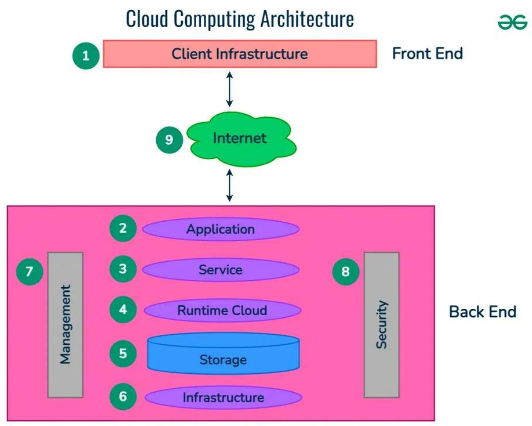
Cloud Computing

Cloud computing refers to delivering computing services—like storage, servers, databases, networking, software, and analytics—over the internet (“the cloud” instead of relying on local servers or personal devices . Essentially, you access and use shared resources as needed, without managing the underlying infrastructure.



Key Characteristics (per NIST/ISO)

1. On- demand self- service: Users provision resources automatically without human intervention.

2. Broad network access: Accessible via standard devices (PCs, mobiles, etc.).

3. Resource pooling: Multiple users share computing resources dynamically (multi-tenancy).

4. Rapid elasticity: Resources can rapidly scale up or down as demand changes.

5. Measured service: Usage is monitored, metered, and billed accordingly.

Service Models

1. **Infrastructure as a Service (IaaS)** – Provides virtual machines, storage, and networks. Offers high flexibility and control over infrastructure

2. **Platform as a Service (PaaS)** – Offers an environment to develop, test, and deploy applications without managing servers (e.g., AWS Elastic Beanstalk)

3. **Software as a Service (SaaS)**– Delivers software over the internet, managed entirely by the provider (e.g., Google Docs)

4. **Serverless / FaaS:** Allows you to run functions or code without provisioning servers—the infrastructure scales automatically

Deployment Models

Public Cloud: Services offered by third-party providers over the internet.

Private Cloud: Dedicated infrastructure for a single organization.

Hybrid/Intercloud:A mix of public and private clouds, enabling flexibility and data portability

How It Works (Architecture)

Front-end: Clients (thin or fat) used to interact with cloud services.

Back-end platforms: Consist of servers, storage systems, and virtualization layers.

Network/delivery: The cloud infrastructure is delivered via the Internet, intranets, or across clouds

Benefits

Cost savings: Pay-as-you-go eliminates upfront hardware costs

Scalability & elasticity: Quickly adjust resources based on demand

Accessibility: Access resources from anywhere with internet

Automatic updates & maintenance: Providers handle patches, security, and upgrades .

Fast deployment: Enables quicker rollout of applications and services .

Drawbacks & Challenges

Security and privacy: Outsourced data storage raises concerns about access, control, and compliance

Downtime/reliability: Dependence on internet connectivity and provider uptime

Cost management: Pay-as-you-go can lead to unexpected costs without careful monitoring

Internet necessity: Without stable connectivity, cloud services are inaccessible

Ecosystem & Trends

Top providers: AWS, Microsoft Azure, and Google Cloud continue to lead the market

Multi-cloud strategies: Many organizations use services from multiple providers to improve resilience, reduce vendor lock-in, and optimize costs .

Summary

Cloud computing transforms how organizations build, store, and manage applications by delivering scalable, flexible, and cost-effective services through shared, internet-based infrastructure. It spans:

Service models: IaaS, PaaS, SaaS, Serverless

Deployment modes: Public, Private, Hybrid

Offers major benefits—but it comes with challenges in security, reliability, and cost oversight.

Cluster and Grid computing

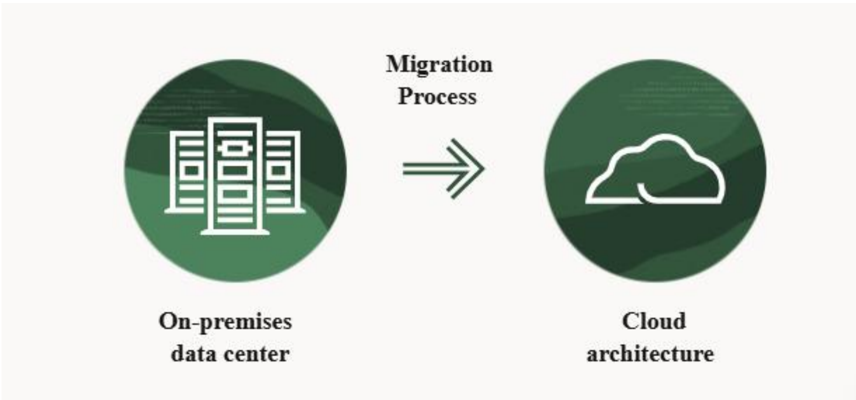
Aspect	Cluster Computing	Grid Computing
Definition	Group of computers working together as a single system, managed centrally	Network of independent, geographically distributed computers working on shared tasks
Computer types	Homogeneous: same hardware & OS across nodes	Heterogeneous: differing hardware, OS, locations
Network & location	Co-located, high- speed LAN interconnect	Geographically distributed, connected via Internet or lower-speed links
Task management	Centralized scheduler; all nodes run same task	Distributed scheduling; tasks split into subtasks and assigned across nodes
Resource sharing	Centrally managed; purpose- dedicated resources	Opportunistic use of idle resources; nodes retain autonomy
Coupling	Tightly coupled, closely integrated nodes	Loosely coupled, flexible coordination
Typical purposes	High-performance computing: simulations, redundancy, load balancing	Large-scale data processing, volunteer scientific tasks
Scalability	Limited to local expansion, costlier as hardware must match	Highly scalable across geographies, flexible inclusion of heterogeneous nodes
Scheduling	Centralized control	Distributed scheduling; nodes autonomous
Real-world use cases	Scientific computing, enterprise databases, fault tolerance	SETI@home, weather forecasting, academic research

Cluster , Grid & Cloud Computing

Aspect	Cluster Computing	Grid Computing	Cloud Computing
Definition	Connected computers in the same location working as one system	Distributed computers sharing resources to work on a task	On-demand computing services via the internet
Location	Same physical location	Different geographic locations	Remote servers accessed online
Ownership	Owned and managed by a single organization	Shared by multiple organizations or users	Managed by third-party providers (e.g., AWS, Azure)
Resource Sharing	Tightly coupled and centrally managed	Loosely coupled; uses idle resources	Virtualized, pooled, and shared among users
Scalability	Limited (fixed nodes)	Moderate (based on participating nodes)	Highly scalable on demand
Usage	HPC, simulations, load balancing	Research, large scientific tasks	Web apps, data storage, business solutions
Cost	High setup cost	Low cost (reuses existing systems)	Pay-as-you-go, cost-efficient
Dependency	Requires high-speed LAN	Requires internet or WAN	Fully internet-based

Migrating to the cloud

A cloud migration strategy is a plan to move digital assets such as applications, databases, and services from on-premises or one cloud



platform to another. This can include full or partial moves and even transfers between clouds.

- ### Benefits

  Scalability: Cloud environments easily handle larger workloads compared to on-premises systems.

  Cost reduction: Operational overhead decreases, enabling focus on innovation.

  Performance improvement: Applications scale and run closer to users to reduce latency.

  Accessibility: Data and services can be accessed from any location.

- ### Challenges

  Lack of strategy: Migrating without a clear plan leads to inefficiency.

  Cost management: Difficulty tracking spend and savings without KPIs.

  Vendor lock-in: Switching providers later can be complex and expensive.

  Security and compliance: Shared responsibility models require careful data protection.

- ### Migration Strategies (7 Rs)

  1- **Rehosting:** Lift and shift existing workloads.

  2- **Replatforming:** Modify to better fit the cloud platform.

  3- **Refactoring:** Re-architect for cloud-native features.

  4- **Repurchasing:** Replace with SaaS alternatives.

  5- **Retiring:** Decommission obsolete systems.

  6- **Retaining:** Keep on-premises for certain workloads.

  7- **Repackaging:** Make minimal changes and move.

- ### Phases of Migration

  1- **Prepare:** Assess current infrastructure, risks, dependencies, and select strategy.

  2- **Plan:** Define objectives, choose provider, map out tools and resources.

  3- **Migrate:** Configure cloud resources, transfer data, test applications.

  4- **Operate:** Monitor, maintain, update security and performance.

  5- **Optimize:** Adjust resources, enhance performance, reduce costs.

Cloud based services

Cloud computing uses the internet to store, manage, and process data on remote servers instead of local devices. Providers like Amazon, Google, and Microsoft charge based on usage.

Cloud Service Models

IaaS (Infrastructure as a Service):

Virtualized computing resources (servers, storage, networking) delivered over the internet. Users manage their own operating systems and applications.

PaaS (Platform as a Service):

Provides a complete platform (development tools, database, middleware) for building, testing, and deploying applications without managing infrastructure.

SaaS (Software as a Service):

Delivers software applications over the internet on a subscription basis. Users access via browser; provider maintains infrastructure.

Serverless / Function-as-a-Service:

Enables running code without managing servers. Infrastructure provisioning and scaling are handled by the provider.

Deployment Models

Public Cloud: Resources delivered over the public internet; shared among multiple users.

Private Cloud: Dedicated infrastructure used by a single organization; may be on-premises or hosted.

Hybrid Cloud: Combines public and private clouds, allowing data and applications to be shared between them.

Community / Multi-cloud: Multiple organizations share cloud infrastructure (community), or an organization uses services from multiple providers (multi-cloud).

Key Architecture Components

Frontend: Client interfaces (web browsers, thin or fat clients) used to interact with cloud services.

Backend: Server hardware, storage, virtualization layer, and networking managed by the provider.

Management & Security: Tools for provisioning, monitoring, load balancing, and enforcing security.

Networking & Database: Underlying infrastructure enabling connectivity (load-balancers, DNS) and data storage (SQL/NoSQL).

Advantages

On-demand self-service and broad network access.

Scalability, cost savings through pay-per-use models.

Automated resource management and reduced operational overhead.

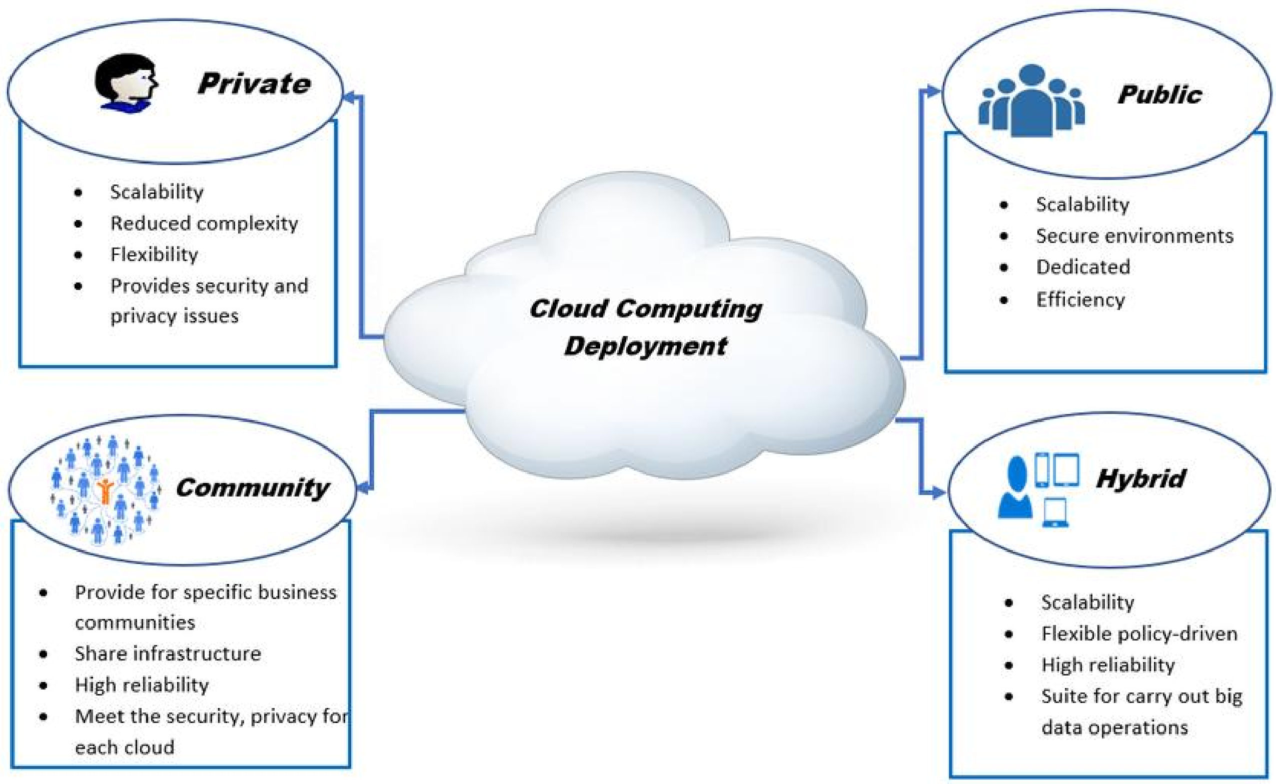
Challenges

Security, privacy, and compliance risks due to shared infrastructure.

Reliance on internet connectivity and potential downtime.

Vendor lock-in and integration complexity across services.

Cloud deployment models



Model	Description	Advantages	Disadvantages
Public Cloud	Infrastructure is owned by a third-party provider and shared among multiple users via the internet	Low cost, no setup or maintenance, scalable, accessible	Less secure, limited customization
Private Cloud	Dedicated infrastructure used by a single organization, managed internally or by a provider	High control, strong data security, supports legacy systems, customizable	Higher cost, less scalable
Hybrid Cloud	Combines public and private clouds, allowing data and apps to move between them	Flexible, cost-effective, secure separation of data	Complex to manage, potential latency
Community Cloud	Shared by several organizations with common concerns (security, compliance, etc.)	Cost-effective, secure, enables collaboration	Limited scalability, less customization
Multi-Cloud	Uses multiple public clouds from different providers	Avoids provider lock-in, improved reliability	Complex integration and management

Data Storage in Clouds

Cloud storage lets you save and access data on remote servers via the internet instead of local devices. Files are uploaded, stored redundantly across multiple data centers, and accessed through APIs or web interfaces.

Delivery Models

Cloud delivery models define how services are provided:
• IaaS offers virtual servers, storage, and networks.
• PaaS gives a managed environment for app development.
• SaaS delivers fully operational applications online.

Cost Matrices and Pricing Models

Cloud pricing includes:
• Tiered pricing with service-level tiers
• Per-unit pricing (e.g., RAM/hour)
• Subscription-based fees
• Spot and reserved instances for different use cases

Service Quality Matrices

Quality is measured by metrics such as uptime, latency, throughput, and SLA compliance. Providers must monitor and maintain these to ensure performance and reliability.

CloudSim

- ✧ CloudSim is a simulation toolkit that models cloud infrastructures like data centers, virtual machines, and scheduling policies to test performance, resource allocation, and energy use in a controlled environment.
- ✧ CloudSim is a popular open-source simulation framework used for modeling and simulating cloud computing environments. It allows researchers and developers to test and evaluate cloud-based systems, applications, and services in a controlled and repeatable manner.

Cloud Management

Cloud management involves orchestration and governance tools to allocate resources, maintain compliance, monitor usage, and enforce security and cost controls across cloud environments.

Advanced Cloud Architectures

Modern architectures include autoscaling, microservices, container orchestration, and serverless designs. They aim for reliability, elasticity, and optimized cloud-native performance.

Inter-Cloud Resource Management

This deals with sharing and migrating resources across multiple cloud environments—public, private, or hybrid—while handling load balancing, cost, and compliance considerations.

Cloud Security Threats and Mechanisms

Main threats include data loss, insecure APIs, account hijacking, misconfigurations, DoS attacks, and vendor lock-in. Mechanisms like encryption, access control, intrusion detection, and governance frameworks help mitigate these.

Disaster Recovery

Cloud disaster recovery involves backing up data and services in separate regions or clouds and restoring them during outages. It includes strategies like cross-region failover, backup-and-restore, warm/cold standby, and active-active deployments.

Open Issues in Cloud Computing

Persistent challenges include vendor lock-in, cost optimization, security vulnerabilities, integration complexity, governance gaps, and skills shortages that require ongoing research and improvement