Advantages of public cloud over private cloud:

Advantages	Public Cloud	Private Cloud
Cost	Generally cost-effective with pay-as-you-go models.	Can be more expensive due to infrastructure ownership.
Scalability	Highly scalable, on-demand resources.	Scalability might be limited by on-premises hardware.
Flexibility	Offers a wide range of services and resources.	Limited flexibility, especially in resource types.
Ease of Implementation	Quick setup and minimal hardware management.	Requires more time for implementation and management.
Global Reach	Accessible from anywhere with an internet connection.	Limited by the physical location of private data centers.
Resource Management	Outsourced maintenance and updates.	Full control over resource management and configurations.
Redundancy and Reliability	Built-in redundancy and multiple data centers.	Relies on the infrastructure set up by the organization.
Security Updates	Automatic updates managed by the cloud provider.	Requires proactive management of security updates.
Disaster Recovery	Typically has robust disaster recovery options.	Relies on the organization's own disaster recovery plans.
Focus on Core Competencies	Allows organizations to focus on their core business.	Requires more resources for IT infrastructure management.

Advantages of private cloud over public clou...

Advantages	Private Cloud	Public Cloud
Control and Customization	Full control over infrastructure and configurations.	Limited customization due to shared infrastructure.
Security and Compliance	Enhanced security and compliance adherence.	Shared environment may raise security and compliance concerns.
Performance and Predictability	Dedicated resources for consistent performance.	Performance may be influenced by shared resources.
Regulatory Requirements	Ideal for industries with strict regulatory requirements.	May face challenges with certain industry regulations.
Data Residency and Privacy	Provides control over data location and privacy.	Data may reside in different regions, affecting privacy.
Custom Applications	Suited for organizations with unique application needs.	Standardized services may not fit specialized requirements.
Cost Predictability	Predictable costs without unexpected charges.	Variable costs based on usage, potentially less predictable.
Network Performance	Dedicated network resources for improved performance.	Network performance may be influenced by shared infrastructure.
Legacy System Integration	Easier integration with existing legacy systems.	May require additional effort for integration with legacy systems.
Resource Allocation	More control over resource allocation and optimization.	Limited control over underlying infrastructure.

Terms use in Cloud

- **cloud subscriber or subscriber:** a person or organization that is a customer of a cloud;
- **client:** a machine or software application that accesses a cloud over a network connection, perhaps on behalf of a subscriber.
- **cloud provider or provider:** an organization that provides cloud services.

Historical Development

- 1950s when large-scale **mainframes** were made available to schools and corporations.
- 1970s, IBM released an **OS called VM** that allowed
  - admin on their System/370 mainframe systems to have multiple virtual systems, or —Virtual Machines (VMs) on a single physical node.
- 1990s, telecommunications companies started offering **virtualized private network**
- Cloud computing is realized through the advent of the Internet.

Historical Development (Cont...)

- 1960's John McCarthy noted:
  - computation may someday be organized as a **public utility**.
  - **McCarthy**'s premonition foresaw the advent of **grid computing** in the early 1990's.
- One of the first companies to embrace the cloud was Salesforce.com
  - CRM services via the Internet
- Amazon Web Service (2002), Google Docs (2006), and Amazon's Elastic Compute Cloud (EC2).
- In 2007 Google and IBM partnered with higher education to introduce cloud computing to academia.

Historical Development (Cont...)

- Microsoft entered the arena with the introduction of Windows Azure in November 2009

History of cloud computing

- **1960s - 1970s:** Early Concepts
  - The concept of time-sharing emerged, allowing multiple users to access a single computer simultaneously.
  - ARPANET laid the foundation for the development of computer networks.
- **1990s:** Emergence of Internet
  - The internet's commercialization led to the growth of web-based applications.
  - Salesforce introduced the Software as a Service (SaaS) model with its customer relationship management (CRM) platform.
- **Late 1990s - Early 2000s:** Grid and Utility Computing
  - Grid computing projects like SETI@home distributed computation to volunteers' computers.
  - Amazon launched Amazon Web Services (AWS), a pioneer in utility computing.
- **Mid-2000s:** The Term "Cloud Computing"
  - The term "cloud computing" gained popularity, referring to the abstraction of computing resources over the internet.
- **2006:** Amazon Web Services (AWS)
  - AWS launched Elastic Compute Cloud (EC2) and Simple Storage Service (S3), revolutionizing the provisioning of computing resources.
- **2007:** Google's Entry
  - Google introduced Google Apps, offering online productivity tools and email services.

History of cloud computing

- **2008:** OpenStack Foundation
  - OpenStack, an open-source cloud computing platform, was founded, fostering interoperability and innovation.
- **2010s:** Rapid Expansion and Adoption
  - Cloud computing adoption accelerated across industries, enabling scalable and cost-effective solutions.
  - Microsoft Azure, Google Cloud Platform, and other major cloud providers emerged.
- **2012:** Hybrid Clouds
  - The concept of hybrid clouds gained traction, allowing organizations to combine private and public cloud environments.
- **2015:** Serverless Computing
  - Serverless architecture emerged, abstracting infrastructure management and enabling event-driven computing.
- **2020s:** Edge and Multi-Cloud
  - Edge computing gained prominence, focusing on processing data closer to the data source.
  - Multi-cloud strategies emerged to avoid vendor lock-in and enhance redundancy.
- **Ongoing:** Continued Innovation
  - Cloud computing continues to evolve with advancements in artificial intelligence, machine learning, and quantum computing.

Client-server architecture v/s cloud computing architecture

Aspect	Client-Server Architecture	Cloud Computing Architecture
Definition	A network architecture where clients request services from a centralized server.	A distributed model providing on-demand resources and services over the internet.
Resource Ownership	Server resources are owned and managed by the organization.	Cloud resources are owned and managed by a cloud service provider.
Scalability	Scaling requires adding more server hardware, often resulting in more cost and complexity.	Easily scalable by provisioning or deprovisioning resources as needed.
Resource Sharing	Limited resource sharing between clients connected to the same server.	Extensive resource sharing across multiple users, organizations, and applications.
Latency	Latency depends on the distance between the client and the server.	Latency varies based on the proximity of the cloud data center and network conditions.
Infrastructure Management	Organizations manage their own infrastructure and server maintenance.	Cloud providers handle infrastructure management, updates, and maintenance.
Cost Model	Organizations incur costs for server maintenance, hardware, and software.	Pay-as-you-go model, with costs based on resource consumption and usage.
Accessibility	Accessibility depends on network connectivity to the specific server.	Accessible from anywhere with internet connectivity, providing high availability.
Data Storage	Data is primarily stored on the server, potentially leading to data concentration.	Data storage is distributed across multiple data centers, improving redundancy and resilience.
Security	Organizations are responsible for server security and data protection.	Cloud providers implement security measures, but data security is a shared responsibility.
Application Deployment	Application deployment and updates are managed individually on each server.	Applications can be easily deployed, updated, and managed centrally through the cloud platform.
Use Cases	Common in traditional applications with a centralized data or service structure.	Versatile, suitable for a wide range of applications, from simple web apps to complex analytics.

History of cloud computing

- **1960s - 1970s:** Early Concepts
  - The concept of time-sharing emerged, allowing multiple users to access a single computer simultaneously.
  - ARPANET laid the foundation for the development of computer networks.
- **1990s:** Emergence of Internet
  - The internet's commercialization led to the growth of web-based applications.
  - Salesforce introduced the Software as a Service (SaaS) model with its customer relationship management (CRM) platform.
- **Late 1990s - Early 2000s:** Grid and Utility Computing
  - Grid computing projects like SETI@home distributed computation to volunteers' computers.
  - Amazon launched Amazon Web Services (AWS), a pioneer in utility computing.
- **Mid-2000s:** The Term "Cloud Computing"
  - The term "cloud computing" gained popularity, referring to the abstraction of computing resources over the internet.
- **2006:** Amazon Web Services (AWS)
  - AWS launched Elastic Compute Cloud (EC2) and Simple Storage Service (S3), revolutionizing the provisioning of computing resources.
- **2007:** Google's Entry
  - Google introduced Google Apps, offering online productivity tools and email services.

- **2008:** OpenStack Foundation
  - OpenStack, an open-source cloud computing platform, was founded, fostering interoperability and innovation.
- **2010s:** Rapid Expansion and Adoption
  - Cloud computing adoption accelerated across industries, enabling scalable and cost-effective solutions.
  - Microsoft Azure, Google Cloud Platform, and other major cloud providers emerged.
- **2012:** Hybrid Clouds
  - The concept of hybrid clouds gained traction, allowing organizations to combine private and public cloud environments.
- **2015:** Serverless Computing
  - Serverless architecture emerged, abstracting infrastructure management and enabling event-driven computing.
- **2020s:** Edge and Multi-Cloud
  - Edge computing gained prominence, focusing on processing data closer to the data source.
  - Multi-cloud strategies emerged to avoid vendor lock-in and enhance redundancy.
- **Ongoing:** Continued Innovation
  - Cloud computing continues to evolve with advancements in artificial intelligence, machine learning, and quantum computing.

Historical Development (Cont...)

- five core technologies that played an important role in the realization of Cloud computing:
  - distributed systems,
  - virtualization,
  - Web 2.0,
  - service-oriented computing
  - utility computing.

Distributed Systems

- Collection of independent computers
- Appears to its users as a single coherent system."

- Clouds are essentially large distributed computing facilities that make available their services to third parties on demand.
- Purpose of distributed systems
  - to share resources.
  - to utilize them better.
  - true in the case of Cloud computing.
- Properties: heterogeneity, openness, scalability, transparency, concurrency, continuous availability, and independent failures

Historical Development/Distributed Systems (Cont...)

- Three major milestones have led to Cloud computing:
  - mainframe computing
  - cluster computing
  - Grid computing.

Clarification

(Cluster, Grid and Cloud)

- Computer cluster
  - ✓ Is a group of linked computers,
  - ✓ Working together closely thus in many respects forming a single computer.
  - ✓ The components of a cluster are connected to each other through fast local area networks
- Types of Cluster
  - High Availability Cluster
  - Load Balancing Cluster
  - HPC Cluster

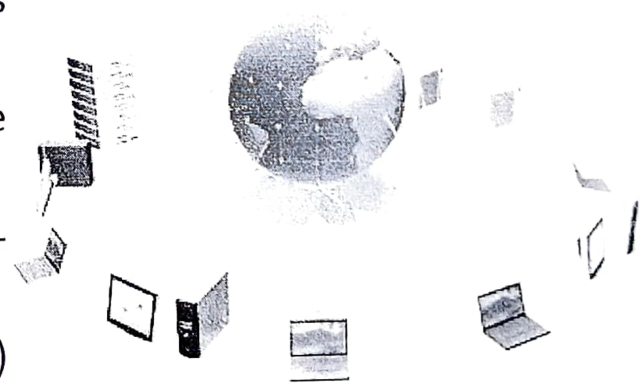
Comparison between Three

	Cluster	Grid	Cloud
On demand Self Service	NO	NO	YES
Broad Network Access	YES	YES	YES
Resource Pooling	Yes	Yes	Yes
Rapid Elasticity	NO	NO	YES
Measured Service	NO	YES	YES

Clarification

(Cluster, Grid and Cloud)

- Grid computing is a term referring to the **combination of** computer **resources** from **multiple** administrative domains to reach a **common goal**.
- Coordinates resources that are not subject to centralized control
- Uses standard, open, general-purpose protocols and interfaces
- Delivers nontrivial (importent) qualities of service



Vision of Cloud Computing

→ Cloud computing provides the facility to provision virtual hardware, runtime environment and services to a person having money.

→ These all things can be used as long as they are needed by the user, there is no requirement for the upfront commitment.

→ The whole collection of computing system is transformed into a collection of utilities, which can be provisioned and composed together to deploy systems in hours rather than days, with no maintenance costs.

→ The long term vision of a cloud computing is that IT services are traded as utilities in an open market without technological and legal barriers.

Vision of Cloud Computing

→ In the near future we can imagine that it will be possible to find the solution that matches with our requirements by simply entering our request in a global digital market that trades with cloud computing services.

→ The existence of such market will enable the automation of the discovery process and its integration into its existing software systems.

→ Due to the existence of a global platform for trading cloud services will also help service providers to potentially increase their revenue.

→ A cloud provider can also become a consumer of a competitor service in order to fulfill its promises to customers.

Cloud-Computing Reference Model

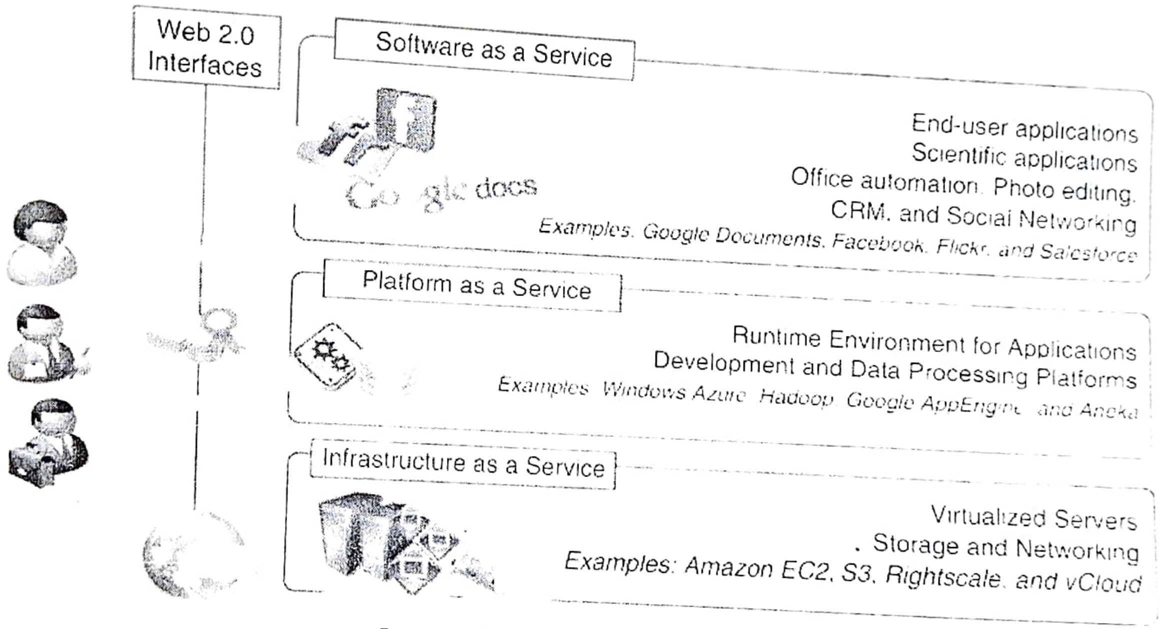


Fig. 1.5. Cloud-Computing Reference Model

NIST cloud computing reference architecture

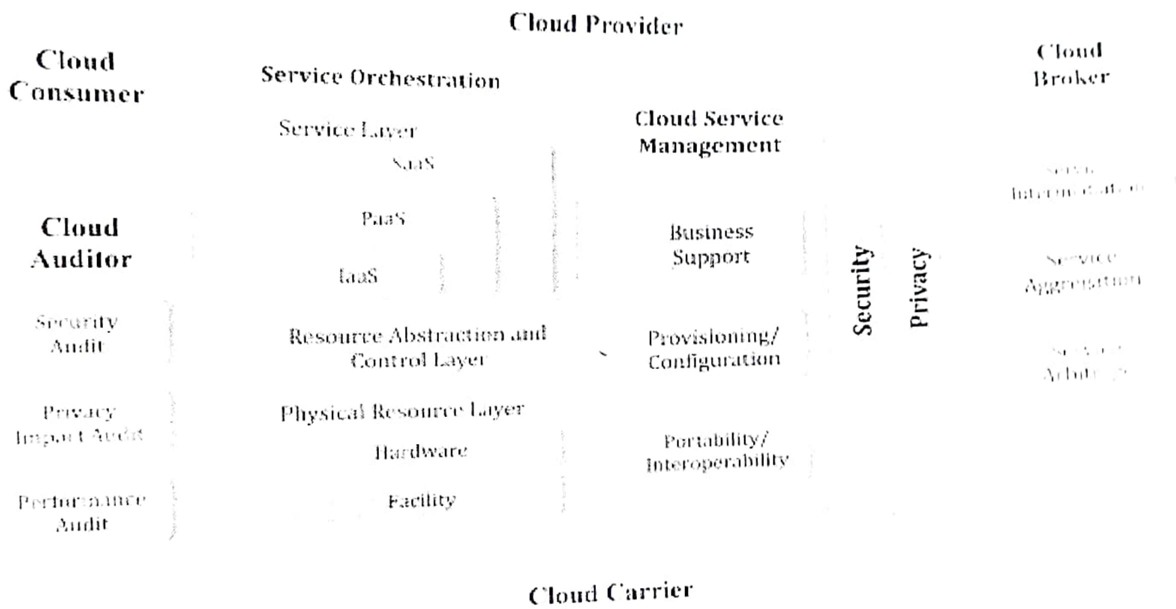


Figure 1: The Conceptual Reference Model

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

Table 1: Actors in Cloud Computing

Cloud v/s Grid computing

Aspect	Cloud Computing	Grid Computing
Resource Ownership	Owned and managed by service providers	Shared among multiple organizations
Service Models	IaaS, PaaS, SaaS	Focuses on resource sharing
Elasticity/Scalability	Dynamic scaling and elasticity	May offer scaling but not as dynamic
Cost Model	Pay-as-you-go	Shared costs among participating entities
Deployment Models	Public, private, hybrid, community cloud	Primarily used within organizations or collaborations
Resource Management	Managed by cloud provider	May require manual coordination
Interoperability	Standardized APIs and protocols	May involve diverse resources and technologies
Commercial vs. Research	Commercially driven	Often research-focused applications

Cluster computing

- It refers to the use of multiple interconnected computers or servers, known as nodes, that work together as a single, unified system to solve complex computational tasks.
- These nodes are typically located in close physical proximity and are connected via a local area network (LAN) or a high-speed interconnect.

Characteristics of cluster computing

1. **Parallel Processing:** Cluster computing allows multiple tasks or parts of a task to be executed simultaneously across different nodes, resulting in faster processing and reduced execution time.
2. **Resource Sharing:** Nodes in a cluster share resources such as processing power, memory, storage, and network bandwidth, enabling efficient utilization of hardware.
3. **High Performance:** Clusters are designed to deliver high computational performance by aggregating the processing capabilities of individual nodes.
4. **Scalability:** Clusters can be easily scaled by adding or removing nodes, allowing organizations to adapt to changing computational demands.
5. **Fault Tolerance:** Clusters often incorporate redundancy and fault-tolerant mechanisms to ensure system reliability and availability.
6. **Distributed Applications:** Cluster computing is commonly used for scientific simulations, data analysis, simulations, and other compute-intensive applications.

Cluster computing classification

1. **High-Performance Computing (HPC) Clusters:** These clusters are designed to deliver maximum computational power for tasks that require massive processing capabilities, such as scientific research, weather forecasting, and complex simulations.
2. **Load-Balanced Clusters:** These clusters distribute incoming tasks or workloads evenly across nodes to optimize resource utilization and improve overall system efficiency.

Distributed computing

- Distributed computing refers to the use of multiple interconnected computers or devices, often geographically dispersed, to work together as a unified system to perform a task or solve a problem.
- In distributed computing, the processing and data storage are not centralized in a single machine, but are distributed across the network of interconnected devices.

Characteristics of distributed computing

1. **Parallel Processing:** Distributed computing allows different parts of a task to be processed simultaneously on different devices, leading to faster execution and improved performance.
2. **Resource Sharing:** Devices in a distributed system share resources such as processing power, memory, storage, and data, allowing for efficient utilization of available hardware.
3. **Scalability:** Distributed systems can be easily scaled by adding more devices to the network, accommodating larger workloads or increased demand.
4. **Fault Tolerance:** Distributed computing often includes redundancy and fault-tolerant mechanisms to ensure system reliability even if some devices fail.
5. **Decentralization:** Unlike centralized computing, where all processing happens on a single machine, distributed computing spreads the workload across multiple devices.
6. **Collaborative Processing:** Distributed computing is suitable for applications that require collaboration and coordination among different devices to achieve a common goal.

Grid computing

Grid computing

- Grid computing is a distributed computing paradigm that leverages the collective power of interconnected and geographically dispersed computers, servers, storage, and other resources to solve complex problems, perform intensive computations, and execute large-scale tasks.
- It involves creating a virtual computing environment where diverse resources from different domains and organizations are shared and coordinated through middleware and standardized protocols to achieve enhanced computational capabilities, collaboration, and resource utilization.