# Introduction to Cloud Computing

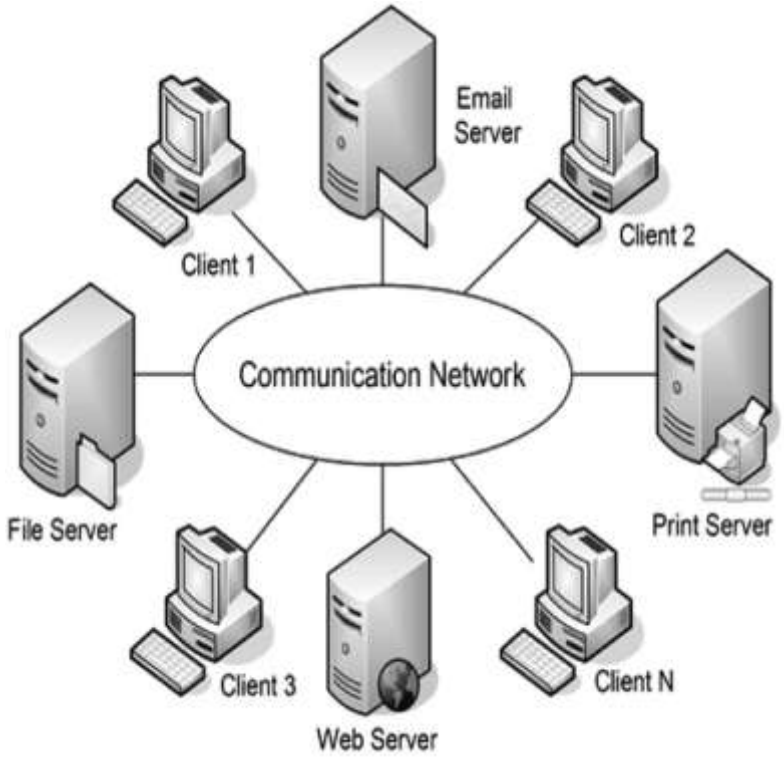
Trends in computing - Grid Computing, Cluster Computing, Distributed Computing, Utility Computing, Cloud Computing Defining a Cloud, Vision of Cloud, Cloud Computing Reference Model, Characteristics and benefits, Challenges of Cloud, Distributed computing principles, Business drivers for cloud adoption

# Computing

- any goal-oriented activity requiring, benefiting from, or creating computing machinery.
- includes the study and experimentation of algorithmic processes, and development of both hardware and software.
- Computing has scientific, engineering, mathematical, technological and social aspects.
- They are used in homes, business, educational institutions, research organizations, medical field, government offices, entertainment, etc.

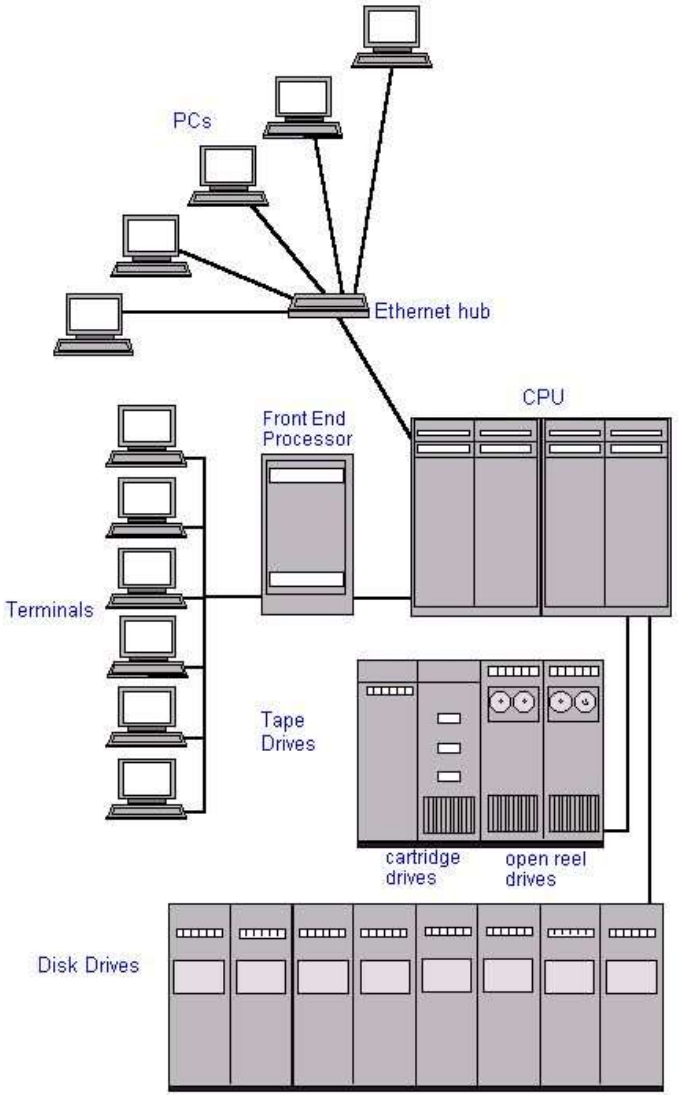
# Distributed computing

- It is a composition of multiple independent systems but serve as a single entity to the users.
- Share resources and also use them effectively and efficiently.
- scalability, concurrency, continuous availability, heterogeneity, and independence in failures.
- main problem - used for same geographical location.
- **mobile systems, social media networks, weather monitoring systems, and e-commerce systems**



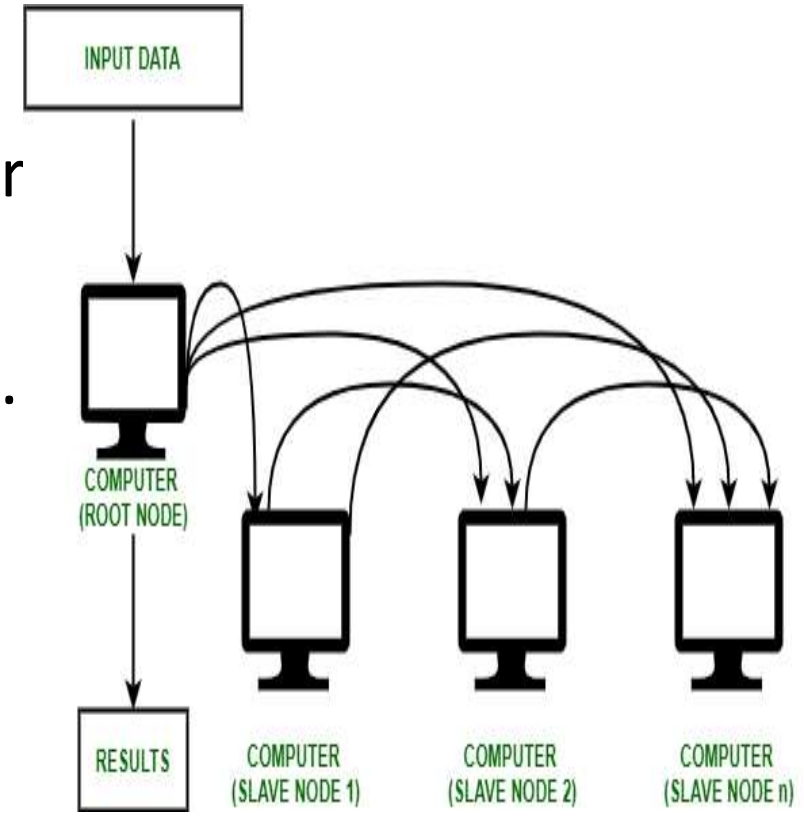
# Mainframe computing

- Highly powerful and reliable computing machines.
- Responsible for handling large data such as massive input-output operations.
- These systems have almost no downtime with high fault tolerance., these increased the processing capabilities of the system.
- Very expensive.
- To reduce this cost, cluster computing came as an alternative to mainframe technology.



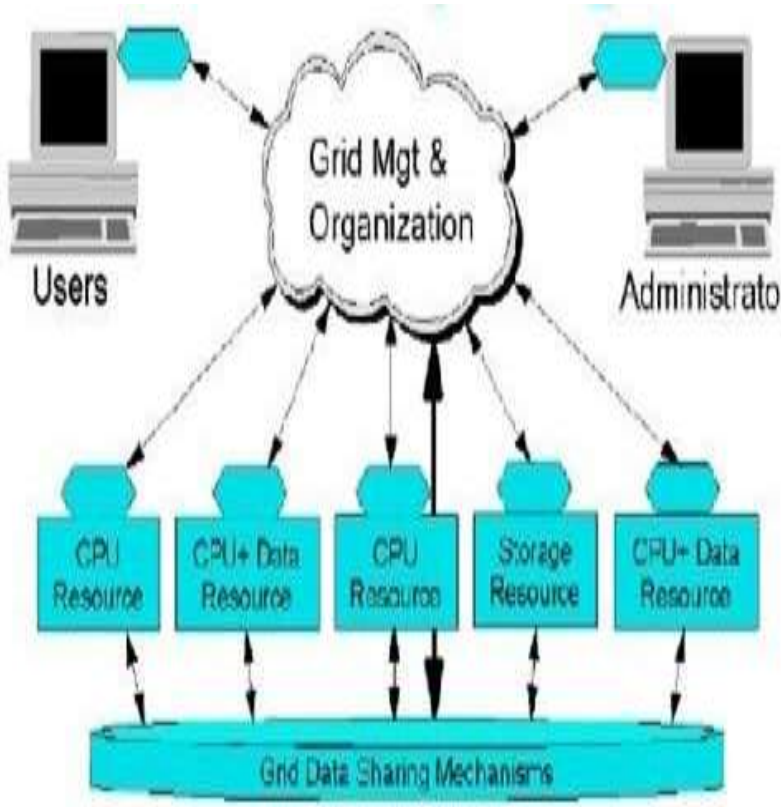
# Cluster computing

- Each machine in the cluster was connected to each other by a network with high bandwidth.
- These were way cheaper than those mainframe systems.
- These were equally capable of high computations.
- Also, new nodes could easily be added to the cluster if it was required.



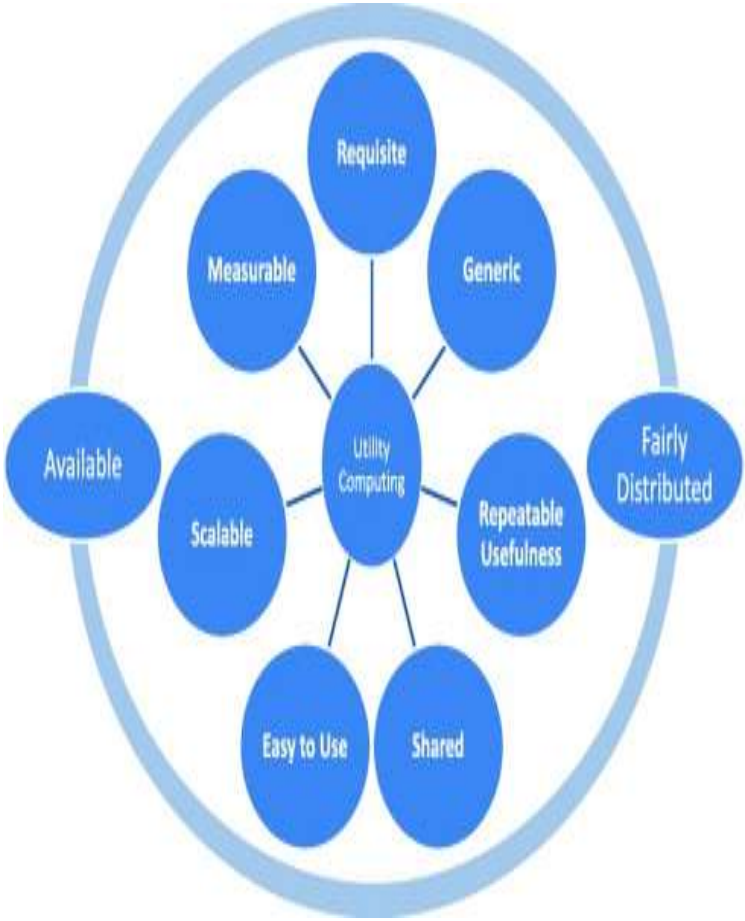
# Grid Computing

- It is a computing infrastructure that combines computer resources spread over different geographical locations t achieve a common goal.
- All unused resources on multiple computers are pooled together and made available for a single task.
- Organizations use grid computing to perform large tasks or solve complex problems that are difficult to do on a single computer.
- Example: weather modeling



# Utility computing

- It is a service provisioning model that offers computing resources such as hardware, software, and network bandwidth to clients as and when they require them on an on-demand basis.
- The service provider charges only as per the consumption of the services, rather than a fixed charge or a flat rate.



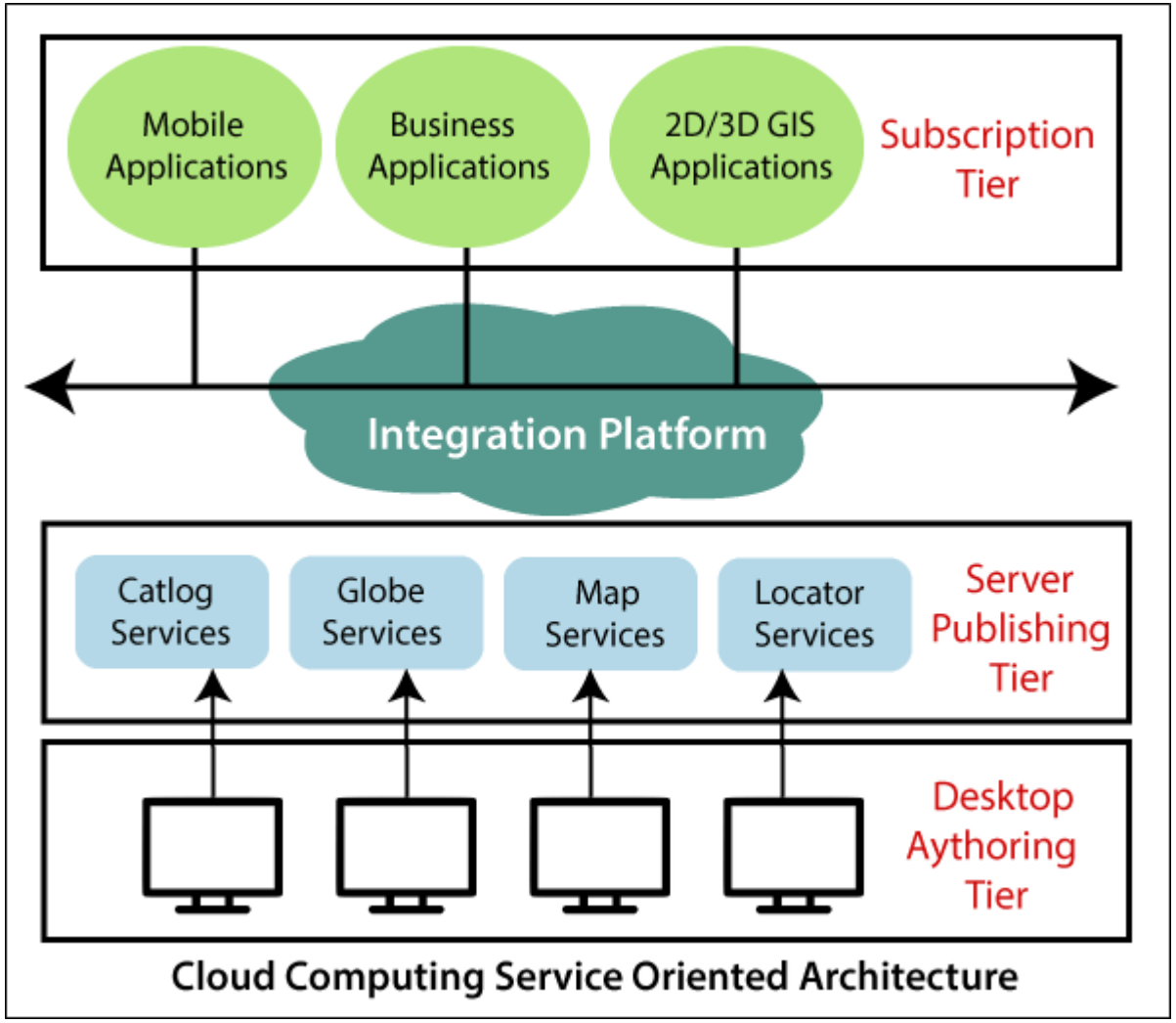
| Grid Computing | Utility Computing |
| --- | --- |
| It is a process architecture that combines **different computing resources from multiple locations to achieve desired and common goal**. | It is process architecture that **provide on-demand computing resources and infrastructure on basis of pay per use method**. |
| It makes better **use of existing resources, address rapid fluctuations in customer demands, improve computational capabilities, provide flexibility, etc.** | It simply reduces IT costs, **easier to manage, provide greater flexibility, compatibility, provide more convenience, etc**. |
| It mainly focuses on **sharing computing resources.** | It mainly focuses on **acquiring computing resources.** |
| It is of three types i.e., computational grid, data grid, and collaborative grid. | It is of two type i.e., Internal and external utility. |
| It is used in **ATMs, back-end infrastructures, marketing research, etc.** | It is used in large organizations such as A**mazon, Google, etc., where they establish their own utility services for computing storage and applications.** |

# Web 2.0

- Web 2.0 also **gave rise to web apps, self-publishing platforms like WordPress, as well as social media sites**.
- A Web 2.0 website **allows users to interact and collaborate with each other through social media dialogue as creators of user-generated content in a virtual community**.
- E.g. Wikipedia, Facebook, Twitter, and various blogs.

# Service-Oriented Architecture (SOA)

- It supports low-cost, flexible, and evolvable applications.
- These were Quality of Service (QoS) which also includes the SLA (Service Level Agreement) and Software as a Service (SaaS).

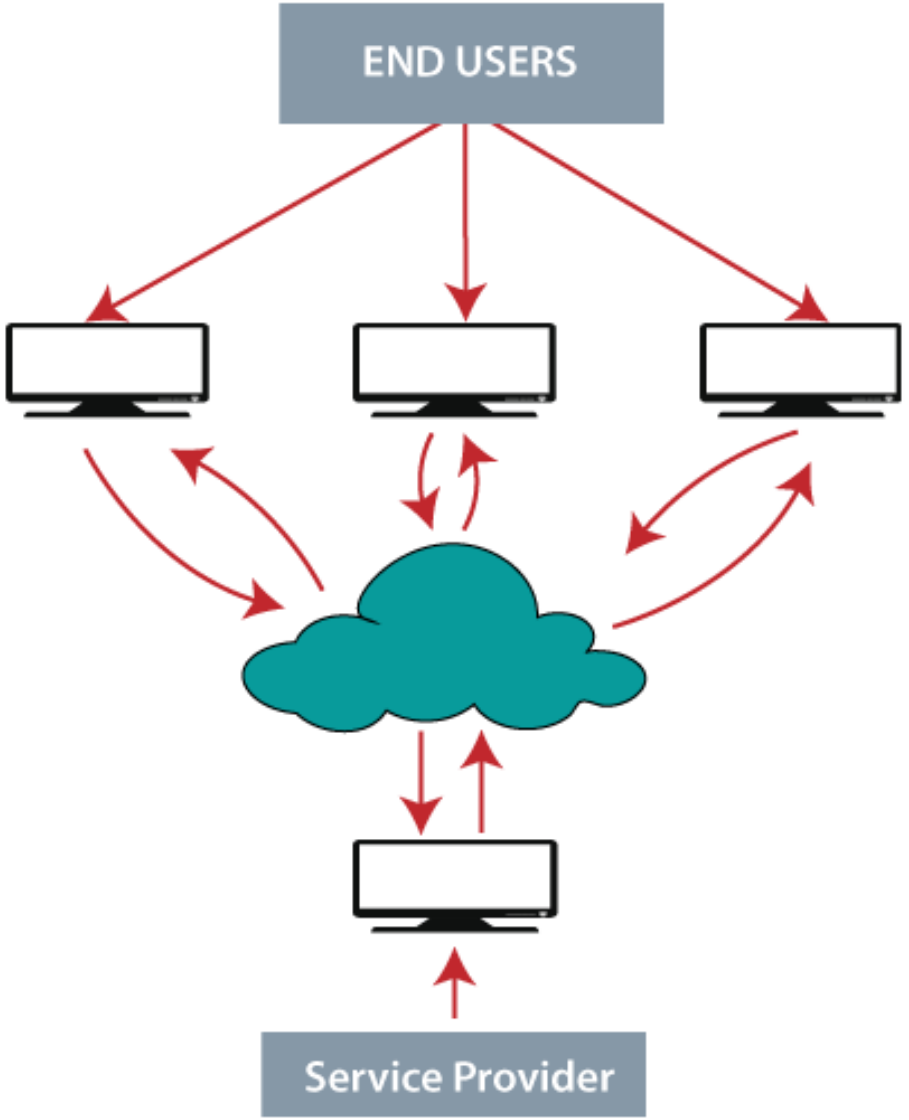


# Utility Computing

- It is a computing model that defines service provisioning techniques for services such as compute services along with other major services such as storage, infrastructure, etc which are provisioned on a pay-per-use basis.
- Utility computing is **a model in which computing resources are provided to the customer based on specific demand**. The service provider charges exactly for the services provided, instead of a flat rate.
- Examples of these IT services are **storage, computing power, and applications**.

# Why named Cloud?

- The term **Cloud** refers to a **Network** or **Internet.**
- In other words, we can say that Cloud is something, which is present at remote location.



# Features of Cloud Computing

- The features of cloud computing are:
  1. **On-demand self-services:-**
  2. **Broad network access:**-
  3. **Resource pooling:-**
  4. **Rapid Elasticity:**-
  5. **Multi-sharing:-**
  6. **Maintenance:**-

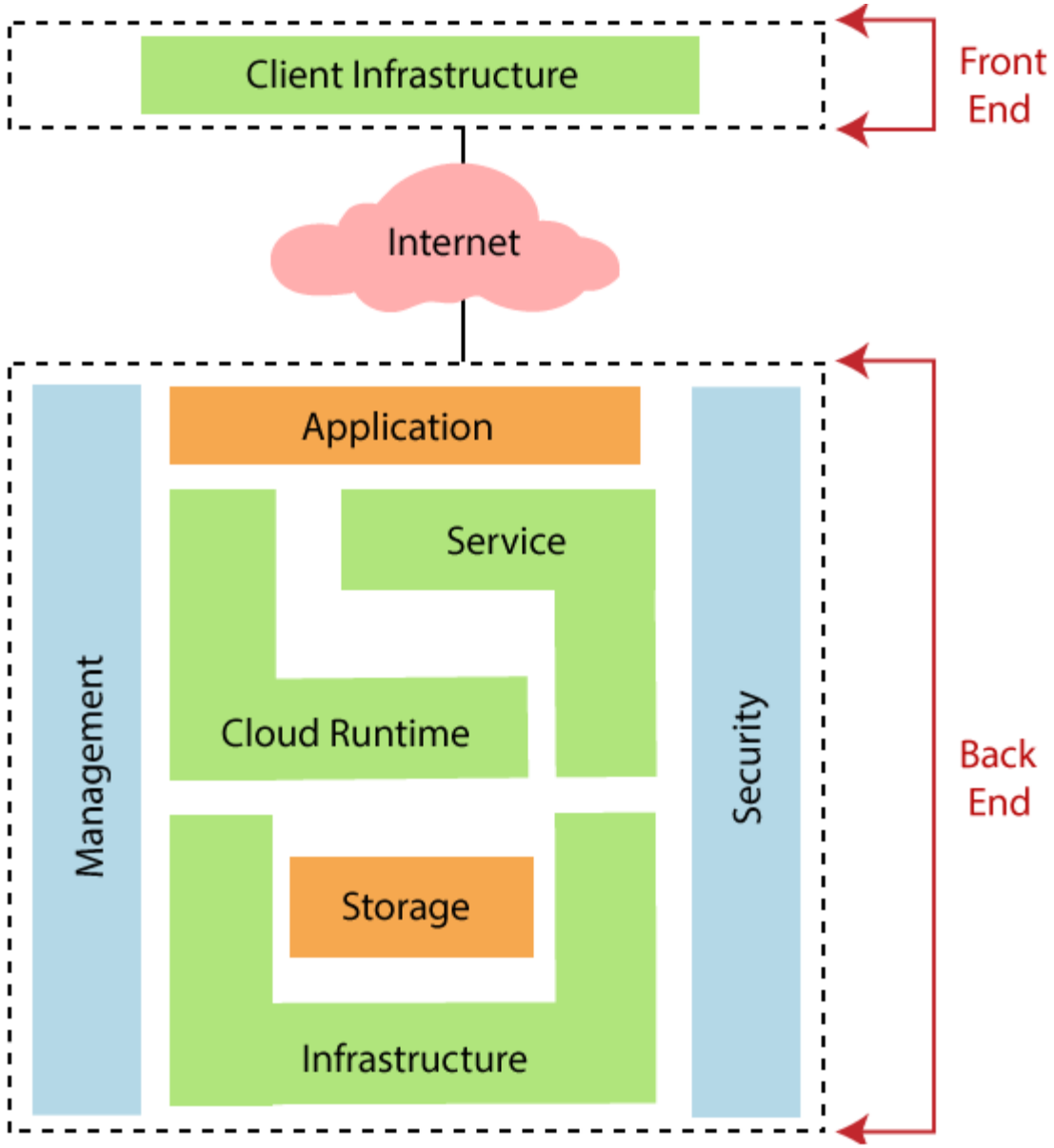
# Benefits of Cloud Computing

1. **Wide applications:**
2. **Reduced upfront licensing cost:**
3. **Lower cost of hardware:**
4. **Allows working from any computer anywhere:**
5. **Saves money:**
6. **Drives sales:**

# Architecture of Cloud Computing

- **he architecture of cloud computing is broadly divided into two parts.**

1. Front end
2. Back end



# Components of Cloud Computing Architecture

1. **Client infrastructure:**
2. **Application:**
3. **Service:**
4. **Runtime cloud:**
5. **Storage:**
6. **Infrastructure:**
7. **Management:**
8. **Security:**
9. **Internet:**

# Cloud Computing

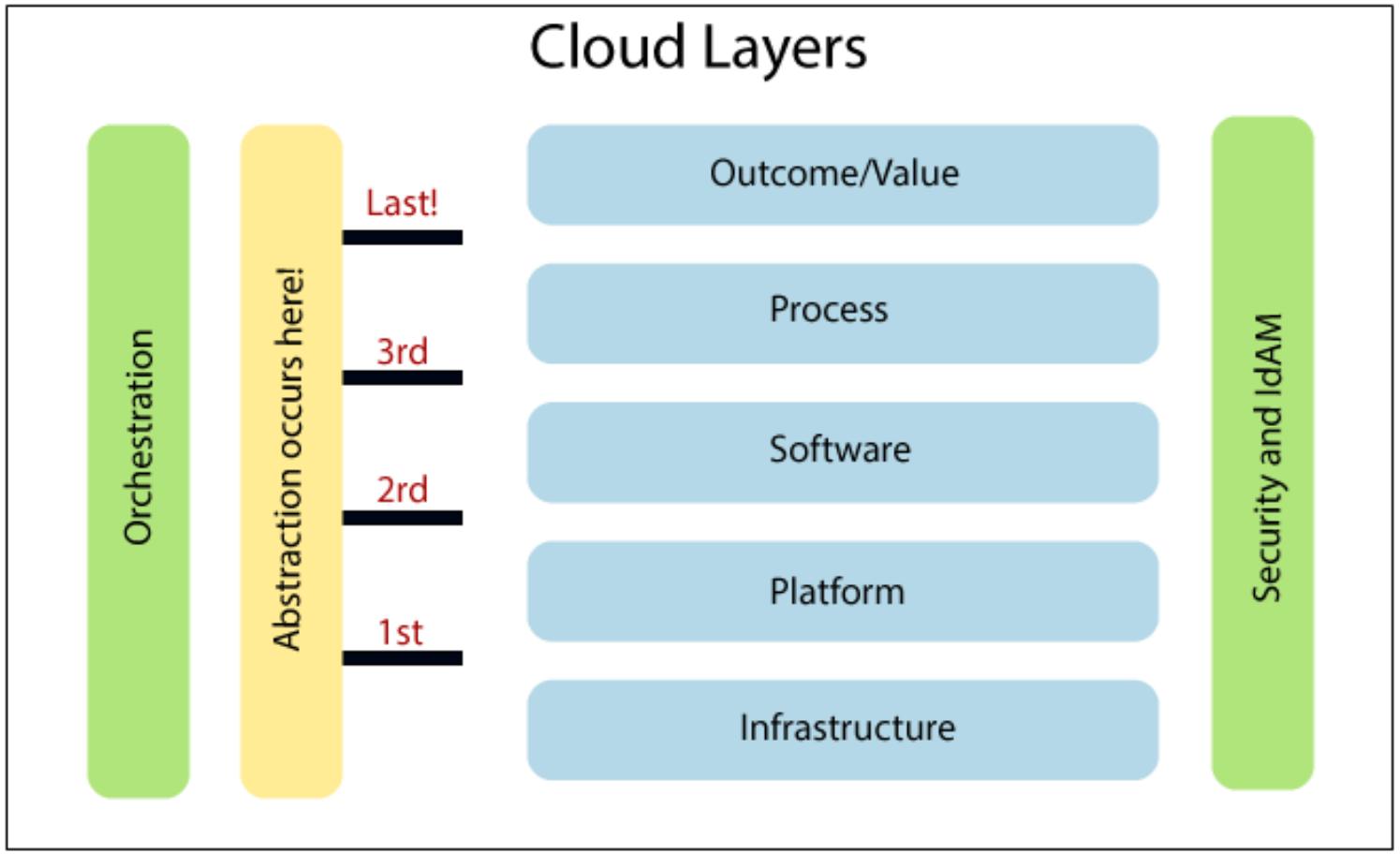
- Cloud computing is the delivery of different services through the Internet. These resources include tools and applications like data storage, servers, databases, networking, and software.
- Cloud computing takes all the heavy lifting involved in crunching and processing data away from the device you carry around or sit and work at. It also moves all of that work to huge computer clusters far away in cyberspace.
- The Internet becomes the cloud, and voilà—your data, work, and applications are available from any device with which you can connect to the Internet, anywhere in the world.

# Top benefits of cloud computing

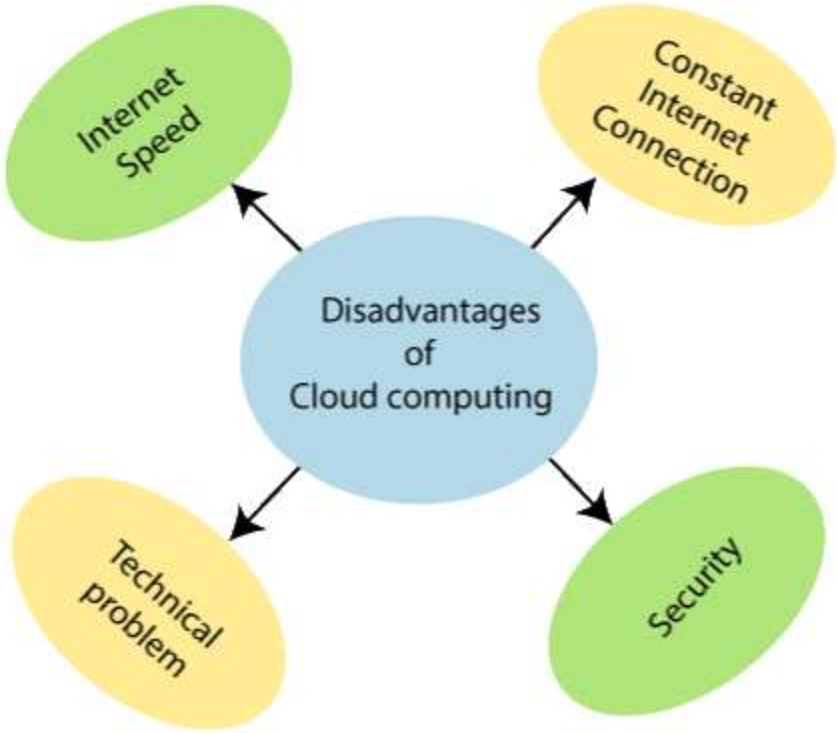
- Cost
- Speed
- Global scale: The benefits of cloud computing services include the ability to scale elastically. In cloud speak, that means delivering the right amount of IT resources—for example, more or less computing power, storage, bandwidth—right when they're needed, and from the right geographic location.
- Productivity: Onsite datacenters typically require a lot of "racking and stacking"—hardware setup, software patching, and other time-consuming IT management chores. Cloud computing removes the need for many of these tasks, so IT teams can spend time on achieving more important business goals.
- Performance: The biggest cloud computing services run on a worldwide network of secure datacenters, which are regularly upgraded to the latest generation of fast and efficient computing hardware. This offers several benefits over a single corporate datacenter, including reduced network latency for applications and greater economies of scale.
- Reliability: Cloud computing makes data backup, disaster recovery, and business continuity easier and less expensive because data can be mirrored at multiple redundant sites on the cloud provider's network.
- Security: Many cloud providers offer a broad set of policies, technologies, and controls that strengthen your security posture overall, helping protect your data, apps, and infrastructure from potential threats.

| Cloud Computing | Grid Computing |
| --- | --- |
| Cloud Computing follows client-server computing architecture. | Grid computing follows a distributed computing architecture. |
| Scalability is high. | Scalability is normal. |
| Cloud Computing is more flexible than grid computing. | Grid Computing is less flexible than cloud computing. |
| Cloud operates as a centralized management system. | Grid operates as a decentralized management system. |
| In cloud computing, cloud servers are owned by infrastructure providers. | In Grid computing, grids are owned and managed by the organization. |
| Cloud computing uses services like Iaas, PaaS, and SaaS. | Grid computing uses systems like distributed computing, distributed information, and distributed pervasive. |
| Cloud Computing is Service-oriented. | Grid Computing is Application-oriented. |
| It is accessible through standard web protocols. | It is accessible through grid middleware. |

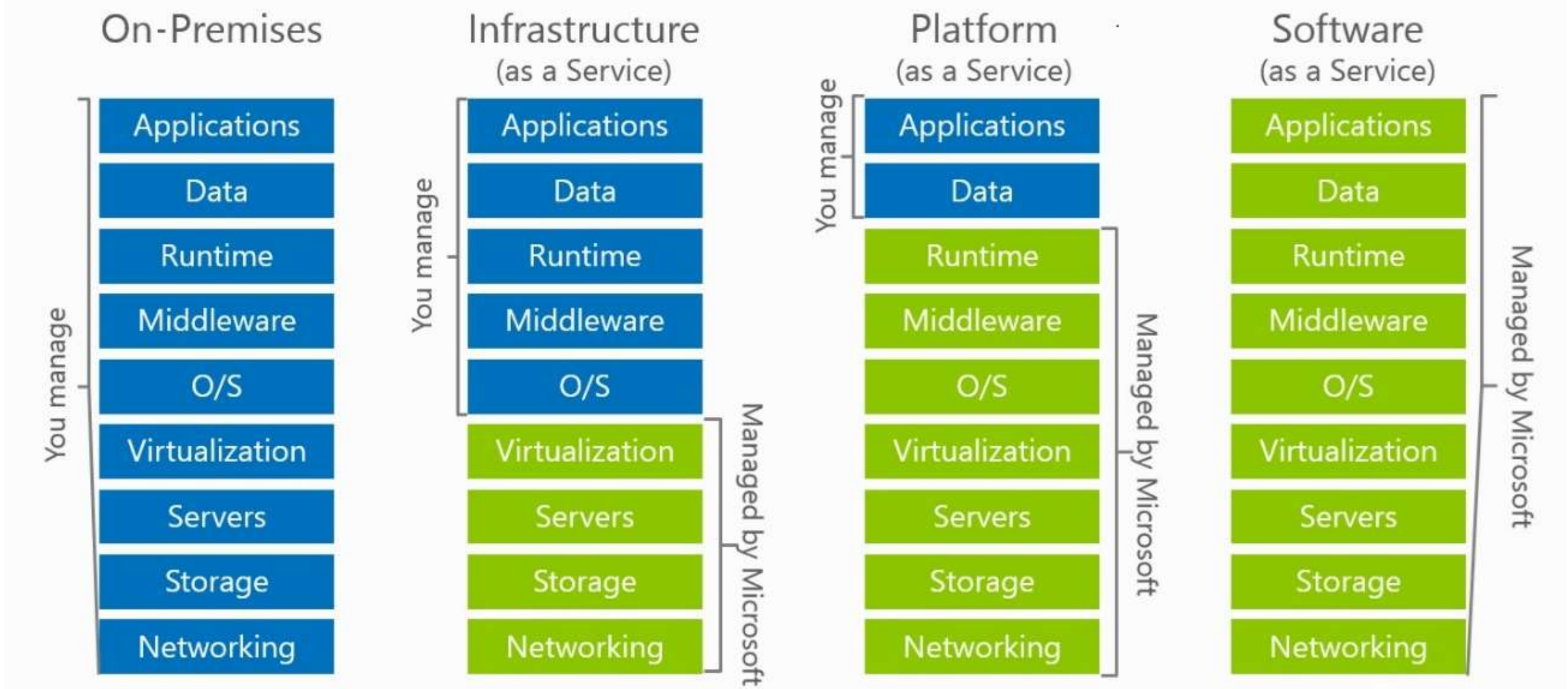
# How does Cloud Computing Works



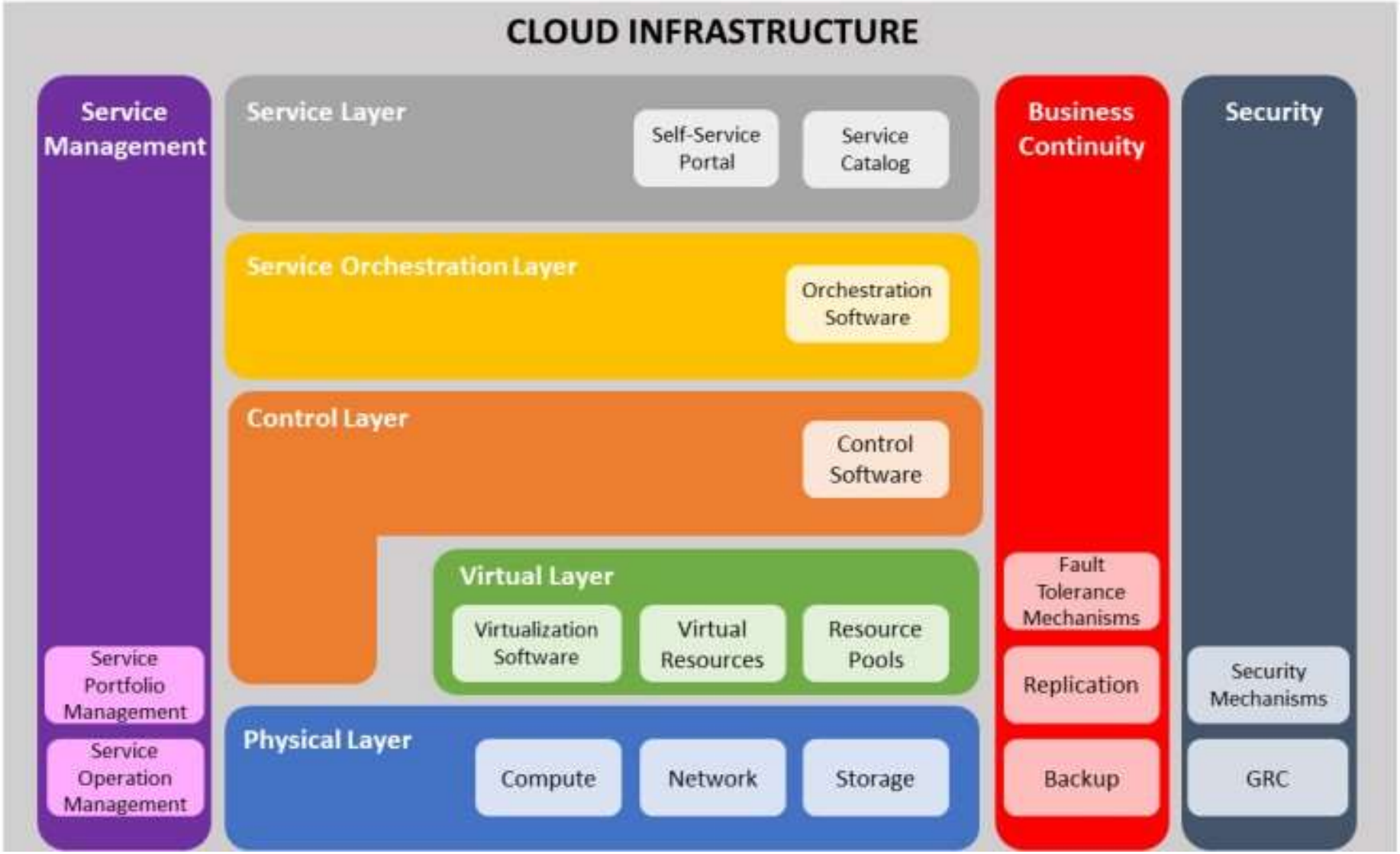
# Disadvantages of Cloud Computing



# Cloud Deployment Service Model



# The cloud computing reference model



# Cloud computing layers

**Physical Layer**

- Foundation layer of the **cloud infrastructure**.
- Specifies entities that **operate** at this layer : Compute systems, network devices and storage devices. Operating environment, protocol, tools and processes.
- Functions of physical layer : **Executes requests** generated by the virtualization and control layer.

**Virtual Layer**

- **Deployed on** the physical layer.
- Specifies entities that operate at this layer : Virtualization software, resource pools, virtual resources.
- Functions of virtual layer : **Abstracts physical resources and makes them appear as virtual resources** (enables multi tenant environment). **Executes the requests generated by control layer.**
- Specifies the **adoption of** : Administrative mechanisms (security and personnel policies, standard procedures to direct safe execution of operations) and technical mechanisms (firewall, intrusion detection and prevention systems, antivirus).
- **Deploys security mechanisms to meet GRC requirements**.
- Supports all the layers to **provide secure services.**

# Cloud computing layers

**Control Layer**

- **Deployed either on virtual layer or on physical layer**
- Specifies entities that operate at this layer : **control software**
- Functions of control layer : Enables resource configuration, resource pool configuration and resource provisioning. Executes requests generated by service layer. Exposes resources to and supports the service layer. Collaborates with the virtualization software and enables resource pooling and creating virtual resources, dynamic allocation and optimizing utilization of resources.

**Service Orchestration Layer**

- **Specifies the entities that operate** at this layer : Orchestration software.
- Functions of orchestration layer : **Provides workflows** for executing automated tasks. Interacts with various entities to invoke provisioning tasks.

**Service Layer**

- Consumers **interact and consume cloud resources** via this layer.
- Specifies the entities that operate at this layer : **Service catalog and self-service portal**.
- Functions of service layer : Store information about cloud services in service catalog and presents them to the consumers. Enables consumers to access and manage cloud services via a self-service portal.

# Cloud computing layers

**Cross-layer function**

- **Business continuity**
- Specifies adoption of proactive and reactive measures to mitigate the impact of downtime.
- Enables ensuring the availability of services in line with SLA.
- Supports all the layers to provide uninterrupted services.

**Security**

- Specifies the adoption of : Administrative mechanisms (security and personnel policies, standard procedures to direct safe execution of operations) and technical mechanisms (firewall, intrusion detection and prevention systems, antivirus).
- Deploys **security mechanisms to meet GRC requirements.**
- **Supports all the layers** to provide secure services.

# Challenges of Cloud,

# Distributed System Hardware Concept

Two Types

1. Multiprocessor System
    1. Private Memory Architecture
    2. Shared Memory Architecture
2. Multicomputer System

# Distributed System Software Concept

The software of the distributed system is nothing but selection of different operating system platforms.

The operating system is the interaction between user and the hardware.

There are three largely used operating system types:

a) Distributed operating system

b) Network operating system

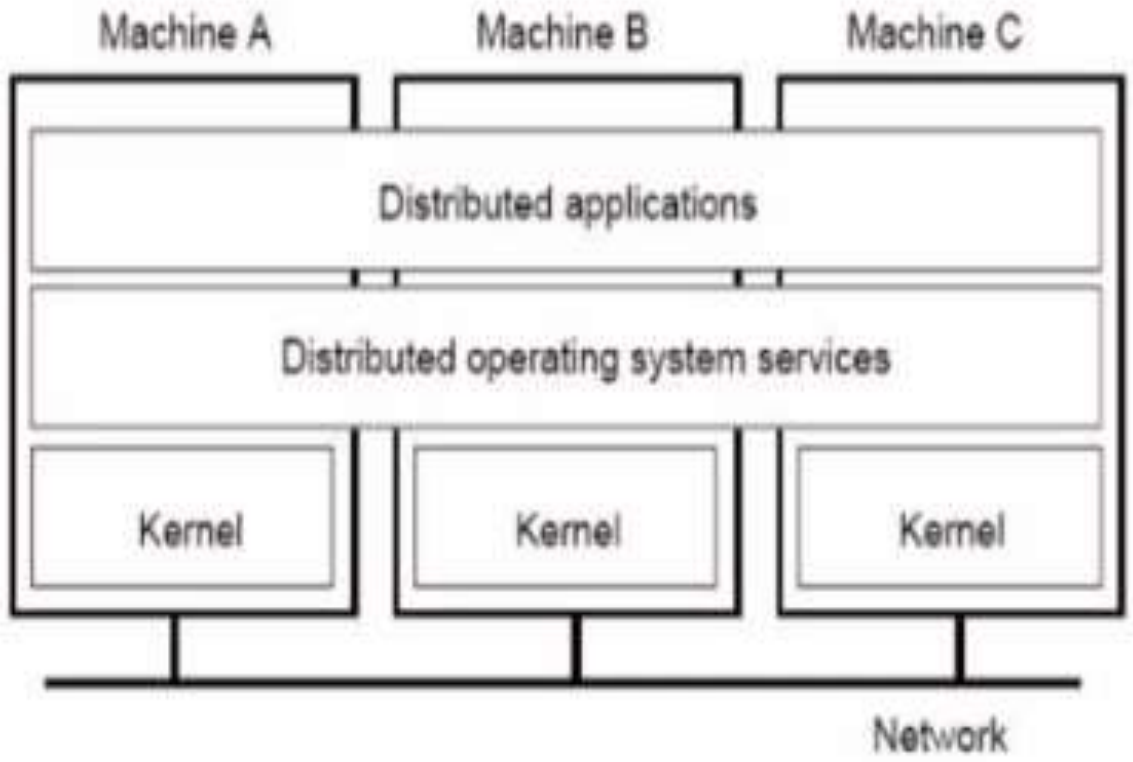
c) Middleware operating system

# Distributed Operating System

- It is different from multiprocessor and multicomputer hardware.
- Multiprocessor- uses different system services to manage resources connected in a system and use system calls to communicate with the processor.
- Multicomputer- the distributed Operating system uses a separate uniprocessor OS on each computer for communicating between different computers.
- In distributed OS, a common set of services is shared among multiple processors in such a way that they are meant to execute a distributed application effectively and also provide services to separate independent computers connected in a network as shown in fig below
- It communicates with all the computer using message passing interface(MPI).
- It follows the tightly coupled architecture pattern.
- It uses Data structure like queue to manages the messages and avoid message loss between sender and receiver computer.

**Disadvantages:**

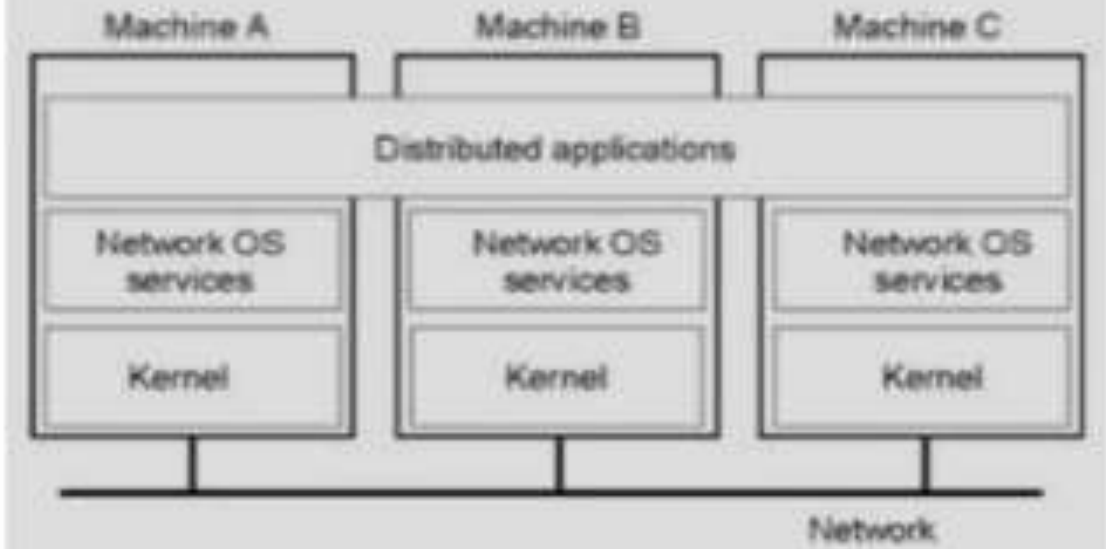
- It has a problem of scalability as it supports only limited number of independent computers with shared resources.
- There is need to define message passing semantics prior to the execution of messages



# Network Operating System

- It is specifically designed for heterogeneous multicomputer system, where multiple hardware and network platforms are supported.
- It has multiple operating system running on different hardware platforms connected in network.
- It provides to each computer connected in network.
- It follows the loosely coupled architecture pattern which allow user to use services provided by the local machine itself as shown in fig below.
- Eg Remote login where user workstation is used to log in to the remoter server and execute remote commands over the network.
- Eg Centralized file storage system.
- **Advantage:**
- It has scalability feature, where large number of resources and users are supported.
- **Disadvantage:**
- It fails to provide a single coherent view.

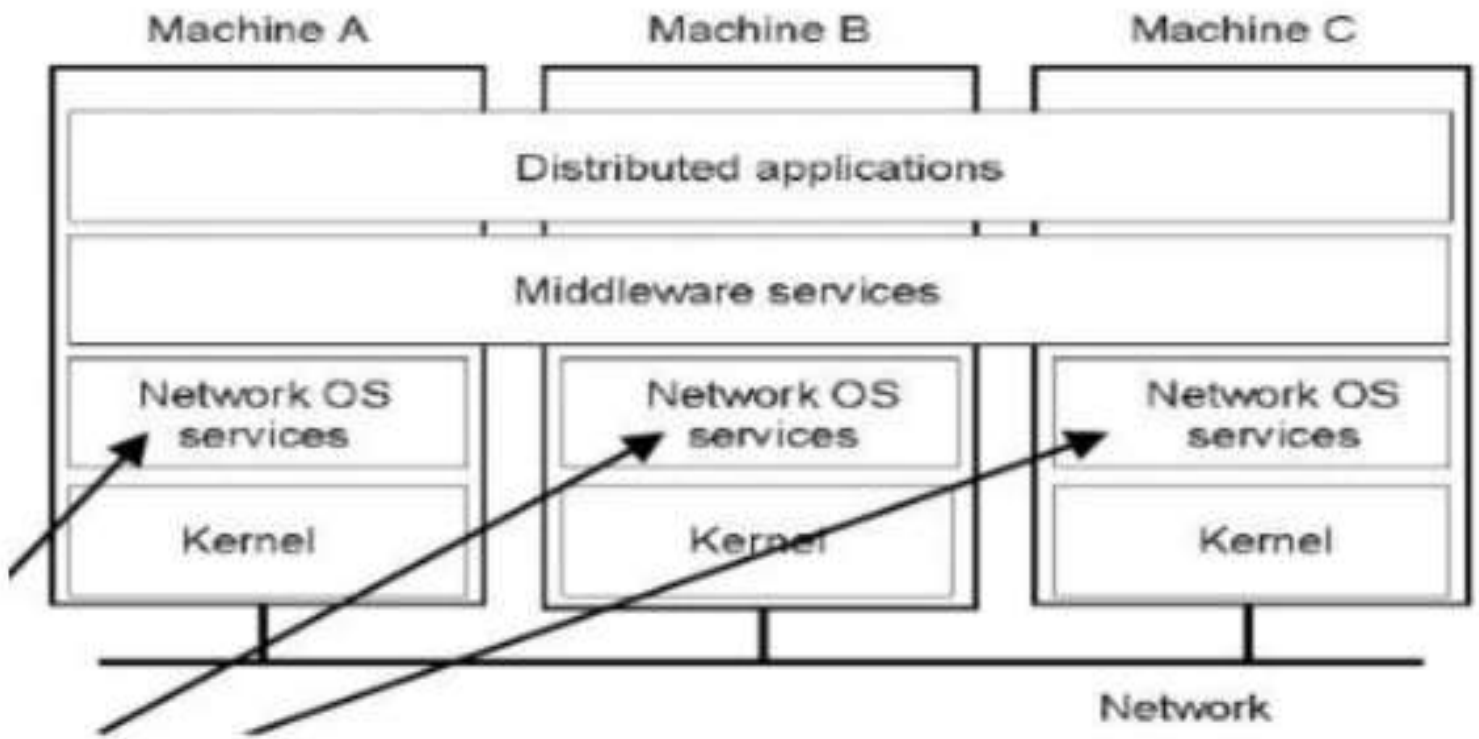
# Network Operating System (1)




General structure of a network operating system

# Middleware Operating System

- As distributed operating system has lack of scalability and network operating system fails to provide a single coherent view, therefore a new layer is formed between the distributed and network operating system is called the middleware operating system.
- It has a common set of services is provided for the local applications and independent set of services for the remote applications.
- It support heterogeneity that is it supports multiple languages and operating system where user gets freedom to write the application using the any of the supported language under any platform.
- It provide the services such as locating the objects or interfaces by their names, finding the location of objects, maintaining the quality of services handling the protocol information, synchronization, concurrency and security of the objects etc.


Machine A
Machine B
Machine C
Distributed applications
Middleware services
Network OS services
Network OS services
Network OS services
Kernel
Kernel
Kernel
Network

# Services offered by Middleware System

- Naming service-used to locate objects/interfaces
- Persistence service- used to store distributed objects permanently on to data store
- Messaging service – used to send or receive messages in terms of request response primitive
- Querying service – used to query on distributed objects
- Concurrency service - used to share and access the resources concurrently
- Security service- used to provide security to the various shared resources

# Distributed computing principles

- Decentralization:
- Communication:
- Scalability:
- Fault Tolerance:
- Consistency:
- Concurrency:
- Transparency:
- Resource Sharing:
- Load Balancing:

# Business drivers for cloud adoption

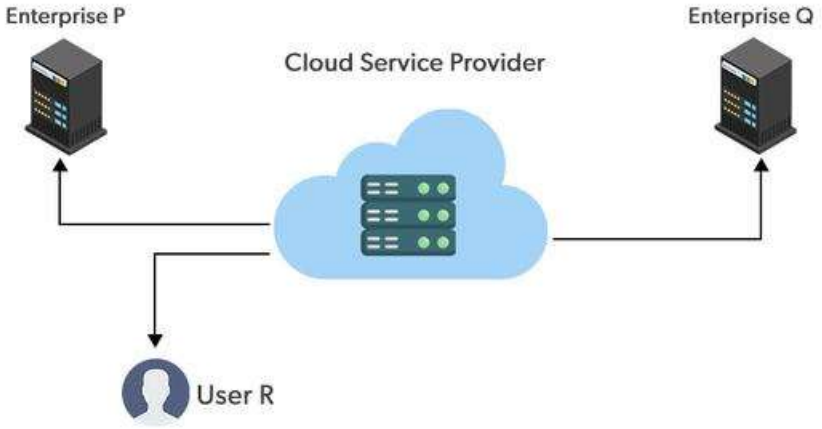
- **Increasing business agility –** It has been found that enterprises who have adopted Cloud have gained competitive advantage by reducing complexity and increasing business agility. Enterprises that have adopted Cloud have observed improved agility due to on-demand self-service and rapid elasticity. Moreover, IT resources can be acquired and deployed more quickly and, once deployed, they can be increased or decreased as needed to meet the demand.
- **Reducing cost –** This is definitely one of the key drivers behind Cloud adoption In many cases it has been found that the cost of replatforming to the cloud is actually much lower than the license renewal of their legacy apps. Cloud computing enables organizations to reduce cost through server consolidation, thin clients and community cost sharing.
- **Enforcing mobility –** An increasing number of enterprises are driven towards Cloud technology, because it is ubiquitous, self-configurable and cost effective. With remote working gaining popularity among organizations, Cloud computing is enabling employees to work at any place, at any time, and on any device
- **Improving productivity –** Every organization is concerned about improving productivity and Cloud computing is seen as an ideal option by many organizations. Use of Cloud-based tools for email, instant messaging, voice communication, information sharing and development, event scheduling, and conferencing is becoming an increasingly common feature of business life.
- **Creating new business avenues –** An enterprise can get new business opportunities as a provider of cloud services or added services. Organizations that have good track record of its own IT can become a public Infrastructure-as-a-Service (IaaS) or Platform-as-a-Service (PaaS) provider. One business opportunity could be, if a company implements a private cloud and has spare capacity, it can sell that additional capacity as public Cloud to another company.

# The common cloud deployment models

- Public Cloud: Resources are owned and managed by a third-party provider and accessed by multiple users over the internet. Examples include Amazon Web Services (AWS), Microsoft Azure, and Google Cloud Platform.
- Private Cloud: Resources are dedicated to a single organization, either on-premises or hosted by a third-party. This offers greater control and security but may require more upfront investment.
- Hybrid Cloud: Combines public and private clouds, allowing organizations to leverage the benefits of both environments. For example, sensitive data might be stored on a private cloud while less critical workloads run on a public cloud.
- Community Cloud: Resources are shared by several organizations with common interests or regulatory requirements. This model offers a balance between cost and control
- Multi-Cloud

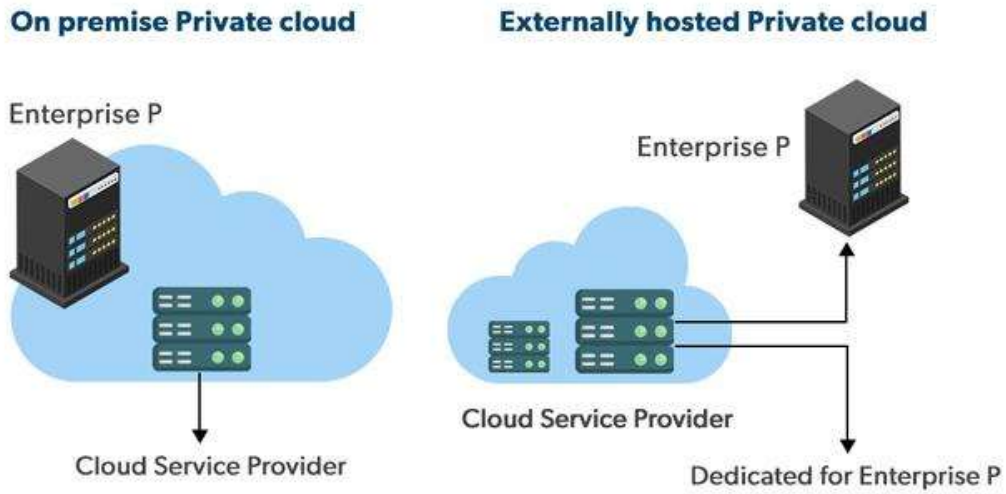
# Public Cloud

example, Google App Engine



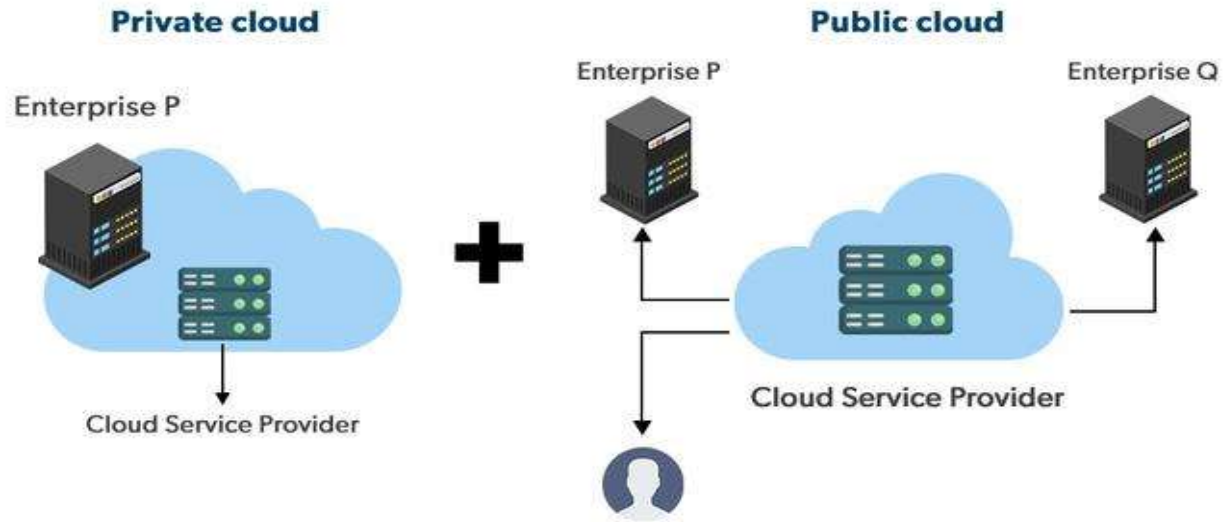

- **Advantages of the Public Cloud Model**
- **Minimal Investment:** Because it is a pay-per-use service, there is no substantial upfront fee, making it excellent for enterprises that require immediate access to resources.
- **No setup cost:** The entire infrastructure is fully subsidized by the cloud service providers, thus there is no need to set up any hardware.
- **Infrastructure Management is not required:** Using the public cloud does not necessitate infrastructure management.
- **No maintenance:** The maintenance work is done by the service provider (not users).
- **Dynamic Scalability:** To fulfill your company's needs, on-demand resources are accessible.
- **Disadvantages of the Public Cloud Model**
- **Less secure:** Public cloud is less secure as resources are public so there is no guarantee of high-level security.
- **Low customization:** It is accessed by many public so it can't be customized according to personal requirements.

# Private Cloud



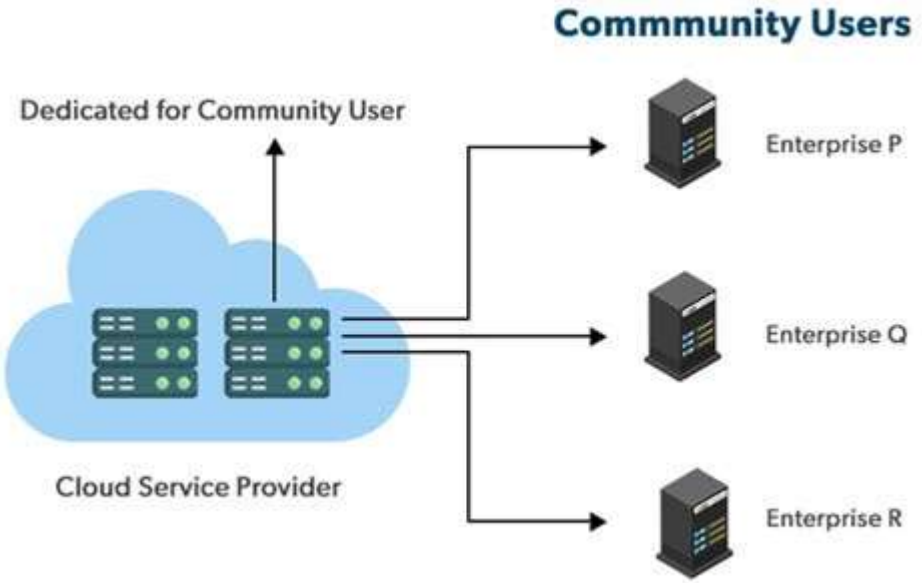

- **Advantages of the Private Cloud Model**
- **Better Control:** You are the sole owner of the property. You gain complete command over service integration, IT operations, policies, and user behavior.
- **Data Security and Privacy:** It's suitable for storing corporate information to which only authorized staff have access. By segmenting resources within the same infrastructure, improved access and security can be achieved.
- **Supports Legacy Systems:** This approach is designed to work with legacy systems that are unable to access the public cloud.
- **Customization:** Unlike a public cloud deployment, a private cloud allows a company to tailor its solution to meet its specific needs.
- **Disadvantages of the Private Cloud Model**
- **Less scalable:** Private clouds are scaled within a certain range as there is less number of clients.
- **Costly:** Private clouds are more costly as they provide personalized facilities

# Hybrid Cloud



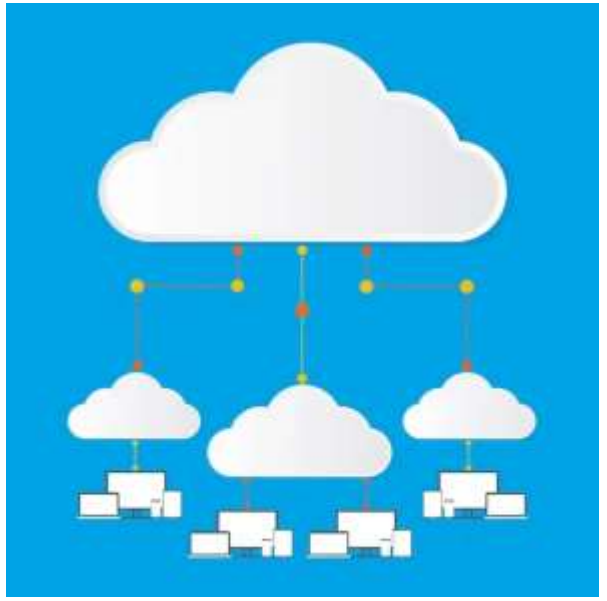

- **Advantages of the Hybrid Cloud Model**
- **Flexibility and control:** Businesses with more flexibility can design personalized solutions that meet their particular needs.
- **Cost:** Because public clouds provide scalability, you'll only be responsible for paying for the extra capacity if you require it.
- **Security:** Because data is properly separated, the chances of data theft by attackers are considerably reduced.
- **Disadvantages of the Hybrid Cloud Model**
- **Difficult to manage:** Hybrid clouds are difficult to manage as it is a combination of both public and private cloud. So, it is complex.
- **Slow data transmission:** Data transmission in the hybrid cloud takes place through the public cloud so latency occurs.

# Community Cloud




- **Advantages of the Community Cloud Model**
- **Cost Effective:** It is cost-effective because the cloud is shared by multiple organizations or communities.
- **Security:** Community cloud provides better security.
- **Shared resources:** It allows you to share resources, infrastructure, etc. with multiple organizations.
- **Collaboration and data sharing:** It is suitable for both collaboration and data sharing.
- **Disadvantages of the Community Cloud Model**
- **Limited Scalability:** Community cloud is relatively less scalable as many organizations share the same resources according to their collaborative interests.
- **Rigid in customization:** As the data and resources are shared among different organizations according to their mutual interests if an organization wants some changes according to their needs they cannot do so because it will have an impact on other organizations.

# Multi-Cloud



- **Advantages of the Multi-Cloud Model**
- You can mix and match the best features of each cloud provider's services to suit the demands of your apps, workloads, and business by choosing different cloud providers.
- **Reduced Latency:** To reduce latency and improve user experience, you can choose cloud regions and zones that are close to your clients.
- **High availability of service:** It's quite rare that two distinct clouds would have an incident at the same moment. So, the multi-cloud deployment improves the high availability of your services.
- **Disadvantages of the Multi-Cloud Model**
- **Complex:** The combination of many clouds makes the system complex and bottlenecks may occur.
- **Security issue:** Due to the complex structure, there may be loopholes to which a hacker can take advantage hence, makes the data insecure.

# What is the Right Choice for Cloud Deployment Model?

- Cost: Cost is an important factor for the cloud deployment model as it tells how much amount you want to pay for these things.
- Scalability: Scalability tells about the current activity status and how much we can scale it.
- Easy to use: It tells how much your resources are trained and how easily can you manage these models.
- Compliance: Compliance tells about the laws and regulations which impact the implementation of the model.
- Privacy: Privacy tells about what data you gather for the model.

# Cloud Deployment Models Comparison

| Attribute \ Deployment Model | Public Cloud | Private Cloud | Hybrid Cloud | Community Cloud |
|---|---|---|---|---|
| **Ownership** | Owned by customers | Owned by single organization | Partially owned by Service Provider and partially by consumer | Owned by two or more organizations which has common goal |
| **Performance** | Low to medium | Excellent | Good | Very Good |
| **Setup cost of building datacentre** | Low initial cost | High | Medium | Varies from number of organizations |
| **Used by** | Anyone can access | Limited people can access | Medium accessibility | Depend upon number of cooperatives |
| **Security** | Less | Highest | Medium | High |
| **User's control** | Limited control | Full control | Full control over private part and limited at public part | High control but limited by community policies |
| **Maintenance cost** | Lowest | Highest | Moderate | High |
| **Space required** | Very low | Very large | Medium | Depends on number of cooperatives |
| **Workload** | Normal workload with short-spikes in demand | Not suitable for handling large workload | Highly dynamic or changeable | Suitable for handling large workload |
| **Size of Datacentres** | Around 50,000s | Around 50,000s | Less than private cloud | Public cloud>15,000>Private cloud |
| **Virtualization** | Resource utilization is optimized via server virtualization | Resource utilization efficiency gains through server virtualization | Resource utilization is optimized via server virtualization | Resource utilization efficiency gains via server virtualization |
| **Reliability** | Medium | Highest | Medium | High |
| **Cloud Bursting** | Not supported | Not supported | Supported | Not supported |
| **Example** | Amazon EC2 | Microsoft Azure | Rackspace Hybrid cloud | Microsoft government community cloud |