows –

Asymmetric Clustering System

In this system, one of the nodes in the clustered system is in hot standby mode and all the others run the required applications. The hot standby mode is a failsafe in which a hot standby node is part of the system . The hot standby node continuously monitors the server and if it fails, the hot standby node takes its place.

Symmetric Clustering System

In symmetric clustering system two or more nodes all run applications as well as monitor each other. This is more efficient than asymmetric system as it uses all the hardware and doesn't keep a node merely as a hot standby.

Attributes of Clustered Systems

There are many different purposes that a clustered system can be used for. Some of these can be scientific calculations, web support etc. The clustering systems that embody some major attributes are –

- **Load Balancing Clusters**

In this type of clusters, the nodes in the system share the workload to provide a better performance. For example: A web based cluster may assign different web queries to different nodes so that the system performance is optimized. Some clustered systems use a round robin mechanism to assign requests to different nodes in the system.

- **High Availability Clusters**

These clusters improve the availability of the clustered system. They have extra nodes which are only used if some of the system components fail. So, high availability clusters remove single points of failure i.e. nodes whose failure leads to the failure of the system. These types of clusters are also known as failover clusters or HA clusters.

Benefits of Clustered Systems

The difference benefits of clustered systems are as follows –

- **Performance**

Clustered systems result in high performance as they contain two or more individual computer systems merged together. These work as a parallel unit and result in much better performance for the system.

- **Fault Tolerance**

Clustered systems are quite fault tolerant and the loss of one node does not result in the loss of the system. They may even contain one or more nodes in hot standby mode which allows them to take the place of failed nodes.

- **Scalability**

Clustered systems are quite scalable as it is easy to add a new node to the system. There is no need to take the entire cluster down to add a new node.

UTILITY COMPUTING

Antivirus

A virus can be defined as a malicious program that attaches itself to a host program and makes multiple copies of itself, slowing down, corrupting or destroying the system. A software that assists the OS in providing virus free environment to the users is

called **antivirus**. An anti-virus scans the system for any virus and if detected, gets rid of it by deleting or isolating it. It can detect many types of virus like **boot virus, Trojan, worm, spyware**, etc.

When any external storage device like USB drive is attached to the system, anti-virus software scans it and gives an alert if a virus is detected. You can set up your system for periodic scans or scan whenever you feel the need. A combination of both the techniques is advisable to keep your system virus free.

File management tools

As you know, file management is an important function of operating systems as all data and instructions are stored in the computer in form of files. Utility software providing regular file management tasks like browse, search, update, preview, etc. are called file management tools. **Windows Explorer** in Windows OS, **Google desktop, Directory Opus, Double Commander**, etc. are examples of such tools.

Compression tools

Storage space is always at a premium in computer systems. So operating systems are always looking at ways to minimize amount of storage space taken by files. **Compression tools** are utilities that assist operating systems in shortening files so that they take less space. After compression files are stored in a different format and cannot be read or edited directly. It needs to be uncompressed before it can be accessed for further use. Some of the popular compression tools are **WinRAR, PeaZip, The Unarchiver**, etc.

Disk Cleanup

Disk cleanup tools assist users in freeing up disk space. The software scans hard disks to find files that are no longer used and frees up space by deleting them.

Disk Defragmenter

Disk defragmenter is a **disk management utility** that increases file access speeds by rearranging **fragmented files** on **contiguous locations**. Large files are broken down into fragments and may be stores in **non-contiguous** locations if contiguous ones are not available. When such files are accessed by the user, access speed is slow due to fragmentation. Disk defragmenter utility scans the hard disk and tries to assemble file fragments so that they may be stored in contiguous locations.

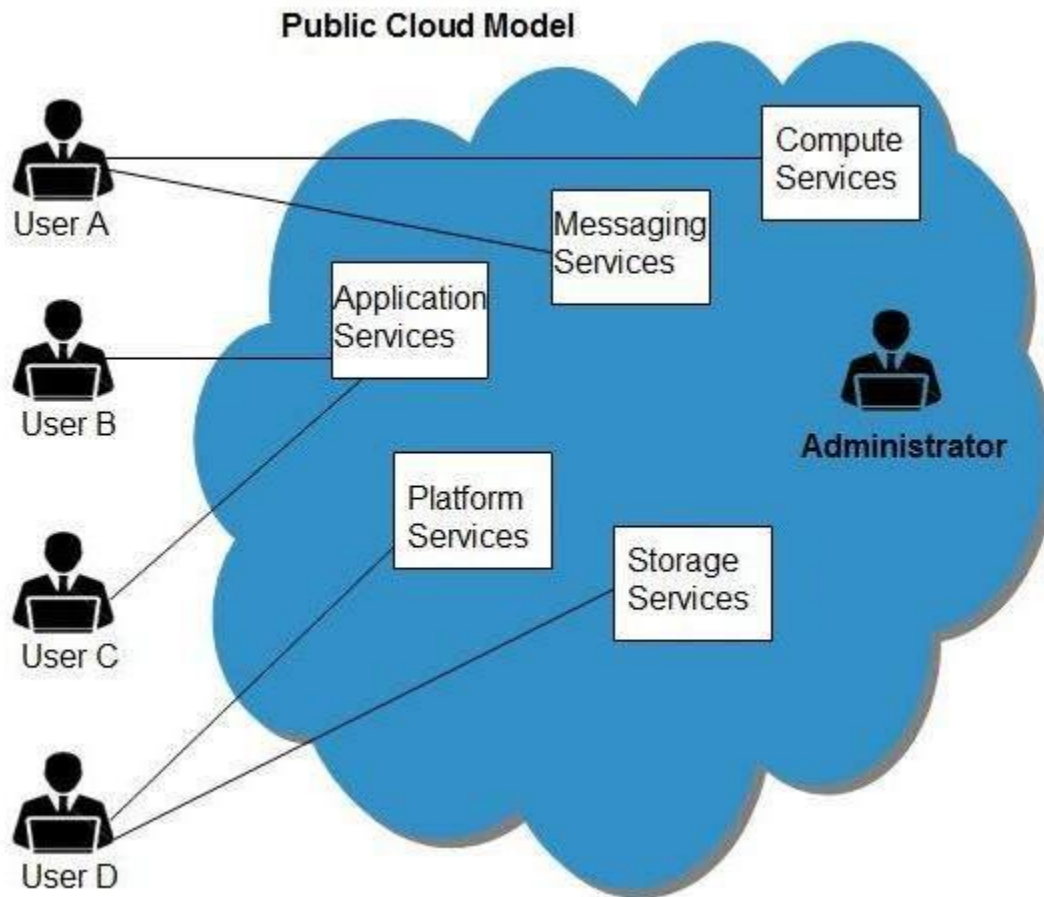
Backup

Backup utility enables backing up of files, folders, databases or complete disks. Backups are taken so that data may be restored in case of data loss. Backup is a

service provided by all operating systems. In stand-alone systems backup may be taken in the same or different drive. In case of networked systems backup may be done on backup servers.

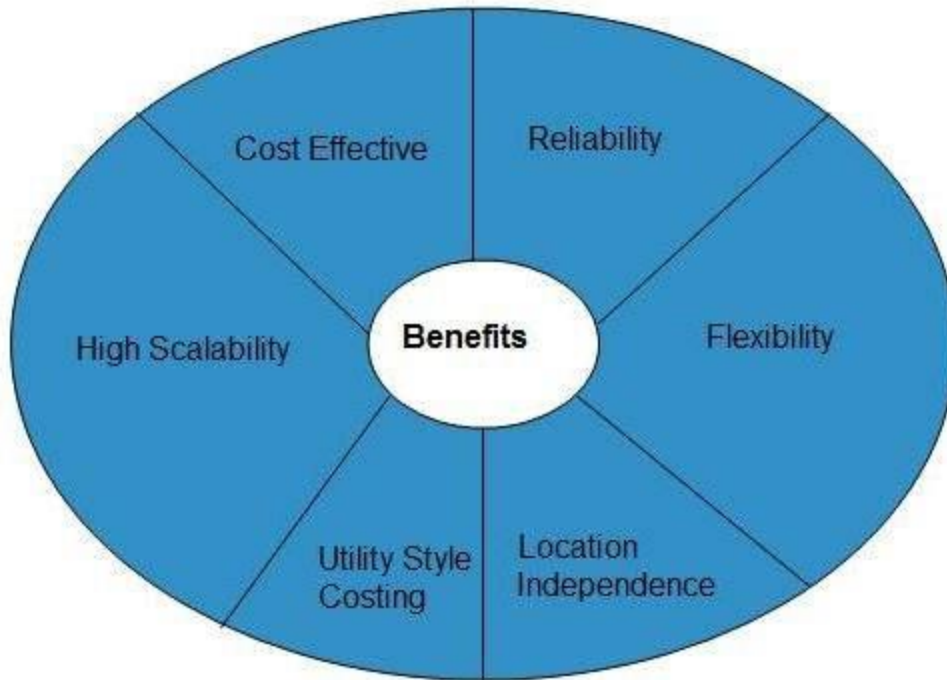
DEPLOYMENT MODEL

Public Cloud allows systems and services to be easily accessible to general public. The IT giants such as **Google**, **Amazon** and **Microsoft** offer cloud services via Internet. The Public Cloud Model is shown in the diagram below.



Benefits

There are many benefits of deploying cloud as public cloud model. The following diagram shows some of those benefits:



Cost Effective

Since **public cloud** shares same resources with large number of customers it turns out inexpensive.

Reliability

The **public cloud** employs large number of resources from different locations. If any of the resources fails, public cloud can employ another one.

Flexibility

The public cloud can smoothly integrate with private cloud, which gives customers a flexible approach.

Location Independence

Public cloud services are delivered through Internet, ensuring location independence.

Utility Style Costing

Public cloud is also based on **pay-per-use** model and resources are accessible whenever customer needs them.

High Scalability

Cloud resources are made available on demand from a pool of resources, i.e., they can be scaled up or down according the requirement.

Disadvantages

In **public cloud model**, data is hosted off-site and resources are shared publicly, therefore does not ensure higher level of security.

Less Customizable

Here are some disadvantages of public cloud model:

Low Security

It is comparatively less customizable than private cloud.

CLOUD COMPUTING

Cloud Computing provides us means of accessing the applications as utilities over the Internet. It allows us to create, configure, and customize the applications online.

What is Cloud?

The term **Cloud** refers to a **Network** or **Internet**. In other words, we can say that Cloud is something, which is present at remote location. Cloud can provide services over public and private networks, i.e., WAN, LAN or VPN.

Applications such as e-mail, web conferencing, customer relationship management (CRM) execute on cloud.

What is Cloud Computing?

Cloud Computing refers to **manipulating**, **configuring**, and **accessing** the hardware and software resources remotely. It offers online data storage, infrastructure, and application.



Cloud computing offers **platform independency**, as the software is not required to be installed locally on the PC. Hence, the Cloud Computing is making our business applications **mobile** and **collaborative**.

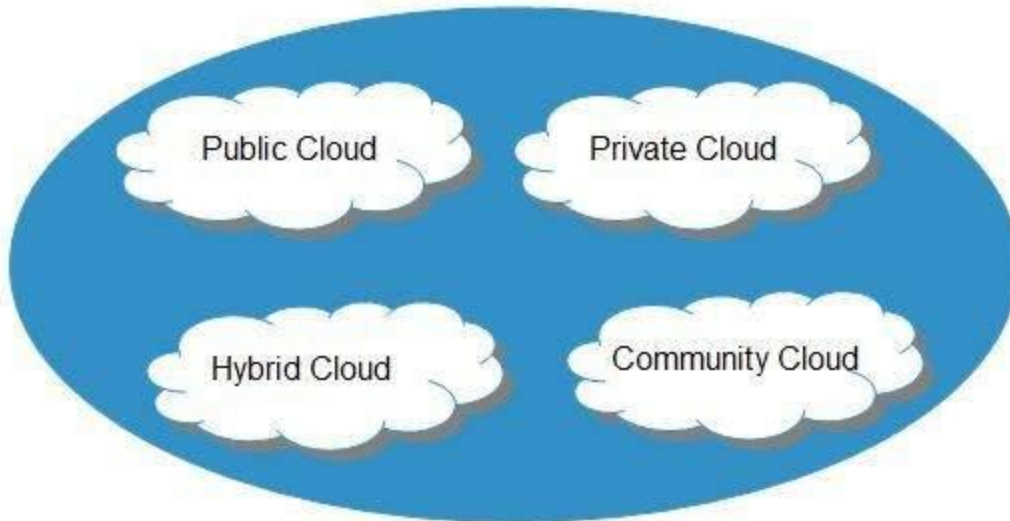
Basic Concepts

There are certain services and models working behind the scene making the cloud computing feasible and accessible to end users. Following are the working models for cloud computing:

- Deployment Models
- Service Models

Deployment Models

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, Hybrid, and Community.



Public Cloud

The **public cloud** allows systems and services to be easily accessible to the general public. Public cloud may be less secure because of its openness.

Private Cloud

The **private cloud** allows systems and services to be accessible within an organization. It is more secured because of its private nature.

Community Cloud

The **community cloud** allows systems and services to be accessible by a group of organizations.

Hybrid Cloud

The **hybrid cloud** is a mixture of public and private cloud, in which the critical activities are performed using private cloud while the non-critical activities are performed using public cloud.

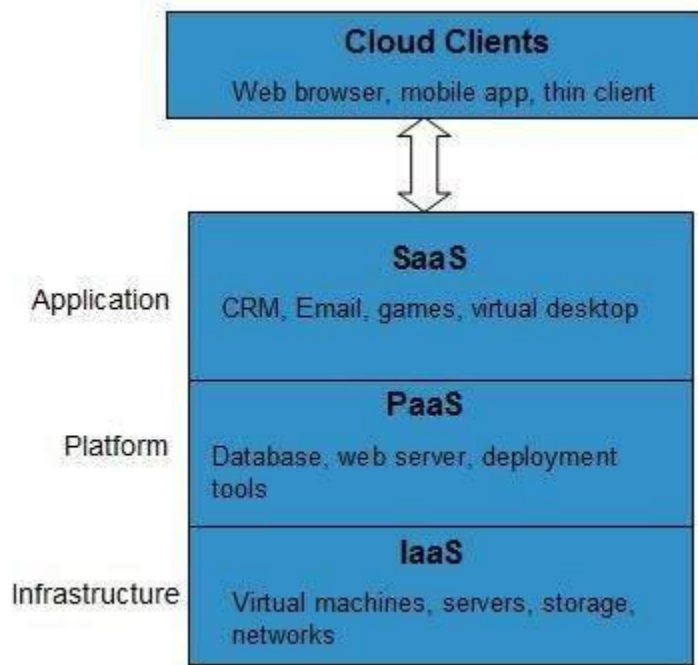
Service Models

Cloud computing is based on service models. These are categorized into three basic service models which are -

- Infrastructure-as-a-Service (IaaS)
- Platform-as-a-Service (PaaS)
- Software-as-a-Service (SaaS)

Anything-as-a-Service (XaaS) is yet another service model, which includes Network-as-a-Service, Business-as-a-Service, Identity-as-a-Service, Database-as-a-Service or Strategy-as-a-Service.

The **Infrastructure-as-a-Service (IaaS)** is the most basic level of service. Each of the service models inherit the security and management mechanism from the underlying model, as shown in the following diagram:



Infrastructure-as-a-Service (IaaS)

IaaS provides access to fundamental resources such as physical machines, virtual machines, virtual storage, etc.

Platform-as-a-Service (PaaS)

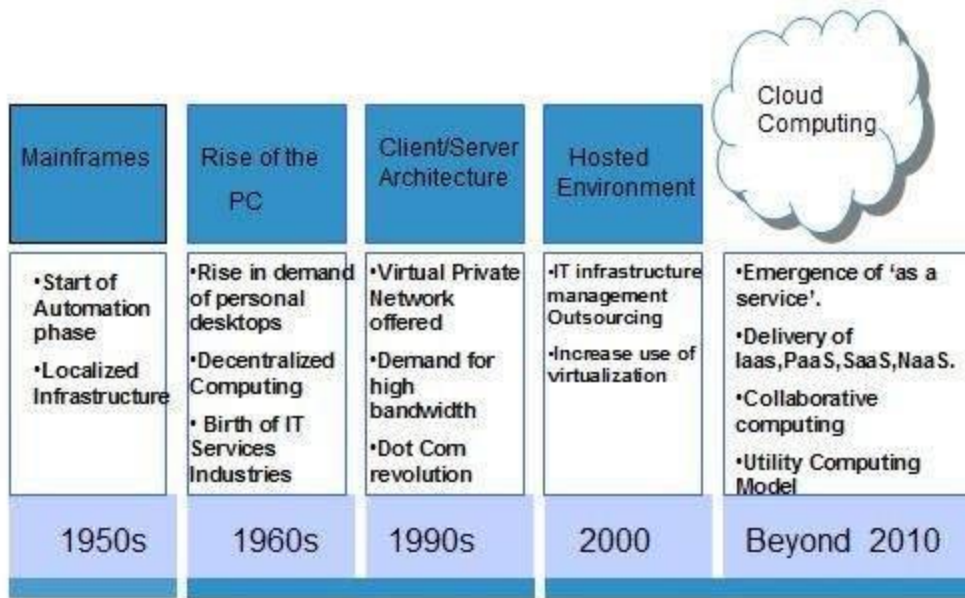
PaaS provides the runtime environment for applications, development and deployment tools, etc.

Software-as-a-Service (SaaS)

SaaS model allows to use software applications as a service to end-users.

History of Cloud Computing

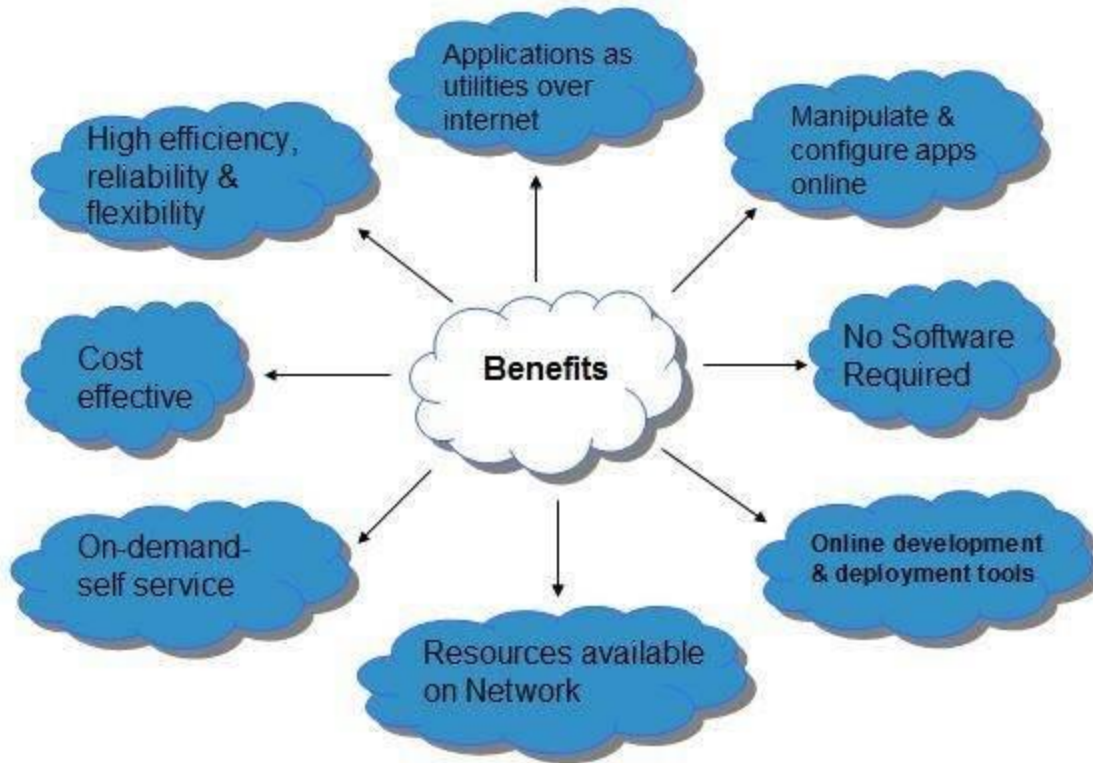
The concept of **Cloud Computing** came into existence in the year 1950 with implementation of mainframe computers, accessible via **thin/static clients**. Since then, cloud computing has been evolved from static clients to dynamic ones and from software to services. The following diagram explains the evolution of cloud computing:



Benefits

Cloud Computing has numerous advantages. Some of them are listed below -

- One can access applications as utilities, over the Internet.
- One can manipulate and configure the applications online at any time.
- It does not require to install a software to access or manipulate cloud application.
- Cloud Computing offers online development and deployment tools, programming runtime environment through **PaaS model**.
- Cloud resources are available over the network in a manner that provide platform independent access to any type of clients.
- Cloud Computing offers **on-demand self-service**. The resources can be used without interaction with cloud service provider.
- Cloud Computing is highly cost effective because it operates at high efficiency with optimum utilization. It just requires an Internet connection
- Cloud Computing offers load balancing that makes it more reliable.



Risks related to Cloud Computing

Although cloud Computing is a promising innovation with various benefits in the world of computing, it comes with risks. Some of them are discussed below:

Security and Privacy

It is the biggest concern about cloud computing. Since data management and infrastructure management in cloud is provided by third-party, it is always a risk to handover the sensitive information to cloud service providers.

Although the cloud computing vendors ensure highly secured password protected accounts, any sign of security breach may result in loss of customers and businesses.

Lock In

It is very difficult for the customers to switch from one **Cloud Service Provider (CSP)** to another. It results in dependency on a particular CSP for service.

Isolation Failure

This risk involves the failure of isolation mechanism that separates storage, memory, and routing between the different tenants.

Management Interface Compromise

In case of public cloud provider, the customer management interfaces are accessible through the Internet.

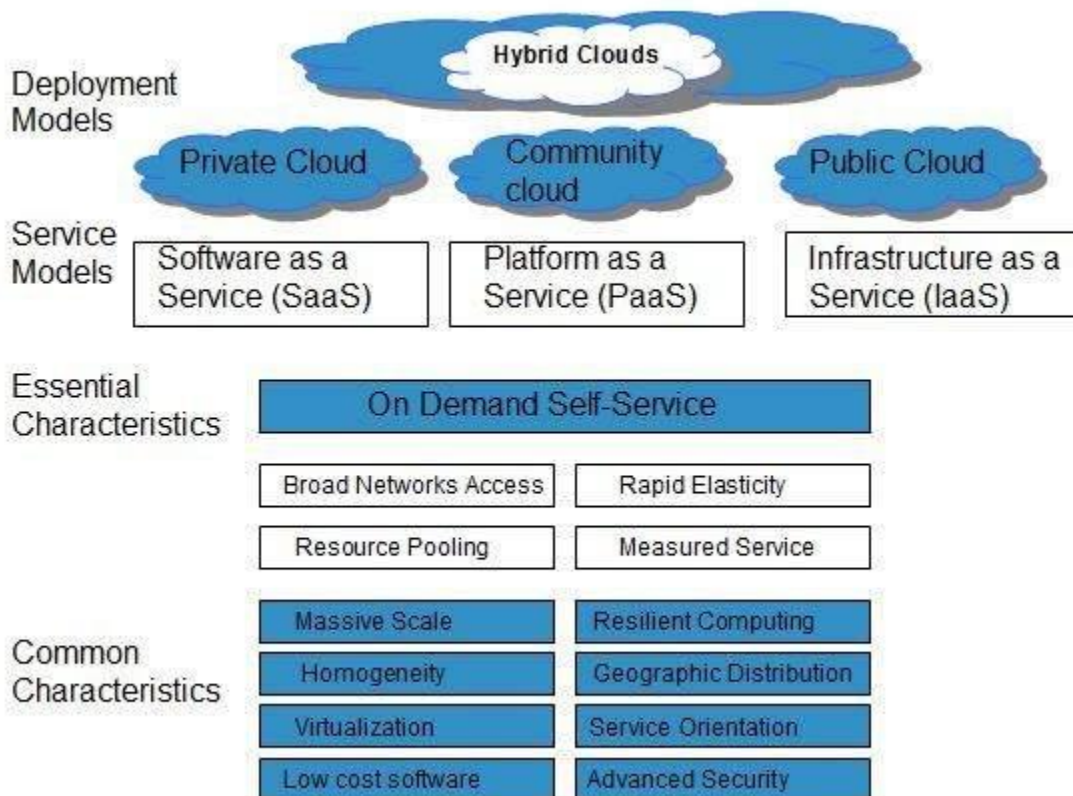
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Characteristics of Cloud Computing

There are four key characteristics of cloud computing. They are shown in the following diagram:



On Demand Self Service

Cloud Computing allows the users to use web services and resources on demand. One can logon to a website at any time and use them.

Broad Network Access

Since cloud computing is completely web based, it can be accessed from anywhere and at any time.

Resource Pooling

Cloud computing allows multiple tenants to share a pool of resources. One can share single physical instance of hardware, database and basic infrastructure.

Rapid Elasticity

It is very easy to scale the resources vertically or horizontally at any time. Scaling of resources means the ability of resources to deal with increasing or decreasing demand.

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Measured Service

In this service cloud provider controls and monitors all the aspects of cloud service. Resource optimization, billing, and capacity planning etc. depend on it.

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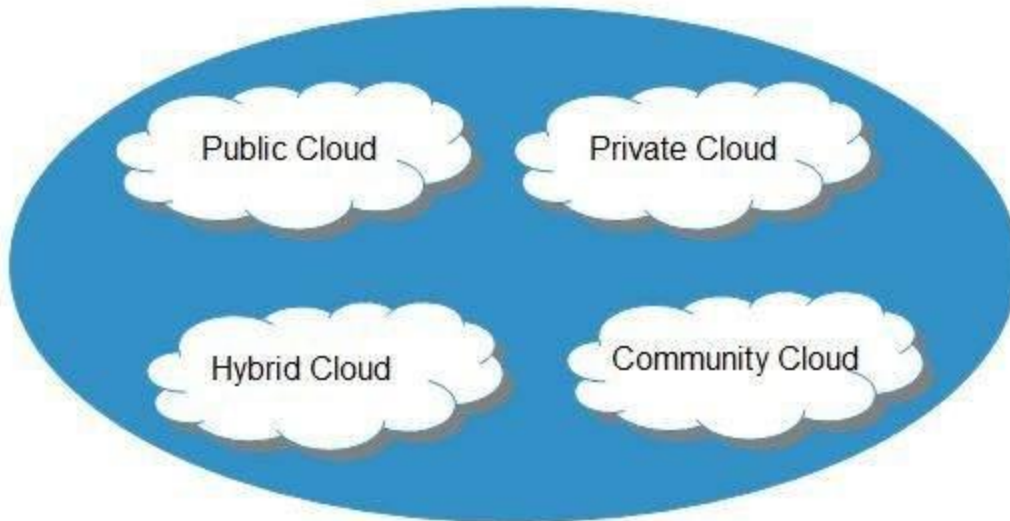
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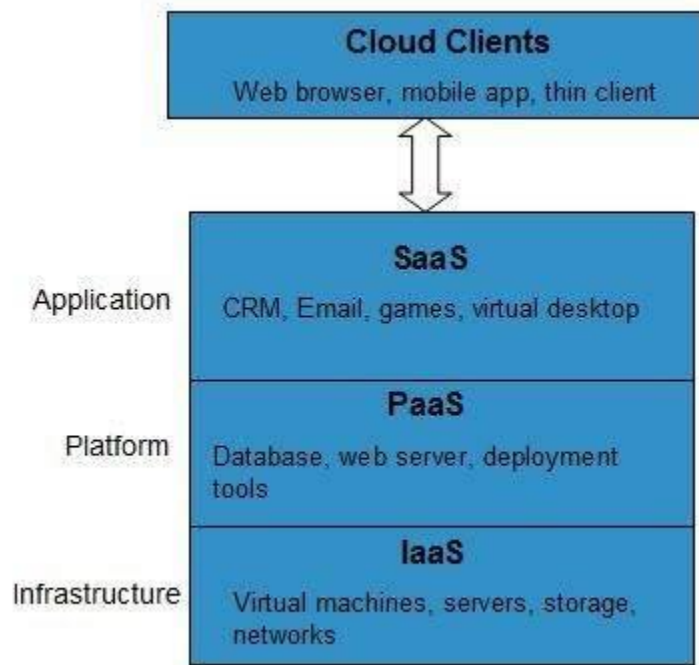
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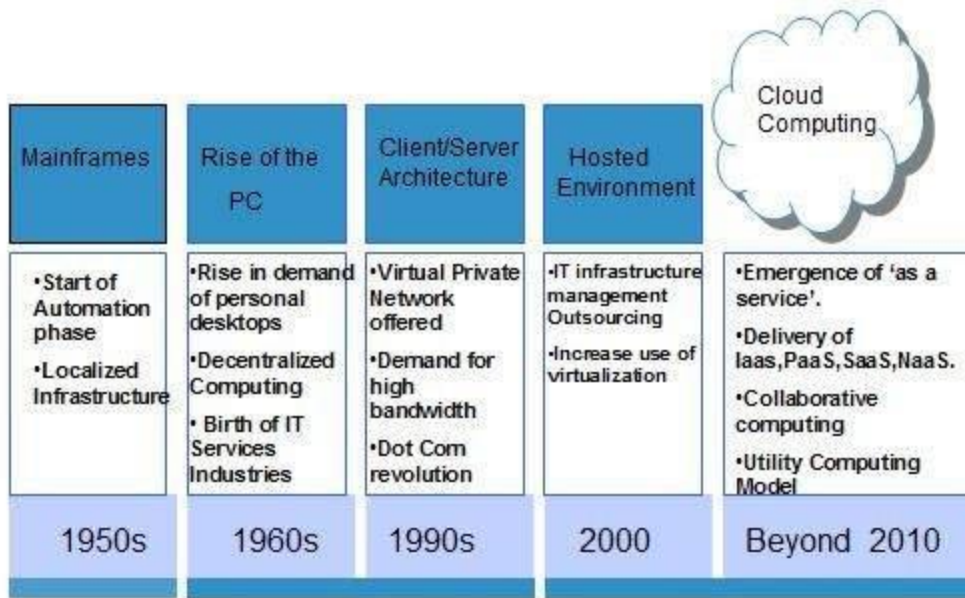
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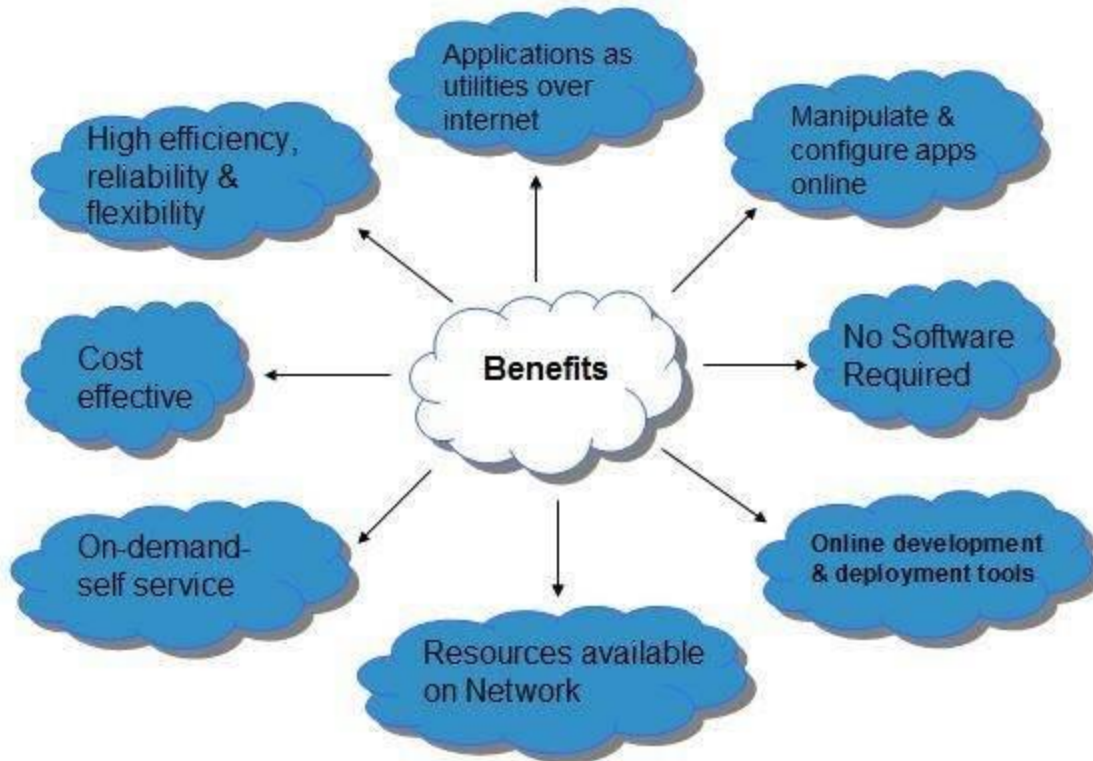
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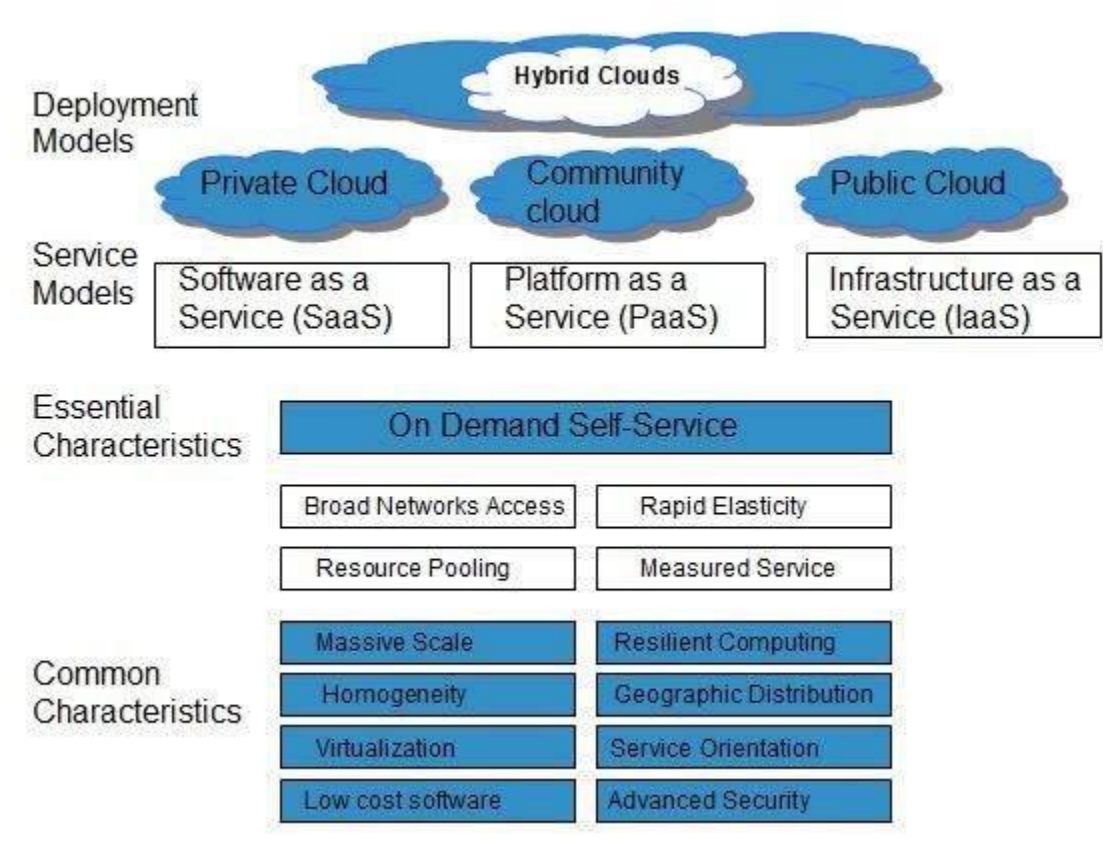
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Cloud Computing Software as a Service (SaaS)

Software-as-a-Service (SaaS) model allows to provide software application as a service to the end users. It refers to a software that is deployed on a host service and is accessible via Internet.

There are several SaaS applications listed below:

- Billing and invoicing system
- Customer Relationship Management (CRM) applications
- Help desk applications
- Human Resource (HR) solutions

Some of the SaaS applications are not customizable such as **Microsoft Office Suite**. But SaaS provides us **Application Programming Interface (API)**, which allows the developer to develop a customized application.

Characteristics

Here are the characteristics of SaaS service model:

- SaaS makes the software available over the Internet.
- The software applications are maintained by the vendor.

- The license to the software may be subscription based or usage based. And it is billed on recurring basis.
- SaaS applications are cost-effective since they do not require any maintenance at end user side.
- They are available on demand.
- They can be scaled up or down on demand.
- They are automatically upgraded and updated.
- SaaS offers shared data model. Therefore, multiple users can share single instance of infrastructure. It is not required to hard code the functionality for individual users.
- All users run the same version of the software.

Benefits

Using SaaS has proved to be beneficial in terms of scalability, efficiency and performance. Some of the benefits are listed below:

- Modest software tools
- Efficient use of software licenses
- Centralized management and data
- Platform responsibilities managed by provider
- Multitenant solutions

Modest software tools

The SaaS application deployment requires a little or no client side software installation, which results in the following benefits:

- No requirement for complex software packages at client side
- Little or no risk of configuration at client side
- Low distribution cost

Efficient use of software licenses

The customer can have single license for multiple computers running at different locations which reduces the licensing cost. Also, there is no requirement for license servers because the software runs in the provider's infrastructure.

Centralized management and data

The cloud provider stores data centrally. However, the cloud providers may store data in a decentralized manner for the sake of redundancy and reliability.

Platform responsibilities managed by providers

All platform responsibilities such as backups, system maintenance, security, hardware refresh, power management, etc. are performed by the cloud provider. The customer does not need to bother about them.

Multitenant solutions

Multitenant solutions allow multiple users to share single instance of different resources in virtual isolation. Customers can customize their application without affecting the core functionality.

Issues

There are several issues associated with SaaS, some of them are listed below:

- Browser based risks
- Network dependence
- Lack of portability between SaaS clouds

Browser based risks

If the customer visits malicious website and browser becomes infected, the subsequent access to SaaS application might compromise the customer's data.

To avoid such risks, the customer can use multiple browsers and dedicate a specific browser to access SaaS applications or can use virtual desktop while accessing the SaaS applications.

Network dependence

The SaaS application can be delivered only when network is continuously available. Also network should be reliable but the network reliability cannot be guaranteed either by cloud provider or by the customer.

Lack of portability between SaaS clouds

Transferring workloads from one SaaS cloud to another is not so easy because work flow, business logics, user interfaces, support scripts can be provider specific.

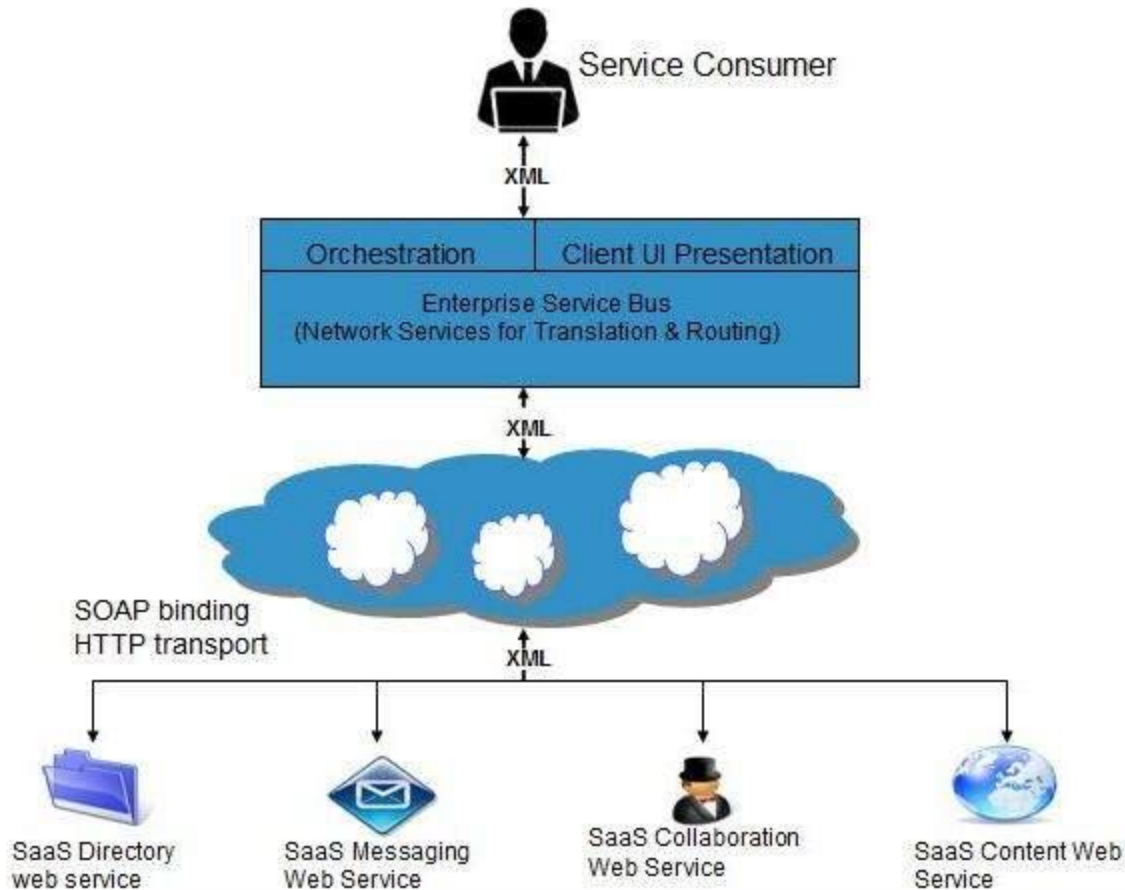
Open SaaS and SOA

Open SaaS uses those SaaS applications, which are developed using open source programming language. These SaaS applications can run on any open source operating system and database.

Open SaaS has several benefits listed below:

- No License Required
- Low Deployment Cost
- Less Vendor Lock-in
- More portable applications
- More Robust Solution

The following diagram shows the SaaS implementation based on SOA:

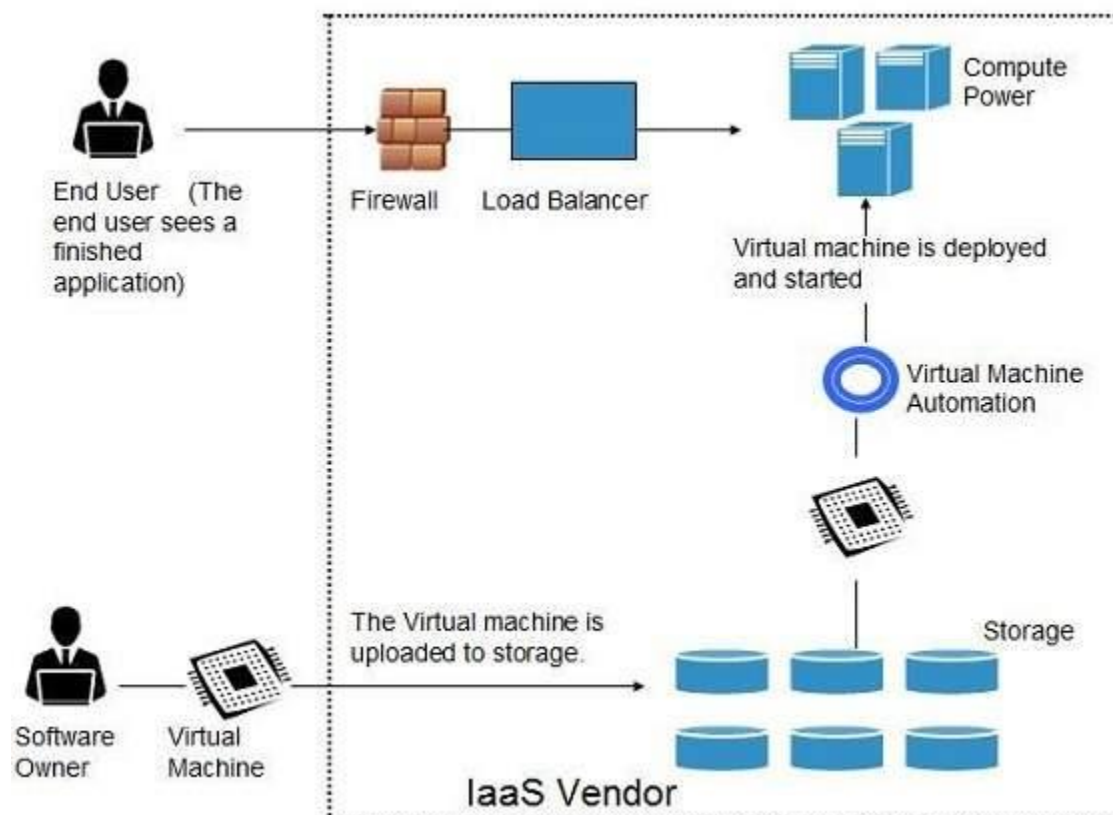


Cloud Computing Infrastructure as a Service (IaaS)

Infrastructure-as-a-Service provides access to fundamental resources such as physical machines, virtual machines, virtual storage, etc. Apart from these resources, the IaaS also offers:

- Virtual machine disk storage
- Virtual local area network (VLANs)
- Load balancers
- IP addresses
- Software bundles

All of the above resources are made available to end user via **server virtualization**. Moreover, these resources are accessed by the customers as if they own them.



Benefits

IaaS allows the cloud provider to freely locate the infrastructure over the Internet in a cost-effective manner. Some of the key benefits of IaaS are listed below:

- Full control of the computing resources through administrative access to VMs.
- Flexible and efficient renting of computer hardware.
- Portability, interoperability with legacy applications.

[Full control over computing resources through administrative access to VMs](#)

IaaS allows the customer to access computing resources through administrative access to virtual machines in the following manner:

- Customer issues administrative command to cloud provider to run the virtual machine or to save data on cloud server.
- Customer issues administrative command to virtual machines they owned to start web server or to install new applications.

Flexible and efficient renting of computer hardware

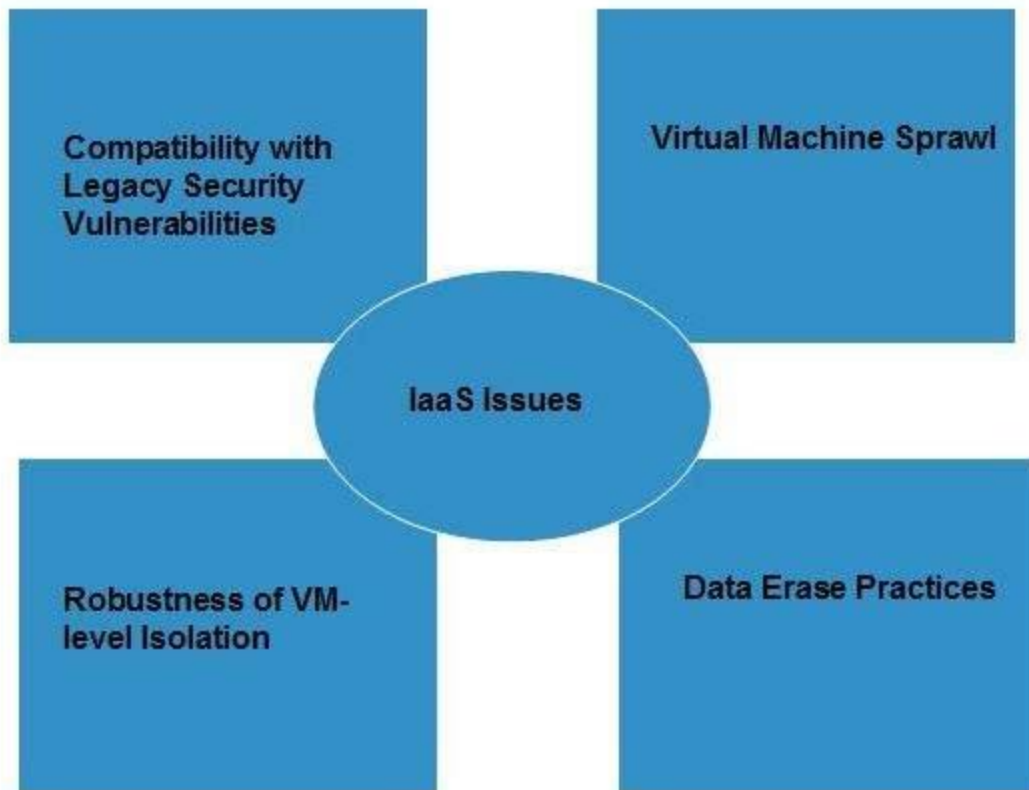
IaaS resources such as virtual machines, storage devices, bandwidth, IP addresses, monitoring services, firewalls, etc. are made available to the customers on rent. The payment is based upon the amount of time the customer retains a resource. Also with administrative access to virtual machines, the customer can run any software, even a custom operating system.

Portability, interoperability with legacy applications

It is possible to maintain legacy between applications and workloads between IaaS clouds. For example, network applications such as web server or e-mail server that normally runs on customer-owned server hardware can also run from VMs in IaaS cloud.

Issues

IaaS shares issues with PaaS and SaaS, such as Network dependence and browser based risks. It also has some specific issues, which are mentioned in the following diagram:



Compatibility with legacy security vulnerabilities

Because IaaS offers the customer to run legacy software in provider's infrastructure, it exposes customers to all of the security vulnerabilities of such legacy software.

Virtual Machine sprawl

The VM can become out-of-date with respect to security updates because IaaS allows the customer to operate the virtual machines in running, suspended and off state. However, the provider can automatically update such VMs, but this mechanism is hard and complex.

Robustness of VM-level isolation

IaaS offers an isolated environment to individual customers through hypervisor. Hypervisor is a software layer that includes hardware support for virtualization to split a physical computer into multiple virtual machines.

Data erase practices

The customer uses virtual machines that in turn use the common disk resources provided by the cloud provider. When the customer releases the resource, the cloud provider must ensure that next customer to rent the resource does not observe data residue from previous customer.

Characteristics

Here are the characteristics of IaaS service model:

- Virtual machines with pre-installed software.
- Virtual machines with pre-installed operating systems such as Windows, Linux, and Solaris.
- On-demand availability of resources.
- Allows to store copies of particular data at different locations.
- The computing resources can be easily scaled up and down.

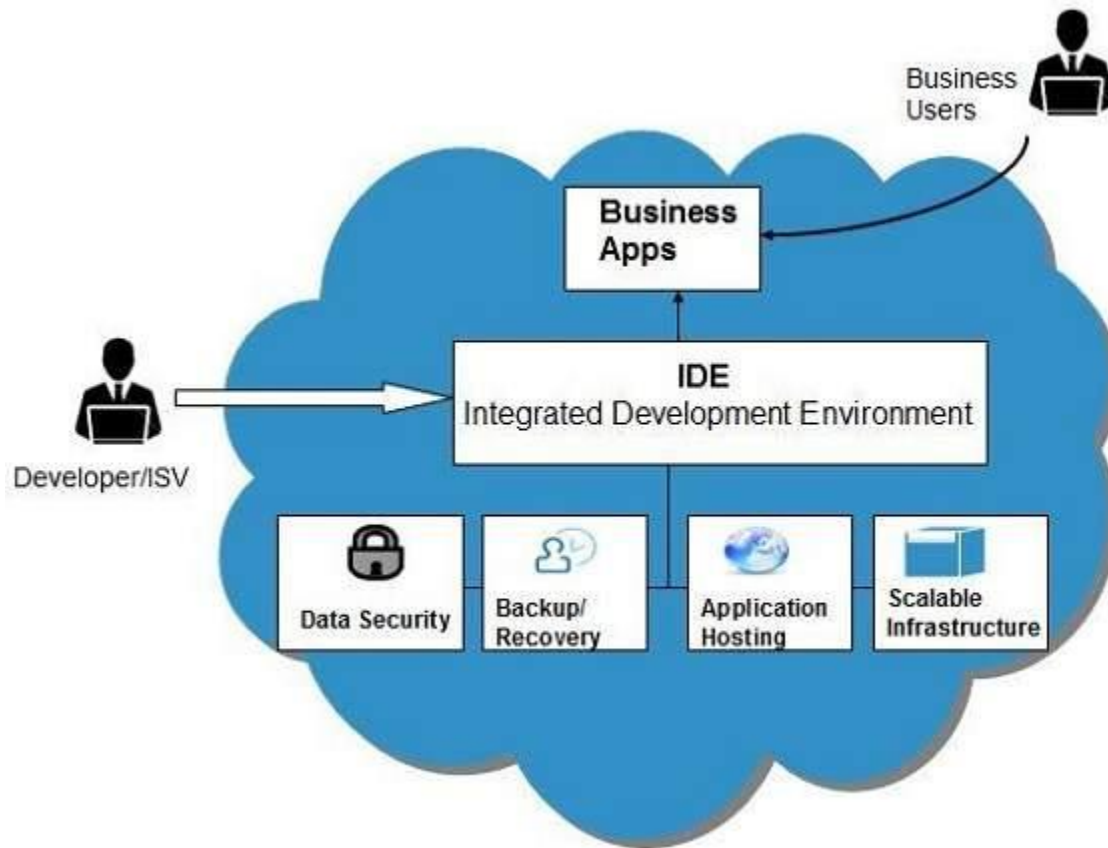
Cloud Computing Platform as a Service (PaaS)

Platform-as-a-Service offers the runtime environment for applications. It also offers development and deployment tools required to develop applications. PaaS has a feature of **point-and-click** tools that enables non-developers to create web applications.

App Engine of Google and **Force.com** are examples of PaaS offering vendors. Developer may log on to these websites and use the **built-in API** to create web-based applications.

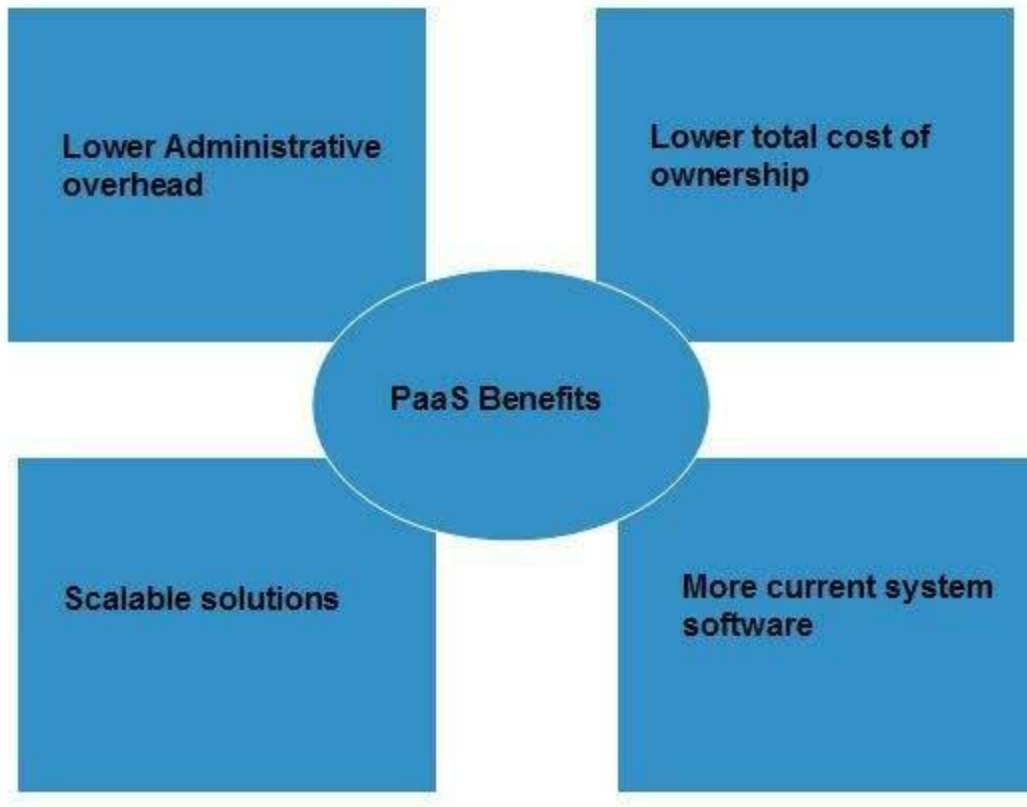
But the disadvantage of using PaaS is that, the developer **locks-in** with a particular vendor. For example, an application written in Python against API of Google, and using App Engine of Google is likely to work only in that environment.

The following diagram shows how PaaS offers an API and development tools to the developers and how it helps the end user to access business applications.



Benefits

Following are the benefits of PaaS model:



Lower administrative overhead

Customer need not bother about the administration because it is the responsibility of cloud provider.

Lower total cost of ownership

Customer need not purchase expensive hardware, servers, power, and data storage.

Scalable solutions

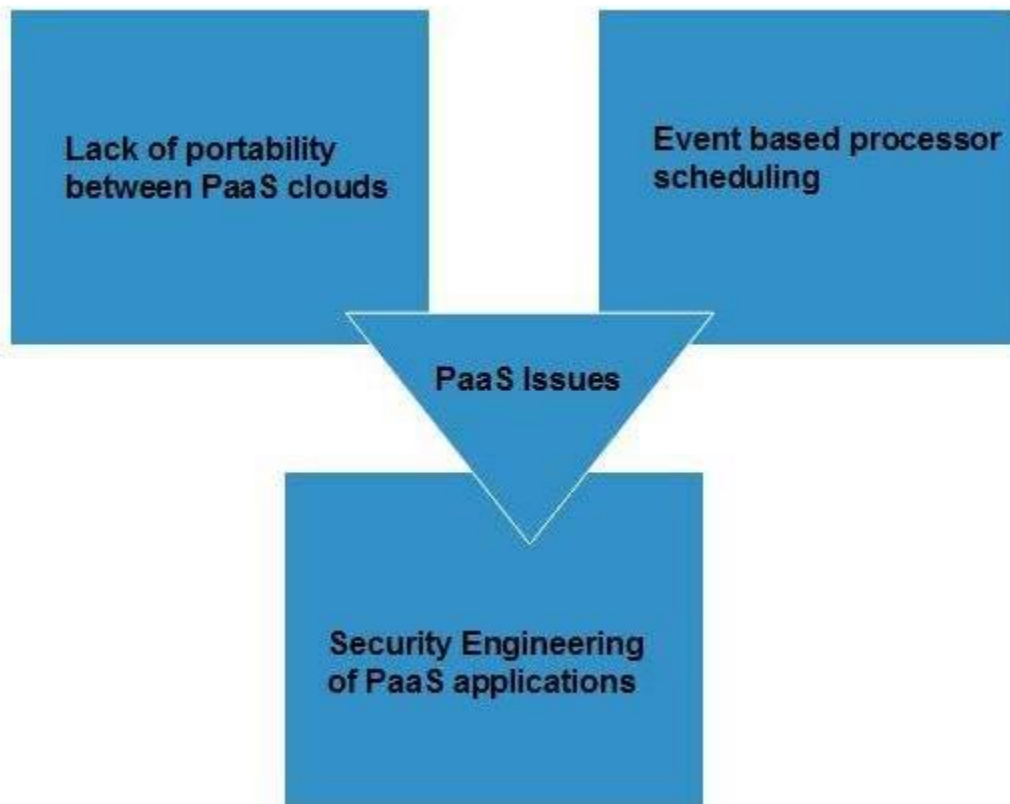
It is very easy to scale the resources up or down automatically, based on their demand.

More current system software

It is the responsibility of the cloud provider to maintain software versions and patch installations.

Issues

Like **SaaS**, **PaaS** also places significant burdens on customer's browsers to maintain reliable and secure connections to the provider's systems. Therefore, PaaS shares many of the issues of SaaS. However, there are some specific issues associated with PaaS as shown in the following diagram:



Lack of portability between PaaS clouds

Although standard languages are used, yet the implementations of platform services may vary. For example, file, queue, or hash table interfaces of one platform may differ from another, making it difficult to transfer the workloads from one platform to another.

Event based processor scheduling

The PaaS applications are event-oriented which poses resource constraints on applications, i.e., they have to answer a request in a given interval of time.

Security engineering of PaaS applications

Since PaaS applications are dependent on network, they must explicitly use cryptography and manage security exposures.

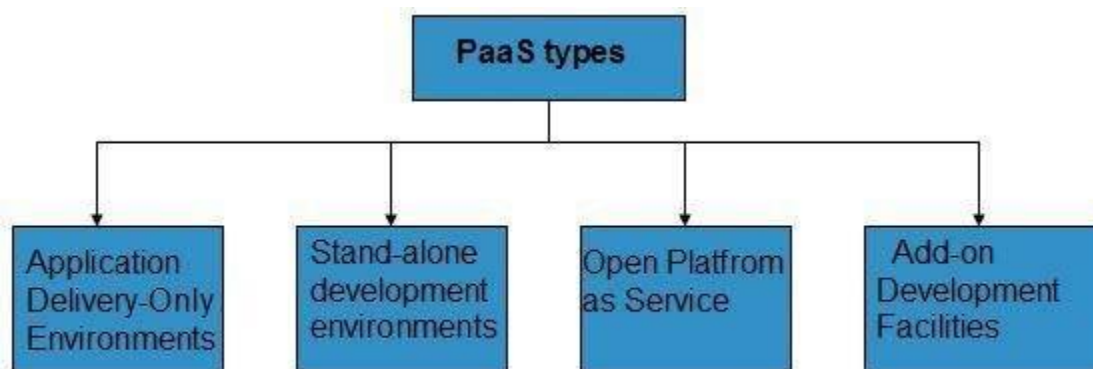
Characteristics

Here are the characteristics of PaaS service model:

- PaaS offers **browser based development environment**. It allows the developer to create database and edit the application code either via Application Programming Interface or point-and-click tools.
- PaaS provides **built-in security, scalability, and web service interfaces**.
- PaaS provides built-in tools for defining **workflow, approval processes,**and business rules.
- It is easy to integrate PaaS with other applications on the same platform.
- PaaS also provides web services interfaces that allow us to connect the applications outside the platform.

PaaS Types

Based on the functions, PaaS can be classified into four types as shown in the following diagram:



Stand-alone development environments

The **stand-alone PaaS** works as an independent entity for a specific function. It does not include licensing or technical dependencies on specific SaaS applications.

Application delivery-only environments

The **application delivery PaaS** includes **on-demand scaling** and **application security**.

Open platform as a service

Open PaaS offers an **open source software** that helps a PaaS provider to run applications.

Add-on development facilities

The **add-on PaaS** allows to customize the existing SaaS platform.