# Cloud Computing

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**What is Cloud Computing?**

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

Instead of owning and maintaining physical data centers or servers, users can access technology services from a cloud provider like **Amazon Web Services (AWS)**, **Microsoft Azure**, or **Google Cloud Platform (GCP)** on demand.

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**Why is Cloud Computing Needed?**

| **Traditional Approach** | **Cloud-Based Approach** |
|---|---|
| High upfront costs (hardware) | Pay-as-you-go model |
| Requires on-site maintenance | Managed by cloud provider |
| Limited scalability | Instantly scalable |
| Disaster recovery is complex | Built-in redundancy and backup |
| Local infrastructure limitations | Global access and high availability |

Thus, cloud computing addresses **cost**, **complexity**, **scalability**, **accessibility**, and **reliability**.

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**Key Aspects of Cloud Computing**

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**1. Service Models**

| Model | Description | Examples |
|---|---|---|
| **IaaS** *(Infrastructure as a Service)* | Provides virtualized hardware resources like servers and storage | AWS EC2, Azure Virtual Machines |
| **PaaS** *(Platform as a Service)* | Offers a platform to develop, run, and manage applications | Google App Engine, Heroku |
| **SaaS** *(Software as a Service)* | Delivers software applications over the internet | Google Workspace, Dropbox |

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**2. Deployment Models**

| Type | Description |
|---|---|
| **Public Cloud** | Services provided over the internet to multiple customers (e.g., AWS) |
| **Private Cloud** | Used exclusively by a single organization, either on-prem or hosted |
| **Hybrid Cloud** | Combines public and private cloud for more flexibility |
| **Community Cloud** | Shared infrastructure for specific community (e.g., banks, universities) |

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**3. Essential Characteristics (as defined by NIST)**

| Feature | Description |
|---|---|
| **On-demand self-service** | Users can provision resources as needed automatically |
| **Broad network access** | Services accessible from anywhere via internet |
| **Resource pooling** | Multiple users share a pool of computing resources |
| **Rapid elasticity** | Resources scale up or down quickly based on demand |
| **Measured service** | Pay only for what you use (like electricity) |

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**Advantages of Cloud Computing**

1. **Cost Efficiency** – No need to invest in hardware or maintenance.
2. **Scalability** – Resources scale with demand (auto-scaling).
3. **Accessibility** – Access services from anywhere with internet.
4. **Disaster Recovery & Backup** – Automated and geographically redundant.
5. **Security** – Built-in security layers, encryption, IAM.
6. **Innovation** – Easy to experiment with AI, ML, big data, and IoT tools.

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**Challenges / Concerns**

1. **Data Security & Privacy**
2. **Vendor Lock-in**
3. **Downtime Risks**
4. **Compliance with Data Regulations (GDPR, HIPAA, etc.)**
5. **Internet Dependency**

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**Popular Cloud Providers**

| Provider | Notable Services |
|---|---|
| **AWS** | EC2, S3, Lambda, SageMaker |
| **Microsoft Azure** | Azure VMs, Cosmos DB, Azure ML |
| **Google Cloud** | Compute Engine, BigQuery, Vertex AI |
| **IBM Cloud** | Cloud Foundry, Watson |
| **Oracle Cloud** | Autonomous DB, OCI |

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**Use Cases of Cloud Computing**

- **Startups** deploying web apps quickly
- **Banks** running high-availability systems
- **Schools** using Google Classroom and online collaboration tools
- **Healthcare** for storing and processing patient data
- **Retail** using cloud for e-commerce platforms
- **Data Scientists** training ML models on powerful cloud GPUs

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**Real-World Example:**

**IoT + Cloud Example:**

- A Raspberry Pi collects sensor data (e.g., temperature).
- It uploads the data to AWS IoT Core.
- A Lambda function processes it.
- Data is stored in DynamoDB and visualized using QuickSight.