

1.1 Introduction to Cloud Computing

- Cloud computing refer to a variety of services available over the Internet that deliver compute functionality on the service provider's infrastructure.
- Its environment (infrastructure) may actually be hosted on either a grid or utility computing environment, but that doesn't matter to a service user.
- Cloud computing is a general term used to describe a new class of network based computing that takes place over the Internet, basically a step on from utility computing.
- In other words, this is a collection/group of integrated and networked hardware, software and Internet infrastructure (called a platform).
- Cloud computing refers to applications and services that run on a distributed network using virtualized resources and accessed by common Internet protocols and networking standards.
- Fig. 1.1.1 shows cloud symbol. It denotes cloud boundary.
- Using the Internet for communication and transport provides hardware, software and networking services to clients.
- These platforms hide the complexity and details of the underlying infrastructure from users and applications by providing very simple graphical interface or API.
- In addition, the platform provides on demand services that are always on anywhere, anytime and anyplace. Pay for use and as needed.
- The hardware and software services are available to the general public, enterprises, corporations and business markets.

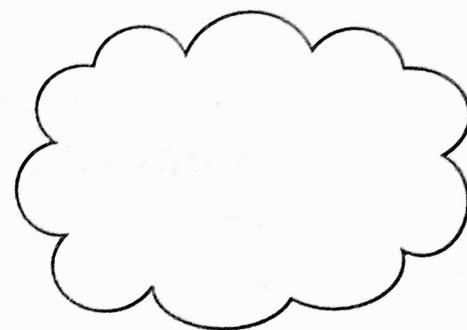


Fig. 1.1.1 Cloud symbol

1.1.1 Cloud Components

- Cloud computing solutions are made up of several elements. Fig. 1.1.2 shows cloud components.
 1. Clients : Mobile, terminals or regular computers.
 2. Benefits : Lower hardware costs, lower IT costs, security, data security, less power consumption, ease of repair or replacement, less noise,

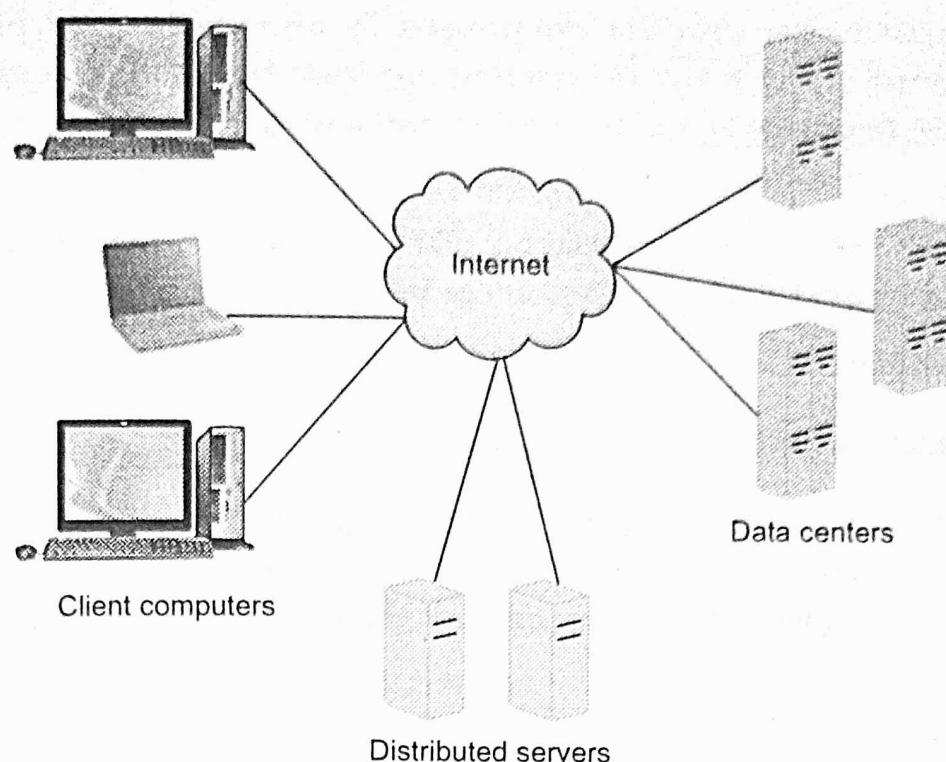


Fig. 1.1.2 Cloud components

3. **Data centers** : Collection of servers where the application to subscribe is housed. It could be a large room in the basement of your building or a room full of servers on the other side of the world.
4. **Virtualizing servers** : Software can be installed allowing multiple instances of virtual servers to be used and a dozen virtual servers can run on one physical server.
5. **Distributed servers** : Servers don't all have to be housed in the same location. It can be in geographically disparate locations. If something were to happen at one site, causing a failure, the service would still be accessed through another site. If the cloud needs more hardware, they can add them at another site.

1.1.2 Cloud Service and Consumer

- Cloud service is any service made available to users on demand via the internet from a cloud computing provider's servers as opposed to being provided from a company's own on-premises servers.
- A cloud service can exist as a simple web-based software program with a technical interface invoked via the use of a message protocol or as a remote access point for administrative tools or larger environments and other IT resources.

- The organization that provides cloud-based IT resources is cloud provider. Cloud providers normally own the IT resources for lease by cloud consumers and could also resell IT resources leased from other providers.

Cloud consumer

- A cloud consumer is an organization that has a formal contract or arrangement with a cloud provider to use IT resources made available by the cloud provider.
- The cloud consumer uses a cloud service consumer to access a cloud service.

1.1.3 Roles and Boundaries of Cloud

- Organizations and humans can assume different types of predefined roles depending on how they relate to and/or interact with a cloud and its hosted IT resources. The cloud computing defines these roles and identifies their main interactions.

1. Cloud provider :

- A person, organization or entity responsible for making a service available to interested parties. When assuming the role of cloud provider, an organization is responsible for making cloud services available to cloud consumers, as per agreed upon Service Level Agreement (SLA) guarantees. Cloud providers have their own IT resources.
- Fig. 1.1.3 shows cloud provider.

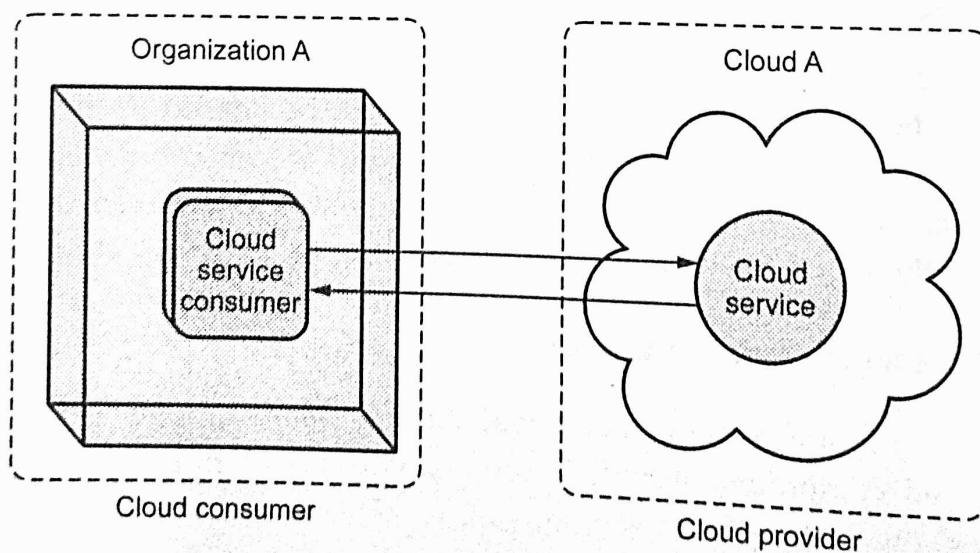


Fig. 1.1.3 Cloud service and cloud service consumer

- A cloud provider would have a significant number of roles responsible for the management of its cloud resources including those responsible for selling, onboarding, configuring and supporting cloud services for its consumers.

2. Cloud consumer :

- A person or organization that maintains a business relationship with and uses service from, cloud providers. The cloud consumer uses a cloud service consumer to access a cloud service.
- Anyone who purchases a cloud service is a consumer, and within the consumer there could be an array of roles responsible for configuring and managing the resources from the cloud provider depending on the services obtained.

3. Cloud service owner :

- The person or organization that legally owns a cloud service is called a cloud service owner. The cloud service owner can be the cloud consumer or the cloud provider that owns the cloud within which the cloud service resides,
- Fig. 1.1.4 shows cloud service owner.

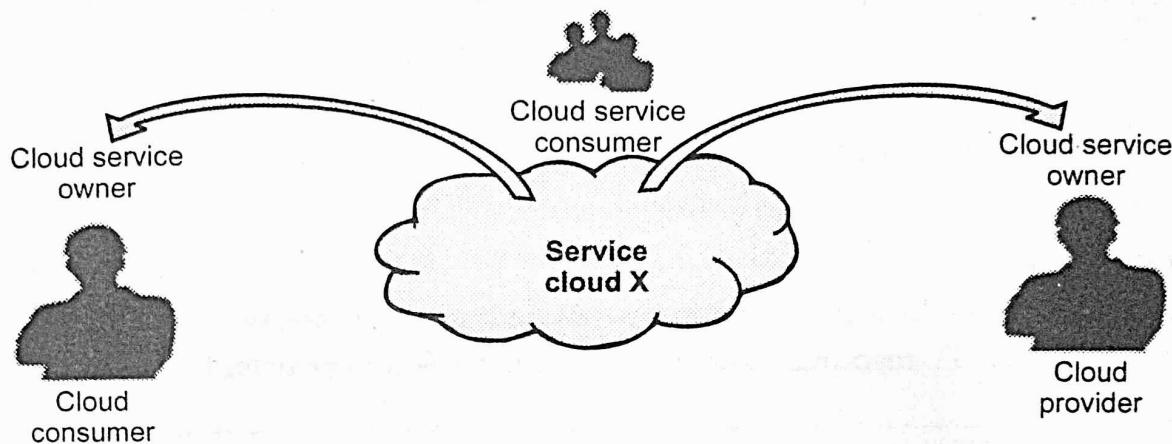


Fig. 1.1.4 Cloud service owner

- The reason a cloud service owner is not called a cloud resource owner is because the cloud service owner role only applies to cloud services.

4. Resource administrator :

- Cloud resource administrator is the person or organization responsible for administering a cloud-based IT resource. The cloud consumer or cloud provider or even third-party organization could be a cloud resource administrator.
- For example, a cloud service owner can contract a cloud resource administrator to administer a cloud service.

5. Cloud auditor :

- Cloud auditor is a party that can conduct independent assessment of cloud services, information system operations, performance and security of the cloud implementation. Generally, cloud auditors are categorized based on intent.

- For the most part, their focus is on risk and compliance, especially around information security. Other auditors can provide advisory services especially to consumers looking to cut down their bills or raise the level of efficiency in the resources consumed.

6. Cloud broker :

- Cloud broker is any entity that manages the use, performance, and delivery of cloud services and negotiates relationships between cloud providers and cloud consumers.
- Cloud brokers support consumers to get value for money by playing the advisory role especially for consumers who have a hybrid mix of resources from multiple providers.

7. Cloud carrier :

- Cloud carrier is an intermediary that provides connectivity and transport of cloud services from cloud providers to cloud consumers.
- Most ISPs have taken the role of cloud carriers as they provide the requisite bandwidth needed to connect consumers with providers as well as capabilities that support the connectivity.

8. Trust boundary :

- Logical perimeter that typically spans beyond physical boundaries to represent the extent to which IT resources are trusted. Fig. 1.1.5 shows trust boundary.

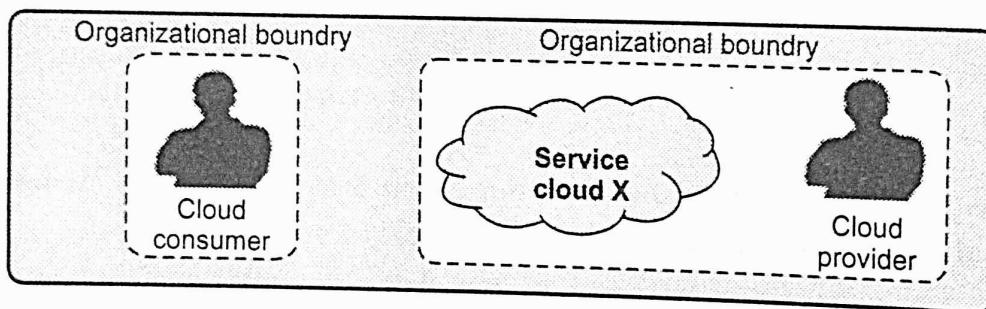


Fig. 1.1.5 Trust boundary

- When analysing cloud environments, the trust boundary is most frequently associated with the trust issued by the organization acting as the cloud consumer.

1.1.4 Risks and Challenges

- Increased Security Vulnerabilities.
- Reduced Operational Governance Control.
- Limited Portability Between Cloud Providers.
- Multi-Regional Compliance and Legal Issues.

- Use of cloud for business purpose means that the responsibility over data security becomes shared with the cloud provider. Organization extends their trust boundary to cloud consumer to external cloud.
- It is clear that the security issue has played the most important role in hindering cloud computing acceptance.
- Without doubt, putting your data, running your software on someone else's hard disk using someone else's CPU appears daunting to many.
- Well-known security issues such as data loss, phishing, pose serious threats to organization's data and software.

1.2 History of Cloud Computing

- Idea of cloud computing was introduced by computer scientist John McCarthy publicly in 1961.
- Then in 1969, Leonard Kleinrock, a chief scientist of the ARPANET project comments about Internet.
- The general public has been leveraging forms of Internet-based computer utilities since the mid-1990s through various incarnations of search engines, e-mail services, open publishing platforms and other types of social media.
- Though consumer-centric, these services popularized and validated core concepts that form the basis of modern-day cloud computing.
- The Salesforce.com provides remote service from 1990 to organization. Amazon launched its web services in 2002 and it provides services to organization for storage and remote computing.
- In 2002, Amazon introduced its web-based retail services. It was the first major business to think of using only 10 % of their capacity as a problem to be solved.
- The cloud computing infrastructure model gave them the flexibility to use their computer's capacity much more efficiently. Soon after, other large organizations followed their example.
- In 2006, Amazon launched Amazon web services, which offers online services to other websites, or clients. One of Amazon web services' sites, called Amazon Mechanical Turk, provides a variety of cloud-based services including storage, computation and "human intelligence."
- Another of Amazon web services' sites is the Elastic Compute Cloud (EC2), allowing individuals to rent virtual computers and use their own programs and applications.

- In the same year, Google launched the Google Docs services. Google Docs was originally based on two separate products, Google Spreadsheets and Writely.
- Google purchased Writely, which offers renters the ability to save documents, edit documents, and transfer them into blogging systems.
- Cloud computing definition as per Gartner "A style of computing in which scalable and elastic IT-enabled capabilities are delivered as a service to external customers using Internet technologies".
- In 2008, Gartner's original definition of cloud was changed. In the definition, "massively scalable" was used instead of "scalable and elastic."
- NIST definition of cloud : Cloud computing is a pay-per-use model for enabling available, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, services) that can be rapidly provisioned and released with minimal management effort or service-provider interaction.
- The above cloud definition was published by NIST in 2009, followed by a revised version after further review and industry input that was published in September of 2011.
- Cloud computing refer to a variety of services available over the Internet that deliver compute functionality on the service provider's infrastructure.
- Its environment (infrastructure) may actually be hosted on either a grid or utility computing environment, but that doesn't matter to a service user

1.3 Characteristics of Cloud Computing

1. On-demand self-service : A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed without requiring human interaction with each service's provider.
2. Ubiquitous network access : Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms.
3. Location-independent resource pooling : The provider's computing resources are pooled to serve all consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand.
4. Rapid elasticity : Capabilities can be rapidly and elastically provisioned to quickly scale up, and rapidly released to quickly scale down.
5. Pay per use : Capabilities are charged using a metered, fee-for-service or advertising-based billing model to promote optimization of resource use.

1.4 Cloud Types

- Most of user, divided cloud computing into two distinct sets of models :
 - Deployment models : This refers to the location and management of the cloud's infrastructure.
 - Service models : This consists of the particular types of services that user can access on a cloud computing platform.

1.4.1 NIST Model

- Fig. 1.4.1 shows National Institute of Standards and Technology (NIST) cloud model.

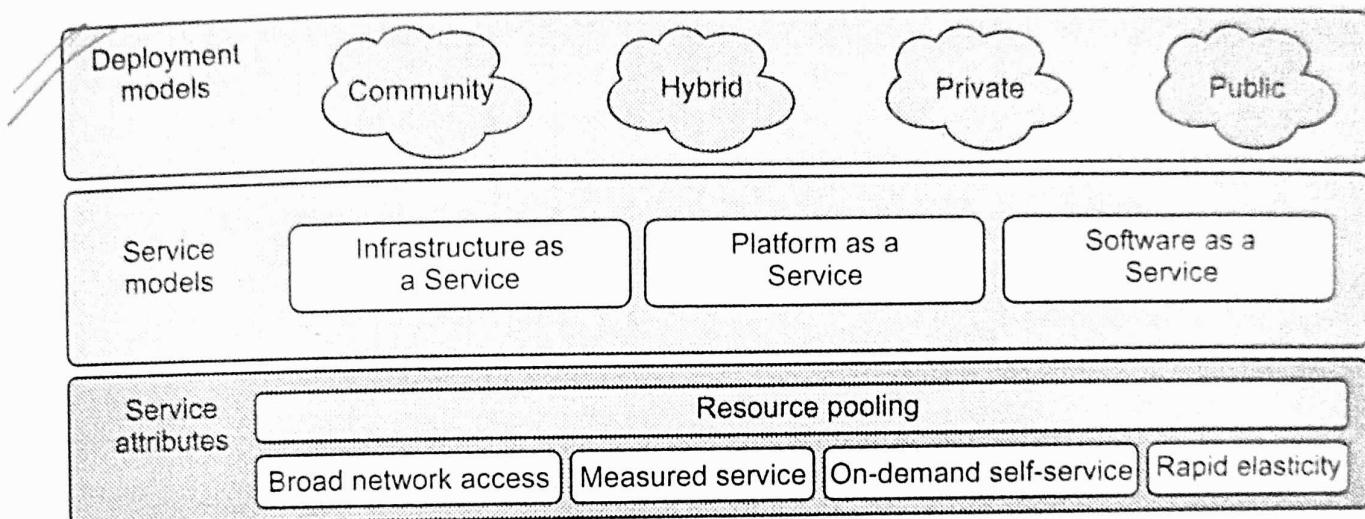


Fig. 1.4.1 NIST cloud Model

- The NIST define cloud computing as : "Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models."
- Cloud provider is responsible for the physical infrastructure and the cloud consumer is responsible for application configuration, personalization, and data.
- Broad network access refers to resources hosted in a cloud network that are available for access from a wide range of devices. Rapid elasticity is used to describe the capability to provide scalable cloud computing services.
- In measured services, NIST talks about measured service as a setup where cloud systems may control a user or tenant's use of resources by a metering capability somewhere in the system.

- On-demand self-service refers to the service provided by cloud computing vendors that enables the provision of cloud resources on demand whenever they are required.

1.4.2 Cloud Cube

- Fig. 1.4.2 shows cloud cube model.

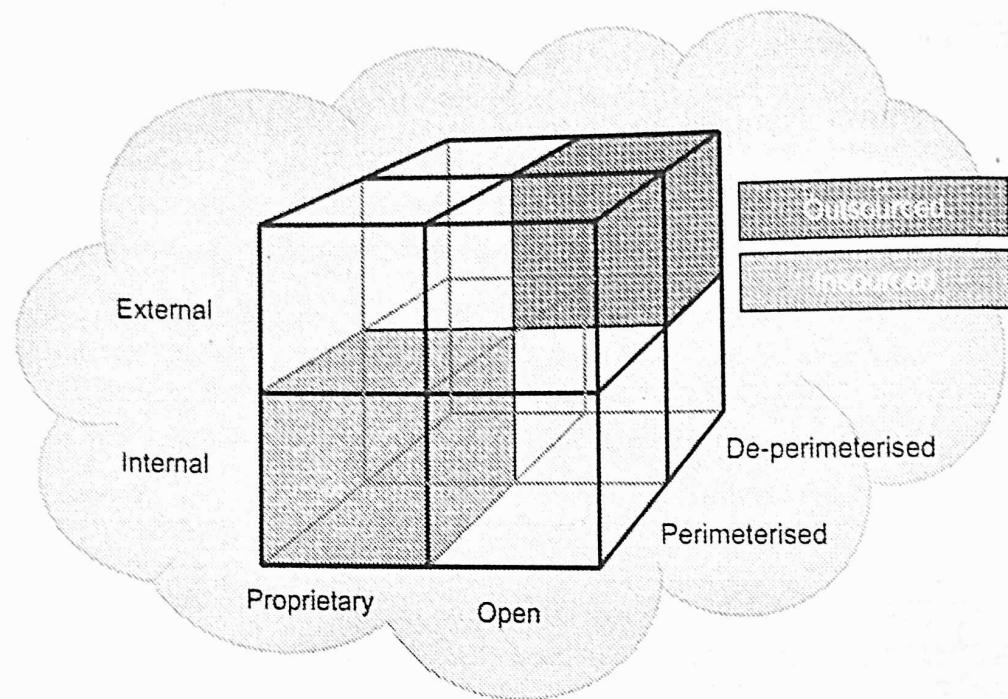


Fig. 1.4.2 cloud cube model

- The cloud cube model has four dimensions to differentiate cloud formations :
 - External / Internal
 - Proprietary / Open
 - Perimeterised / De-Perimeterised
 - Outsourced / Insourced

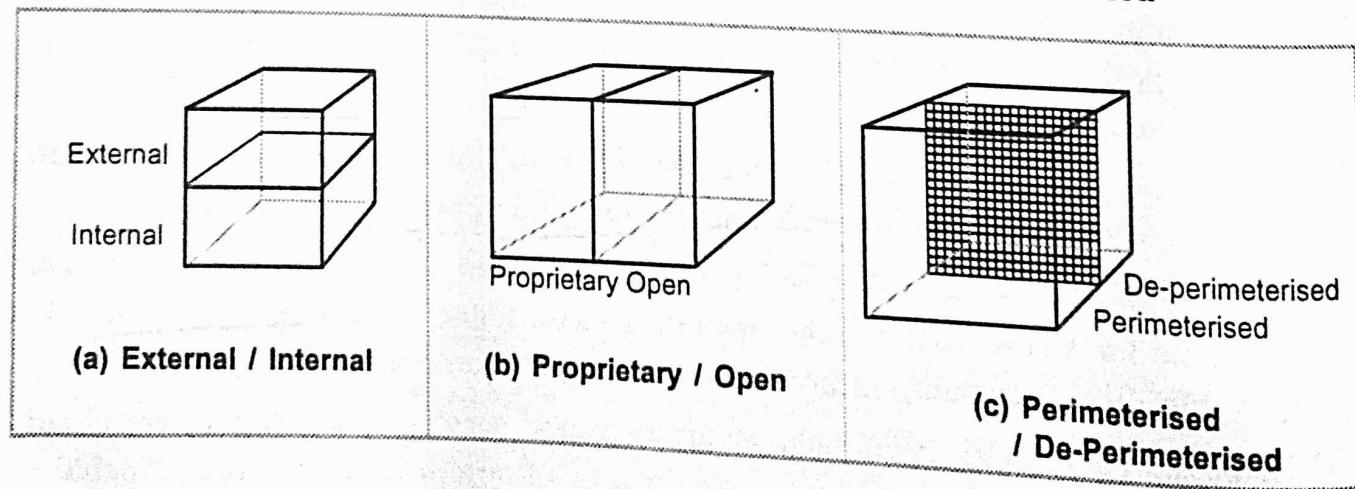


Fig. 1.4.3

- External / Internal : Physical location of data is defined by external / internal dimension. It defines the organization's boundary.
- Example : Information inside a datacenter using a private cloud deployment would be considered internal and data that resided on Amazon EC2 would be considered external.
- Proprietary / Open : Ownership is proprietary or open; is a measurement for not only ownership of technology but also its interoperability, use of data and ease of data-transfer and degree of vendor's application's lock-in.
- Proprietary means that the organization providing the service is keeping the means of provision under their ownership. Clouds that are Open are using technology that is not proprietary, meaning that there are likely to be more suppliers.
- Perimeterised / De-Perimeterised : Security Range : is parameterized or de-parameterized; which measures whether the operations are inside or outside the security boundary, firewall, etc.
- Encryption and key management will be the technology means for providing data confidentiality and integrity in a de-perimeterised model.
- Outsourced / Insourced : Out-sourcing/In-sourcing; which defines whether the customer or the service provider provides the service.
- Outsourced means the service is provided by a third party. It refers to letting contractors or service providers handle all requests and most of cloud business models fall into this.
- Insourced is the services provided by your own staff under organization control. Insourced means in-house development of clouds.

1.5 Cloud Service Models

- Service models describe the type of service that the service provider is offering. The best-known service models are software as a service, platform as a service, and Infrastructure as a service.
- The service models build on one another and define what a vendor must manage and what the client's responsibility is.
- Service models : This consists of the particular types of services that you can access on a cloud computing platform.)
- Cloud service is any service made available to users on demand via the Internet from a cloud computing provider's servers as opposed to being provided from a company's own on-premises servers.

- Cloud services are designed to provide easy, scalable access to applications, resources and services and are fully managed by a cloud services provider.
- A cloud service can exist as a simple web-based software program with a technical interface invoked via the use of a messaging protocol or as a remote access point for administrative tools or larger environments and other IT resources.
- The organization that provides cloud-based IT resources is the cloud provider. Cloud providers normally own the IT resources for lease by cloud consumers and could also resell IT resources leased from other providers.
- Cloud computing, often described as a stack, has a broad range of services built on top of one another under the name cloud.
- Fig. 1.5.1 shows cloud computing stack.
- Flavors of cloud computing is as follows;
 1. SaaS applications are designed for end-users, delivered over the web.
 2. PaaS is the set of tools and services designed to make coding and deploying those applications quick and efficient,
 3. IaaS is the hardware and software that powers it all - servers, storage, networks, operating systems.

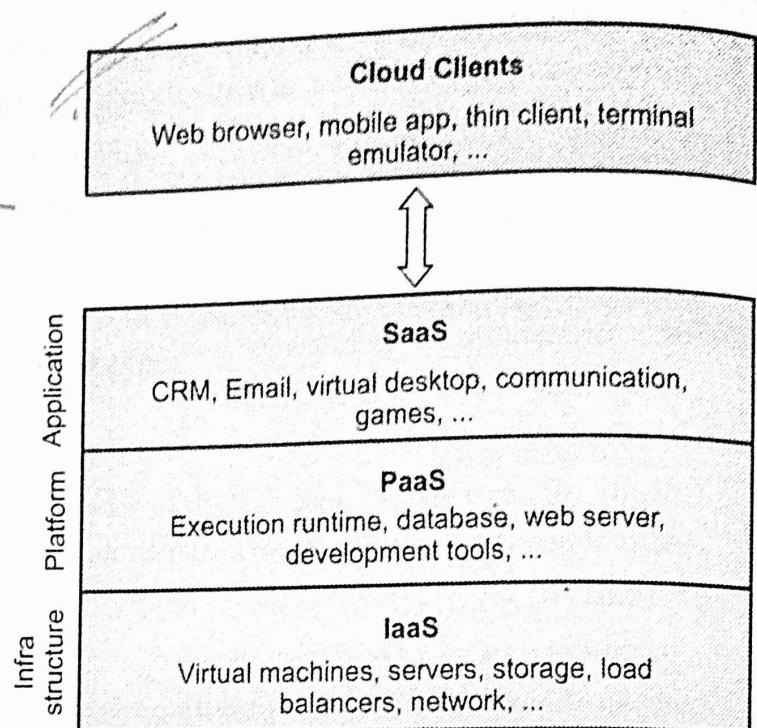
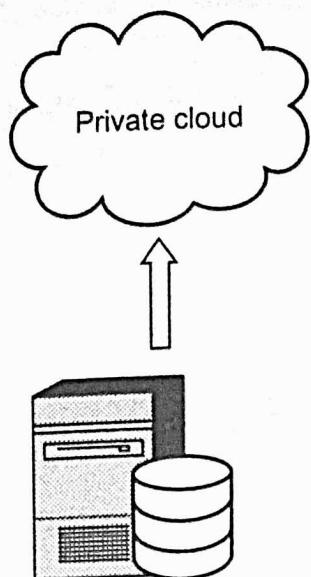


Fig. 1.5.1 Cloud computing stack

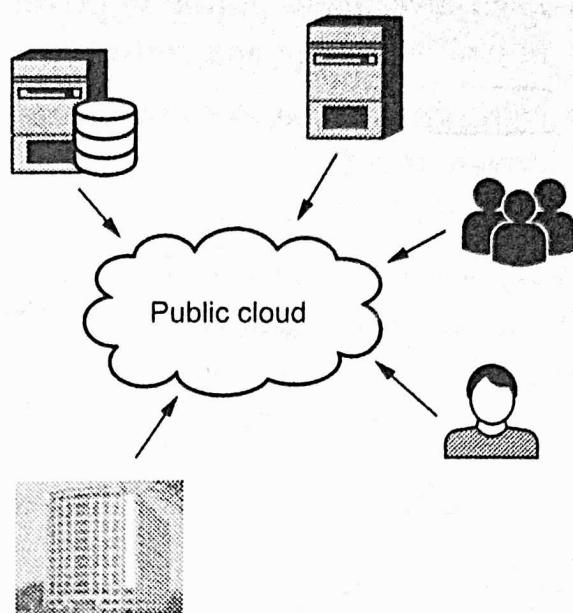
1.6 Cloud Computing Deployment Models

- Cloud deployment models are refers to the location and management of the cloud's infrastructure.
- Deployment models are defined by the ownership and control of architectural design and the degree of available customization. Cloud deployment models are private public and community clouds.

- Fig. 1.6.1 shows cloud deployment model.



(a) Private cloud



(b) Public cloud

Fig. 1.6.1 Cloud deployment model

1. Public cloud :

- The cloud infrastructure is made available to the general public or a large industry group and is owned by an organization selling cloud services.
- Public cloud is a huge data centre that offers the same services to all its users. The services are accessible for everyone and much used for the consumer segment.
- Examples of public services are Facebook, Google and LinkedIn.
- Public cloud benefits :
 - Low investment hurdle : Pay for what user use.
 - Good test/development environment for applications that scale to many servers.
- Public cloud risks :
 - Security concerns : Multi-tenancy and transfers over the Internet.
 - IT organization may react negatively to loss of control over data center function.

2. Private cloud :

- The cloud infrastructure is operated solely for a single organization. It may be managed by the organization or a third party and may exist on-premises or off-premises.
- Private cloud benefits :
 - Fewer security concerns as existing data center security stays in place.
 - IT organization retains control over data center.

- **Private cloud risks :**
 - High investment hurdle in private cloud implementation, along with purchases of new hardware and software.
 - New operational processes are required; old processes not all suitable for private cloud.

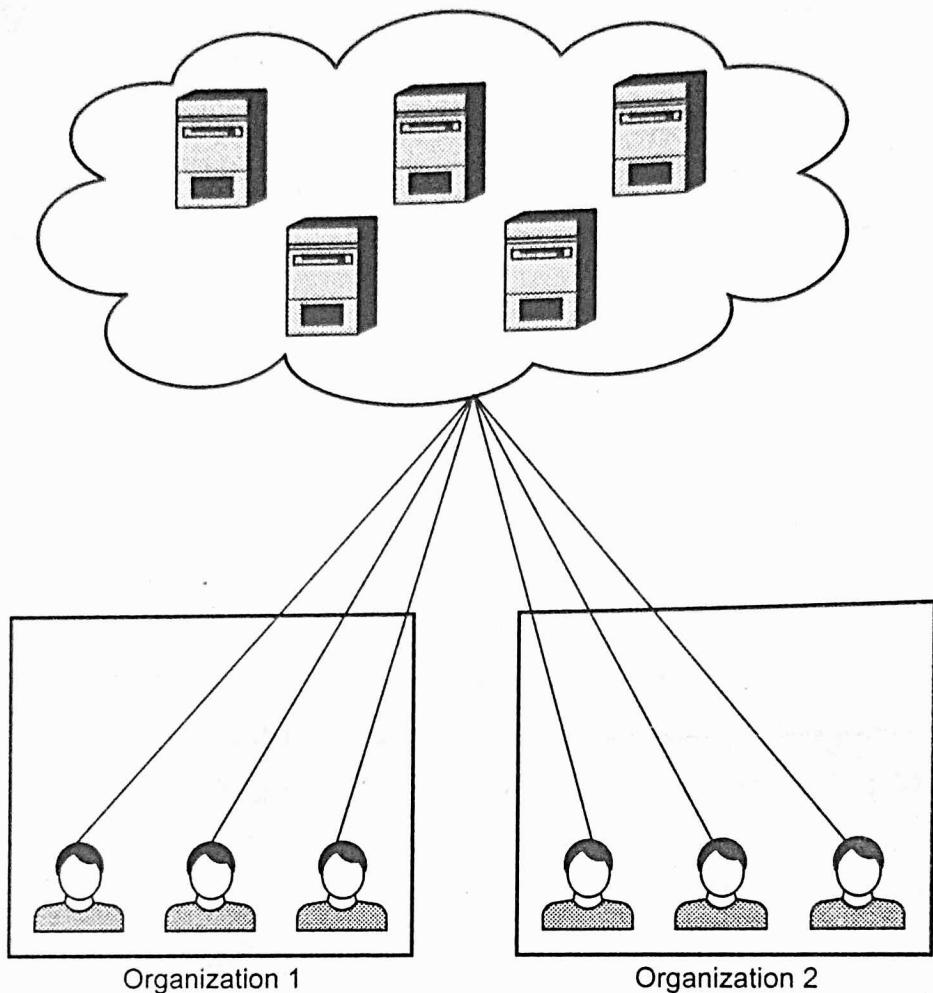


Fig. 1.6.2 Community cloud

3. Community cloud :

- The cloud infrastructure is shared by several organizations and supports a specific community that has shared concerns (e.g. mission, security requirements, policy or compliance considerations). It may be managed by the organizations or a third party and may exist on-premises or off-premises.

4. Hybrid cloud :

- The cloud infrastructure is a composition of two or more clouds (private, community or public) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load-balancing between clouds).

- **Hybrid cloud benefits :**
 - Operational flexibility : Run mission critical on private cloud, dev/test on public cloud.
 - Scalability : Run peak and bursty workloads on the public cloud.
- **Hybrid cloud risks :**
 - Hybrid clouds are still being developed; not many in real use.
 - Control of security between private and public clouds, some of same concerns as in public cloud.

1.6.1 Difference between Public and Private Cloud

Public cloud	Private cloud
Public cloud infrastructure is offered via web applications and also as web services over Internet to the public.	Private cloud infrastructure is dedicated to a single organization.
Support multiple customer.	Support dedicated customer.
Full utilized of infrastructure.	Does not utilize shared infrastructure.
Security is low as compared to private cloud.	High level of security.
Low cost	High cost
Azure, Amazon Web Services, Google App Engine and Force.com are a few examples of public clouds.	An example of the Private Cloud is NIRIX's one Server with dedicated servers.

1.7 Exploring the Cloud Computing Stack

- A compute cloud requires virtualized storage to support the staging and storage of data. From a user's perspective, it is important that the resources appear to be infinitely scalable, that the service be measurable and that the pricing be metered.
 - Composability : In composable infrastructure, compute, storage, and networking resources are abstracted from their physical locations and can be managed by software through a web-based interface. Composable infrastructure makes data center resources as readily available as cloud services and is the foundation for private and hybrid cloud solutions.
- There is a tendency for cloud computing systems to become less composable for users as the services incorporate more of the cloud computing stack.
 - Infrastructure : Most large Infrastructure as a Service (IaaS) providers rely on virtual machine technology to deliver servers that can run applications.
 - Platforms : A platform in the cloud is a software layer that is used to create higher levels of service.

- Cloud computing is often described as a stack, as a response to the broad range of services built on top of one another under the "Cloud". A cloud computing stack is a cloud architecture built in layers of one or more cloud-managed services (SaaS, PaaS, IaaS, etc.).
- Cloud computing stacks are used for all sorts of applications and systems. They are especially good in microservices and scalable applications, as each tier is dynamically scaling and replaceable.
- The cloud computing pile makes up a threefold system that comprises its lower-level elements. These components function as formalized cloud computing delivery models :
 - a) Software as a Service (SaaS)
 - b) Platform as a Service (PaaS)
 - c) Infrastructure as a Service (IaaS)
- Fig. 1.7.1 shows cloud computing stack.

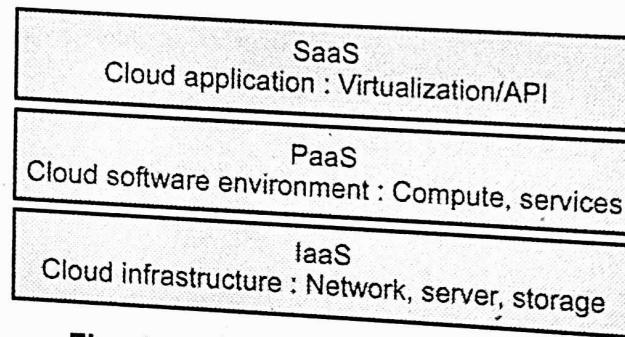


Fig. 1.7.1 Cloud Computing Stack

- The layers of the cloud computing stacks are usually formed in lower to higher levels of services abstraction, starting with Infrastructure as a Service, then Platform as a Service and finally Software as a Service at the top.
- SaaS applications are designed for end-users and delivered over the web.
- PaaS is the set of tools and services designed to make coding and deploying those applications quick and efficient.
- IaaS is the hardware and software that powers it all, including servers, storage, networks and operating systems.
- Benefits of using a cloud computing stack :
 1. The expertise of running your components is delegated to the vendor with expertise.
 2. Resources are available on demand, speeding up the go-to-market.
 3. Focusing the development teams on the actual business use cases improves developer productivity.

1.8 Advantages and Disadvantages of Cloud Computing

Pros of cloud computing :

1. **Lower computer costs** : Since applications run in the cloud, not on the desktop PC, your desktop PC does not need the processing power or hard disk space demanded by traditional desktop software.
2. **Improved performance** : Computers in a cloud computing system boot and run faster because they have fewer programs and processes loaded into memory.
3. **Reduced software costs** : Instead of purchasing expensive software applications, you can get most of what you need for free.
4. **Instant software updates** : When you access a web-based application, you get the latest version - without needing to pay for or download an upgrade.
5. **Improved document format compatibility** : You do not have to worry about the documents you create on your machine being compatible with other user's applications or operating systems.
6. **Unlimited storage capacity** : Cloud computing offers virtually limitless storage.
7. **Increased data reliability** : Unlike desktop computing, in which if a hard disk crashes and destroys all your valuable data, a computer crashing in the cloud should not affect the storage of your data.
8. **Universal document access** : All your documents are instantly available from wherever you are.
9. **Latest version availability** : The cloud always hosts the latest version of your documents; as long as you are connected, you are not in danger of having an outdated version.
10. **Easier group collaboration** : Sharing documents leads directly to better collaboration.
11. **Device independence** : Move to a portable device and your applications and documents are still available.

Cons of cloud computing :

1. **It requires a constant Internet connection** : Cloud computing is impossible if you cannot connect to the Internet.
2. **Features might be limited**.
3. **Stored data might not be secure** : With cloud computing, all your data is stored on the cloud.
4. **Does not work well with low-speed connections**.

1.9 Applications of Cloud Computing

1. Through cloud cost flexibility, online marketplace gains access to more powerful analytics online. Cloud takes away the need to fund the building of hardware, installing software or paying dedicated software license fees.
2. Greater business scalability enables online video retailer to meet spikes in demand: Cloud enables businesses not just IT operations to add or provision computing resources just at the time they're needed.
3. Greater market adaptability provides online entertainment platform the ability to reach any type of customer device. A third of the executives we surveyed believe cloud can help them adapt to diverse user groups with a diverse assortment of devices.
4. Masked complexity enables access to services, no matter how intricate the technology they're built on.
5. With context-driven variability, "intelligent assistants" are possible. "Because of its expanded computing power and capacity, cloud can store information about user preferences, which can enable product or service customization," the report states.
6. Ecosystem connectivity enables information exchange across business partners.

