CHENNAI INSTITUTE OF TECHNOLOGY
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Sarathy Nagar, Kundrathur, Chennai – 600069, India.

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

CCS335-CLOUD COMPUTING

LECTURE NOTES UNIT – 1

UNIT I

CLOUD ARCHITECTURE MODEL AND INFRASTRUCTURE

Cloud Architecture: System Models for Distributed and Cloud Computing – NIST Cloud Computing Reference Architecture – Cloud deployment models – Cloud service models; Cloud Infrastructure: Architectural Design of Compute and Storage Clouds – Design Challenges.

Cloud Architecture:

1.System Models for Distributed and Cloud Computing:

Introduction:

Distributed Computing:

Distributed computing is the technique of linking together multiple computer servers over a network into a cluster, to share data and to coordinate processing power.

Cloud Computing:

*cloud computing is the delivery of computing services—including servers, storage, databases, networking, software, analytics, and intelligence—over the internet ("the cloud") to offer faster innovation, flexible resources, and economies of scale.

*Distributed and cloud computing systems are built over a large number of autonomous computer nodes. These node machines are interconnected by SANs, LANs, or WANs in a hierarchical manner.

Exmaples:

Distributed Computing:Peer-to-Peer,Grid,Clusters

Cloud Computing:AWS,Azure and Google Cloud Platform

Centralized:

Distributed Computing:Decentralized

Cloud computing:Cloud Service Provider monitor and control

System Models:

1.Clusters of Cooperative Computers

2.Grid Computing Infrastructures

3.Peer-to-Peer Network Families

4.Cloud Computing over the Internet

1.Clusters of Cooperative Computers

*A computing cluster consists of interconnected stand-alone computers which work cooperatively as a single integrated computing resource.

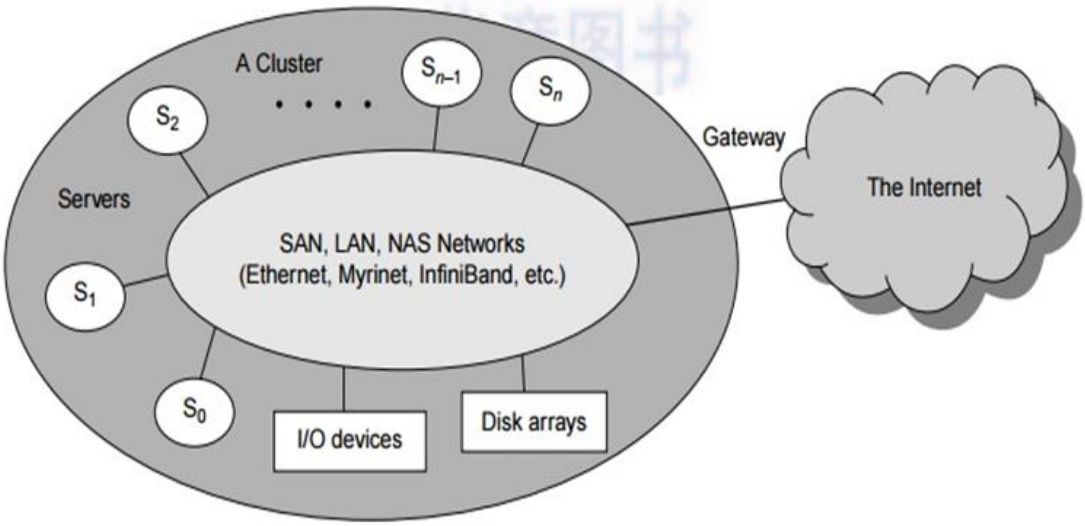
*Cluster architecture of a typical server cluster built around a low-latency, high-bandwidth interconnection network.

*This network can be as simple as a SAN or a LAN (e.g., Ethernet). To build a larger cluster with more nodes, the interconnection network can be built with multiple levels of Gigabit Ethernet, Myrinet, or InfiniBand switches.

*Through hierarchical construction using a SAN, LAN, or WAN, one can build scalable clusters with an increasing number of nodes.

*The cluster is connected to the Internet via a virtual private network (VPN) gateway. The gateway IP address locates the cluster. The system image of a computer is decided by the way the OS manages the shared cluster resources.

*Most clusters have loosely coupled node computers. All resources of a server node are managed by their own OS. Thus, most clusters have multiple system images as a result of having many autonomous nodes under different OS control



A cluster of servers interconnected by a high-bandwidth SAN or LAN with shared I/O devices and disk arrays; the cluster acts as a single computer attached to the Internet.

2.Grid Computing Infrastructures

*Grid Computing is a subset of distributed computing, where a virtual supercomputer comprises machines on a network connected by some bus, mostly Ethernet or sometimes the Internet.

*Grid Computing can be defined as a network of computers working together to perform a task that would rather be difficult for a single machine. All machines on that network work under the same protocol to act as a virtual supercomputer.

Computational Grids

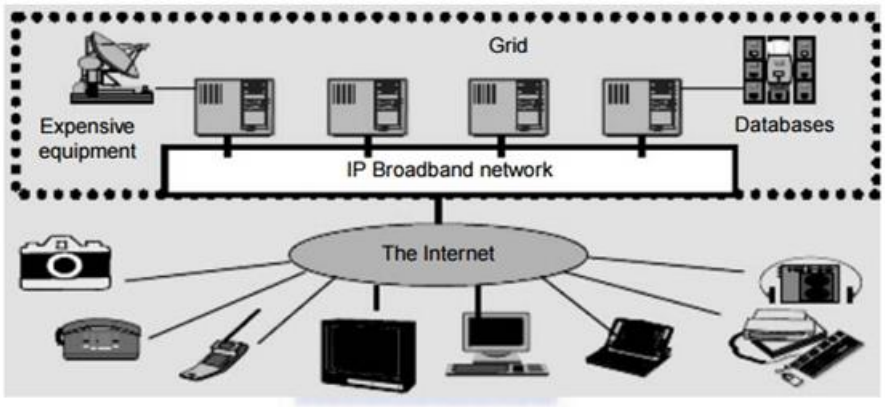
*Like an electric utility power grid, a computing grid offers an infrastructure that couples computers, software/middleware, special instruments, and people and sensors together.

*The grid is often constructed across LAN, WAN, or Internet backbone networks at a regional, national, or global scale.

*Enterprises or organizations present grids as integrated computing resources. They can also be viewed as virtual platforms to support virtual organizations.

*The computers used in a grid are primarily workstations, servers, clusters, and supercomputers. Personal computers, laptops, and PDAs can be used as access devices to a grid system.

Architecture an example computational grid built over multiple resource sites owned by different organizations. The resource sites offer complementary computing resources, including workstations, large servers, a mesh of processors, and Linux clusters to satisfy a chain of computational needs. The grid is built across various IP broadband networks including LANs and WANs already used by enterprises or organizations over the Internet. The grid is presented to users as an integrated resource pool as shown in the upper half of the figure.Grid technology demands new distributed computing models, software/middleware support, network protocols, and hardware infrastructures. National grid projects are followed by industrial grid plat-form development by IBM, Microsoft, Sun, HP, Dell, Cisco, EMC, Platform Computing, and others. New grid service providers (GSPs) and new grid applications have emerged rapidly, similar to the growth of Internet and web services in the past two decades. grid systems are classified in essentially two categories: computational or data grids and P2P grids. Computing or data grids are built primarily at the national level.



Computational grid or data grid providing computing utility, data, and information services through resource sharing and cooperation among participating organizations.

3.Peer-to-Peer Network Families

*An example of a well-established distributed system is the client-server architecture. In this scenario, client machines (PCs and workstations) are connected to a central server for compute, e-mail, file access, and database applications.

*The P2P architecture offers a distributed model of networked systems. First, a P2P network is client-oriented instead of server-oriented. In this section, P2P systems are introduced at the physical level and overlay networks at the logical level.

P2P Systems

In a P2P system, every node acts as both a client and a server, providing part of the system resources. Peer machines are simply client computers connected to the Internet. All client machines act autonomously to join or leave the system freely.

*This implies that no master-slave relationship exists among the peers. No central coordination or central database is needed.

*In other words, no peer machine has a global view of the entire P2P system. The system is self-organizing with distributed control.

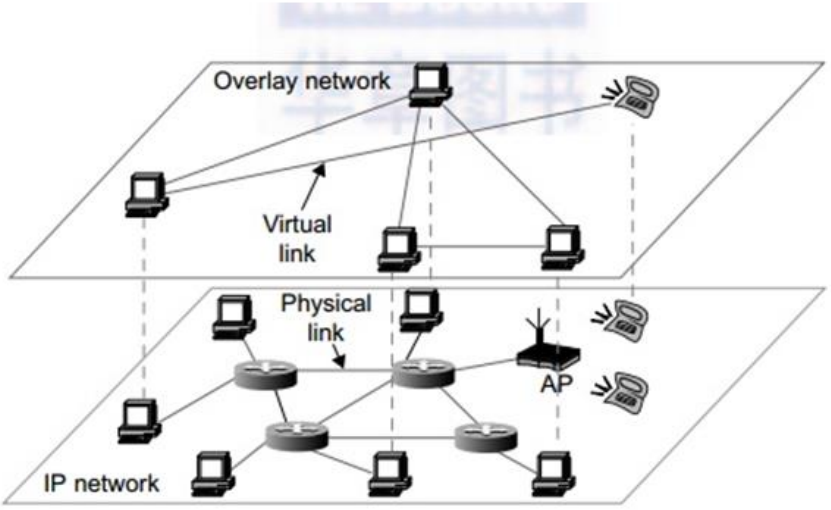
*The architecture of a P2P network at two abstraction levels. Initially, the peers are totally unrelated. Each peer machine joins or leaves the P2P network voluntarily.

* Only the participating peers form the physical network at any time. Unlike the cluster or grid, a P2P network does not use a dedicated interconnection network.

* The physical network is simply an ad hoc network formed at various Internet domains randomly using the TCP/IP and NAI protocols. Thus, the physical network varies in size and topology dynamically due to the free membership in the P2P network

Overlay Networks

Data items or files are distributed in the participating peers. Based on communication or file-sharing needs, the peer IDs form an overlay network at the logical level. This overlay is a virtual network



The structure of a P2P system by mapping a physical IP network to an overlay network built with virtual links.

formed by mapping each physical machine with its ID, logically, through a virtual mapping as shown in Figure 1.17. When a new peer joins the system, its peer ID is added as a node in the overlay network. When an existing peer leaves the system, its peer ID is removed from the overlay network automatically. Therefore, it is the P2P overlay network that characterizes the logical connectivity among the peers.

There are two types of overlay networks: unstructured and structured. An unstructured overlay network is characterized by a random graph. There is no fixed route to send messages or files among the nodes. Often, flooding is applied to send a query to all nodes in an unstructured overlay, thus resulting in heavy network traffic and nondeterministic search results. Structured overlay net-works follow certain connectivity topology and rules for inserting and removing nodes (peer

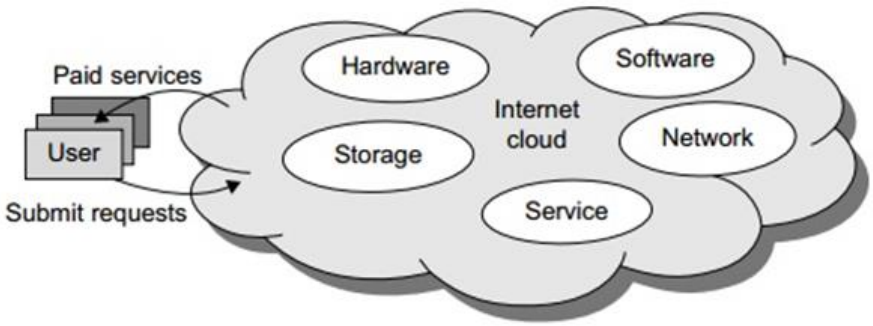
IDs) from the overlay graph. Routing mechanisms are developed to take advantage of the structured overlays.

4.Cloud Computing over the Internet

* “A cloud is a pool of virtualized computer resources. A cloud can host a variety of different workloads, including batch-style backend jobs and interactive and user-facing applications.”

Internet Clouds

*Cloud computing applies a virtualized platform with elastic resources on demand by provisioning hardware, software, and data sets dynamically.The idea is to move desktop computing to a service-oriented platform using server clusters and huge databases at data centers. Cloud computing leverages its low cost and simplicity to benefit both users and providers. Machine virtualization has enabled such cost-effectiveness. Cloud computing intends to satisfy many user applications simultaneously.



Virtualized resources from data centers to form an Internet cloud, provisioned with hardware, software, storage, network, and services for paid users to run their applications.

The cloud ecosystem must be designed to be secure, trustworthy, and dependable. Some computer users think of the cloud as a centralized resource pool. Others consider the cloud to be a server cluster which practices distributed computing over all the servers used.

2.**NIST Cloud Computing Reference Architecture Model**

Introduction:

Cloud Computing:

*****cloud computing is the delivery of computing services including servers, storage, databases, networking, software, analytic, and intelligence—over the internet ("the cloud") to offer faster innovation, flexible resources, and economies of scale.

*****NIST cloud computing reference model is a cloud computing reference model designed by the National Institute of Standards and Technology (NIST).

*Instead of focusing on a "how to" design solution and implementation, the NIST cloud computing reference architecture focuses on the requirements of "what" cloud services must offer.

*****The reference architecture aims to make it easier to comprehend the operational nuances of cloud computing.

Working Groups:

*Cloud Computing Target Business Use Cases Working Group

*Cloud Computing Reference Architecture and Taxonomy Working Group

*Cloud Computing Standards Road map Working Group

* Cloud Computing SAJACC Working Group

*Cloud Computing Security Working Group.

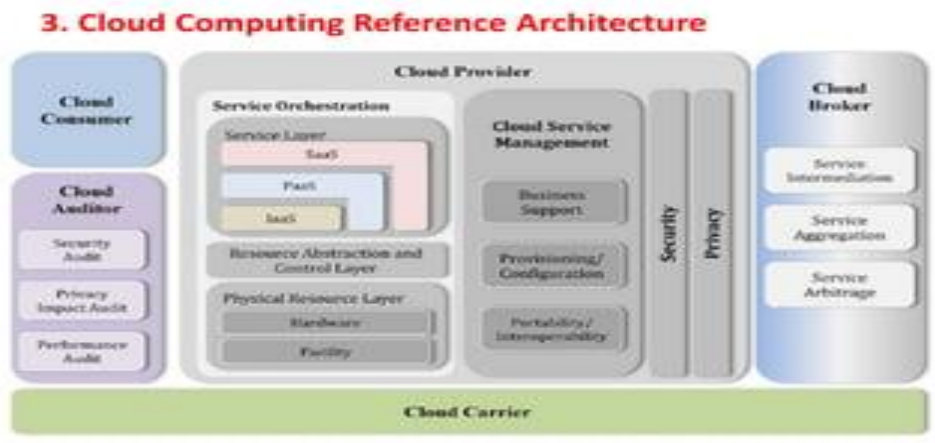


Figure 1: The Conceptual Reference Model

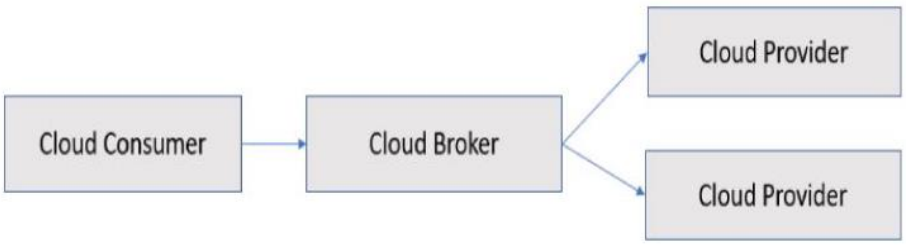
Cloud Computing Components:

Cloud Consumer	person or organization that maintains a business relationship with, and service from, Cloud Providers.
Cloud Provider	person, organization, or entity responsible for making a service available to interested parties.
Cloud Auditor	party that can conduct independent assessment of cloud services, information system operations, performance and security of the cloud implementation.
Cloud Broker	entity that manages the use, performance and delivery of cloud services, and negotiates relationships between Cloud Providers and cloud Consumers.
Cloud Carrier	intermediary that provides connectivity and transport of cloud services from Cloud Providers to Cloud Consumers.

1.Cloud Consumer
2.Cloud Provider
3.Cloud Auditor
4.Cloud Broker
5.Cloud Carrier.

1.Cloud Consumer:

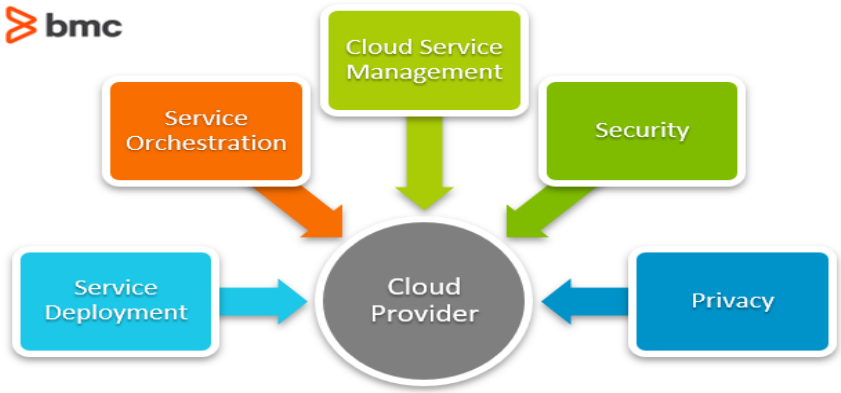
A cloud consumer may request service from a cloud broker instead of contacting a cloud provider directly. The cloud broker may create a new service by combining multiple services or by enhancing an existing service. In this example, the actual cloud providers are invisible to the cloud consumer and the cloud consumer interacts directly with the cloud broker.



2.Cloud Provider:

*Main responsible is provide the the services,A Cloud Provider acquires and manages the computing infrastructure required for providing the services, runs the cloud software that provides the services, and makes arrangement to deliver the cloud services to the Cloud Consumers through network access.

*a cloud provider conducts its activities in the areas of service deployment, service orchestration, cloud service management, security, and privacy



3.Cloud Auditor:

*A cloud auditor can evaluate the services provided by a cloud provider in terms of security controls, privacy impact, performance, etc.

*Audits are performed to verify conformance to standards through review of objective evidence.

4.Cloud Broker:

*A cloud consumer may request cloud services from a cloud broker, instead of contacting a cloud provider directly.

*A cloud broker is an entity that manages the use, performance and delivery of cloud services and negotiates relationships between cloud providers and cloud consumers.

*** cloud broker can provide services in three categories:**

->Service Intermediation: A cloud broker enhances a given service by improving some specific capability and providing value-added services to cloud consumers. The improvement can be managing access to cloud services, identity management, performance reporting, enhanced security, etc.

->Service Aggregation: A cloud broker combines and integrates multiple services into one or more new services. The broker provides data integration and ensures the secure data movement between the cloud consumer and multiple cloud providers.

-> **Service Arbitrage:** Service arbitrage is similar to service aggregation except that the services being aggregated are not fixed. Service arbitrage means a broker has the flexibility to choose services from multiple agencies. The cloud broker, for example, can use a credit-scoring service to measure and select an agency with the best score.

5.Cloud Carrier.

A cloud carrier acts as an intermediary that provides connectivity and transport of cloud services between cloud consumers and cloud providers.

*Cloud carriers provide access to consumers through network, telecommunication and other access devices. For example, cloud consumers can obtain cloud services through network access devices, such as computers, laptops, mobile phones, mobile Internet devices (MIDs), etc.

3.Cloud deployment models:

Introduction:

Cloud Computing:

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*Cloud Deployment Model functions as a virtual computing environment with a deployment architecture that varies depending on the amount of data you want to store and who has access to the infrastructure.

Models:

1.Public Cloud

2.Private Cloud

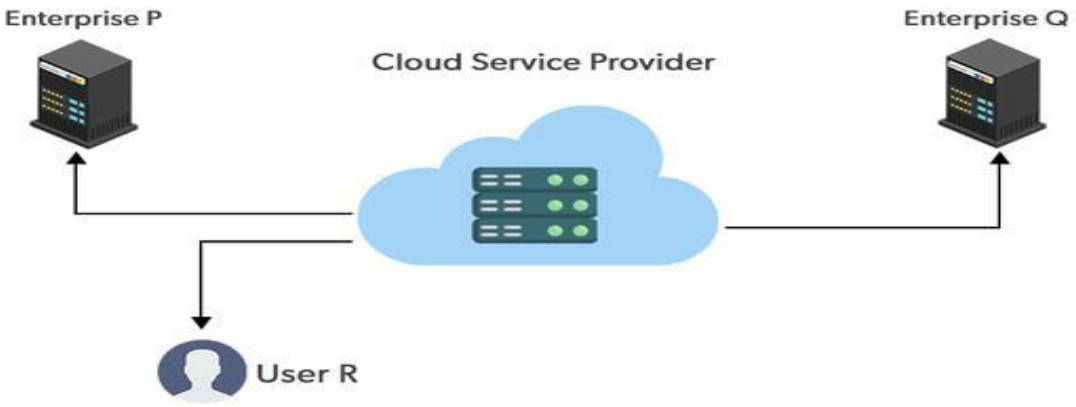
3.Hybrid Cloud

4.Community Cloud

1.Public Cloud:

*The public cloud makes it possible for anybody to access systems and services. The public cloud may be less secure as it is open to everyone.

*The public cloud is one in which cloud infrastructure services are provided over the internet to the general people or major industry groups. The infrastructure in this cloud model is owned by the entity that delivers the cloud services, not by the consumer



Advantages of the Public Cloud Model:

1.Minimal Investment:

Because it is a pay-per-use service, there is no substantial upfront fee, making it excellent for enterprises that require immediate access to resources.

2.No setup cost:

The entire infrastructure is fully subsidized by the cloud service providers, thus there is no need to set up any hardware.

3.Infrastructure Management is not required:

Using the public cloud does not necessitate infrastructure management.

4.No maintenance:

The maintenance work is done by the service provider (not users).

5.Dynamic Scalability:

To fulfill your company's needs, on-demand resources are accessible.

Disadvantages of the Public Cloud Model

1.Less secure:

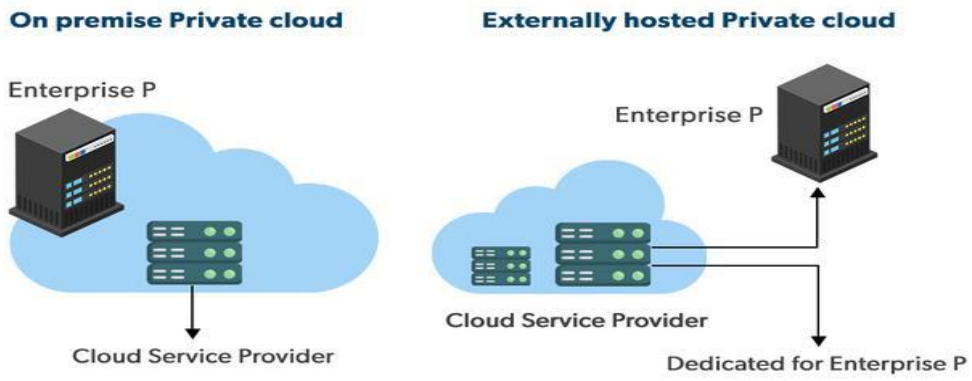
Public cloud is less secure as resources are public so there is no guarantee of high-level security.

2.Low customization:

It is accessed by many public so it can't be customized according to personal requirements.

2.Private Cloud

*A private cloud is a cloud computing environment dedicated to a single organization. Any cloud infrastructure has underlying compute resources like CPU and storage that you provision on demand through a self-service portal. In a private cloud, all resources are isolated and in the control of one organization.



*Examples of private clouds are – Amazon VPC, HPE, VMware, and IBM.

Advantages of the Private Cloud Model

Better Control:

You are the sole owner of the property. You gain complete command over service integration, IT operations, policies, and user behavior.

Data Security and Privacy:

It's suitable for storing corporate information to which only authorized staff have access. By segmenting resources within the same infrastructure, improved access and security can be achieved.

Supports Legacy Systems:

This approach is designed to work with legacy systems that are unable to access the public cloud.

Customization:

Unlike a public cloud deployment, a private cloud allows a company to tailor its solution to meet its specific needs.

Disadvantages of the Private Cloud Model:

Less scalable:

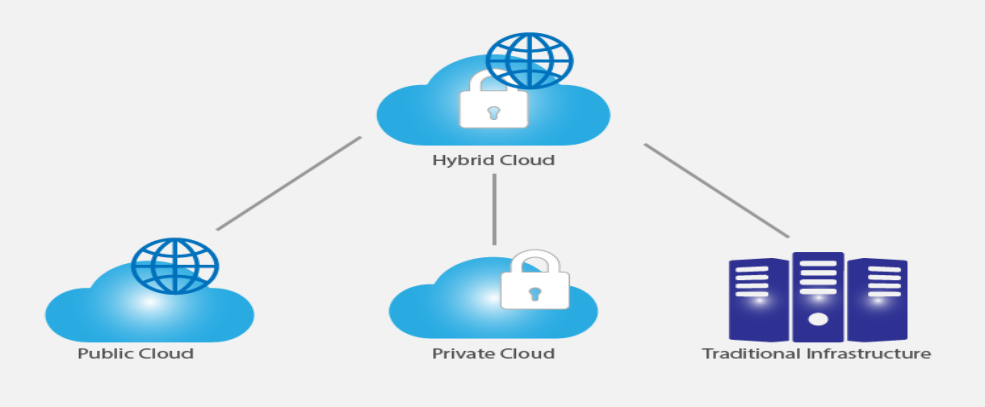
Private clouds are scaled within a certain range as there is less number of clients.

Costly:

Private clouds are more costly as they provide personalized facilities.

3.Hybrid Cloud

*A hybrid cloud is a mixed computing environment where applications are run using a combination of computing, storage, and services in different environments—public clouds and private clouds, including on-premises data centers or "edge" locations.



Advantages of the Hybrid Cloud Model

Flexibility and control:

Businesses with more flexibility can design personalized solutions that meet their particular needs.

Cost:

Because public clouds provide scalability, you'll only be responsible for paying for the extra capacity if you require it.

Security:

Because data is properly separated, the chances of data theft by attackers are considerably reduced.

Disadvantages of the Hybrid Cloud Model

Difficult to manage:

Hybrid clouds are difficult to manage as it is a combination of both public and private cloud. So, it is complex.

Slow data transmission:

Data transmission in the hybrid cloud takes place through the public cloud so latency occurs.

4.Community Cloud

*A community cloud is a cloud infrastructure in which multiple organizations share resources and services based on common operational and regulatory requirements.

*The concept of a community cloud is akin to a community garden, where different individuals grow produce on a single piece of shared land.

4.Cloud service models

Introduction:

Cloud Computing:

*cloud computing is the delivery of computing services—including servers, storage, databases, networking, software, analytic, and intelligence—over the internet ("the cloud") to offer faster innovation, flexible resources, and economies of scale.

*The term "cloud services" refers to a wide range of services delivered on demand to companies and customers over the internet. These services are designed to provide easy, affordable access to applications and resources, without the need for internal infrastructure or hardware.

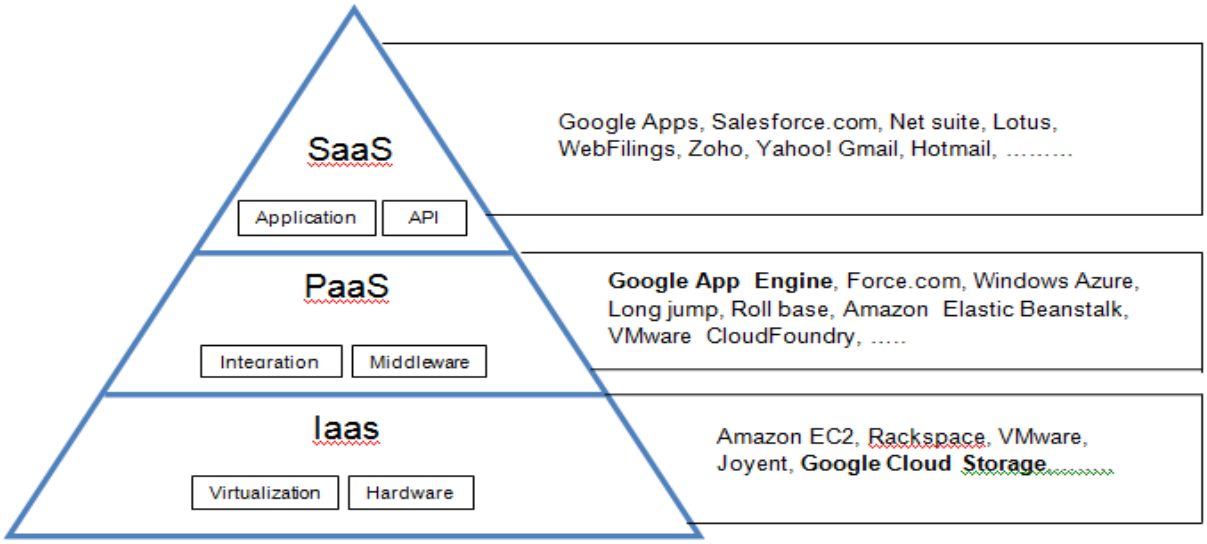
*Cloud services facilitate the flow of user data from front-end clients (e.g., users' servers, tablets, desktops, laptops—anything on the users' ends), through the internet, to the provider's systems, and back. Cloud services promote the building of cloud-native applications and the flexibility of working in the cloud.

Services Model :

1.Software as a service (SaaS)

2.Platform as a service (PaaS)

3.Infrastructure as a service (IaaS)



1.Software-as-a-Service (SaaS):

*It is a way of delivering services and applications over the Internet. Instead of installing and maintaining software, we simply access it via the Internet, freeing ourselves from the complex software and hardware management.

* It removes the need to install and run applications on our own computers or in the data centers eliminating the expenses of hardware as well as software maintenance.

*SaaS provides a complete software solution that you purchase on a pay-as-you-go basis from a cloud service provider.

*Most SaaS applications can be run directly from a web browser without any downloads or installations required.

*The SaaS applications are sometimes called Web-based software, on-demand software, or hosted software.

Advantages of SaaS

1.**Cost-Effective:** Pay only for what you use.

2.**Reduced time:** Users can run most SaaS apps directly from their web browser without needing to download and install any software. This reduces the time spent in installation and configuration and can reduce the issues that can get in the way of the software deployment.

3.**Accessibility:** We can Access app data from anywhere.

4.**Automatic updates:** Rather than purchasing new software, customers rely on a SaaS provider to automatically perform the updates.

5.**Scalability**: It allows the users to access the services and features on-demand.

Disadvantages of Saas :

1.Limited customization: SaaS solutions are typically not as customizable as on-premises software, meaning that users may have to work within the constraints of the SaaS provider's platform and may not be able to tailor the software to their specific needs.

2.Dependence on internet connectivity: SaaS solutions are typically cloud-based, which means that they require a stable internet connection to function properly. This can be problematic for users in areas with poor connectivity or for those who need to access the software in offline environments.

3.Security concerns: SaaS providers are responsible for maintaining the security of the data stored on their servers, but there is still a risk of data breaches or other security incidents.

4.Limited control over data: SaaS providers may have access to a user's data, which can be a concern for organizations that need to maintain strict control over their data for regulatory or other reasons.

2.Platform as a Service:

*PaaS is a category of cloud computing that provides a platform and environment to allow developers to build applications and services over the internet. PaaS services are hosted in the cloud and accessed by users simply via their web browser.

*A PaaS provider hosts the hardware and software on its own infrastructure. As a result, PaaS frees users from having to install in-house hardware and software to develop or run a new application. Thus, the development and deployment of the application take place independent of the hardware.

Advantages of PaaS:

1.**Simple and convenient for users**: It provides much of the infrastructure and other IT services, which users can access anywhere via a web browser.

2.**Cost-Effective:** It charges for the services provided on a per-use basis thus eliminating the expenses one may have for on-premises hardware and software.

3.**Efficiently managing the lifecycle**: It is designed to support the complete web application life-cycle: building, testing, deploying, managing, and updating.

4.**Efficiency:** It allows for higher-level programming with reduced complexity thus, the overall development of the application can be more effective.

Disadvantages of Paas:

1.**Limited control over infrastructure**: PaaS providers typically manage the underlying infrastructure and take care of maintenance and updates, but this can also mean that users have less control over the environment and may not be able to make certain customization.

2.**Dependence on the provider:** Users are dependent on the PaaS provider for the availability, scalability, and reliability of the platform, which can be a risk if the provider experiences outages or other issues.

3.**Limited flexibility:** PaaS solutions may not be able to accommodate certain types of workloads or applications, which can limit the value of the solution for certain organizations.

3.Infrastructure as a Service

*Infrastructure as a service (IaaS) is a service model that delivers computer infrastructure on an outsourced basis to support various operations. Typically IaaS is a service where infrastructure is provided as outsourcing to enterprises such as networking equipment, devices, database, and web servers.

*IaaS customers pay on a per-user basis, typically by the hour, week, or month. Some providers also charge customers based on the amount of virtual machine space they use.

*It simply provides the underlying operating systems, security, networking, and servers for developing such applications, and services, and deploying development tools, databases, etc.

Advantages of IaaS:

1.**Cost-Effective**: Eliminates capital expense and reduces ongoing cost and IaaS customers pay on a per-user basis, typically by the hour, week, or month.

Website hosting: Running websites using IaaS can be less expensive than traditional web hosting.

2.Security: The IaaS Cloud Provider may provide better security than your existing software.

3.Maintenance: There is no need to manage the underlying data center or the introduction of new releases of the development or underlying software. This is all handled by the IaaS Cloud Provider.

Disadvantages of laaS :

1.Limited control over infrastructure: IaaS providers typically manage the underlying infrastructure and take care of maintenance and updates, but this can also mean that users have less control over the environment and may not be able to make certain customization.

2.Security concerns: Users are responsible for securing their own data and applications, which can be a significant undertaking.

3.Limited access: Cloud computing may not be accessible in certain regions and countries due to legal policies.

Cloud Infrastructure:

5. Architectural Design of Compute and Storage Clouds :

Introduction:

Cloud Computing:

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1. **A Generic Cloud Architecture Design**
2. **Layered Cloud Architecture Deployment**
3. **Virtualization support and disaster Recovery**
4. **Architectural design Challenges.**

1.A Generic Cloud Architecture Design:

Cloud Computing , which is one of the demanding technology of the current time and which is giving a new shape to every organization by providing on demand virtualized services/resources. Starting from small to medium and medium to large, every organization use cloud computing services for storing information and accessing it from anywhere and any time only with the help of internet. In this article, we will know more about the internal architecture of cloud computing.

Transparency, scalability, security and intelligent monitoring are some of the most important constraints which every cloud infrastructure should experience. Current research on other important constraints is helping cloud computing system to come up with new features and strategies with a great capability of providing more advanced cloud solutions.

Cloud Computing Architecture :

The cloud architecture is divided into 2 parts i.e.

->Frontend

->Backend

The below figure represents an internal architectural view of cloud computing.

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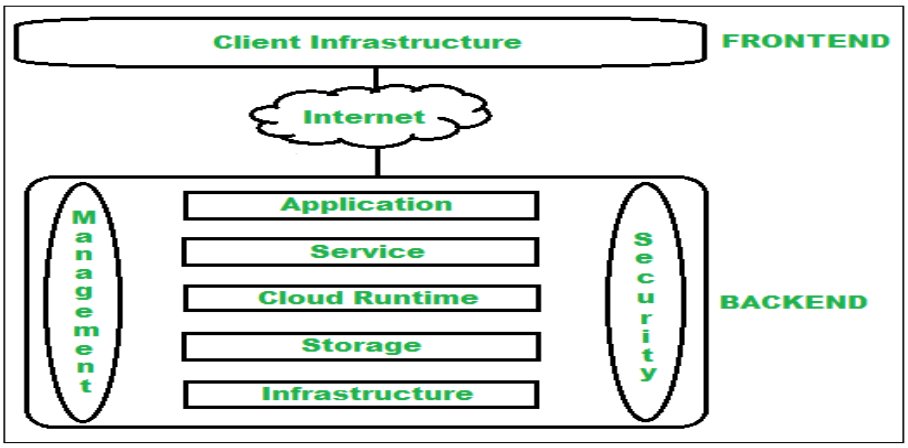


Architecture of cloud computing is the combination of both SOA (Service Oriented Architecture) and EDA (Event Driven Architecture). Client infrastructure, application, service, runtime cloud, storage, infrastructure, management and security all these are the components of cloud computing architecture.

1. Frontend :

Frontend of the cloud architecture refers to the client side of cloud computing system. Means it contains all the user interfaces and applications which are used by the client to access the cloud computing services/resources. For example, use of a web browser to access the cloud platform.

Client Infrastructure – Client Infrastructure is a part of the frontend component. It contains the applications and user interfaces which are required to access the cloud platform.

In other words, it provides a GUI(Graphical User Interface) to interact with the cloud.

2. Backend :

Backend refers to the cloud itself which is used by the service provider. It contains the resources as well as manages the resources and provides security

mechanisms. Along with this, it includes huge storage, virtual applications, virtual machines, traffic control mechanisms, deployment models, etc.

Application –Application in backend refers to a software or platform to which client accesses. Means it provides the service in backend as per the client requirement.

Service –Service in backend refers to the major three types of cloud based services like SaaS, PaaS and IaaS. Also manages which type of service the user accesses.

Runtime Cloud-Runtime cloud in backend provides the execution and Runtime platform/environment to the Virtual machine.

Storage –Storage in backend provides flexible and scalable storage service and management of stored data.

Infrastructure –Cloud Infrastructure in backend refers to the hardware and software components of cloud like it includes servers, storage, network devices, virtualization software etc.

Management –Management in backend refers to management of backend components like application, service, runtime cloud, storage, infrastructure, and other security mechanisms etc.

Security –Security in backend refers to implementation of different security mechanisms in the backend for secure cloud resources, systems, files, and infrastructure to end-users.

Internet –Internet connection acts as the medium or a bridge between frontend and backend and establishes the interaction and communication between frontend and backend.

Database– Database in backend refers to provide database for storing structured data, such as SQL and NOSQL databases. Example of Databases services include Amazon RDS, Microsoft Azure SQL database and Google Clod SQL.

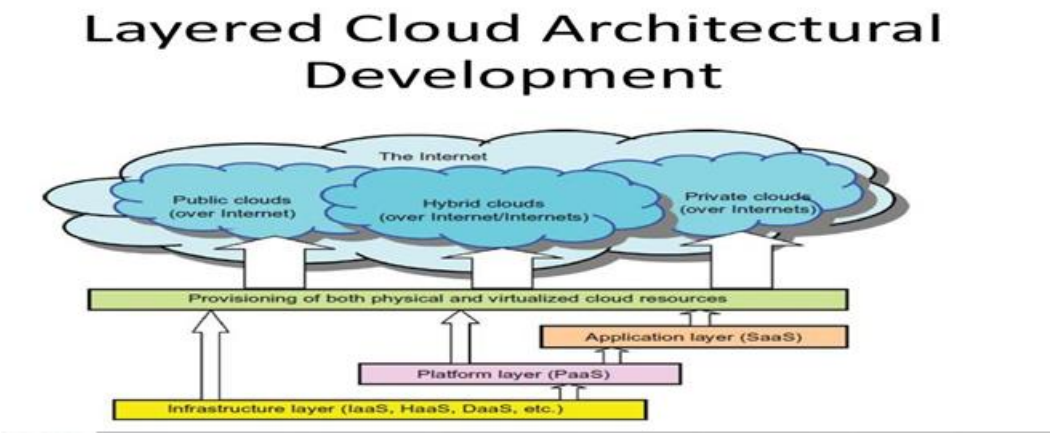
Networking– Networking in backend services that provide networking infrastructure for application in the cloud, such as load balancing, DNS and virtual private networks.

Analytics– Analytics in backend service that provides analytics capabilities for data in the cloud, such as warehousing, business intelligence and machine learning.

Benefits of Cloud Computing Architecture :

- Makes overall cloud computing system simpler.
- Improves data processing requirements.
- Helps in providing high security.
- Makes it more modularized.
- Results in better disaster recovery.
- Gives good user accessibility.
- Reduces IT operating costs.
- Provides high level reliability.
- Scalability.

2.Layered Cloud Architecture Deployment:



There are three types of layers:

1. **Saas(Software as a Service)**
2. **PssS(Platform as a Service)**
3. **Iaas(Infrastructure as a service)**

Application Layer

*The application layer, which is at the top of the stack, is where the actual cloud apps are located. Cloud applications, as opposed to traditional applications, can take advantage of the automatic-scaling functionality to gain greater performance, availability, and lower operational costs.

*This layer consists of different Cloud Services which are used by cloud users. Users can access these applications according to their needs. Applications are divided into Execution layers and Application layers.

*In order for an application to transfer data, the application layer determines whether communication partners are available. Whether enough cloud resources are accessible for the required communication is decided at the application layer.

*Applications must cooperate in order to communicate, and an application layer is in charge of this.

The application layer, in particular, is responsible for processing IP traffic handling protocols like Telnet and FTP. Other examples of application layer systems include web browsers, SNMP protocols, HTTP protocols, or HTTPS, which is HTTP successor protocol.

2. Platform Layer:

The operating system and application software make up this layer.

*Users should be able to rely on the platform to provide them with Scalability, Dependability, and Security Protection which gives users a space to create their

apps, test operational processes, and keep track of execution outcomes and performance. SaaS application implementation's application layer foundation.

*The objective of this layer is to deploy applications directly on virtual machines.

*Operating systems and application frameworks make up the platform layer, which is built on top of the infrastructure layer. The platform layer's goal is to lessen the difficulty of deploying programmers directly into VM containers.

*By way of illustration, Google App Engine functions at the platform layer to provide API support for implementing storage, databases, and business logic of ordinary web apps.

3.Infrastructure Layer:

*It is a layer of virtualization where physical resources are divided into a collection of virtual resources using virtualization technologies like Xen, KVM, and VMware.

*This layer serves as the Central Hub of the Cloud Environment, where resources are constantly added utilizing a variety of virtualization techniques.

*A base upon which to create the platform layer. constructed using the virtualized network, storage, and computing resources. Give users the flexibility they want.

*Automated resource provisioning is made possible by virtualization, which also improves infrastructure management.

*The infrastructure layer sometimes referred to as the virtualization layer, partitions the physical resources using virtualization technologies like Xen, KVM, Hyper-V, and VM-ware to create a pool of compute and storage resources.

* infrastructure layer is crucial to cloud computing since virtualization technologies are the only ones that can provide many vital capabilities, like dynamic resource assignment.

4.Data center Layer:

*In a cloud environment, this layer is responsible for Managing Physical Resources such as servers, switches, routers, power supplies, and cooling systems.
*Providing end users with services requires all resources to be available and managed in data centers.
*Physical servers connect through high-speed devices such as routers and switches to the data center.
*In software application designs, the division of business logic from the persistent data it manipulates is well-established. This is due to the fact that the same data cannot be incorporated into a single application because it can be used in numerous ways to support numerous use cases. The requirement for this data to become a service has arisen with the introduction of micro services.
*A single database used by many micro services creates a very close coupling. As a result, it is hard to deploy new or emerging services separately if such services need database modifications that may have an impact on other services. A data layer containing many databases, each serving a single micro service or perhaps a few closely related micro services, is needed to break complex service interdependent.

Virtualization support and disaster Recovery:

*There are three public clouds in the context of virtualization support:

1. AWS
2. Microsoft Azure
3. GAE

*AWS provides extreme flexibility (VMS) for users to execute their own applications.
*GAE Provides limited application level virtualization for users to build applications only based on the services that are created by Google.
*Microsoft Azure:Provides programming level virtualization(.NET virtualization)for users to build their applications.

Architectural design Challenges:

*There are Six open challenges in cloud architecture development:

1. Service availability Data Lock
2. Data Privacy and Security
3. Unpredictable Performance and bottlenecks
4. Distributed storage
5. Cloud Scalability
6. 6.Software Licensing