

CLOUD COMPUTING

Unit - I

① Computing Paradigms :

Cloud Computing means it is way of delivering Computing Services - like servers, storage, databases, networking, software analytics ... over the internet ("the cloud") instead of using our own local computers or data Centers.

Example :

- Storing photos in Google Drive instead of our computer.
- Using MS office 365 online instead of installing it on our PC.
- Running a website on Amazon web services (AWS) rather than buying our own servers.
- Cloud Computing is combination of network with internet. It is a technology which is manipulating, configuring and accessing the hardware and software resources remotely. It offers online data storage, infrastructure, and application. It is the on-demand delivery of IT resources over the internet.
- cloud computing offers platform independency, that means software is not required to be installed in a local PC.



- cloud can provide services over public & private n/w, i.e., WAN, LAN or VPN.

In the computing paradigm, the term paradigm conveys that there is a set of practices to be followed to accomplish (fulfill) a task. In this domain of computing, there are many different standard practices being followed based on inventions and technological advancements.

In this chapter, we look into various computing paradigms:

a) High-Performance Computing:

HPC is the use of powerful computers and parallel processing techniques to solve complex computational problems that are too large or too slow for standard computers.

→ It is to perform calculations or process data much fast.

→ It is used in scientific research, engineering simulations, weather forecasting, data analytics and similar fields that need huge computing power.

→ In HPC systems, a pool of processors (processor machine or central processing units [CPUs]) connected (networked) with other resources like memory, storage and I/O devices.

→ The processor machines can be of homogeneous (single provider) or heterogeneous type (multiple provider).

b) Parallel Computing:

Parallel computing is also one of the facets (angle) of HPC.

→ These processor machines or CPUs are mostly of homogeneous type.

→ Parallel computing is a type of computing where multiple tasks or calculations are carried out simultaneously by dividing them among multiple processors or cores.

- In parallel computing we can split the work and run parts of it at the same time.
- This makes programs run faster and handle large problems.
- In this when a large computational task is divided into smaller subtasks that can be executed at the same time (in parallel) by multiple processors or cores.
- where it's used:
 - weather forecasting (simulating weather requires huge data)
 - Scientific simulations (Physics, chemistry, biology models)
 - Big data Analytics
 - Machine learning and AI training.

c) Distributed Computing:

Distributed Computing is also a computing system that consists of multiple computers or processor machines connected through a network, which can be homogeneous or heterogeneous, but run as a single system.

- In simple terms: Instead of using a single big computer we can use many separate computers working together.
- Each computer does part of the work, and together they complete the whole task.

where it's used:

- cloud computing (Eg: Google, Amazon, Microsoft cloud services)
- Big data processing (Hadoop)
- Search engines (indexing web pages)
- Scientific research using computing grids

d) Cluster Computing:

Basically cluster computing is when multiple computers (nodes) are connected and work together as a single system to perform computing tasks.

- A cluster computing system consists of a set of the same or similar type of processor machines connected using dedicated network infrastructure.
- In simple words: A cluster is a group of computers linked by a fast local network.
- They work together so that they appear to the user of applications as one powerful computer.

Difference from distributed computing:

<u>cluster computing</u>	<u>distributed computing</u>
→ nodes are tightly coupled and usually in one location	→ nodes may be far apart, geographically distributed
→ often homogeneous hardware/software	→ often heterogeneous hardware/software
→ connected by fast local network	→ connected over LAN, WAN or internet.

Homogeneous: All components are similar or identical, In computing, it means all nodes (computers) in a system have:
→ The same or similar hardware (eg., same CPU type, memory size).
→ The same operating system and software environment.

Heterogeneous: components are different or varied, In computing, it means nodes have:
→ Different hardware, different OS and software versions

e) Grid Computing:

Grid Computing is a computing paradigm where resources, like (Computers, storage, software) located in different geographical locations are connected together over a network to solve large-scale problems.

- In simple words: It combines the power of many distributed often heterogeneous computers (desktops, servers, clusters).
- These computers may belong to different organizations or locations.
- They work together on a common task, like a one big virtual supercomputer.

Electrical power Grid:

- A physical network that sends electricity from power stations to users.
- provides continuous power; users don't know exactly which plant supplies it.

Grid Computing:

- A virtual network connecting many computers to share computing work.
- users get computing results without knowing which computer did the work.

note: Both use the idea of "grid" to mean many distributed units working together to provide a shared resource, but one provides electricity and the other provides computational power.

4) cloud computing:

The computing trend moved toward cloud from the concept of grid computing, particularly when large computing resources are required to solve single problem, using the ideas of computing power as a utility and other allied concepts.

→ cloud computing is a model for delivering computing services (like services, storage, databases, networking, software and analytics) over the internet ("the cloud"), instead of on our local computer or private servers.

→ In simple words: Instead of buying & maintaining our own hardware & software, we rent and use computing resources from cloud providers (like Amazon web services, Google cloud).

5) Biocomputing:

Biocomputing (also called computational biology or bioinformatics) is the use of computers, algorithms and computational techniques to analyze and understand biological data and processes.

In simple words: It combines biology, computer science & mathematics, to help us to study complex biological systems and big data, like DNA sequences, protein structures, and cell functions.

Examples:

→ BLAST: A tool to compare DNA or protein sequences

→ Human Genome project: Used biocomputing to map all human genes, simulating how a virus binds to human cells to design vaccines (6)

n) Mobile Computing:

In mobile Computing, the processing elements are small (i.e., handheld devices) and communications between various resources is taking place using wireless media.

→ Mobile Computing is a technology that allows people to access data, applications, and computing power anytime and anywhere using portable devices that can move freely.

In simple words: It means using computers or smart devices (like smartphones, tablets, laptops) while on the move.

→ we can work, communicate, or access the internet without being tied to a fixed location.

Examples:

- Using a smartphone to check email or social media on bus
- Using GPS app for navigation
- Mobile banking or shopping apps.

) Quantum Computing:

Quantum Computing is a type of computing that uses the principle of quantum mechanics (the science of very small particles like ^{charge carriers} electrons and ^{light wave/light particle} photons) to process information in fundamentally new ways.

- Quantum computers are millions of times faster than even our most powerful supercomputers today.
- Since quantum computing works differently on the most fundamental level than the current technology.

where it's useful:

- Cryptography (eg., breaking large number encryption)
- Optimization problem (eg., route planning, finance)
- ML and AI.

3) Optical Computing:

Optical Computing is a type of computing that uses light (photons) instead of electricity (electrons) to represent, process and transmit information.

- optical computing system uses the photons in visible light or infrared beams, rather than electric current, to perform digital computations.
- In other words: Traditional computers send signals through wires using electrical currents, and optical computers use light beams, passing through lenses, mirrors and optical circuits.

4) Nano Computing:

Nanocomputing is a field of computing that explores building computers and processing devices at the nanometer scale (one nanometer = 1 billionth of a meter) → 1.0×10^{-9} meters

In simple words: It means designing and using extremely small components (made of molecules, atoms or nanoscale materials).

- to build computing systems that are much smaller, faster and more energy-efficient than current silicon-based microchips.

Where it's used:

- Medicine & Healthcare (eg., smart drug delivery systems)
- Data Storage and Memory (nano-scale memory devices)
- Electronics and Computing
- Environmental monitoring (8)

2) Network Computing:

Network computing is a computing model where multiple computers are connected through a network and share resources, data, and computing power.

→ network computing is a way of designing systems to take advantage of the latest technology and maximize its positive impact on business solutions and their ability to serve their customers using a strong underlying n/w of computing resources.

In simple words: Instead of each computer working alone, they work together using a network (like the internet or a local area network - LAN).

→ This allows users to access files, software or processing power on other machines.

Examples:

→ File sharing b/w computers in an office.

→ cloud services where software runs on a remote server.

→ Email systems (we access our emails stored on a n/w server)

→ Remote desktop access (using one computer to operate another over the network).

Types of network computing:

→ client-server model: (client request services; the server provides them)

→ Peer-to-Peer (P2P) Model: All devices act as both clients & servers

2) Cloud Computing Fundamentals:

2.1 Motivation for cloud computing:

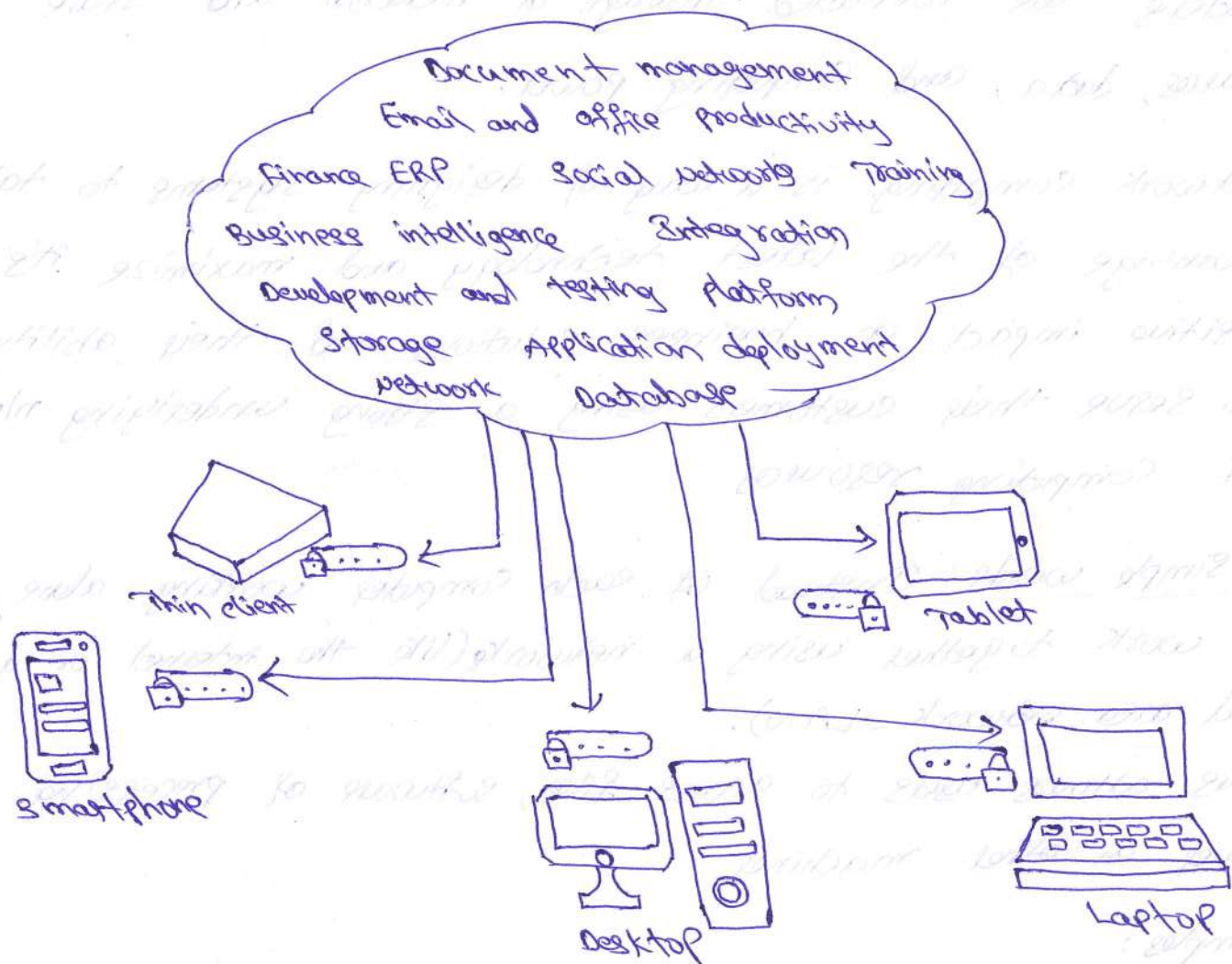


Fig: Cloud Computing (2.1)

In the scenario of computing prior to the announcement and availability of Cloud Computing: The users who are in need of computing are expected to invest money on computing resource such as hardware, software, networking and storage; this investment naturally costs a bulk amount to the user.

→ But on the other hand, it is easy & handy to get the required computing power and resource from some provider (or supplier) as and when it is needed and pay only for that usage. This would cost only a reasonable investment compared to previous scenario. This can be viewed as capital (10) expenditure (vs) operational expenditure.

→ The motivation behind cloud computing arises from the "limitations of traditional IT infrastructure and need for more scalable, efficient and cost effective computing".

Here are the main drivers:

- i) Capital vs operational expenditure:
 - Before CC, individuals and businesses had to buy and maintain computing resources, which led to large capital expenditure (CapEx).
 - cloud computing resources allow them to "rent on-demand" computing resources from providers & pay only for what they use. This transforming CapEx into operational expenditure (OpEx).
- ii) Convenience & Reliability: using cloud means we don't worry about local device issues: even if a laptop is lost or damaged, data remains safe & accessible because it's stored remotely.
- iii) Flexibility & Elasticity: It allows organizations to quickly add capacity or services on the fly - as needed - without investment in new infrastructure, staffing, or licensing.

2.1.1 The need for cloud computing:

The main reasons for the need & use of CC are convenience and reliability.

→ In the past, we wanted to bring a file, we save it to a USB, CD, hard drive and bring that device to a different place.

→ But, saving a file to the cloud it ensures that we will be able to access it with any computer that has an Internet connection.

→ While using the cloud, losing our data/file is much less. However there is always a risk that someone may try to gain access to our personal data. So that choose an access control with strong password & pay attention to any settings for cloud service. (11)

2.2 Defining Cloud Computing:

In the simplest terms, cloud computing means storing and accessing data and programs over the internet from a remote location or computer instead of our computer's hard drive. This is so called remote location.

→ It has several properties such as Scalability, elasticity etc. which is significantly different from simple remote machine. This cloud is just a metaphor for the internet.

ability to handle the increased work load by adding resources.
Ability to automatically adjust resources based on demand.

2.2.1 NIST Definition of Cloud Computing:

The formal definition of cloud computing comes from the National Institute of Standards & Technology (NIST): "cloud computing is a model for enabling Ubiquitous (present everywhere or existing everywhere at the same time), convenient on-demand network access to a shared pool of configurable computing resources (eg., n/w, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort of service provider intervention.

→ [This cloud model is composed of five (5) essential characteristics, three (3) service models, and four (4) deployment models.]

→ Many vendors, pundits, and experts refer to NIST, and both the International Standards Organization (ISO) and the Institute of Electrical & Electronics Engineering (IEEE) back the NIST definition.

There are two (2) other perspectives to understand the cloud computing as — "as a service and a platform".

[Note: NIST, U.S Govt agency, it develops measurement standards, technology & guidelines — including (2) for cybersecurity and cloud computing.]

2.2.2 cloud Computing is a service :

The simplest thing that any computer does it allow us to store and retrieve information. we can store photos, songs, movies on it, which is most basic service offered by cloud computing.

→ The best example of a popular Application called "FLICKR".
→ Flickr is an image & video hosting service that allows user to upload, store, manage and share photos online. It operates using cloud computing in the background.

a) First, Flickr allows us to easily access our images no matter where we are. while we might upload the photos of our vacation from our home computer, then later we can easily access them from our laptop at the office.

b) Second, Flickr is share the images. There is no need to burn them to a CD or save them on a flash drive. we can just send someone our Flickr address to share these photos or images.

c) Third, Flickr provide data security. By uploading the images to Flickr, we are providing data security by creating a backup on the web.

2.2.3 Cloud Computing is a platform:

The world wide web (WWW) can be considered as the operating system for all our internet-based applications.

→ However, we always need a local operating system in our computer to access web-based applications.

→ The basic meaning of the term "platform" is that it is the support on which applications run on given requests to the users.

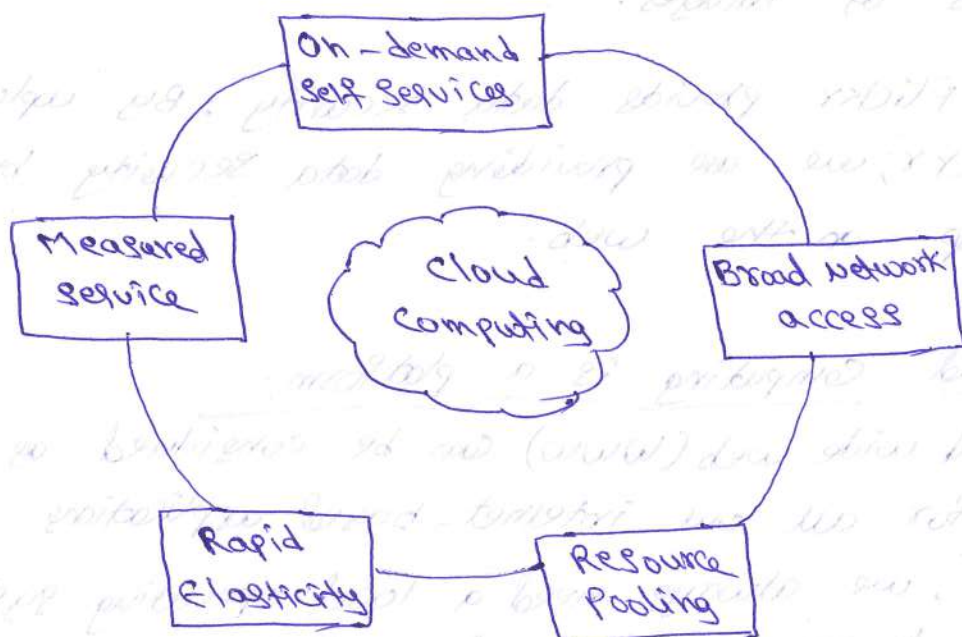
- for example, Microsoft windows is a platform. But, a platform does not have to be an OS. Java is a platform even though it is not an operating system.
- Through CC, the web is becoming a platform. with trend such as office 2.0, more & more applications that were originally available on desktop Computers are now being converted into web-cloud applications.
- The word processing like Buzzword & office suites like Google Docs providing applications like via the cloud are turning CC into a platform or to act as a platform.

2.3 5-4-3 principles of cloud Computing:

This 5-4-3 principles are referenced from NIST (National Institute of Standards and Technology) definition of cloud Computing.

2.3.1 Five (5) Essential characteristics:

cloud computing has five (5) essential characteristics,



- i) On-demand Self-service: users can automatically access computing resources (e.g., servers, storage) whenever needed, without human interaction with the provider.
Eg: Launching a virtual machine from AWS or Azure.
- ii) Broad-network access: services are available over the network and can be accessed from various devices (laptops, phones, tablets).
Eg: Accessing Google Doc from your phone or PC.
- iii) Elastic resource pooling: cloud providers use a multi-tenant model to serve multiple customers from a shared pool of resources (like storage, CPU, memory).
→ Resources are dynamically assigned and reassigned based on demand.
- iv) Rapid Elasticity: Resources can be rapidly scaled up or down according to user demand.
Eg: A website handles more traffic during sales by automatically scaling servers.
- v) Measured Service: cloud systems automatically control and optimize resource usage through metering capability.
→ users are billed based on usage (like pay-as-you-go-electricity).
Eg: Storage, processing, bandwidth, and user active accounts.

2.3.2 Four (4) cloud Deployment Models:

Deployment models describe the ways with which the cloud services can be deployed or made available to its customers, depending on the organizational structure and the provisioning location.

→ The Four (4) deployment models are usually distinguished, namely as public, private, hybrid and community cloud service.

i) Private cloud: cloud infrastructure used "exclusively" by one organization. It can be managed internally or by a third party.

Ex: A bank runs its secure cloud within its own data center.

ii) Public cloud: Services are provided to the general public over the internet. It may be owned, managed & operated by a business, academic or govt. organizations.

Eg: Google cloud, Amazon web services (AWS), Microsoft Azure.

iii) Hybrid cloud: It combines both public and private clouds, allowing data and apps to move between them.

Eg: cloud bursting for load balancing b/w clouds.

iv) Community cloud: The cloud infrastructure is shared by several organizations and supports a specific community that has shared concerns (like mission, security requirements, policy and compliance considerations).

Eg: Universities sharing a research data cloud.

2.3.3 Three (3) Service offering Modules:

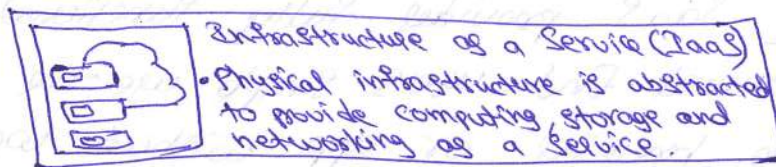
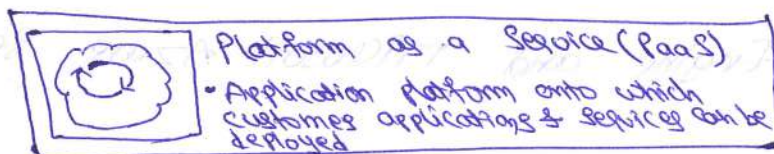
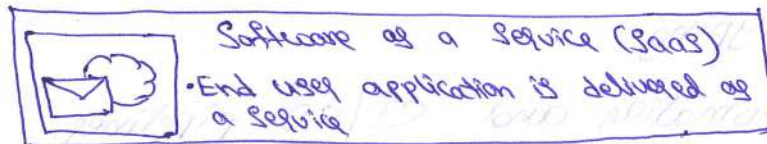
The three kinds of service with which the cloud-based computing resource are available to end customers are as follows:

Software as a Service (SaaS)

Platform as a Service (PaaS)

Infrastructure as a Service (IaaS)

It is also known as the Service - platform - infrastructure (SPI) model of the cloud



i) cloud IaaS: It provides virtualized hardware resources (Compute, Storage, networking) over the internet. Users manage the OS and applications themselves but don't need to worry about physical infrastructure

use cases:

- Hosting websites
- Setting up virtual machines
- Running large scale applications
- Backup & disaster recovery systems.

Eg: Amazon EC2, Microsoft Azure, Google Compute Engine, DigitalOcean.

ii) Cloud PaaS: PaaS provides a development and deployment environment with tools, frameworks and services to build applications quickly without managing infrastructure.

use cases:

- Developing web and mobile apps
- API integration and microservices
- Rapid prototyping
- DevOps automation and CI/CD pipelines.

Eg: Google App Engine and Microsoft Azure Services.

iii) Cloud SaaS: SaaS provides fully functional applications over the internet. End-users simply use the software via a web browser or app without worrying about installation or maintenance.

use cases:

- Email and communication tools
- CRM, ERP systems
- Office productivity tools
- Collaboration & file sharing

Eg: Gmail, Google Drive, Microsoft 365, Salesforce, Zoom, Dropbox

Analogy:

Model Analogy (Pizza-as-a-Service)

IaaS → You buy ingredients and make the pizza yourself

PaaS → You get a prepared dough & oven, you bake & add toppings

SaaS → You get a ready-made pizza delivered to your door.

2.4 cloud Ecosystem

It is a comprehensive network of cloud service providers, users, technologies, tools and partners that work together to deliver, manage, and use cloud computing services.

→ It is like a digital environment where all parts of cloud computing — infrastructure, platforms, software, networks and people interact to create value.

Key Components of the Cloud Ecosystem:

i) Cloud Service Users (CSUs): It is the end users or clients who consume cloud services.

→ They access cloud-based applications, platforms, or infrastructure for various purposes like storage, computation, communication, or app development.

Eg: A person using Google Drive (SaaS)

A developer deploying apps on Heroku (PaaS)

A company running virtual machines on AWS EC2 (IaaS)

ii) Cloud Service Providers (CSPs): The companies or organizations that offer cloud services and infrastructure to customers.

→ They manage and deliver cloud services like IaaS, PaaS & SaaS

Eg: AWS, IBM cloud, Oracle cloud, Microsoft Azure.

iii) Cloud Service Networks (CSNs): The network infrastructure and community services that enable communication b/w cloud service users and providers.

→ It ensures secure, efficient, and reliable data transmission and resource access.

Eg: Data centers, Internet infra.

2.5 Requirements for cloud services:

To build, deploy, and operate a successful cloud computing environment, several technical, operational, and organization requirements must be met. These are the key prerequisites for enabling cloud computing.

→ Multi-tenancy

→ Service life cycle management

→ Security

→ Responsiveness

→ Intelligent service deployment

→ Portability

→ Interoperability

→ Regulatory aspects.

→ Service access

→ Flexibility

→ Accounting and charging

→ Massive data processing.

2.6 Cloud Application:

cloud computing is used in many fields due to its flexibility, scalability, and cost-effectiveness.

Below are the major applications of cloud computing, with examples and use cases:

i) Data storage & Backup → Google Drive, Dropbox

ii) Software as a Service → Gmail, Salesforce, MS 365

iii) Deployment & Testing → Azure App Service

iv) web Hosting → AWS, Netfix

v) Big Data Analytics → Redshift, BigQuery

vi) Scientific Research & Simulation → AWS, HCP on Azure

vii) Gaming → Xbox cloud Gaming

2.7 Benefits and Drawbacks:

Benefits of cloud Computing:

- i) Cost Efficiency → pay only for what we use.
- ii) Scalability → Easily scale resources up or down based on need
- iii) Accessibility → Access data/applications from anywhere with internet
- iv) Automatic updates → providers handle software/hardware updates
- v) Improved security → Strong encryption
- vi) Faster Deployment → Launch apps or services quickly
- vii) Disaster Recovery → Backup & restore data automatically

Drawbacks of cloud Computing:

- i) Internet Dependency → Requiring a stable internet connection
- ii) Data privacy concerns → Risk of data leaks
- iii) On going costs → Monthly/Yearly charges can buildup over time
- iv) Requires skilled staff → need cloud trained professionals to setup and management
- v) Vendor Lock-in → Hard to switch providers due to compatibility of cost.

3) cloud computing Architecture and Management

3.1 Introduction:

cloud computing is similar to other technologies in a way that is also has several basic concepts that one should learn knowing its core concepts.

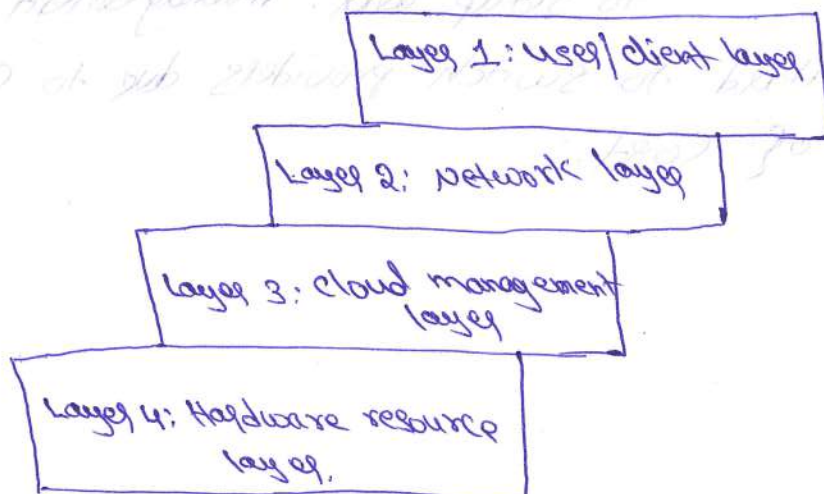
→ Architecture is the hierarchical view of describing a technology. This usually includes the components over which the existing technology is built and the components that are dependent on the technology.

3.2 cloud Architecture:

The cloud has an architecture that describes its working mechanism. It includes the dependencies on which it works and the components that work over it.

→ The cloud is a recent technology that is completely dependent on the internet for its functioning.

→ It divided into 4 layers based on the access of the cloud by the user.



Layer 1 (User/Client Layer)

- This is the interface layer where users interact with the cloud
- It allows end-users, administrators of applications to access cloud services via web browsers, mobile apps, API or command-line tools.

Key Functions:

- Sends service requests to the cloud (e.g., request storage, compute power, or applications)
- Displays results and interface for user interactions

Eg: Google Drive, AWS, Dropbox cloud.

Layer 2 (Network Layer)

- The communication backbone that connects the client layer to the cloud.
- Responsible for securely delivering requests and data between cloud consumers and cloud providers.

Key Functions:

- Handles data transmission, routing and load balancing
- Manages security protocols, bandwidth optimization
- Enables multi-device and global access via internet.

Eg: Zoom cloud meetings

Content delivery networks

Microsoft Azure.

Layer 3 (Cloud Management Layer)

→ automatically managing

→ This is the control and orchestration layer that manages all cloud resources & services.

→ It ensures that cloud services are delivered efficiently, securely and according to Service Level Agreement (SLA).

Key Functions:

- Resource provisioning
- Monitoring & Analytics
- Security
- Billing & metering

Eg: AWS management console, Microsoft Azure portal, Google cloud console.

Layer 4 (Hardware Resource Layer)

→ The foundation of the cloud, consisting of physical infrastructure in cloud data centers.

→ These resources are virtualized and managed by the layers above to provide compute, storage & networking.

Key Components:

- physical servers
- Hard disk & SSDs
- Routers, switches, network interface

Eg: physical servers hosting Amazon EC2 instances.

. Data Center storage systems used for Google cloud storage

3.3 Anatomy of the cloud

Cloud anatomy can be simply defined as the structure of the cloud.

> Cloud anatomy cannot be considered the same as cloud architecture. Thus, anatomy can be considered as a part of architecture.

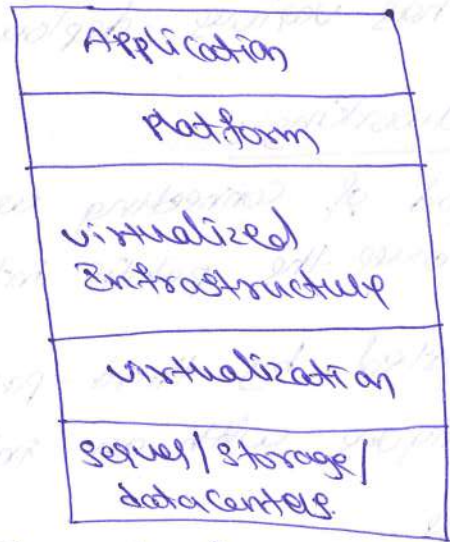


Fig: cloud structure.

Application: The upper layer is the application layer. In this layer, any applications are executed.

Platform: This component consists of platforms that are responsible for the execution of the application. This platform is b/w the infrastructure and the application.

Infrastructure: The infrastructure consists of resources over which the other components work.

virtualization: This process is consists of making logical components of resource over the existing physical resources. The logical components are isolated & independent, which form the infrastructure.

Physical hardware: The physical hardware is provided by Server and Storage units.

3.4 Network Connectivity in cloud Computing.

cloud Computing is a technique of resource sharing where servers, storage, and other computing infrastructure in multiple locations are connected by networks.

→ For many cloud computing applications, network performance will be the key issue to cloud computing performance.

→ Since cloud computing has various deployment options:

i) public cloud Access Networking:

It refers to the method of connecting users and applications to the cloud services over the public internet.

→ These services are hosted by third-party providers and are accessible by anyone with an internet connection and proper credentials.

It is used in:

→ Common in public cloud platforms like AWS, Azure, and Google cloud.

→ used by general users, developers, or businesses to access cloud-hosted services.

ii) private cloud Access Networking:

Connecting a cloud that is privately hosted within an organization or by a private provider, often over secure internal networks or VPNs (Virtual Private Network).

It is used in:

Banks and finance, Government sectors, Healthcare, Large enterprises.

iii) Intracloud Networking for public cloud services:

It refers to the networking within the cloud provider's infrastructure, enabling communication b/w resources and services inside the same public cloud environment (e.g., virtual machines, containers, databases, storage).

→ It is not about connecting to the cloud from outside - instead, it's about how resources inside the cloud talk to each other securely and efficiently.

It is used in:

- cloud-based application deployment (Frontend ↔ Backend)
- microservices architecture
- service integration

iv) Private Intracloud Networking:

It refers to communication b/w cloud resources within the same cloud infrastructure using private IP addresses, fully isolated from the public internet.

→ This ensures secure, low-latency (fast), internal communication among services and workloads hosted in a private virtual n/w.

It is used in:

- web + Database Architecture
- microservices architecture
- cloud-native applications
- Hybrid cloud extension.

[Note: Intracloud is a short for infrastructure cloud. It refers to foundation layer of IaaS]

Infrastructure cloud: It provides virtual machines, storages, n/w on demand]

* public intracloud: communication b/w cloud services that may use public endpoints of internet based access

private intracloud: communication b/w services using private IPs inside a secure network.

- v) New Facets in Private Network
- Conventional private n/w have been architected for on-premise applications & maximum Internet security.
- Typically, applications such as e-mail, file sharing and Enterprise resource planning (ERP) systems are delivered to on-premise-based servers at each corporate data center.
 - Increasingly today, software vendors are offering software as a service (SaaS) as an alternative for their slw support to the corporate offices.

Eg: private link/private endpoint
Software defined networking
Zero trust networking
Private 5G & edge networking

* Facet → sides
phases
Angles

- vi) Path for Internet Traffic
- In cloud computing describes how user requests travel - from a client device, across various networks, to cloud services - and how responses return, involving both public & cloud provider infrastructure.

→ This flow is typically managed internally by the cloud provider and plays a key role in service performance and SLA adherence (SLA → service level agreement)

It is used in:

- public cloud services (SaaS or web apps)
- Intra cloud networking
- Monitoring quality of service (QoS)

3.5 Applications on the cloud

The power of a Computer is realized through the applications. There are several types of applications.

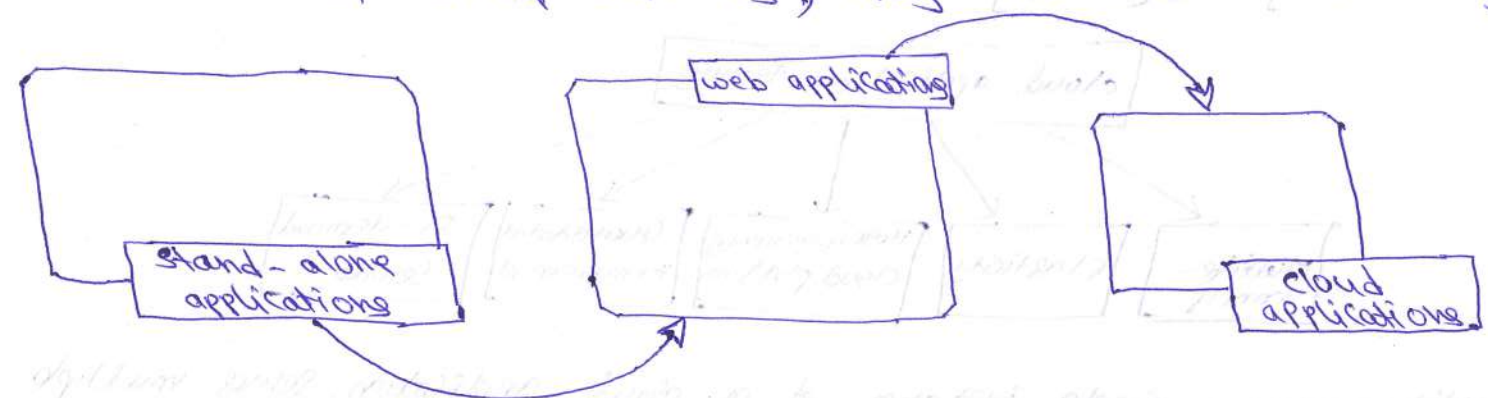
i) Stand-alone applications:

It is developed to be run on a single systems that does not use network for its functioning.

→ These stand-alone systems use only the machine in which they are installed.

→ The functioning of these kinds of systems is totally dependent on the resource of features available within the systems.

→ These systems do not need the data or processing power of other systems; they are self-sustaining.



[Fig: computer application evolution]

* → It runs entirely on local machine. It doesn't need internet connectivity of a remote server to function. All the files, data & execution happen on the user's hardware.

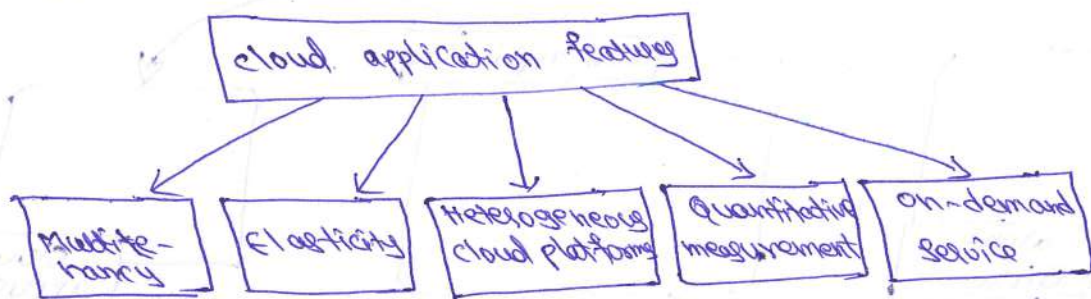
ii) web applications:

It is different from the stand-alone applications in many aspects. The main difference was the client server architecture that was followed by the web application.

- Stand-alone applications systems were totally dependent on the network for its working.
- There are basically two components called as client & the server.
- The server is a high-end machine that consists of the web application installed. The web application is accessed from other client systems.
- A web application is software that runs on remote servers and is accessed through a web browser over the internet. It doesn't need to be installed on the user's device.

iii) cloud applications:

- A cloud application is different from other applications; they have unique features.
- A cloud application usually can be accessed as a web application but its properties are different.
- According to [NIST] it makes cloud application unique as



Multitenancy: A single instance of a cloud application serves multiple customers (tenants), with each user's data securely isolated.

Elasticity: The ability of a cloud system to scale resources up or down dynamically based on demand.

Heterogeneous cloud platform: It supports for multiple operating systems, programming languages and environment within cloud infra's.

Quantitative Measurement: cloud usage (CPU, storage, bandwidth) is monitored & measured, enabling billing & optimization.

On-demand service: Resources (computer, storage, apps) can be provisioned automatically, whenever needed, without human intervention.

3.6 Managing the cloud

Cloud management is aimed at efficiently managing the cloud so as to maintain the QoS. It is one of the prime jobs to be considered.

The whole cloud is dependent on the way it is managed. Cloud management can be divided into 2 parts.

i) Managing the infrastructure of the cloud

- The infrastructure of the cloud is considered to be the backbone of the cloud.
- The component is mainly responsible for the QoS factor.
- If the infrastructure is not properly managed, then the whole cloud can fail and QoS would be adversely affected.
- The core of cloud management is resource management.
- Resource management involves several internal tasks such as resource scheduling, provisioning, load balancing.
- These tasks are mainly managed by the cloud service providers core software capabilities such as the cloud OS that is responsible for providing services to the cloud and internally controls the cloud.
- A cloud infrastructure is a very complex system that consists of a lot of resources. These resources are usually shared by several users.

It involves in:

- Efficient utilization of resource
- Ensuring QoS
- Scalability & flexibility

ii) Managing the cloud Application

- cloud application management is to address these issues all propose solutions to make it possible to have insight into application that run in the cloud, as well as implement or enforce enterprise policies.
- Business Companies are increasingly looking to move or build their corporate applications on cloud platforms.
- Because to improve ^{→ quickly} agility or to meet dynamic requirements that exist in the globalization of business and responsiveness to market demands.
- cloud application management refers to overseeing the life cycle of cloud-based software applications, ensuring that they perform well, scale efficiently, and are always available to users.
- these management services can collect a multitude of events analyze them, and identify critical information that requires additional remedial actions like adjusting capacity of provisioning new services.

It involves in:

- Deploying applications in cloud environments using virtualization
- Monitoring application performance
- Automating tasks like backups, logging & alerts for proactive management.

5. + Migration Application to cloud

Cloud migration encompasses moving one or more enterprise applications and their IT environments from the traditional hosting type to the cloud environment, either public, private or hybrid.

- Migration is described as "relocation".
- cloud migration presents an opportunity to significantly reduce costs incurred on applications.
- This comprises activity, of different phases like "evaluation, migration strategy, prototyping, provisioning and testing."

i) Phases of cloud migration:

- a) Evaluation: It understand the current IT infrastructure, applications and workloads. Evaluation is carried out for all the components like, current infrastructure, environment in terms of Compute storage, monitoring, and management, SLAs, risk, security, and licensing needs are identified to build a business case for moving to the cloud.
- b) Migration strategy: Based on the evaluation, a strategy is used where the applications can be partially migrated; but for a portion of it, there are dependencies based on existing licenses, specialized server requirements.
- c) Prototyping: It means test the "migration process" with a small, non-critical application.
- d) Provisioning: It is prepare the cloud environment for full-scale migration. It set up all internal & external integration points are properly configured.
 - web services, batch jobs, and operation & management s/w are set up in the new environments.

e) Testing: The testing ensure the migrated applications function correctly in the cloud.
→ It performance and load testing, failure and recovery testing and scale-out testing are conducted against the expected traffic load and resource utilization levels.

i) Approaches for cloud migration
The following are the four based approaches for cloud migration that have been adopted effectively by vendors:

a) Migrate existing applications: It is a meaning of (lift and shift) Move existing on-premises applications to the cloud without significant changes to architecture or code.

→ It rebuild or rearchitected some or all the applications, taking advantage of some of the technologies to accelerate the work.

b) Start from scratch: It means rebuild applications specifically for the cloud using modern cloud-native architectures.

→ Rather than cannibalize sales, confuse customers with choice, and tie up engineers trying to rebuild existing application, it may be easier to start again.

c) Separate Company: It means establish a new company or division that operates entirely in the cloud, independent of the existing IT systems.

→ The separate company may even be a subsidiary of the existing company. What is important is that the new company can act, operate, and behave like a cloud-based startup.

d) Buy an existing cloud vendor: It acquire a third-party company or solution that already operates in the cloud.

→ For a large established vendor, buying a cloud-based competitor achieves two things. Firstly, it removes a competitor, and secondly it enables the vendor to hit the ground running in the cloud space.