1.1 What is Cloud?

Introduction

Cloud computing is one of the most transformative technologies of the 21st century. It has changed the way organizations **develop, deploy, and consume IT resources**. Instead of investing heavily in data centers, servers, and maintenance teams, organizations can now **rent computing power, storage, and services** from providers like **Amazon Web Services (AWS)**, **Microsoft Azure**, and **Google Cloud Platform (GCP)**.

The concept of "Cloud" refers to delivering IT services **via the internet ("the cloud")**, where resources can be **provisioned instantly, scaled elastically, and paid for only when used**.

Traditional IT vs Cloud IT

Traditional IT Environment

- Organizations buy physical servers and keep them in data centers.
- Hardware and software must be purchased upfront.
- IT teams are responsible for power, cooling, networking, and security.
- Scaling requires buying new hardware (long procurement cycles).
- Huge waste if servers are underutilized.

Example: A university buys 20 servers to host a student portal. Most of the year, only 5 are used, but during exam season, all 20 are needed. For the rest of the year, 15 sit idle.

Cloud IT Environment

- Servers, storage, and databases are **rented from a cloud provider**.
- Scaling up/down is possible within **minutes**.
- No upfront hardware cost – pay only for usage.
- Providers handle data center operations (power, networking, physical security).
- Developers and organizations focus only on applications.

Example: The same university uses AWS. It runs 5 servers during normal days and automatically scales to 20 during exams. When load reduces, AWS automatically scales back to 5, saving costs.

Key Characteristics of Cloud (NIST Definition)

The National Institute of Standards and Technology (NIST) defines **five essential characteristics** of cloud computing:

1. **On-Demand Self Service**
    - Users can provision computing resources (like storage or servers) whenever they need, without manual intervention.
    - Example: A developer launches a virtual machine (EC2 instance) from AWS Console at midnight without contacting IT.
2. **Broad Network Access**
    - Services are accessible over the network from any device (laptop, mobile, tablet).
    - Example: Accessing Gmail or AWS Console from a browser anywhere in the world.
3. **Resource Pooling**
    - Cloud providers pool resources (servers, storage, bandwidth) and dynamically allocate them among customers.
    - Users don't know the exact physical location of resources, but they get logical isolation.
4. **Rapid Elasticity**
    - Resources can scale out (add servers) or scale in (remove servers) quickly.
    - Example: An e-commerce website doubles its servers during Black Friday sales.
5. **Measured Service**
    - Cloud systems measure and monitor resource usage.
    - Users are billed only for what they consume (like electricity or water).

Advantages of Cloud Computing

1. **Cost Savings**
    - No upfront investment in hardware.
    - Pay-as-you-go pricing.
    - Reduced IT staff requirement.
2. **Agility & Speed**
    - New servers or databases can be launched within minutes.
    - Faster time to market.
3. **Scalability**
    - Scale to millions of users without rewriting infrastructure.
4. **Global Reach**
    - Deploy applications in regions close to users (low latency).
5. **Reliability**
    - Built-in redundancy across multiple data centers.
6. **Focus on Innovation**
    - Teams focus on applications and business goals instead of hardware.

Analogy to Understand Cloud

Think of cloud computing like **electricity supply**:

- You don’t build your own power station at home.
- You rent electricity from a utility provider.
- You pay only for the units consumed.
- You can increase or decrease usage anytime.

Similarly:

- You don’t build data centers.
- You rent computing resources from AWS.
- You pay only for actual usage.
- You can scale resources up/down easily.

Real-Life Examples of Cloud Computing

1. **Netflix**
    - Runs entirely on AWS.
    - During peak hours, AWS scales servers to handle millions of concurrent users.
2. **Spotify**
    - Uses Google Cloud for music streaming.
    - Handles millions of daily active users with elastic storage and compute.
3. **Airbnb**
    - Runs on AWS.
    - Uses the cloud to handle seasonal spikes in travel bookings.
4. **Your Daily Life**
    - Gmail → SaaS cloud email.
    - Google Drive / Dropbox → Cloud storage.
    - Zoom / Teams → Cloud collaboration tools.

Challenges in Cloud Adoption

- **Data Security & Privacy** – Sensitive data may raise compliance concerns.
- **Downtime Risks** – Outages in a region may affect availability.
- **Cost Overruns** – Poorly managed resources can lead to unexpected bills.
- **Vendor Lock-in** – Moving workloads between providers can be complex.

Future of Cloud

- Increasing adoption of **serverless computing** (e.g., AWS Lambda).
- Rise of **multi-cloud** strategies (using AWS + Azure + GCP).
- Greater integration with **AI/ML, IoT, and Edge Computing**.

According to Gartner, **85% of enterprises** will adopt cloud-first principles by 2025.

1.2 Types of Cloud: Public, Private, Hybrid

Introduction

Cloud computing is not a one-size-fits-all solution. Depending on an organization's **business needs, budget, security requirements, and scalability goals**, cloud services can be deployed in different models.

The three primary **deployment models** are:

1. **Public Cloud**
2. **Private Cloud**
3. **Hybrid Cloud**

Each has **unique characteristics, advantages, and trade-offs**.

1.2.1 Public Cloud

Definition

A **public cloud** is owned and managed by **third-party providers** like **AWS, Azure, or Google Cloud**. The infrastructure (servers, storage, networking) is hosted in the provider's data centers and is shared among multiple customers.

Each customer's environment is logically isolated, even though they share the same physical infrastructure.

Key Features of Public Cloud

- **Multi-tenancy**: Many customers share resources but remain isolated.
- **Pay-as-you-go pricing**: No upfront investment.
- **Massive scalability**: Providers can instantly add resources.
- **Accessible over the internet**: No need for dedicated connectivity.
- **Managed by provider**: Security, updates, hardware maintenance handled by AWS/Azure/GCP.

Advantages of Public Cloud

- **Cost Efficiency**: No need to buy and maintain hardware.
- **Global Availability**: Deploy apps in multiple regions worldwide.
- **Flexibility**: Quick setup for experiments, testing, and innovation.
- **Wide Range of Services**: From compute and storage to AI/ML, IoT, DevOps tools.

Limitations of Public Cloud

- **Data Security Concerns**: Shared infrastructure may raise compliance issues.
- **Less Control**: Customers can't choose exact hardware or customize infrastructure deeply.
- **Internet Dependency**: Requires strong internet connectivity.

Use Cases of Public Cloud

- Hosting websites and mobile apps.
- Running SaaS platforms (e.g., Zoom).
- Startups that need scalability without large capital investment.
- Enterprises offloading non-sensitive workloads.

Example:

- **Flipkart** (India's e-commerce giant) runs workloads on AWS for elasticity during sales events.
- **Netflix** uses AWS to serve millions of global customers.

1.2.2 Private Cloud

Definition

A **private cloud** is cloud infrastructure dedicated **exclusively to a single organization**. It can be:

- Hosted **on-premises** in the organization's own data center.
- Hosted by a third-party provider, but dedicated only to one customer.

Key Features of Private Cloud

- **Single-tenant environment**: Only one organization uses the infrastructure.
- **Customizable**: Organizations can tailor security, networking, and hardware.
- **Enhanced security and compliance**: Useful for industries with strict regulations.

Advantages of Private Cloud

- **High Security & Control**: Organizations decide how data is handled.
- **Customization**: Tailored to meet specific business needs.
- **Compliance**: Meets government and industry regulations (banks, healthcare).

Limitations of Private Cloud

- **Expensive**: Requires heavy upfront investment.
- **Maintenance**: Organization is responsible for updates, scaling, and management.
- **Limited Scalability**: Scaling requires buying new hardware.

Use Cases of Private Cloud

- Banking systems (secure transactions, financial data).
- Healthcare (patient records, HIPAA compliance).
- Government agencies handling classified data.

Example:

- **Reserve Bank of India (RBI)** may use a private cloud to store financial data securely.
- Large hospitals build private clouds to store sensitive medical records.

1.2.3 Hybrid Cloud

Definition

A **hybrid cloud** combines **public cloud and private cloud**, connected by secure networking.

Organizations use:

- **Private cloud** for sensitive workloads.
- **Public cloud** for workloads requiring flexibility and scalability.

Key Features of Hybrid Cloud

- **Flexibility**: Choose where to run workloads.
- **Cost Optimization**: Balance expensive private cloud with cheaper public cloud.
- **Scalability**: Burst workloads into public cloud when private cloud capacity is exceeded.

Advantages of Hybrid Cloud

- **Balanced Approach**: Sensitive data in private, scalable apps in public.
- **Business Continuity**: Backup and disaster recovery across both environments.
- **Gradual Cloud Adoption**: Companies can migrate to public cloud step by step.

Limitations of Hybrid Cloud

- **Complex Management**: Requires skills in both private and public cloud.
- **Integration Challenges**: Networking, data synchronization between environments.
- **Cost Management**: Operating two infrastructures can increase complexity.

Use Cases of Hybrid Cloud

- Enterprises that want to keep financial systems private but run customer-facing apps in public cloud.
- Retailers running analytics on AWS but storing customer data locally.
- Universities storing research data privately but using AWS for global collaboration.

Example:

- **HSBC Bank** → Keeps transaction records in private cloud but uses AWS public cloud for customer apps.
- **Healthcare** → Patient data in private, AI models in AWS for diagnostics.

Comparing Cloud Models

Feature	**Public Cloud**	**Private Cloud**	**Hybrid Cloud**
Ownership	Third-party provider	Single organization	Both public + private combined
Cost	Pay-as-you-go	High upfront investment	Mix of both
Security	Moderate (shared infra)	High (dedicated infra)	Balanced
Scalability	Very High	Limited by hardware	High (via public cloud)
Control	Limited	Full control	Shared control
Use Cases	Startups, SaaS apps	Banking, healthcare, govt.	Enterprises with mixed requirements

1.3 Cloud Service Models: IaaS, PaaS, SaaS

Introduction

Cloud services are delivered in **layers**, depending on how much control the customer wants and how much management the provider handles.

The **three main service models** are:

1. **Infrastructure as a Service (IaaS)**
2. **Platform as a Service (PaaS)**
3. **Software as a Service (SaaS)**

Each provides a different **level of abstraction**.

Analogy:

- **IaaS** = Renting an **empty house** → you add furniture, paint, design.
- **PaaS** = Renting a **furnished flat** → you just bring personal items and start living.
- **SaaS** = Staying in a **hotel** → everything is managed, you just use it.

1.3.1 Infrastructure as a Service (IaaS)

Definition

IaaS provides **basic building blocks of IT**—compute, storage, and networking—delivered as on-demand services.

Customers have full control of:

- Operating System (OS)
- Applications
- Runtime
- Security configurations

But the **underlying hardware** (servers, racks, data center operations) is managed by the cloud provider.

Features of IaaS

- On-demand provisioning of virtual servers.
- Flexible configuration of CPU, memory, and storage.
- Choice of operating systems (Windows/Linux).

- Pay-per-use pricing.
- Highly scalable.

Examples of IaaS

- AWS EC2 (Elastic Compute Cloud)
- AWS S3 (Simple Storage Service)
- Google Compute Engine
- Microsoft Azure Virtual Machines

Use Cases of IaaS

- Hosting websites and applications.
- Creating virtual labs for students.
- Running development and testing environments.
- Big data analysis (Hadoop/Spark clusters).

1.3.2 Platform as a Service (PaaS)

Definition

PaaS provides a **pre-built environment** (infrastructure + runtime + middleware) so developers can focus only on **building and deploying applications**.

You don't worry about OS patches, server maintenance, or runtime installation.

Features of PaaS

- Pre-configured application platforms.
- Built-in tools for deployment and scaling.
- Integrated with databases, monitoring, and logging.
- Supports multiple programming languages.

Examples of PaaS

- AWS Elastic Beanstalk
- Google App Engine
- Microsoft Azure App Service

- Heroku

Use Cases of PaaS

- Rapid web app development.
- Mobile backend services.
- APIs and microservices deployment.
- University projects without managing infrastructure.

1.3.3 Software as a Service (SaaS)

Definition

SaaS delivers **ready-to-use software applications** over the internet.

Users don't install, update, or manage the application. Everything is hosted by the provider.

Features of SaaS

- Access via browser or app.
- Subscription or freemium pricing.
- Automatic updates and patches.
- Multi-tenant architecture (shared infrastructure).

Examples of SaaS

- Gmail, Outlook, Yahoo Mail
- Microsoft Office 365, Google Workspace
- Salesforce (CRM)
- Zoom, Microsoft Teams

Use Cases of SaaS

- Email and collaboration tools.
- Customer Relationship Management (CRM).
- Video conferencing.

- File storage and sharing.

Comparison of Service Models

Aspect	**IaaS**	**PaaS**	**SaaS**
Control	High	Medium	Low
User Manages	OS, Apps, Data	Apps, Data	Only usage
Provider Manages	Hardware, Networking	Infra + Runtime	Everything
Examples	AWS EC2, S3	AWS Elastic Beanstalk, Heroku	Gmail, Office 365, Zoom
Use Case	Hosting apps, dev/test env.	Rapid app deployment	Email, collaboration

Real-World Case Studies

1. **IaaS Example – NASA**
    - Uses AWS EC2 and S3 to handle massive scientific data storage and computing.
2. **PaaS Example – Coca-Cola**
    - Uses Heroku (PaaS) for marketing campaigns, scaling apps during promotions.
3. **SaaS Example – Zoom**
    - Provides ready-to-use video conferencing software to millions of users globally.

TASKS

Task for 1.1

1. **Concept Check**
    - Write a one-page summary: "Why is cloud computing compared to electricity?"
2. **Traditional vs Cloud**
    - Create a comparison table of Traditional IT vs Cloud IT (Cost, Speed, Scalability, Maintenance).
3. **Case Study Task**
    - Research how Netflix or Spotify uses cloud. Write 1 page on why cloud is essential for them.
4. **Research Task**
    - Identify 3 Indian companies that moved to AWS and explain their reasons.

Tasks for 1.2

1. **Research Task**
    - Find **5 companies in India** using Public Cloud, 3 using Private Cloud, and 2 using Hybrid Cloud.
2. **Case Study**
    - *Your college wants to digitize student records.*
        - Which model (Public, Private, Hybrid) would you recommend? Justify in 1 page.

Tasks for 1.3

1. **Classification Task**
    - Take 15 software/tools (e.g., Dropbox, Salesforce, AWS EC2, Heroku) and classify into IaaS, PaaS, SaaS.
2. **Mini Case Study**
    - *A startup wants to quickly launch a food delivery app.*
        - Which model (IaaS, PaaS, SaaS) would you recommend? Why?
3. **Research Task**
    - Identify 3 SaaS applications you use daily and write how they make life easier.