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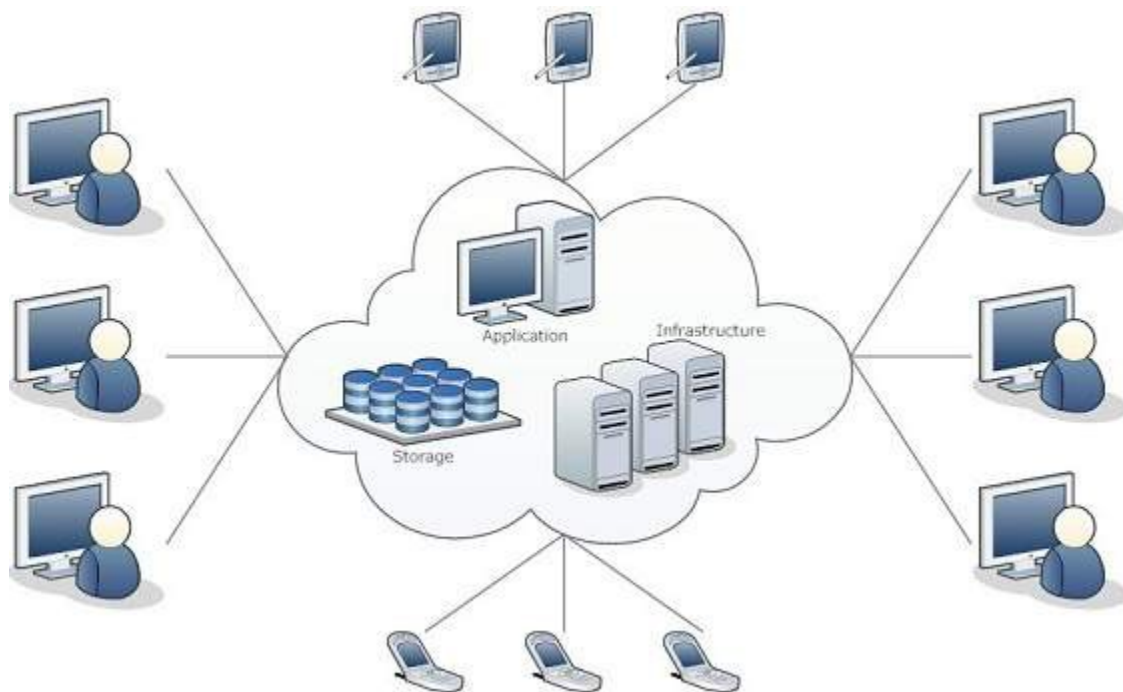
Cloud computing offers **platform independency,** as the software is not required to be installed locally on the PC. Hence, the Cloud Computing is making our business applications **mobile** and **collaborative.**

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.
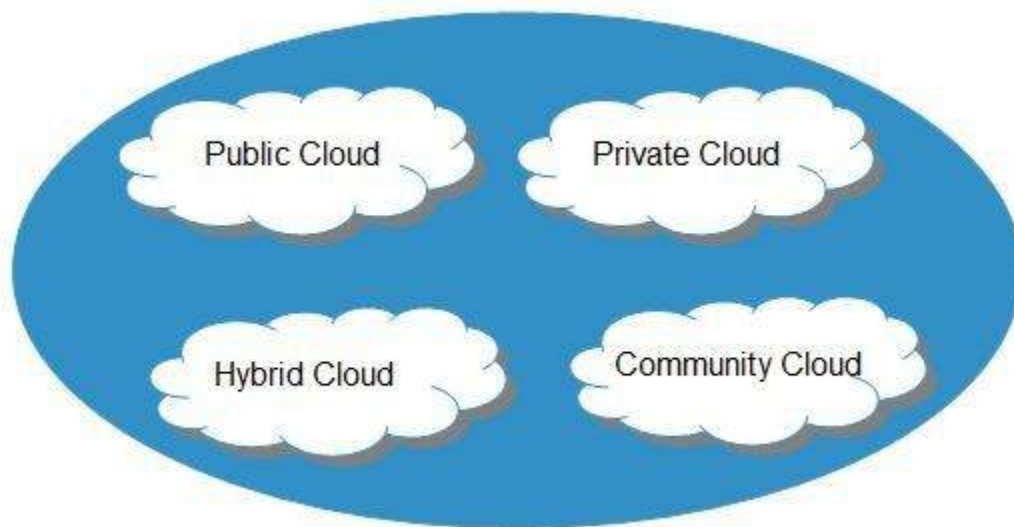
PUBLIC CLOUD

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:
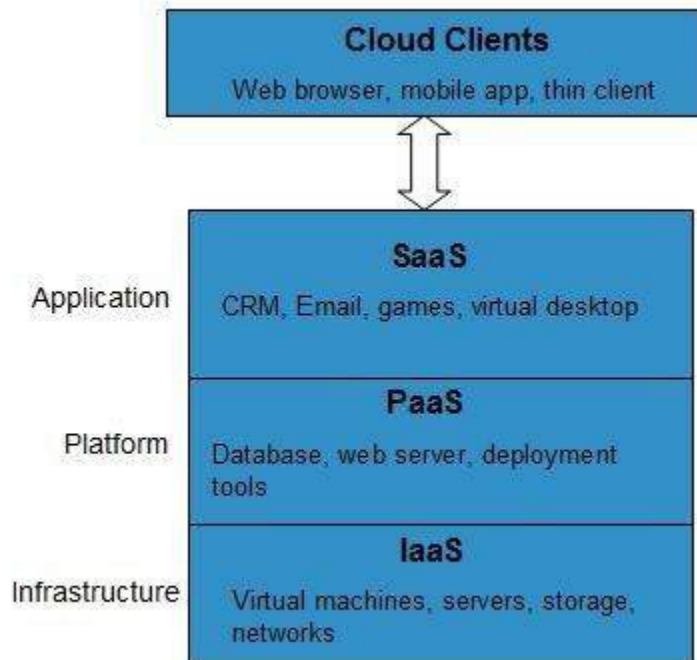
INFRASTRUCTURE-AS-A-SERVICE (IAAS)

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.
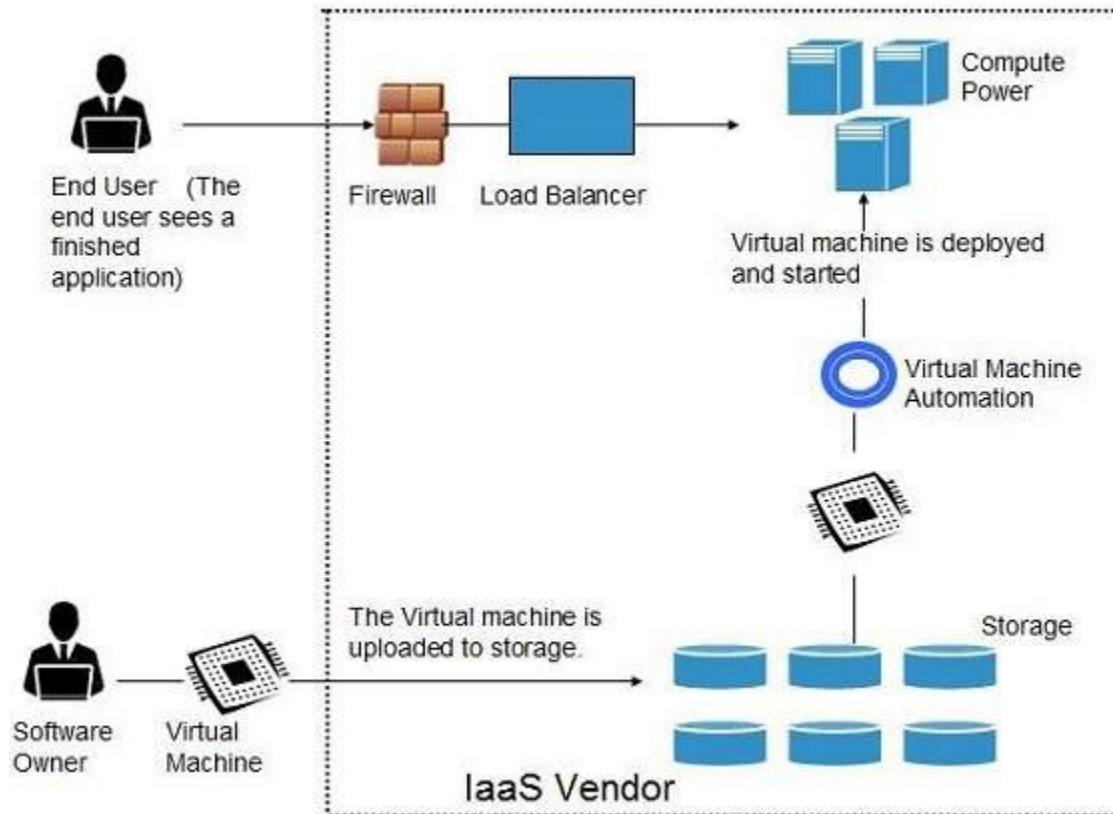
Benefits

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:
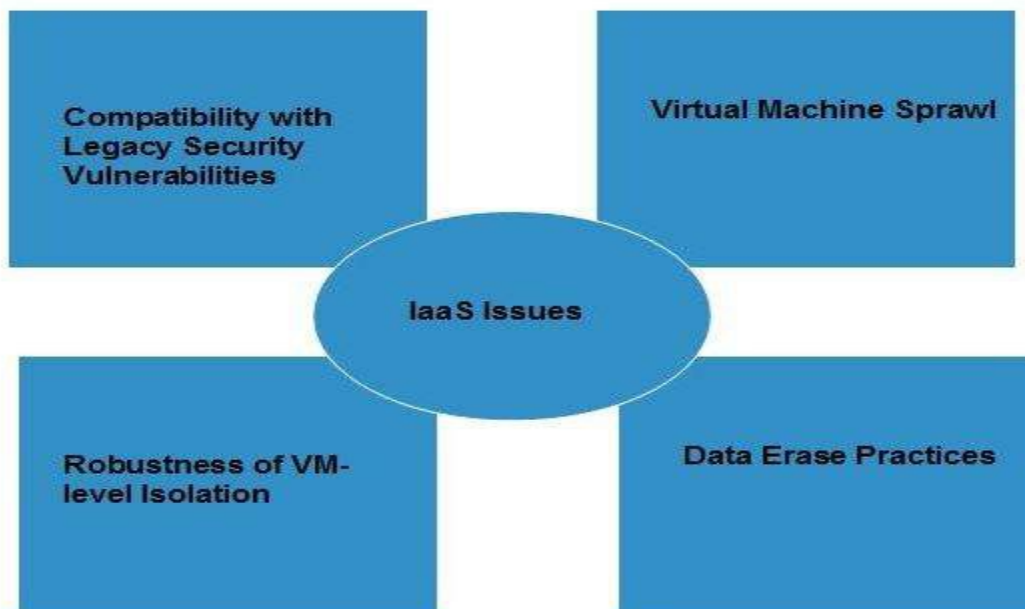
Compatibility with legacy security vulnerabilities

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.

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.
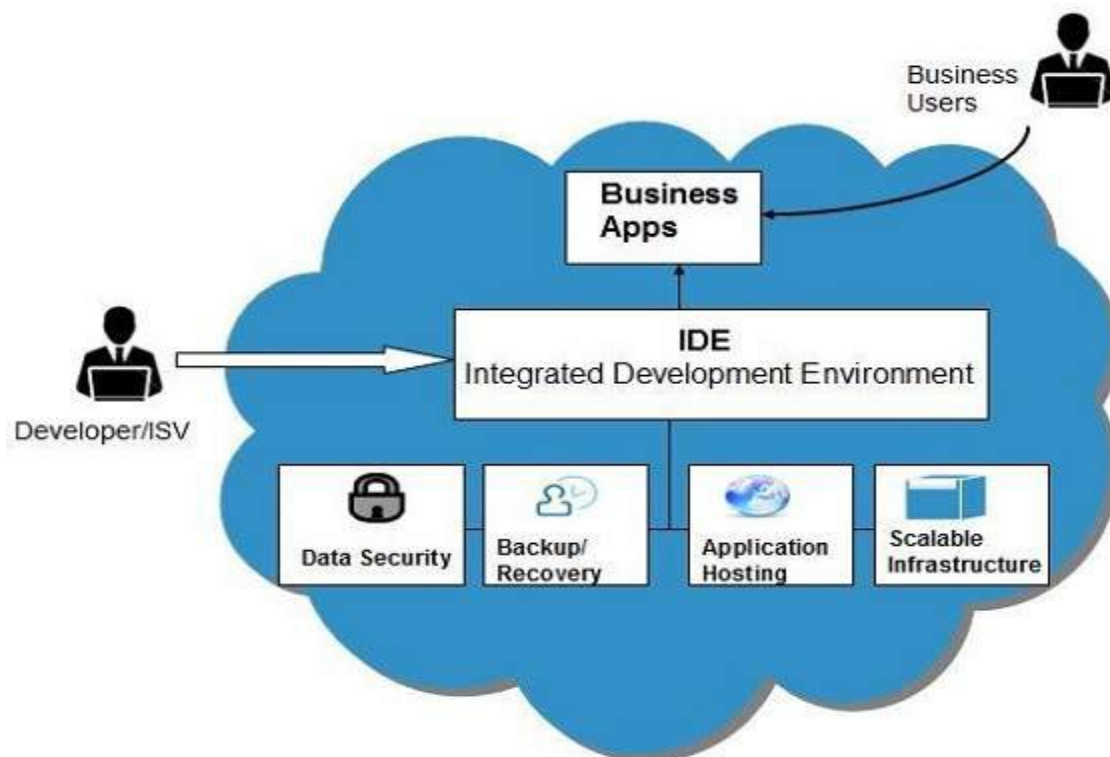
Benefits

Following are the benefits of PaaS model:
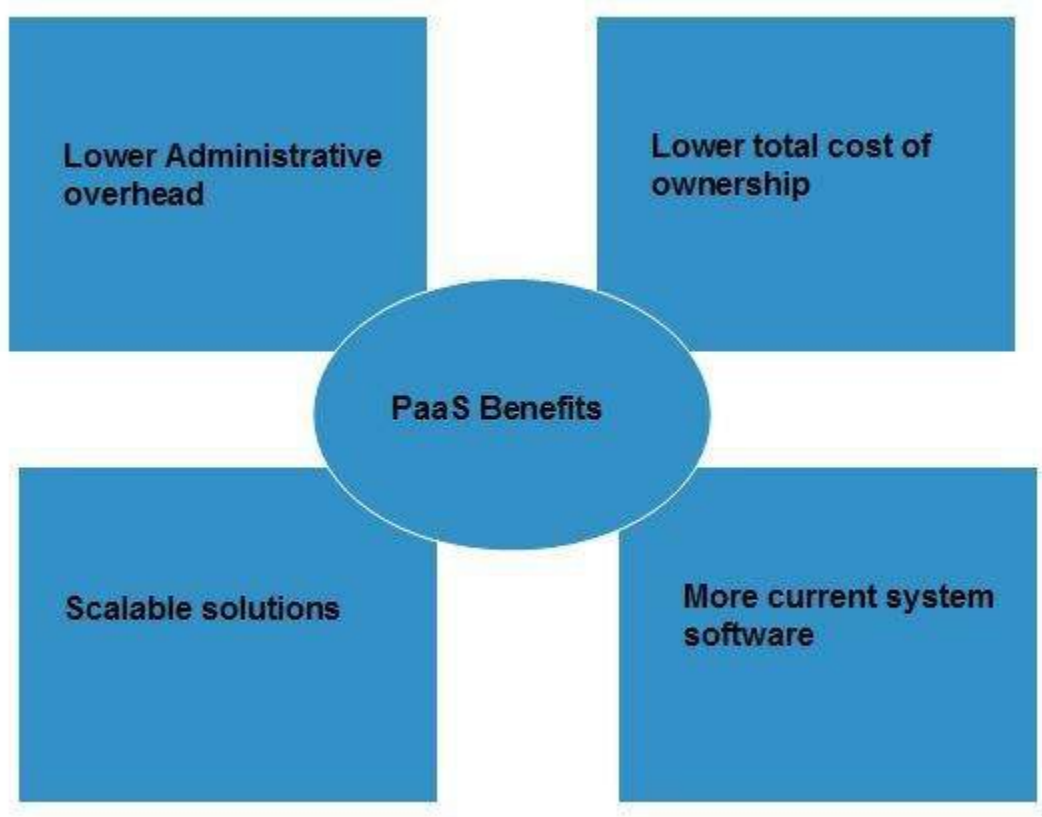
Lower administrative overhead

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:
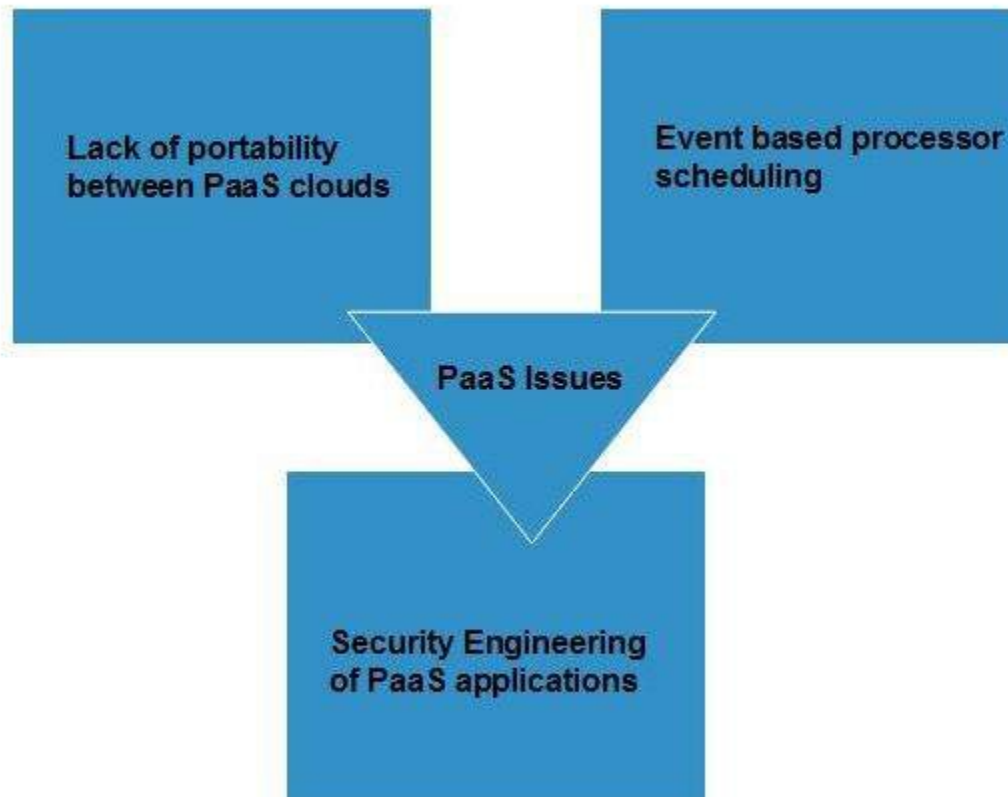
Lack of portability between PaaS clouds

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:
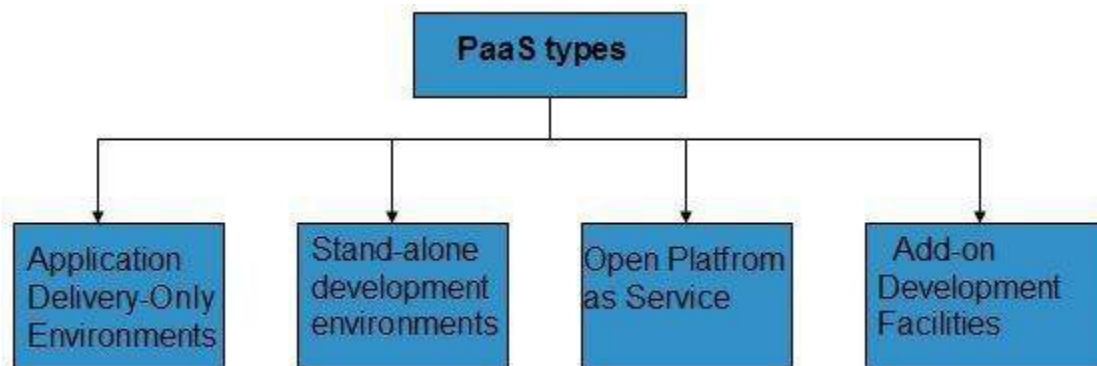
Stand-alone development environments

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

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.

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:
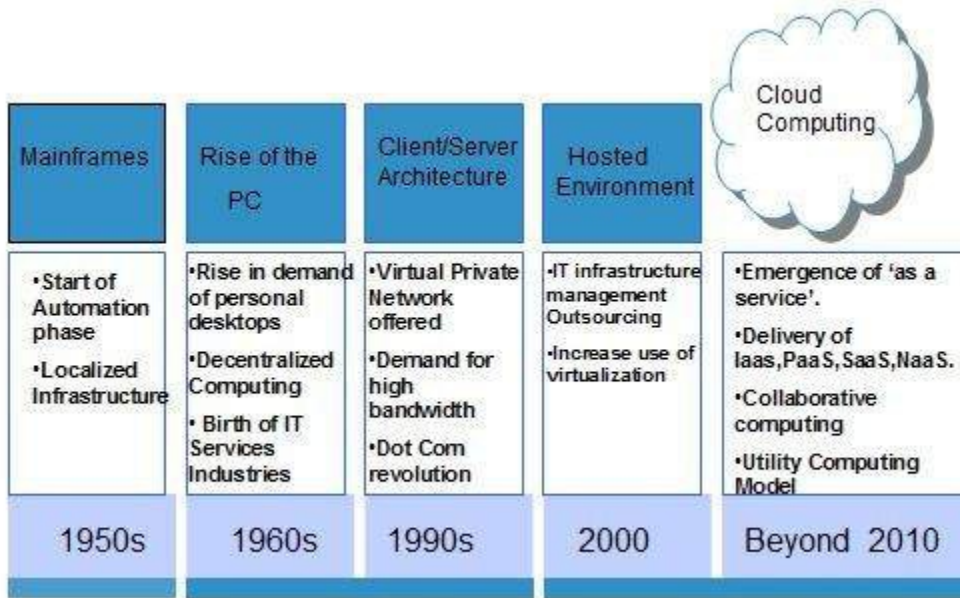
- No License Required

- Low Deployment Cost

- Less Vendor Lock-in

- More portable applications

- More Robust Solution

The following diagram shows the SaaS implementation based on SOA:
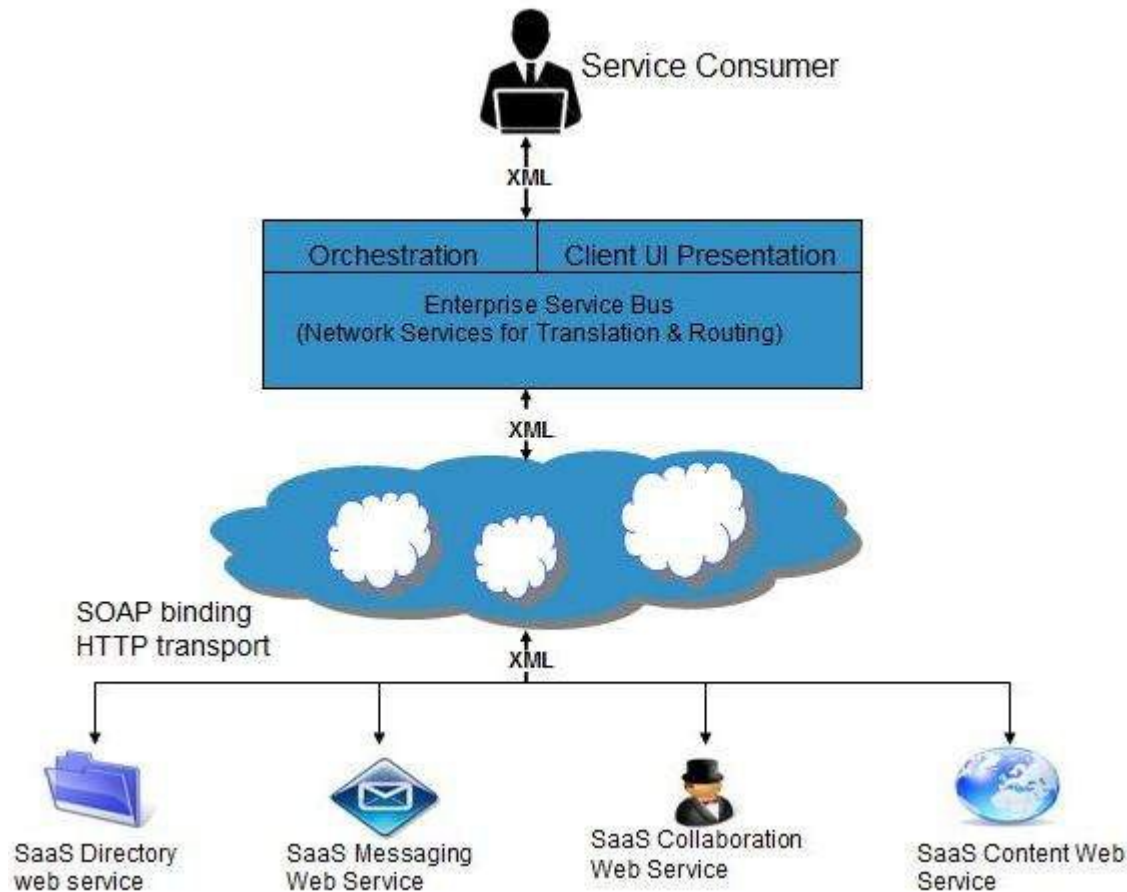
History of Cloud Computing

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:

Cloud Computing
Mainframes | Rise of the PC | Client/Server Architecture | Hosted Environment

Mainframes	Rise of the PC	Client/Server Architecture	Hosted Environment	Cloud Computing
•Start of Automation phase •Localized Infrastructure	•Rise in demand of personal desktops •Decentralized Computing • Birth of IT Services Industries	•Virtual Private Network offered •Demand for high bandwidth •Dot Com revolution	•IT infrastructure management Outsourcing •Increase use of virtualization	•Emergence of 'as a service'. •Delivery of Iaas,PaaS,SaaS,NaaS. •Collaborative computing •Utility Computing Model
1950s	1960s	1990s	2000	Beyond 2010

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.
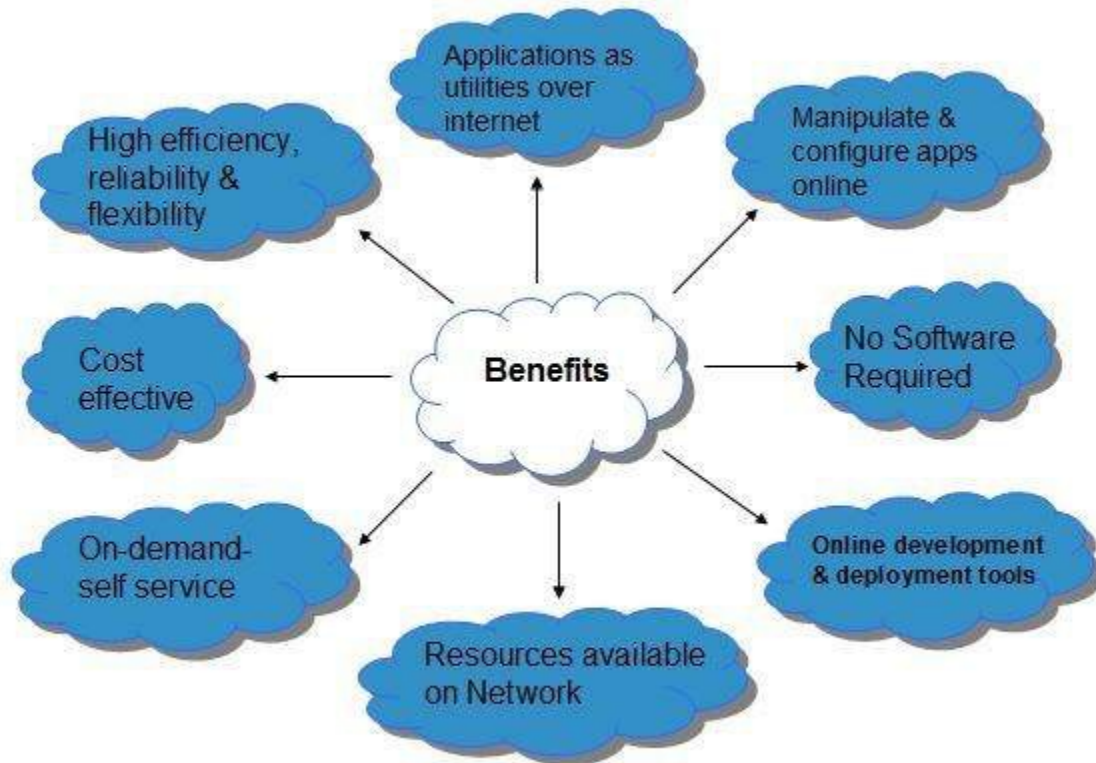
Risks related to Cloud Computing

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.

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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.

Insecure or Incomplete Data Deletion

It is possible that the data requested for deletion may not get deleted. It happens because either of the following reasons

- Extra copies of data are stored but are not available at the time of deletion

- Disk that stores data of multiple tenants is destroyed.

Characteristics of Cloud Computing

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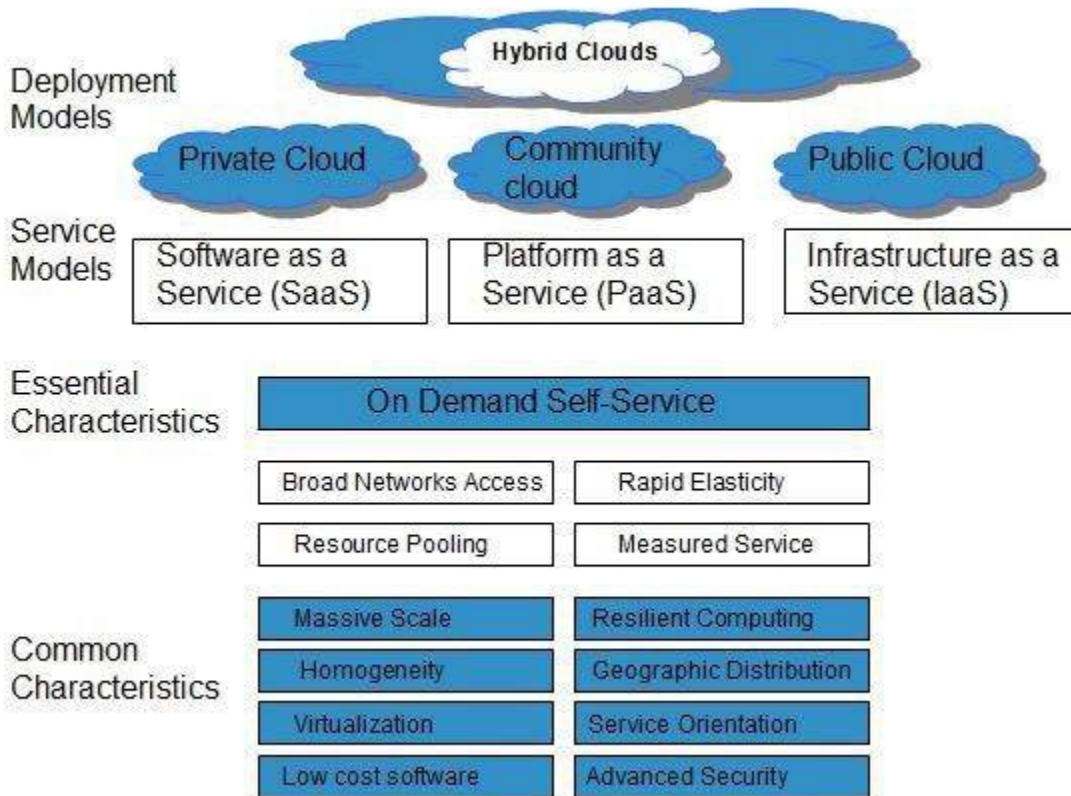
On Demand Self Service

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.

The resources being used by customers at any given point of time are automatically monitored.

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.