

- Clustering is crucial for scalable enterprise applications, as user can improve performance by simply adding more nodes to the cluster.

3. Virtualization technology :

- Virtualization is an already established and proven technology that has enabled IT organizations to repeatedly leverage physical servers for wide, concurrent usage.
- Virtualization is an abstraction layer that decouples the physical hardware from the operating system to deliver greater IT resource utilization and flexibility.
- It allows multiple virtual machines, with heterogeneous operating systems to run in isolation, side-by-side on the same physical machine. Virtualization is an absolute key technology in modern cloud computing environments.
- As cloud computing evolved, a generation of modern virtualization technologies emerged to overcome the performance, reliability and scalability limitations of traditional virtualization platforms.

1.2 Basic Concepts and Terminology

SPPU : April-18, May-19, Dec.-18, March-20

- 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 up 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. 1.2.1 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.

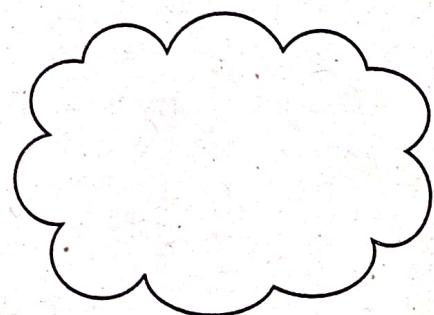


Fig. 1.2.1 Cloud symbol

- 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.

1.2.1 IT Resources

- IT resources are of two types : Software based and hardware based.
- Software based resources are virtual server, custom software program and hardware based means physical server and networking devices.
- IT resources include server, virtual server, storage device, networking device, services and software programs.
- An on-premise IT resource can access and interact with a cloud-based IT resource.

1.2.2 Scaling

- Scaling is the capability of a system, network or process to handle a growing amount of work or its potential to be enlarged to accommodate that growth. For IT resources, scaling represents the ability of the IT resource to handle increased or decreased usage demands.
- One of the key aspects that made cloud popular is scalability, that means you can increase or decrease your resources at any given time.

1. Horizontal scaling :

- It is scaling out and scaling in. The allocating or releasing of IT resources that are of the same type is referred to as horizontal scaling.
- Horizontal scaling, means increasing the number of nodes in the cluster, reduces the responsibilities of each member node by spreading the keyspace wider and providing additional end-points for client connections.
- Fig. 1.2.2 shows horizontal scaling.

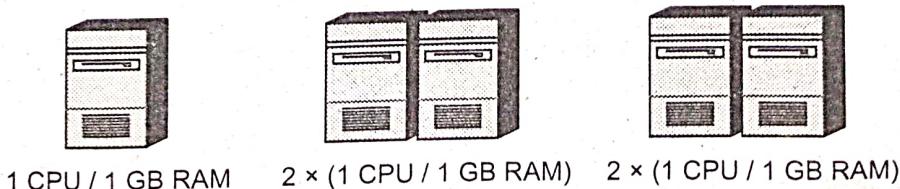


Fig. 1.2.2 Horizontal scaling

- Horizontal scaling affords the ability to scale wider to deal with traffic. It is the ability to connect multiple hardware or software entities, such as servers, so that they work as a single logical unit.

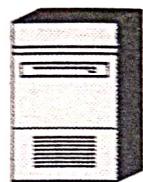
- The horizontal allocation of resources is referred to as scaling out and the horizontal releasing of resources is referred to as scaling in.

2. Vertical scaling :

- Vertical scaling can essentially resize your server with no change to your code. It is the ability to increase the capacity of existing hardware or software by adding resources. Vertical scaling usually means upgrade of server hardware.
- Vertical scaling is limited by the fact that you can only get as big as the size of the server. Fig. 1.2.3 shows vertical scaling.
- The replacing of an IT resource with another that has a higher capacity is referred to as scaling up and the replacing an IT resource with another that has a lower capacity is considered scaling down.
- Vertical scaling is much more used in small and middle-sized companies and in applications and products of middle-range.



1 CPU / 1 GB RAM



2 CPU / 2 GB RAM



4 CPU / 8 GB RAM

Fig. 1.2.3 Vertical scaling

1.2.3 Difference between Horizontal and Vertical Scaling

Horizontal scaling	Vertical scaling
In horizontal scaling, we build to the minimum requirements and then use monitoring and automation to scale it out.	Vertical scaling is where we estimate what we think the maximum requirements will be and add additional capacity beyond this to cover for any potential miscalculations and future expansion.
Cost migration is low.	Cost migration is low.
Upgrading downtime low.	Upgrading downtime is high.
Need load balance and gateway.	No coordination overhead.
Not limited by hardware capacity.	Limited by hardware capacity.
In horizontal scaling, resource of cluster is available.	All resources are in single host.

1.2.4 Cloud Components

- Cloud computing solutions are made up of several elements. Fig. 1.2.4 shows cloud components.

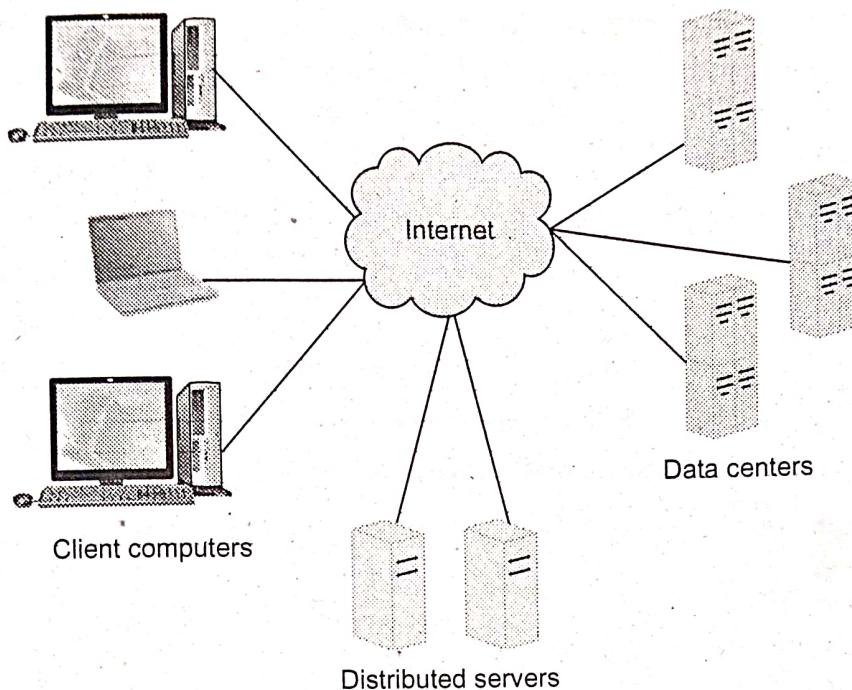


Fig. 1.2.4 Cloud components

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.
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.

1.2.5 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.

Review Questions

1. *What is the difference between horizontal scaling and vertical scaling ?*

SPPU : April-18 In Sem, May-19 End Sem, Marks 4

2. *Define cloud computing. Explain different types of cloud computing.*

SPPU : Dec.-18 End Sem, Marks 8

3. *What is cloud computing ? Explain advantages and disadvantages of cloud computing.*

SPPU : March-20, In Sem, Marks-5

1.3 Goals and Benefits

SPPU : May-18, Dec.-19

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 destroy 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.

Review Questions

1. Explain advantages and limitations of cloud computing in brief.

SPPU : May-18 End Sem, Marks 6

2. Explain advantages and disadvantages of cloud computing.

SPPU : Dec.-19 End Sem, Marks 5

1.4 Risks and Challenges

1. Increased Security Vulnerabilities.
2. Reduced Operational Governance Control.
3. Limited Portability Between Cloud Providers.
4. 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.

1.5 Roles and Boundaries

- 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. 1.5.1 shows cloud provider.

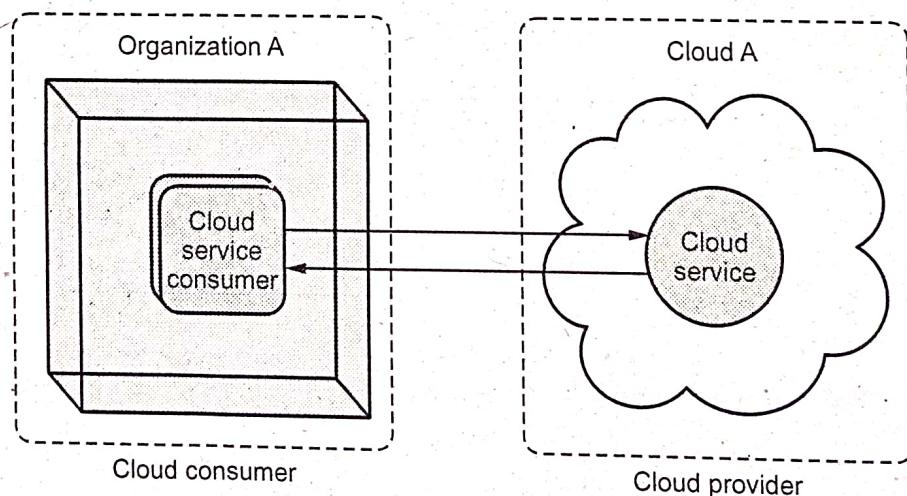


Fig. 1.5.1 Cloud service and cloud service consumer

- 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.

- 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. 1.5.3 shows trust boundary.

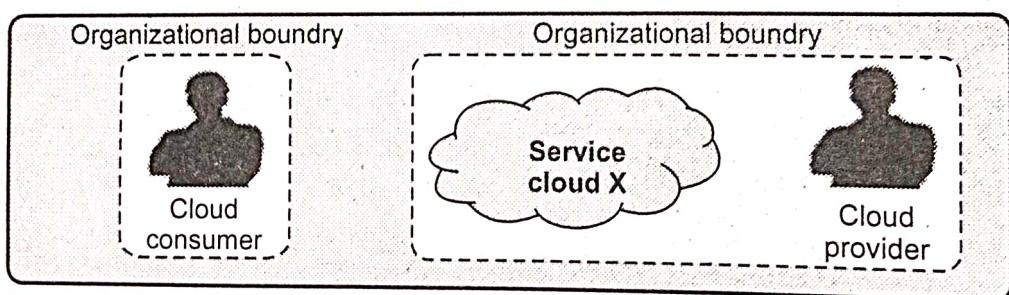


Fig. 1.5.3 Trust boundary

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

1.6 Cloud Characteristics

SPPU : April-18,19, Dec.-18, March-20

- 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.

Review Questions

1. State and explain characteristics of cloud computing.

**SPPU : April-18 In Sem,
Dec.-18 End Sem, Marks 6, March-20, In Sem, Marks 5**

2. Enlist and explain in brief any six characteristics of cloud computing.

SPPU : April-19 In Sem, Marks 6

1.7 Cloud Delivery Models

SPPU : April-18,19, Dec.-18,19, May-19

- 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. 1.7.1 shows cloud computing stack.
- Flavors of cloud computing is as follows;
 - SaaS applications are designed for end-users, 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 - servers, storage, networks, operating systems.

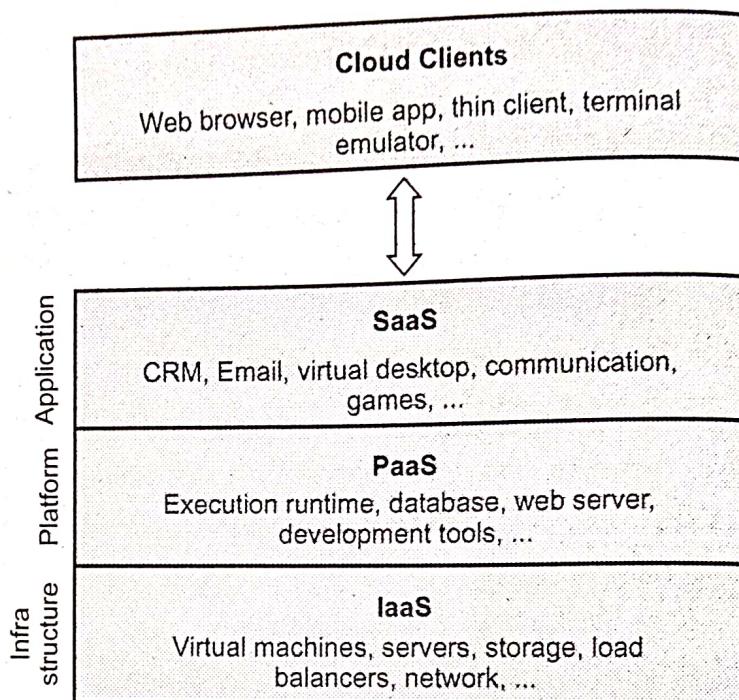


Fig. 1.7.1 Cloud computing stack

1.7.1 Software as a Service (SaaS)

- Model in which an application is hosted as a service to customers who access it via the Internet.
- The provider does all the patching and upgrades as well as keeping the infrastructure running.
- The traditional model of software distribution, in which software is purchased for and installed on personal computers, is referred to as product.
- In this model, the user, client or consumer runs an application from a cloud infrastructure. Through an interface such as a web browser, the client or user may access this application from a variety of devices.
- The complete application is offered as on demand service. This saves the client from having to invest in any software licenses or servers up front and can save

the provider money since they are maintaining and providing only a single application.

- In this model, the client does not manage cloud infrastructure, networks or servers, storage or operating systems. Even, Microsoft, Google and Zoho offer SaaS.
- The SaaS concept can be defined as providing robust "web-based, on-demand software, storage and various applications" to organizations.
- The SaaS model has emerged as an alternative to traditional one-time licensing for providing and maintaining the software needed by knowledge workers within organizations.
- Fig. 1.7.2 shows SaaS.

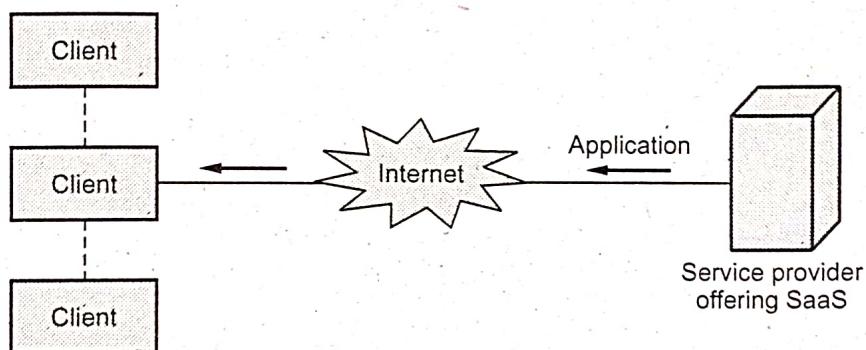


Fig 1.7.2 SaaS

Characteristics of SaaS :

1. Software applications or services are stored remotely.
2. A user can then access these services or software applications via the Internet.
3. In most cases, a user does not have to install anything onto their host machine, all they require is a web browser to access these services and in some cases, a browser may require additional plug-in/add-on for certain services.
4. Network-based management and access to commercially available software from central locations rather than at each customer's site, enabling customers to access applications remotely via the Internet.
5. Application delivery from a one-to-many model, as opposed to a traditional one-to-one model.

Benefits of SaaS :

1. You only pay for what you use.
2. Easier administration and invoicing.

- 3. Automatic updates and patch management.
- 4. Compatibility : All users have access to the same version of software.
- 5. Easier collaboration.
- 6. It support automated update and patch management services.

1.7.2 Platform as a Service (PaaS)

- Platform as a service is another application delivery model and also known as **cloud-ware**. Supplies all the resources required to build applications and services completely from the Internet, without having to download or install software.
- Services include : Application design, development, testing, deployment and hosting, team collaboration, web service integration, database integration, security, scalability, storage, state management and versioning.
- PaaS is closely related to SaaS but delivers a platform from which to work rather than an application to work with.
- This model involves software encapsulated and offered as a service, from which higher levels of service may then be built. The user, customer or client in this model is the one building applications which then run on the provider's infrastructure.
- This in turn provides customers and clients with the capability to deploy applications onto the cloud infrastructure using programming tools and languages, which the provider supports.
- The customer still does not manage the framework, network, servers or operating system, but has control over deployed applications and sometimes over the hosting environment itself.
- Some examples of Platform as a Service include Google's App Engine or Force.com
- PaaS consists of following components :
 1. Browser based development studio.
 2. Pay contrary to billing.
 3. Management and supervising tools:
 4. Seamless deployment to host run time environment.
- **Characteristics of PaaS :**
 1. It support multi-tenant architecture.
 2. It support for development of group collaboration.
 3. PaaS systems can be deployed as public cloud services or as private cloud services.

4. Provision of runtime environments. Typically each runtime environment supports either one or a small set of programming languages and frameworks.
5. Support for custom applications. Support for the development, deployment and operation of custom applications.
6. Preconfigured capabilities. Many PaaS systems are characterized by capabilities that are preconfigured by the provider, with a minimum of configuration available to developers and customer operations staff.
7. Support for porting existing applications. While many PaaS systems are primarily designed to support "born on the cloud" applications.
8. Security is an important characteristic in PaaS. It needs to provide authentication and authorization to differentiate the access rights of different users.

Benefits of Paas :

1. Scalability including rapid allocation and deallocation of resources with a pay-as-you-use model.
2. Reduced capital expenditure.
3. Reduced lead times with on-demand availability of resources.
4. Self-service with reduced administration costs.
5. Reduced skill requirements.
6. Support of team collaboration.
7. Ability to add new users quickly.

1.7.3 Infrastructure as a Service (IaaS)

- IaaS gives the storage room likeness to the in-house datacenter stood out from various organizations sorts.
- Center datacenter framework segments are capacity, servers (registering units), the system itself, and administration apparatuses for foundation upkeep and checking.
- Each of these parts has made a different market specialty. While some little organizations have practical experience in just a single of these IaaS cloud specialties, vast cloud suppliers like Amazon or Right Scale have offerings over all IaaS territories.
- Fig. 1.7.3 shows IaaS.

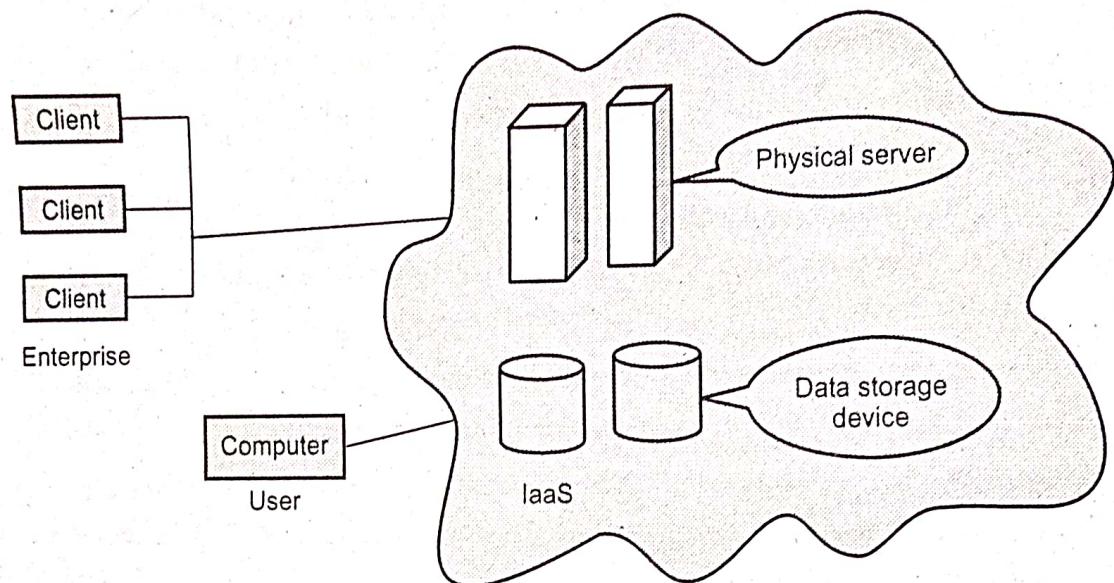


Fig. 1.7.3 IaaS

- It offers the hardware so that your organization can put whatever they want onto it. Rather than purchase servers, software, racks and having to pay for the datacenter space for them, the service provider rents those resources :
 1. Server space 2. Network equipment
 3. Memory 4. CPU cycles 5. Storage space
- Again, the customer is not managing cloud infrastructure, but in this case, the customer does control operating systems, deployed applications, storage and sometimes-certain networking components.
- Examples : Amazon EC2, Rackspace Mosso, GoGrid
- IaaS server types :
 1. **Physical server** : Actual hardware is allocated for the customer's dedicated use.
 2. **Dedicated virtual server** : The customer is allocated a virtual server, which runs on a physical server that may or may not have other virtual servers.
 3. **Shared virtual server** : The customer can access a virtual server on a device that may be shared with other customers.

Advantages of IaaS :

1. Elimination of an expensive and staff-intensive data center.
2. Ease of hardware scalability.
3. Reduced hardware cost.
4. On-demand, pay as you go scalability.

5. Reduction of IT staff.
6. Suitability for ad hoc test environments.
7. Allows complete system administration and management.
8. Support multiple tenants.

1.7.4 Difference between IaaS, PaaS and SaaS

IaaS	PaaS	SaaS
IaaS gives users automated and scalable environments.	PaaS provides a framework for quickly developing and deploying applications.	SaaS makes applications available through the internet.
Amazon Web Services, for example, offers IaaS through the Elastic Compute Cloud or EC2.	Google Cloud Platform provides another PaaS option in App Engine.	SaaS applications such as Gmail, Dropbox, Salesforce or Netflix.
In IaaS, infrastructure as a service.	In PaaS, platform as a service.	In SaaS, software as a service
Virtual platform on which required operating environment and application deployed.	Operating environment was included.	Operating environment largely irrelevant, fully functional application provided.
IaaS is a cloud service that provides basic computing infrastructure : Servers, storage, and networking resources. In other words, IaaS is a virtual data center.	PaaS refers to cloud platforms that provide runtime environments for developing, testing and managing applications.	SaaS allows people to use cloud-based web applications.
Major IaaS providers include Amazon Web Services, Microsoft Azure and Google Compute Engine.	Examples of PaaS services are Heroku and Google App Engine.	email services such as Gmail and Hotmail are examples of cloud-based SaaS services.
IaaS services are available on a pay-for-what-you-use model.	PaaS solutions are available with a pay-as-you-go pricing model.	SaaS services are usually available with a pay-as-you-go pricing model.
Used by IT administrator.	Used by software developers.	Used by end user.

Review Questions

1. Explain any two cloud delivery models.
2. Explain benefits of IaaS.
3. Explain cloud delivery models with example.

SPPU : April-18 In Sem, Marks 4

SPPU : Dec.-18 End Sem, Marks 6

SPPU : April-19 In Sem, Marks 6

4. Compare and contrast IaaS, SaaS, PaaS related to consumer activities and provider activities.
5. Compare different cloud delivery models.

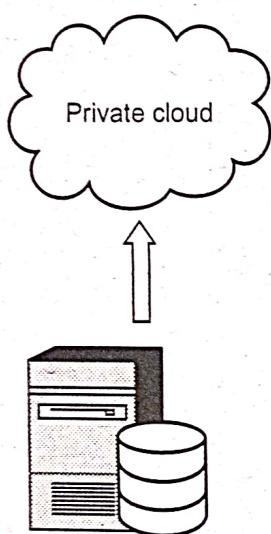
SPPU : May-19 End Sem, Marks 6

SPPU : Dec.-19 End Sem Marks 5

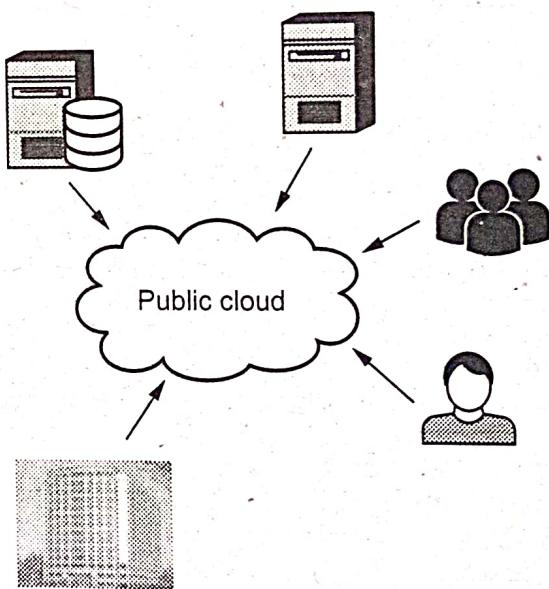
SPPU : May-18, Dec.-18, 19, March-20

1.8 Cloud 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. 1.8.1 shows cloud deployment model.



(a) Private cloud



(b) Public cloud

Fig. 1.8.1 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 :
 - a) Low investment hurdle : Pay for what user use.
 - b) 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.

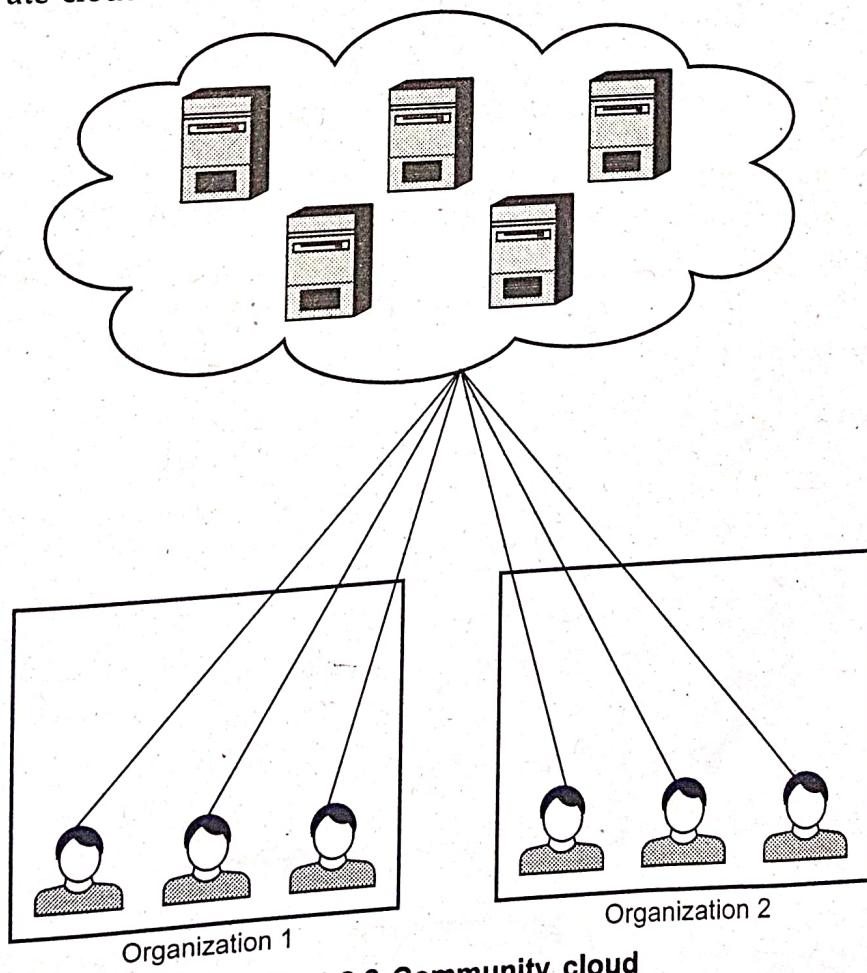


Fig. 1.8.2 Community cloud

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.

1.8.1 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.

Review Questions

- Compare private cloud versus public cloud.

SPPU : May-18 End Sem, Marks 4, Dec.-19, End Sem, Marks 5