MODULE-III

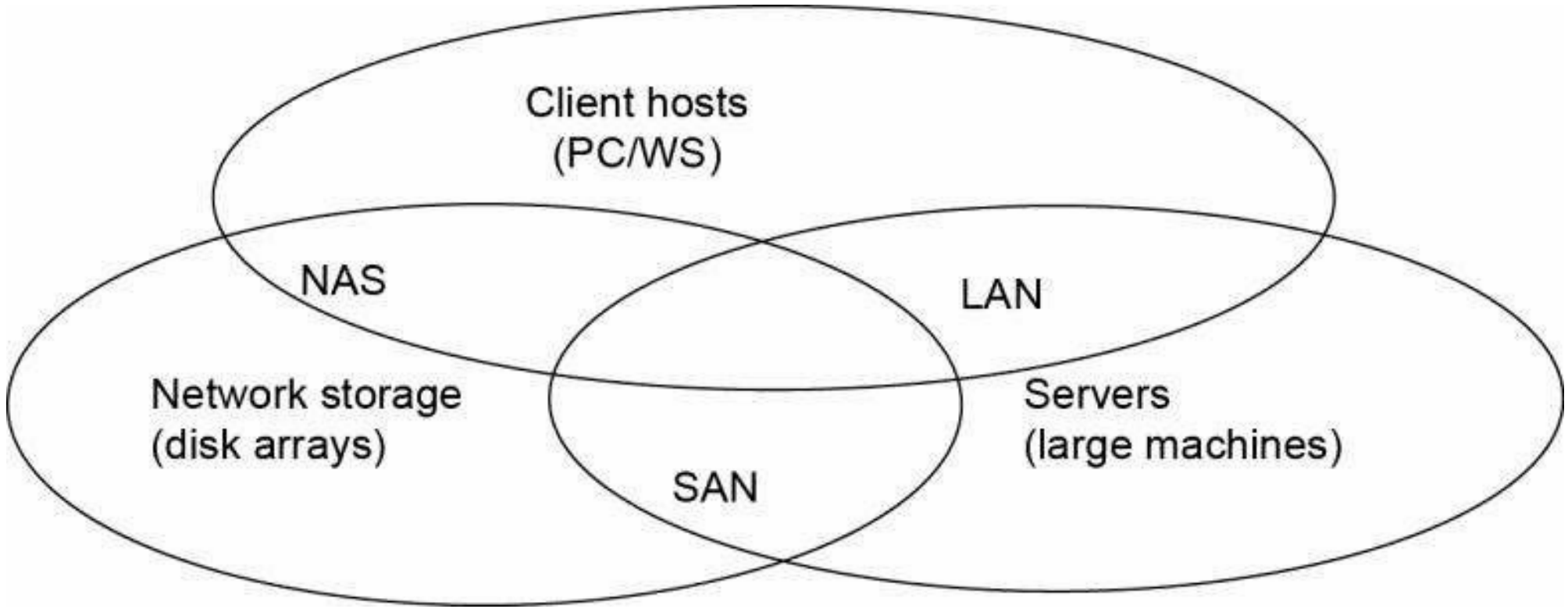
CLOUD FUNDAMENTALS

- , cloud computing is the delivery of computing services—including servers, storage, databases, networking, software, analytics, and intelligence—over the Internet (“the cloud”) to offer faster innovation, flexible resources, and economies of scale.
- You typically pay only for cloud services you use, helping lower your operating costs, run your infrastructure more efficiently and scale as your business needs change.

TECHNOLOGIES FOR NETWORK-BASED SYSTEMS

- **Multicore CPUs and Multithreading Technologies**:
- Today, advanced CPUs or microprocessor chips assume a multicore architecture with dual, quad, six, or more processing cores.
- These processors exploit parallelism at ILP and TLP levels. Both multi-core CPU and many-core GPU processors can handle multiple instruction threads at different magnitudes today.
- Multiple cores are housed in the same chip with an L2 cache that is shared by all cores.
- In the future, multiple CMPs could be built on the same CPU chip with even the L3 cache on the chip.
- Multicore and multithreaded CPUs are equipped with many high-end processors, including the Intel i7, Xeon, AMD Opteron, Sun Niagara, IBM Power 6, and X cell processors.
- Each core could be also multithreaded.

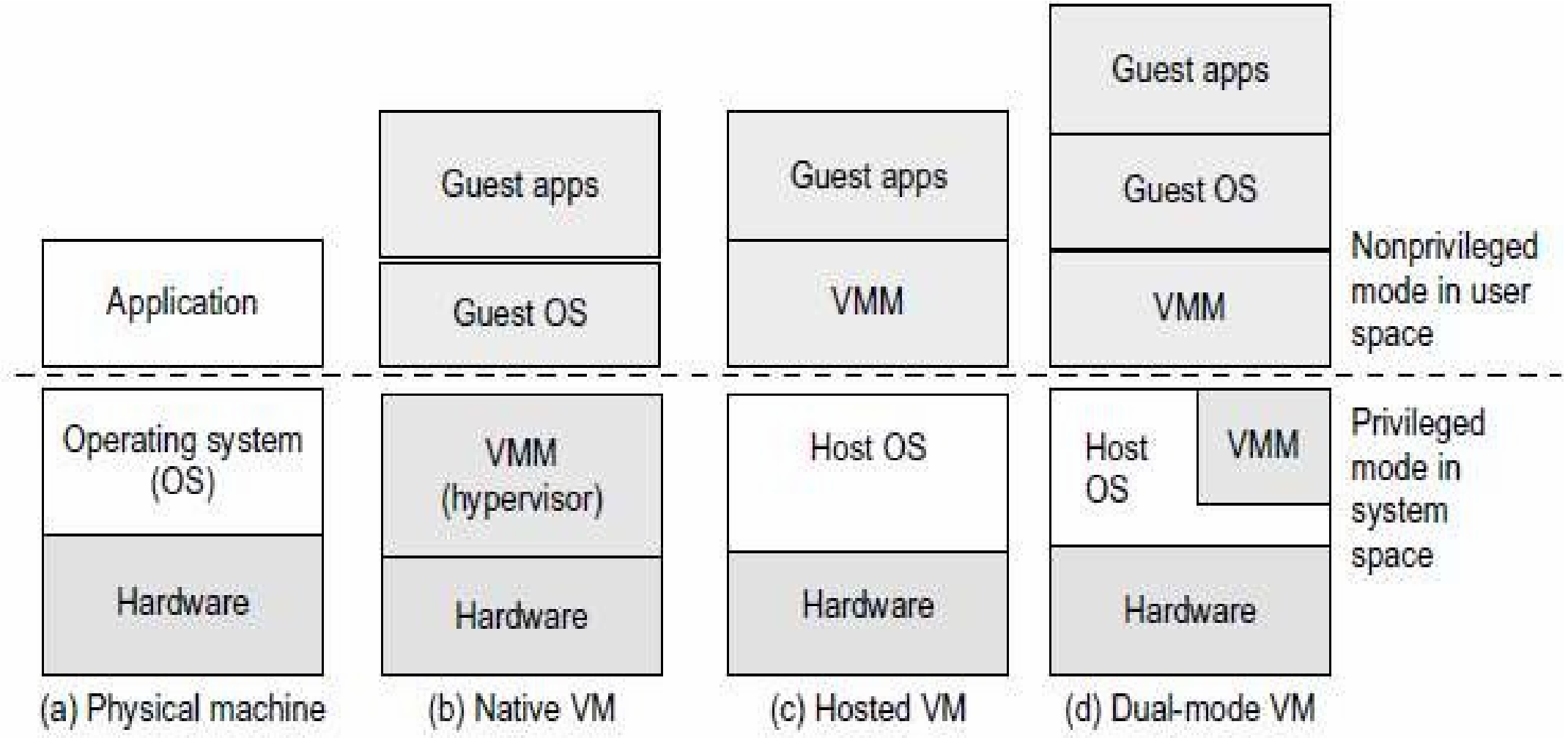
- **Memory, Storage, and Wide-Area Networking:** Memory chips have experienced a 4x increase in capacity every three years. For hard drives, capacity increased from 260 MB in 1981 to 250 GB in 2004.
- Disks or disk arrays have exceeded 3 TB in capacity.
- The rapid growth of flash memory and solid-state drives (SSDs) also impacts the future of HPC and HTC systems.
- **System-Area Interconnects:** The nodes in small clusters are mostly interconnected by an Ethernet switch or a local area network(LAN).


Client hosts
(PC/WS)
NAS
LAN
Network storage
(disk arrays)
Servers
(large machines)
SAN

- As Figure shows, a LAN typically is used to connect client hosts to big servers.A storage area network (SAN) connects servers to network storage such as disk arrays.
- Network attached storage (NAS) connects client hosts directly to the disk arrays.
- All three types of networks often appear in a large cluster built with commercial network components.

- **Wide-Area Networking:** High-bandwidth networking increases the capability of building massively distributed systems.
- The rapid growth of Ethernet bandwidth from 10 Mbps in1979 to 1 Gbps in 1999, and 40 ~ 100 GE in 2011.
- It has been speculated that 1 Tbps network links will become available by 2013.

- **Virtual Machines and Virtualization Middleware**
- Virtual machines (VMs) offer novel solutions to underutilized resources, application inflexibility, software manageability, and security concerns in existing physical machines.
- Today, to build large clusters, grids, and clouds, we need to access large amounts of computing, storage, and networking resources in a virtualized manner.
- We need to aggregate those resources, and hopefully, offer a single system image.
- In particular, a cloud of provisioned resources must rely on virtualization of processors, memory, and I/O facilities dynamically.


Application
Guest apps
Guest OS
Guest apps
VMM
Guest apps
Guest OS
VMM
Nonprivileged mode in user space
Operating system (OS)
Hardware
VMM (hypervisor)
Hardware
Host OS
Hardware
Host OS
VMM
Hardware
Privileged mode in system space
(a) Physical machine
(b) Native VM
(c) Hosted VM
(d) Dual-mode VM

- The host machine is equipped with the physical hardware.
- The VM is built with virtual resources managed by a guest OS to run a specific application.
- Between the VMs and the host platform, one needs to deploy a middleware layer called a virtual machine monitor (VMM).
- Figure shows a native VM installed with the use of a VMM called a hypervisor in privileged Mode.
- The guest OS could be a Linux system and the hypervisor is the XEN system developed at Cambridge University.
- This hypervisor approach is also called bare-metal VM, because the hypervisor handles the bare hardware (CPU, memory, and I/O) directly.
- Architecture is the host VM shown in Figure(c).
- Here the VMM runs in non-privileged mode.
- The host OS need not be modified.
- The VM can also be implemented with a dual mode, as shown in Figure 1.12(d).
- Part of the VMM runs at the user level and another part runs at the supervisor level.
- In this case, the host OS may have to be modified to some extent.
- Multiple VMs can be ported to a given hardware system to support the virtualization process.
- The VM approach offers hardware independence of the OS and applications.

- **VM Primitive Operations:** The VMM provides the VM abstraction to the guest OS. With full virtualization, the VMM exports a VM abstraction identical to the physical machine so that a standard OS such as Windows 2000 or Linux can run just as it would on the physical hardware
- Low-level VMM operations are
- □ the VMs can be multiplexed between hardware machines,
- □ a VM can be suspended and stored in stable storage
- □ a suspended VM can be resumed or provisioned to a new hardware platform
- □ a VM can be migrated from one hardware platform to another

- These VM operations enable a VM to be provisioned to any available hardware platform. They also enable flexibility in porting distributed application executions. Furthermore, the VM approach will significantly enhance the utilization of server resources.

Technologies for Network based Computing

- **1. Software-Defined Networking (SDN)**

  Software-Defined Networking (SDN) revolutionizes traditional networking by separating the control plane from the data plane.
- This allows network administrators to programmatically manage and optimize resources, providing flexibility and efficiency.
- SDN is vital in cloud computing as it enables dynamic provisioning of network resources, improves scalability, and enhances security through centralized control.

  Example:

  Google’s B4 SDN is a private WAN connecting its data centers worldwide. SDN helps Google optimize network bandwidth, ensuring efficient use of resources and reducing latency for services like Google Search and YouTube.

- **2. Network Function Virtualization (NFV)**

  NFV replaces hardware-based network functions with software applications running on virtualized platforms.
- It eliminates the need for specialized hardware, making networks more agile and cost-effective.
- In cloud environments, NFV supports rapid deployment of services, enhances scalability, and simplifies network management, all while reducing operational costs.

  Example:

  Telecom companies like AT&T use NFV to provide on-demand virtual firewalls and load balancers to customers. Instead of waiting for hardware installations, customers can scale network functions in minutes through a dashboard.

- **3. Cloud Load Balancing**

  Load balancing is essential for distributing network traffic evenly across servers, ensuring reliability and performance.
- Cloud load balancers intelligently route traffic to optimize resource utilization and prevent server overloads.
- They also enable high availability and scalability, which are critical for cloud-based systems handling fluctuating workloads.

  Example:

  Amazon Web Services (AWS) Elastic Load Balancer automatically routes traffic across multiple servers in different regions. For instance, during Black Friday sales, e-commerce platforms like Shopify use this to handle surges in traffic smoothly.

- **4. Edge Computing and Content Delivery Networks (CDNs)**

  With the rise of IoT and latency-sensitive applications, edge computing has become a vital component of cloud networking.
- By processing data closer to the user, edge computing reduces latency and improves performance.
- Complementing this, CDNs distribute content across multiple servers globally, enabling faster content delivery and improved user experiences.

  Example:

  Netflix uses CDNs like Akamai to stream videos seamlessly worldwide. By caching popular shows closer to users, buffering is minimized. Similarly, edge computing supports smart cities by processing real-time traffic data for navigation systems like Google Maps.

- **5. Virtual Private Networks (VPNs)**

  Security is a primary concern in cloud networking, and VPNs play a pivotal role in ensuring secure connections.
- By creating encrypted tunnels between devices and the cloud, VPNs safeguard sensitive data from cyber threats.
- This technology is particularly crucial for businesses operating in hybrid cloud environments.

  Example:

  Businesses using cloud services like Microsoft Azure often implement VPNs for secure connections between remote employees and company resources, ensuring sensitive files are protected from hackers.

- **6. IPv6 and Next-Generation Internet Protocols**

  As the demand for internet connectivity grows, IPv6 addresses the limitations of IPv4, offering a virtually unlimited number of IP addresses.
- Cloud networks leverage IPv6 to ensure seamless device connectivity, enhanced routing, and improved security features, paving the way for future innovations.

  Example:

  Amazon Alexa and Google Home devices use IPv6 to maintain unique identities while connecting to cloud systems. This ensures seamless communication and scalability as IoT usage grows.

- **7. Automation and Artificial Intelligence (AI)**

  Automation and AI are transforming network management in cloud computing.
- AI-driven analytics optimize network performance, predict failures, and enhance security through anomaly detection.
- Automation simplifies repetitive tasks, such as configuration and monitoring, enabling efficient management of complex cloud networks.

  Example:

  Cisco’s AI-based network automation tool, DNA Center, predicts and resolves network issues before users notice them. For cloud environments, it ensures uninterrupted operation of apps like Slack or Zoom during peak usage.

- **8. Kubernetes Networking**

  In containerized environments, Kubernetes networking plays a key role in managing communication between microservices.
- Kubernetes ensures seamless connectivity within clusters, enabling scalable and resilient applications in the cloud.
- This technology is indispensable for businesses adopting DevOps and microservices architectures.

  Example:

  Spotify uses Kubernetes to manage its music-streaming services. As users listen to songs, Kubernetes ensures microservices like recommendation algorithms and search features communicate efficiently, scaling up resources as demand rises.

- **9. Security Technologies**

  Technologies like intrusion detection and prevention systems (IDPS), secure access service edge (SASE), and zero-trust network access (ZTNA) ensure robust security for cloud-based systems.
- These tools protect against evolving cyber threats, ensuring data integrity and compliance with regulatory standards.

  Example:

  Cloudflare uses Secure Access Service Edge (SASE) to protect websites from Distributed Denial-of-Service (DDoS) attacks. For example, e-commerce platforms like Etsy use Cloudflare to ensure their online stores remain operational during cyberattacks.

System Models for Distributed and Cloud Computing

- Distributed and cloud computing systems are built over a large number of autonomous computer nodes.
- These node machines are interconnected by SANs, LANs, or WANs
- A massive system is with millions of computers connected to edge networks.
- Massive systems are considered highly scalable

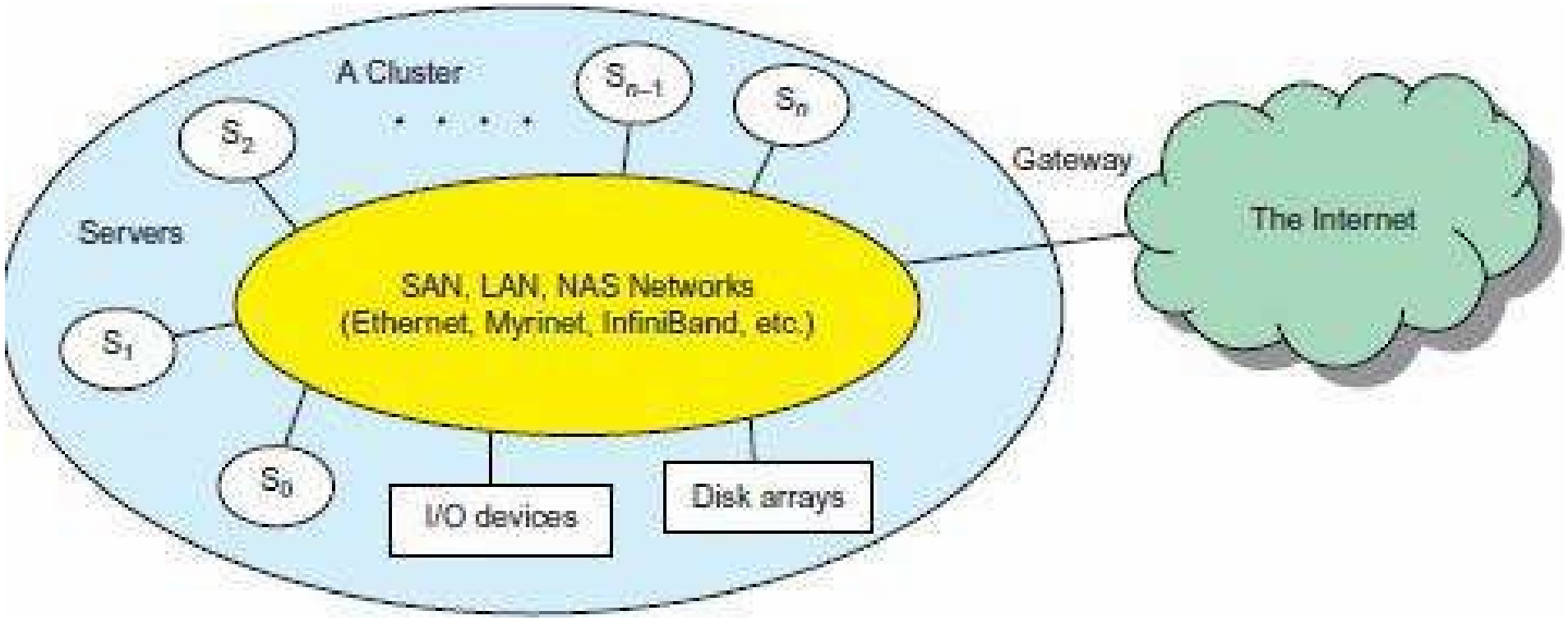
- massive systems are classified into four groups: clusters, P2P networks, computing grids, and Internet clouds

Table 1.2 Classification of Parallel and Distributed Computing Systems

Functionality, Applications	Computer Clusters [10,28,38]	Peer-to-Peer Networks [34,46]	Data/ Computational Grids [6,18,51]	Cloud Platforms [1,9,11,12,30]
Architecture, Network Connectivity, and Size	Network of compute nodes interconnected by SAN, LAN, or WAN hierarchically	Flexible network of client machines logically connected by an overlay network	Heterogeneous clusters interconnected by high-speed network links over selected resource sites	Virtualized cluster of servers over data centers via SLA
Control and Resources Management	Homogeneous nodes with distributed control, running UNIX or Linux	Autonomous client nodes, free in and out, with self-organization	Centralized control, server-oriented with authenticated security	Dynamic resource provisioning of servers, storage, and networks
Applications and Network-centric Services	High-performance computing, search engines, and web services, etc.	Most appealing to business file sharing, content delivery, and social networking	Distributed supercomputing, global problem solving, and data center services	Upgraded web search, utility computing, and outsourced computing services
Representative Operational Systems	Google search engine, SunBlade, IBM Road Runner, Cray XT4, etc.	Gnutella, eMule, BitTorrent, Napster, KaZaA, Skype, JXTA	TeraGrid, GriPhyN, UK EGEE, D-Grid, ChinaGrid, etc.	Google App Engine, IBM Bluecloud, AWS, and Microsoft Azure

- **Computing cluster**
- o A computing cluster consists of interconnected stand-alone computers which work cooperatively as a single integrated computing resource.

- **Cluster Architecture**
- o the architecture consists of a typical server cluster built around a low-latency, high bandwidth interconnection network.
- o build a larger cluster with more nodes, the interconnection network can be built with multiple levels of Gigabit Ethernet, Myrinet, or InfiniBand switches.
- o Through hierarchical construction using a SAN, LAN, or WAN, one can build scalable clusters with an increasing number of nodes
- o cluster is connected to the Internet via a virtual private network (VPN) gateway.
- o gateway IP address locates the cluster
- Clusters have loosely coupled node computers.
- o All resources of a server node are managed by their own OS.
- o Most clusters have multiple system images as a result of having many autonomous nodes under different OS control


A Cluster
S_{n-1}
S_n
S_2
Servers
S_1
S_0
SAN, LAN, NAS Networks
(Ethernet, Myrinet, InfiniBand, etc.)
I/O devices
Disk arrays
Gateway
The Internet

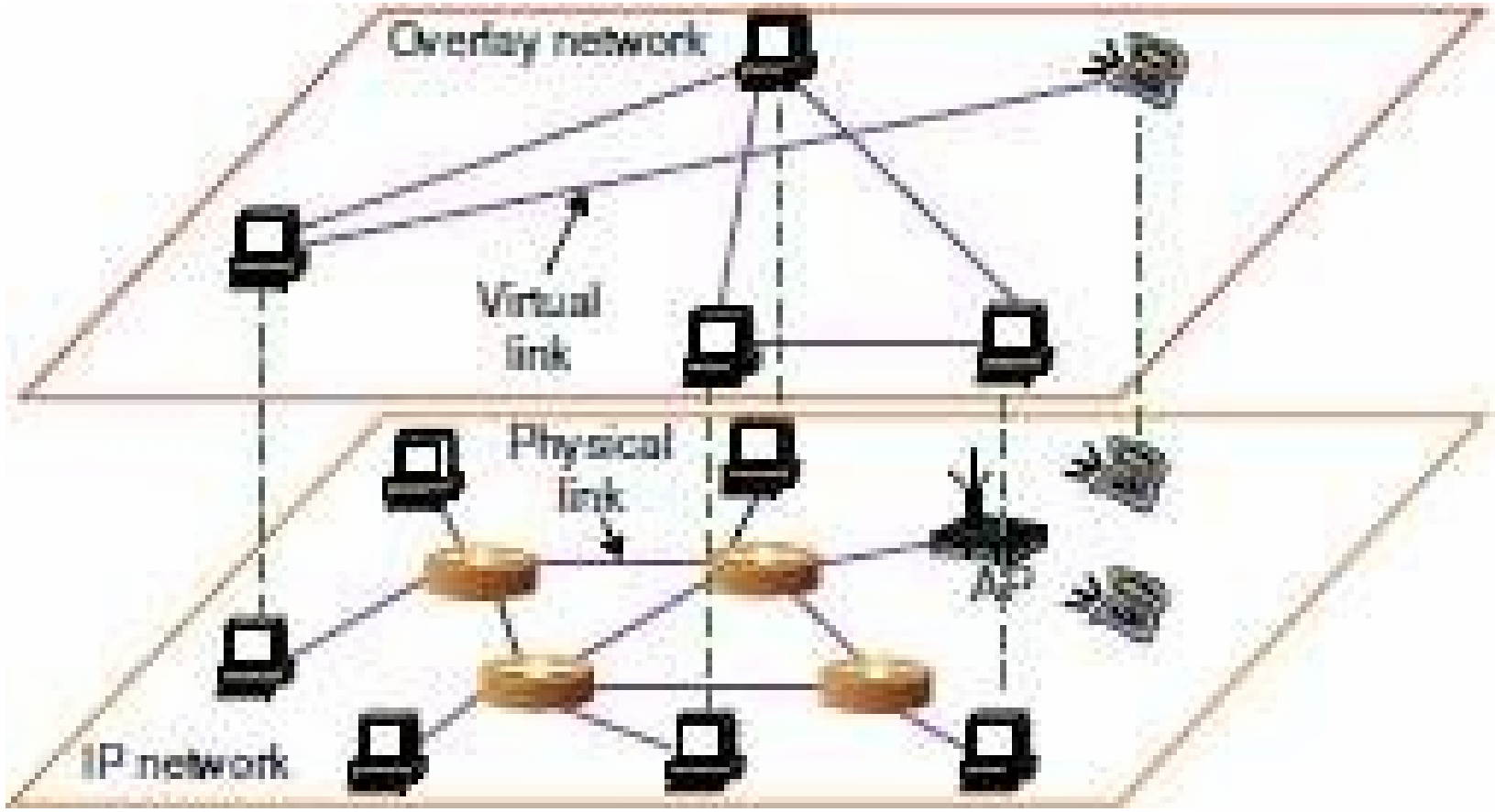
- **Single-System Image -Cluster**
- ○ an ideal cluster should merge multiple system images intoa single-system image (SSI)
- ○ acluster operating system or some middleware have to support SSI at various levels, including the sharing of CPUs, memory, and I/O across all cluster nodes.
- ○ illusion created by software or hardware that presents a collection of resources as one integrated, powerful resource

- ○ SSI makes the cluster appear like a single machine to the user.
- ○ A cluster with multiple system images is nothing but a collection of independent computers.

- **Hardware, Software, and Middleware Support –Cluster**
- ○ Clusters exploring massive parallelism are commonly known as MPPs –Massive Parallel Processing
- ○ The building blocks are computer nodes (PCs, workstations, servers, or SMP), special communication software such as PVM or MPI, and a network interface card in each computer node.
- ○ Most clusters run under the Linux OS.
- ○ nodes are interconnected by a high-bandwidth network
- ○ Special cluster middleware supports are needed to create SSI or high availability (HA).
- ○ all distributed memory to be shared by all servers by forming distributed shared memory (DSM).
- ○ SSI features are expensive
- ○ achieving SSI, many clusters are loosely coupled machines
- ○ virtual clusters are created dynamically, upon user demand

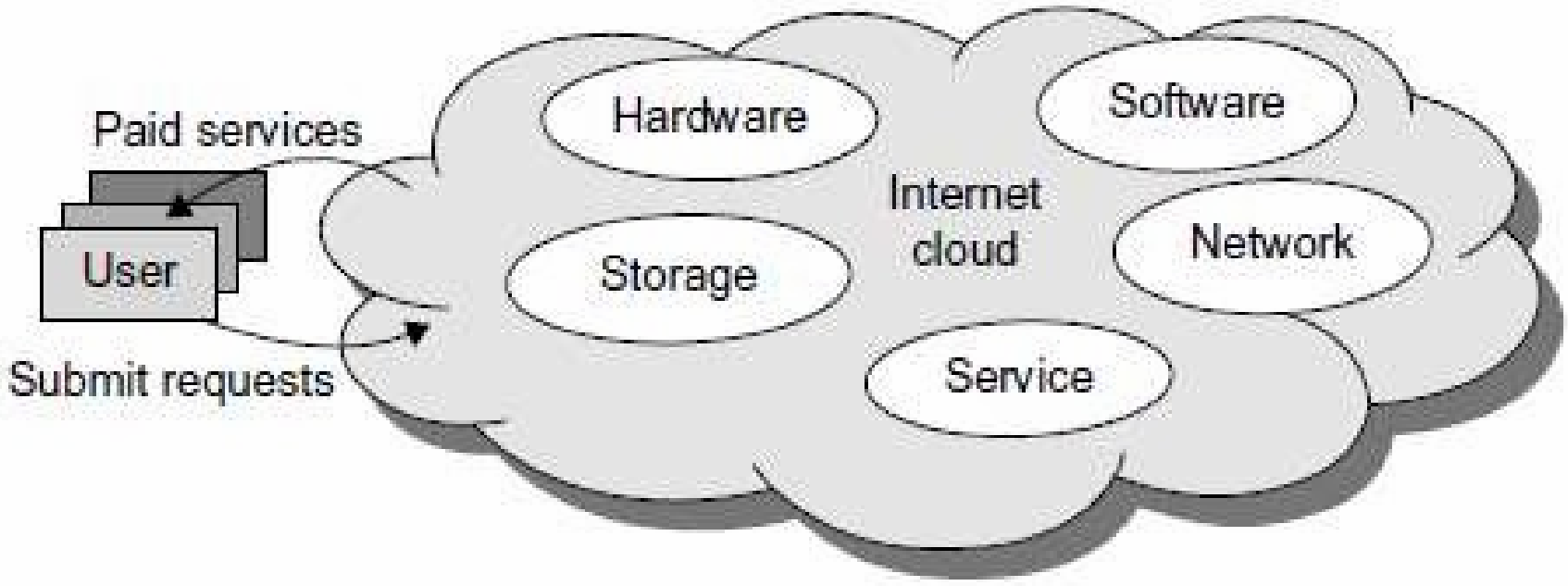
- **Grid Computing**
- A web service such as HTTP enables remote access of remote web pages
- computing grid offers an infrastructure that couples computers, software/middleware, special instruments, and people and sensors together
- Enterprises or organizations present grids as integrated computing resources. They can also beviewed as virtual platforms to support virtual organizations.
- The computers used in a grid are primarilyworkstations, servers, clusters, and supercomputers

- **Peer-to-Peer Network-P2P**
- P2P architecture offers a distributed model of networked systems.
- P2P network is client-oriented instead of server-oriented
- In a P2P system, every node acts as both a client and a server
- Peer machines are simply client computers connected to the Internet.
- All client machines act autonomously to join or leave the system freely. This implies that no master-slave relationship exists among the peers.
- No central coordination or central database is needed. The system is self-organizing with distributed control.
- P2P two layer of abstractions as given in the figure
- Each peer machine joins or leaves the P2P network voluntarily
- Only the participatingpeers form the physical network at any time.
- Physical network is simply an ad hoc networkformed at various Internet domains randomly using the TCP/IP and NAI protocols.


Overlay network
Virtual
link
Physical
link
IP network

- **Peer-to-Peer Network-Overlay network**
- Data items or files are distributed in the participating peers.
- Based on communication or file-sharing needs, the peer IDs form an overlay network at the logical level.
- When a new peer joins the system, its peer ID is added as a node in the overlay network.
- When an existing peer leaves the system, its peer ID is removed from the overlay network automatically.
- An unstructured overlay network is characterized by a random graph. There is no fixed route to send messages or files among the nodes. Often, flooding is applied to send a query to all nodes in an unstructured overlay, thus resulting in heavy network traffic and nondeterministic search results.
- Structured overlay networks follow certain connectivity topology and rules for inserting and removing nodes (peer IDs) from the overlay graph

Cloud Computing



Virtualized resources from data centers to form an Internet cloud

- A cloud is a pool of virtualized computer resources.
- A cloud can host a variety of different workloads, including batch-style backend jobs and interactive and user-facing applications.”
- Cloud computing applies a virtualized platform with elastic resources on demand by provisioning hardware, software, and data sets dynamically

- **The Cloud Landscape Infrastructure as a Service (IaaS)**
- This model puts together infrastructures demanded by users—namely servers, storage, networks, and the data center fabric.
- The user can deploy and run on multiple VMs running guest OSes on specific applications.
- The user does not manage or control the underlying cloud infrastructure, but can specify when to request and release the needed resources.

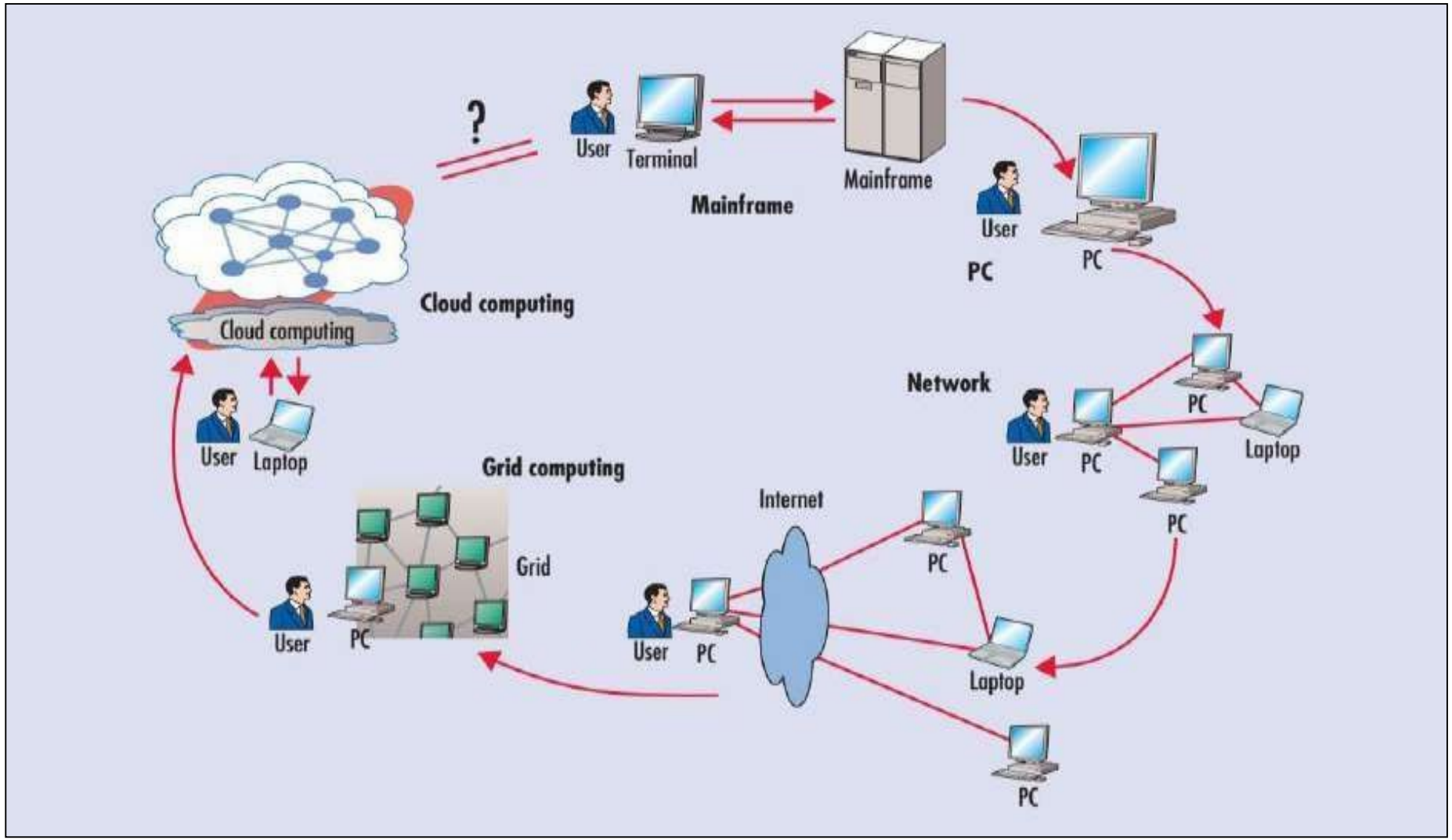
- **Platform as a Service (PaaS)**
- This model enables the user to deploy user-built applications onto a virtualized cloud platform.
- PaaS includes middleware, databases, development tools, andsome runtime support such as Web 2.0 and Java.
- The platform includes both hardware andsoftware integrated with specific programming interfaces.
- The provider supplies the API andsoftware tools (e.g., Java, Python, Web 2.0, .NET). The user is freed from managing the cloudinfrastructure.

- **Software as a Service (SaaS)**
- □ This refers to browser-initiated application software overthousands of paid cloud customers.
- □ The SaaS model applies to business processes, industryapplications, consumer relationship management (CRM), enterprise resources planning (ERP),human resources (HR), and collaborative applications.
- □ On the customer side, there is no upfrontinvestment in servers or software licensing.
- □ On the provider side, costs are rather low, comparedwith conventional hosting of user applications
- Internet clouds offer four deployment modes: private, public, managed, and hybrid

Introduction to Cloud Computing

- **Cloud computing** allowing **access** to large amounts of **computing power** in a **fully virtualized** manner, by aggregating resources and offering a single system view
- • **Cloud computing** has been coined as an umbrella term to describe a category of sophisticated on-demand computing services initially offered by commercial providers, such as Amazon, Google, and Microsoft.
- • The main **principle** behind this model is offering computing, storage, and software **"as a service**
- • **Cloud** is a parallel and distributed computing system consisting of a collection of **inter- connected and virtualised computers t**hat are dynamically **provisioned**
- • The National Institute of Standards and Technology (NIST) characterizes cloud computing as ". . . a pay-per-use model for enabling available, convenient, on-demand network access to a shared pool of configurable computing resources

HISTORY OF CLOUD COMPUTING



- Cloud computing refers to a technology where software and hardware services are delivered over the internet via a network of various remote services.
- The servers store, manage, and process data to enable users to upgrade or expand their current infrastructure.

Characteristics of Cloud Computing

1. **On-demand self-services:** The Cloud computing services does not require any human administrators, user themselves are able to provision, monitor and manage computing resources as needed.

2. **Broad network access:** The Computing services are generally provided over standard networks and heterogeneous devices.

3. **Rapid elasticity:** The Computing services should have IT resources that are able to scale out and in quickly and on a need basis. Whenever the user require services it is provided to him and it is scale out as soon as its requirement gets over.

4. **Resource pooling:** The IT resource (e.g., networks, servers, storage, applications, and services) present are shared across multiple applications and occupant in an uncommitted manner. Multiple clients are provided service from a same physical resource.

5. **Measured service:** The resource utilization is tracked for each application and occupant, it will provide both the user and the resource provider with an account of what has been used. This is done for various reasons like monitoring billing and effective use of resource.

6. **Multi-tenancy:** Cloud computing providers can support multiple tenants (users or organizations) on a single set of shared resources.

7. **Virtualization:** Cloud computing providers use virtualization technology to abstract underlying hardware resources and present them as logical resources to users.

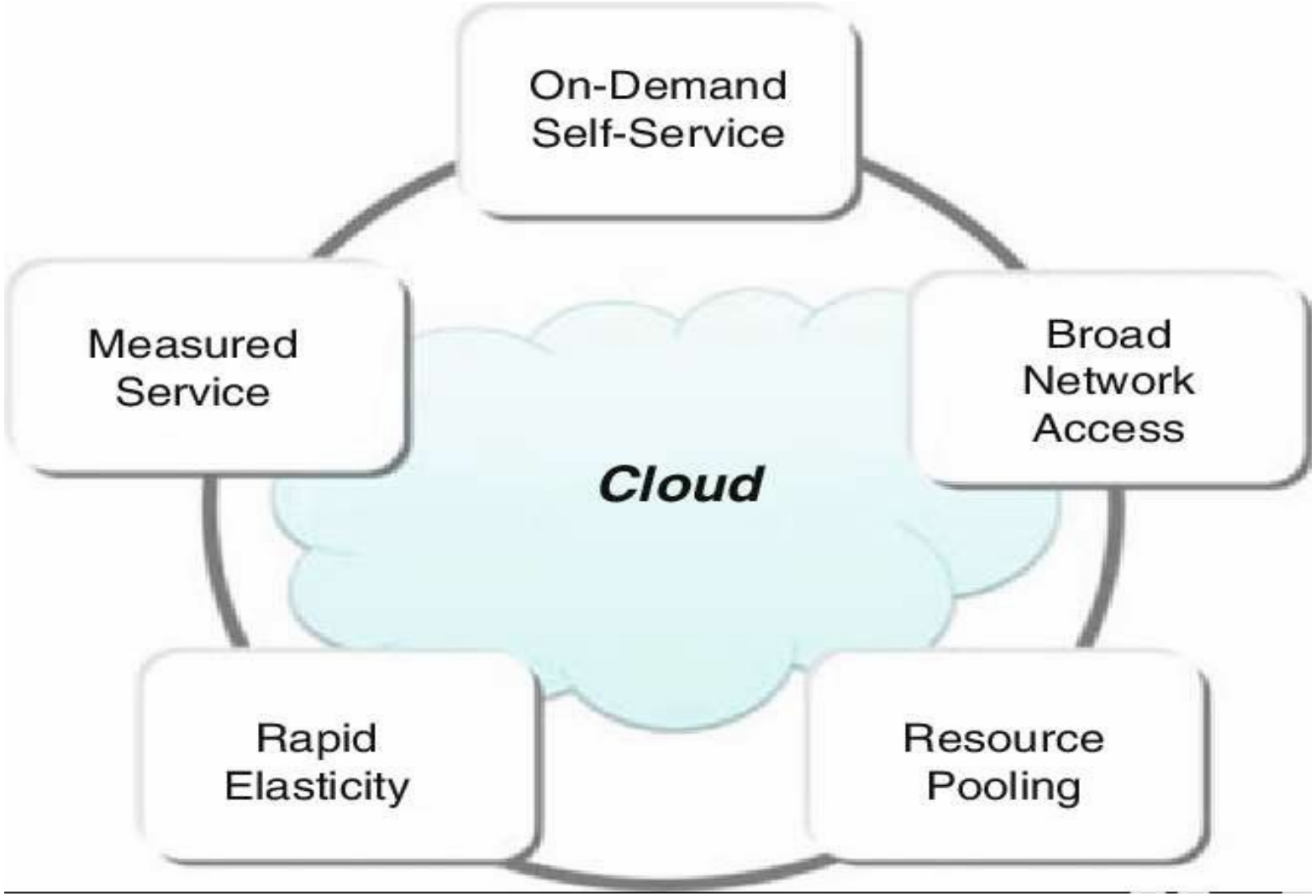
8. **Resilient computing:** Cloud computing services are typically designed with redundancy and fault tolerance in mind, which ensures high availability and reliability.

9. **Flexible pricing models:** Cloud providers offer a variety of pricing models, including pay-per-use, subscription-based, and spot pricing, allowing users to choose the option that best suits their needs.

10. **Security:** Cloud providers invest heavily in security measures to protect their users' data and ensure the privacy of sensitive information.

11. **Automation:** Cloud computing services are often highly automated, allowing users to deploy and manage resources with minimal manual intervention.

12. **Sustainability:** Cloud providers are increasingly focused on sustainable practices, such as energy-efficient data centers and the use of renewable energy sources, to reduce their environmental impact.


On-Demand
Self-Service
Measured
Service
Broad
Network
Access
Cloud
Rapid
Elasticity
Resource
Pooling

CHALLENGES AND RISKS

- Despite the initial success and popularity of the cloud computing paradigm and the extensive availability of providers and tools, a significant number of challenges and risks are inherent to this new model of computing.
- Providers, developers, and end users must consider these challenges and risks to take good advantage of cloud computing.
- Issues to be faced include user privacy, data security, data lock-in, availability of service, disaster recovery, performance, scalability, energy- efficiency, and programmability.

Benefits of Cloud Computing

1. Cost Efficiency

Cloud computing eliminate the need for upfront investments in hardware and infrastructure, allowing businesses to pay only for the resources they use on a subscription basis, and reducing overall IT costs.

2. Scalability

Cloud services can be easily scaled up or down to accommodate fluctuating workloads and business needs, providing organizations with the flexibility to expand or contract resources as required.

3. Accessibility

- Cloud computing enables remote access to data and applications from anywhere with an internet connection, allowing employees to collaborate effectively and work from any location.

Reliability and Redundancy

Cloud providers typically offer high levels of reliability and redundancy, with built-in backup and disaster recovery capabilities to ensure data integrity and minimize downtime.

5. Security

Cloud providers invest heavily in security measures to protect data, applications, and infrastructure from cyber threats, offering robust encryption, access controls, and compliance certifications to safeguard sensitive information.

6. Innovation

- Cloud computing enables rapid deployment of new applications and services, allowing businesses to experiment, innovate, and bring products to market faster than traditional IT environments.

Challenges of Cloud Computing

1.Understand App Requirements

Clearly define the functionality you want to add to your app. Identify specific features or capabilities that need to be implemented or improved.

2. Prototype and Experiment

Create prototypes or proofs-of-concept using the selected frameworks to evaluate their suitability for your app. Experiment with different frameworks to compare their ease of use, flexibility, and performance.

3. Consider Future Scalability and Maintenance

- Anticipate future scalability requirements and the potential impact on maintenance and updates. Choose frameworks that align with your app's long-term goals and roadmap.

4. Seek Expert Advice

Consult with experienced iOS developers or industry experts to get recommendations and insights based on their expertise and experience.

5. Make an Informed Decision

Based on your research, evaluation, and considerations, choose the iOS framework that best meets your app's requirements, development constraints, and long-term objectives.

By following these steps, you can effectively choose the right iOS framework to enhance the functionality of your app and ensure a successful development process.

1. Security Concerns

Security remains a top concern for businesses considering cloud computing services adoption. Data breaches, compliance issues, and unauthorized access are potential risks associated with storing sensitive information in cloud computing security.

2. Data Privacy

- Businesses must ensure that their data is protected and compliant with relevant regulations, such as GDPR or HIPAA, when stored or processed in the cloud. Maintaining data privacy and confidentiality is critical to maintaining trust with customers and stakeholders.

3. Compliance Requirements

Different industries have specific regulatory requirements governing data storage, processing, and transmission. Businesses must ensure that their cloud computing service providers comply with relevant regulations to avoid penalties and legal issues.

4. Downtime and Reliability

Cloud service outages or downtime can disrupt business operations and impact productivity. Organizations need to consider the reliability and uptime guarantees offered by cloud providers and have contingency plans in place to mitigate potential disruptions.

5. Vendor Lock-In

- Businesses may face challenges if they decide to switch cloud computing providers due to vendor lock-in. Migrating data and applications between cloud platforms can be complex, time-consuming, and costly, limiting flexibility and hindering innovation.

Addressing these challenges requires careful planning, strategic decision-making, and ongoing management to ensure a successful cloud adoption and maximize the benefits of cloud computing services for businesses.

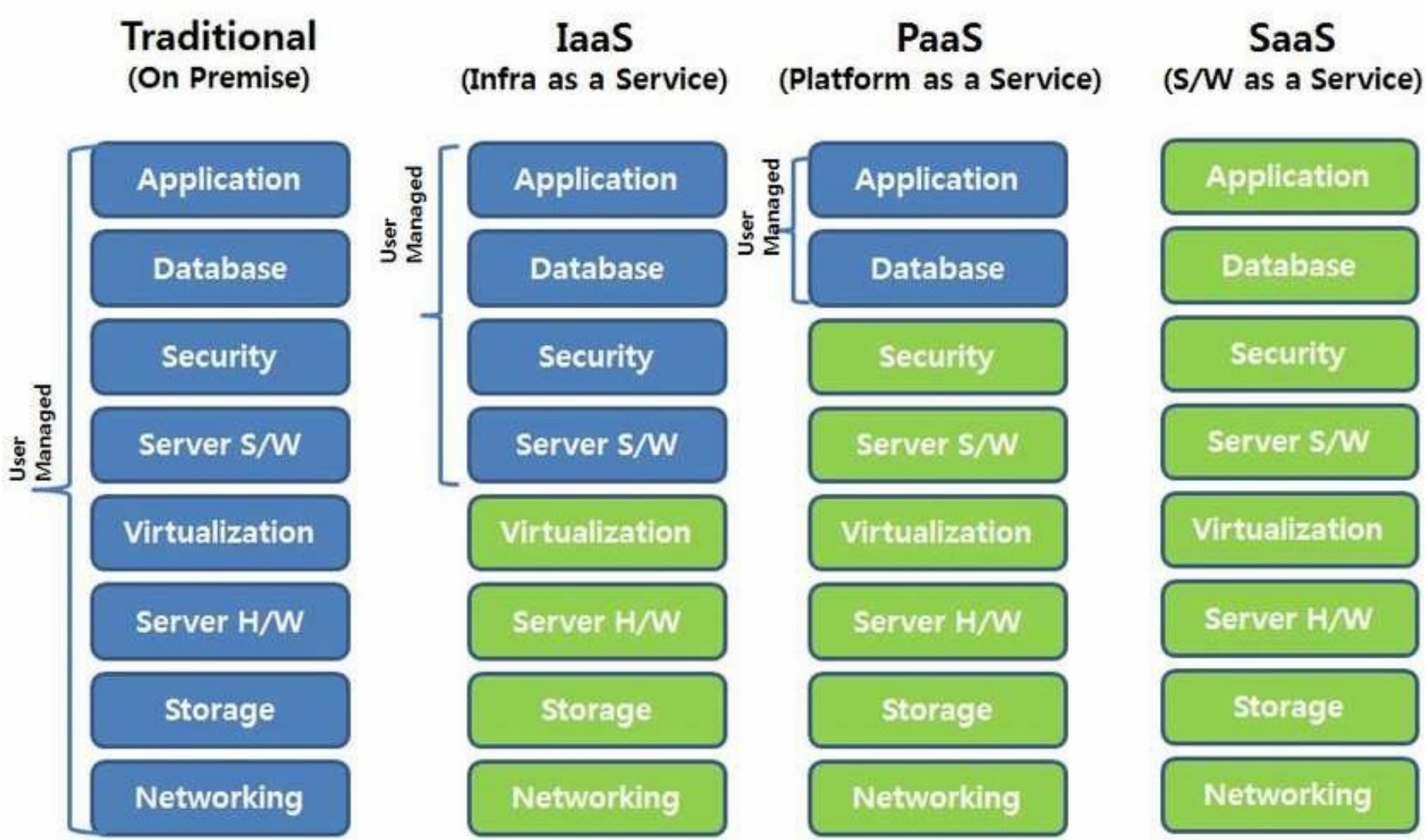
Final Words

- Cloud computing represents a transformative technology that has revolutionized the way businesses operate and manage their IT infrastructure.
- Its benefits are undeniable, offering scalability, flexibility, cost-efficiency, and accessibility to resources on demand.
- Cloud computing enables organizations to innovate faster, improve collaboration, enhance productivity, and gain a competitive edge in the digital economy.
- Cloud computing gives its full potential to drive innovation, agility, and growth in today's dynamic business landscape.

cloud delivery models

When looking for a cloud solution, the first step is understanding the differences between the three common types of cloud delivery models, which are commonly known by their acronyms:

- Software-as-a-Service (SaaS)
- Infrastructure-as-a-Service (IaaS)
- Platform-as-a-Service (PaaS)
- Depending on the use case, a business may need one, two, or all three types of delivery models, as they each serve different purposes and can work together to provide a customized IT solution.


Traditional
(On Premise)
IaaS
(Infra as a Service)
PaaS
(Platform as a Service)
SaaS
(S/W as a Service)
User Managed
Application
Database
Security
Server S/W
Virtualization
Server H/W
Storage
Networking

Infrastructure-as-a-Service (IaaS)

IT infrastructure refers to the components needed to manage a business' IT services and IT environments.

This includes hardware, software, networking components, data storage, and more.

Traditionally, businesses house all of these components in their own corporate data center, which involve a lot of work and maintenance.

With this approach, businesses have to buy server hardware, networking hardware, and other equipment and pay for the space to house it.

They also have to perform regular maintenance on all of this equipment.

- In the **IaaS** cloud delivery model, this infrastructure is provided by the **cloud service provider**.
- Cloud providers use virtualization software to transform physical hardware into metered services that are delivered to customers via the internet.
- With IaaS, businesses can manage their infrastructure in a web browser or through an API instead of through hardware.

Businesses use IaaS because it is:

- **Reliable:** Cloud service providers have redundant resources that are located all over the globe, which eliminates single points of failure.
- **Cost-effective:** With IaaS, you don’t have to purchase hardware and pay only for the resources you use as you use them.
- **Flexible:** IaaS can scale to fit a business’ needs with a click of a button through **virtualization**.

Characteristics of IaaS

- Resource Pooling and Scalability
- Self-Service and On-Demand Availability
- Broad Network Access
- Pay-As-You-Go Pricing
- Automation of Administrative Tasks
- Physical Security of Data Center Locations
- Customization and Control
- Integration and Interoperability
- Disaster Recovery and Business Continuity
- Security and Compliance

Advantages of IaaS

1. **Scalability** – Easily scale resources up or down based on demand, reducing infrastructure costs.
2. **Cost-Effective** – Pay-as-you-go pricing eliminates the need for upfront hardware investments.
3. **Flexibility** – Provides complete control over virtual machines, storage, and networking.
4. **Disaster Recovery** – Ensures high availability and data backup, reducing downtime risks.
5. **Global Accessibility** – Access resources from anywhere, enabling remote collaboration and operations

Disadvantages of IaaS

1. **Security Risks** – Requires strong security measures to prevent data breaches and cyber threats.
2. **Complex Management** – Users need technical expertise to configure and manage cloud infrastructure.
3. **Performance Variability** – Shared resources may lead to fluctuations in performance.
4. **Compliance Challenges** – Ensuring regulatory compliance can be complex due to data location and control issues.
5. **Potential Downtime** – Service outages from cloud providers can impact business operations.

Platform as a Service (PaaS)

- The PaaS delivery model is a pre-defined “ready-to-use” environment that typically contains deployed and configured IT resources.
- PaaS relies on using a ready-made environment that holds a set of pre-packaged products and tools to support the entire lifecycle of custom applications.
- A PaaS requires an IaaS.
- It brings development and deployment together to create an easier way to build, deploy, and scale applications.

A PaaS environment is usually preferred if:

- The consumer wants to extend on-premise environments into the cloud for improved scalability and other economic reasons.
- The consumer uses the environment to substitute an entire on-premise environment.
- The consumer wants to become a cloud provider and deploys their own services to other external cloud consumers.
- By using PaaS, the cloud consumer is spared the administrative burden of setting up and maintaining the infrastructure of the resources provided in the IaaS model.
- It ensures that developers have a well-tested and integrated environment to create applications.
- However, the cloud consumer has less control over the underlying IT resources that host and configure the platform.

Characteristics of PaaS

1. Integrated Development Environment
2. Built-in Scalability of Resources
3. Middleware Services
4. Business Process Management and Integration
5. Automated Backups and Recovery Systems
6. Support for Multiple Programming Languages and Frameworks
7. Collaborative Platform
8. Cost-Effectiveness and Reduced Overhead
9. Security and Compliance Management
10. Customizable and Modular

Advantages of PaaS

1. **Faster Development** – Provides pre-configured development environments, reducing setup time and accelerating application deployment.
2. **Cost Efficiency** – Eliminates the need to manage hardware, reducing infrastructure and maintenance costs.
3. **Automatic Scaling** – Dynamically scales resources based on application demand, ensuring optimal performance.
4. **Built-in Security** – Many PaaS providers include security features like authentication, encryption, and compliance support.
5. **Multi-Platform Support** – Enables development across multiple environments (e.g., web, mobile, cloud) with minimal modifications.

Disadvantages of PaaS

1. **Limited Customization** – Predefined configurations may restrict flexibility for complex applications.
2. **Vendor Lock-in** – Migration to another provider can be difficult due to platform dependencies.
3. **Security Concerns** – Data security relies on the provider, posing potential risks for sensitive applications.
4. **Performance Limitations** – Shared infrastructure can lead to latency or resource constraints for high-performance applications.
5. **Compliance Challenges** – Ensuring regulatory compliance may be difficult due to data hosting restrictions.

Software as a Service (SaaS)

A software program is provided as a cloud service and made available as a service or utility.

Applications are created and hosted by a provider in a multitenant model.

In other words, the SaaS model allows a reusable cloud service to be openly available to a range of cloud consumers.

Customers pay for its consumption on a monthly or yearly basis.

An entire marketplace contains SaaS products that can be leased and used for different purposes.

- A cloud consumer is granted limited administrative control over a SaaS product.
- It is entirely provisioned by the cloud provider, but it can be legally owned by the entity that owns the cloud service.

Characteristics of SaaS

1. Accessibility
2. Subscription-Based Pricing
3. No Hardware or Software Maintenance
4. Automatic Updates and Patch Management
5. Multi-Tenancy Model
6. Customization and Configuration
7. User-friendly and Collaborative Features
8. Data Analytics and Reporting

Advantages of SaaS

1. **Cost-Effective** – No need for hardware, installation, or maintenance; subscription-based pricing makes it affordable.
2. **Ease of Use** – Provides ready-to-use software accessible via the internet, minimizing setup time.
3. **Automatic Updates** – Regular updates and patches are handled by the provider, ensuring the latest features and security.
4. **Accessibility** – Can be accessed from any device with an internet connection, enabling remote work and collaboration.
5. **Scalability** – Easily scale the software based on the number of users or features required without hardware constraints.

Disadvantages of SaaS

1. **Limited Customization** – Some SaaS applications may not offer the level of customization needed for unique business requirements.
2. **Data Security** – Data is stored on third-party servers, increasing the risk of data breaches or loss.
3. **Internet Dependency** – Requires a stable internet connection for uninterrupted access and performance.
4. **Compliance Issues** – Adhering to regulatory requirements can be challenging if the SaaS provider doesn't support specific compliance standards.
5. **Vendor Lock-in** – Switching providers can be difficult, especially if the data or integrations are highly specific to the platform.

Feature	IaaS	PaaS	SaaS
What is Provided	Virtualized hardware (servers, storage, etc.)	Platform for app development (tools, middleware)	Software applications accessible via the internet
Control Level	High (control over infrastructure)	Medium (control over deployed applications)	Low (limited to software customization)
User Responsibility	Managing applications, data, runtime, middleware, OS	Managing applications, data	Limited to using the software application
Provider Responsibility	Physical servers, virtualization, storage, networking	Runtime, middleware, OS, virtualization, servers, storage, networking	Applications, runtime, middleware, OS, virtualization, servers, storage, networking
Use Case	Companies needing control over their environment, but not wanting to purchase hardware	Developers needing a development environment without managing underlying infrastructure	End-users needing to use software without managing infrastructure or platforms
Scalability	Scalable, with user managing scaling	Scalable, platform handles scaling	Scalable, completely managed by provider
Pricing Model	Pay-per-use based on resources consumed	Typically subscription-based with scaling options	Subscription-based, usually per user or feature set
Examples	AWS EC2, Google Compute Engine, Microsoft Azure	Google App Engine, Heroku, Microsoft Azure Web Apps	Google Workspace, Microsoft 365, Salesforce

Cloud Deployment Models

- Cloud Deployment Model functions as a virtual computing environment with a deployment architecture that varies depending on the amount of data you want to store and who has access to the infrastructure.

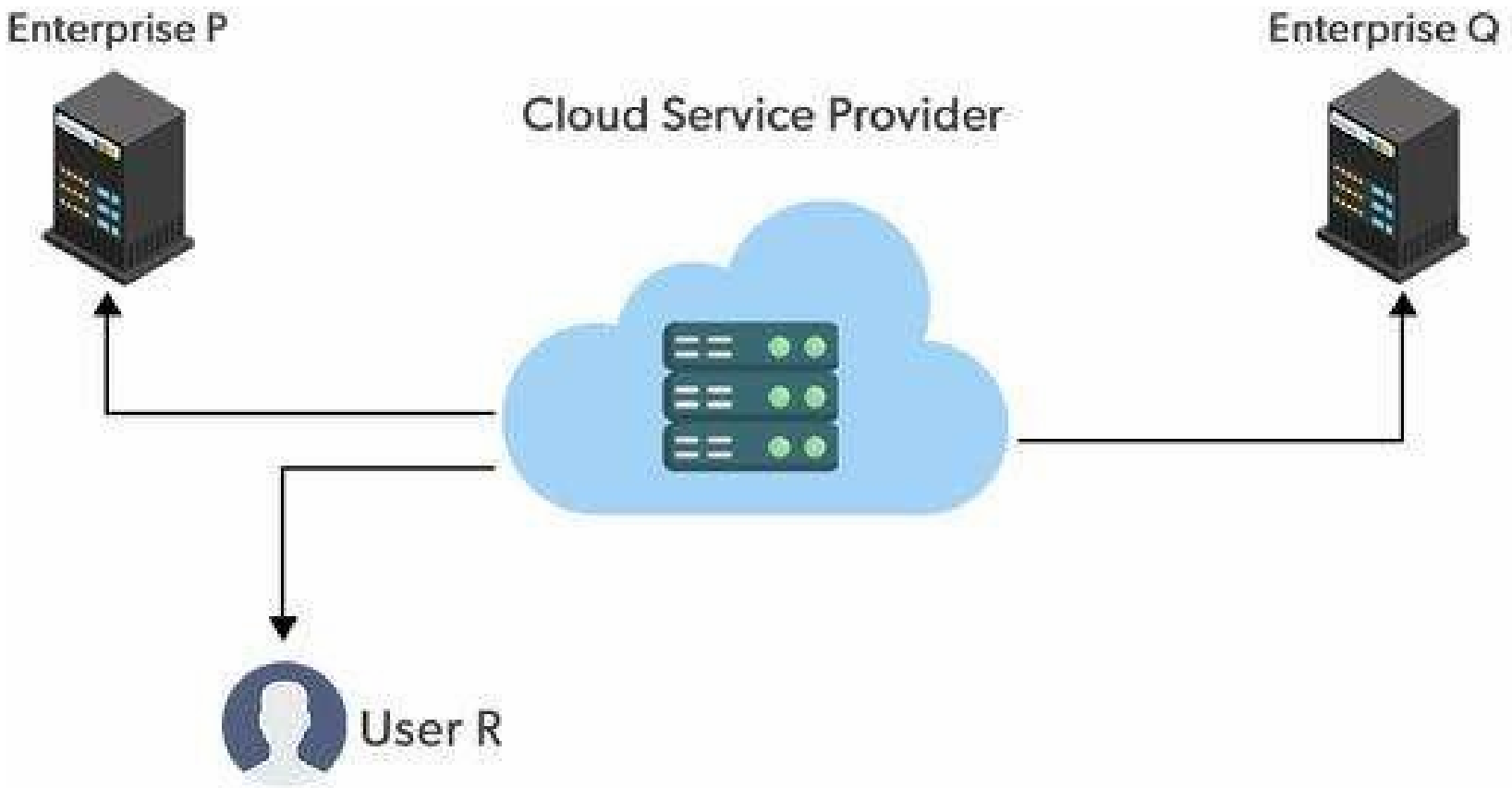
Types of Cloud Computing Deployment Models

- The cloud deployment model identifies the specific type of cloud environment based on ownership, scale, and access, as well as the cloud's nature and purpose.
- The location of the servers you're utilizing and who controls them are defined by a cloud deployment model.
- It specifies how your cloud infrastructure will look, what you can change, and whether you will be given services or will have to create everything yourself.
- Relationships between the infrastructure and your users are also defined by cloud deployment types.
- Different types of cloud computing deployment models are described below.

- Public Cloud
- Private Cloud
- Hybrid Cloud
- Community Cloud
- Multi-Cloud

Public Cloud

- The public cloud makes it possible for anybody to access systems and services.
- The public cloud may be less secure as it is open to everyone.
- The public cloud is one in which cloud infrastructure services are provided over the internet to the general people or major industry groups.
- The infrastructure in this cloud model is owned by the entity that delivers the cloud services, not by the consumer.
- It is a type of cloud hosting that allows customers and users to easily access systems and services.
- This form of cloud computing is an excellent example of cloud hosting, in which service providers supply services to a variety of customers.
- In this arrangement, storage backup and retrieval services are given for free, as a subscription, or on a per-user basis.
- For example, Google App Engine etc.


Enterprise P
Cloud Service Provider
Enterprise Q
User R

Advantages of the Public Cloud Model2

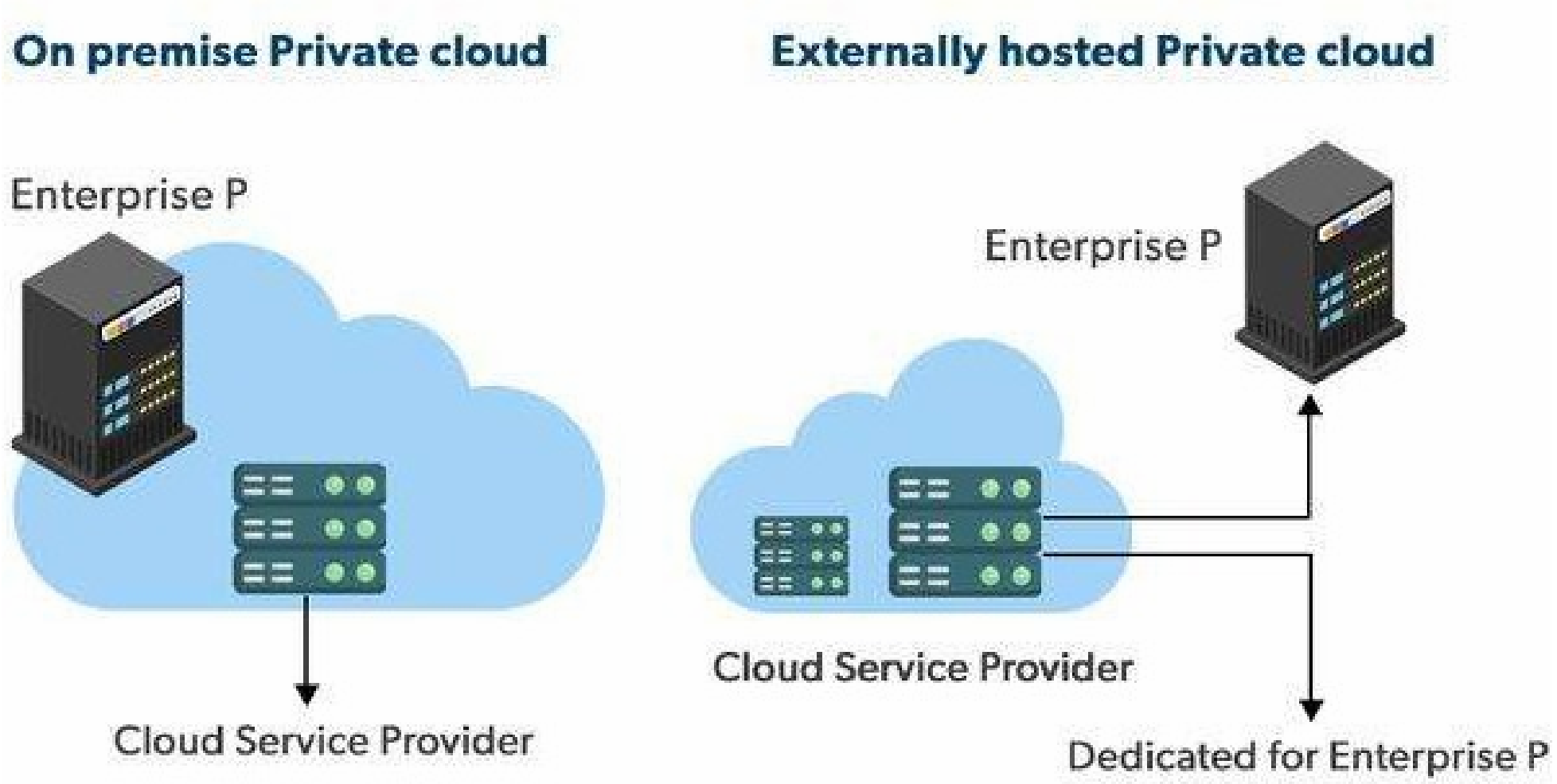
- **Minimal Investment:** Because it is a pay-per-use service, there is no substantial upfront fee, making it excellent for enterprises that require immediate access to resources.
- **No setup cost:** The entire infrastructure is fully subsidized by the cloud service providers, thus there is no need 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

- The private cloud deployment model is the exact opposite of the public cloud deployment model.
- It's a one-on-one environment for a single user (customer).
- There is no need to share your hardware with anyone else.
- The distinction between private and public clouds is in how you handle all of the hardware.
- It is also called the "internal cloud" & it refers to the ability to access systems and services within a given border or organization.
- The cloud platform is implemented in a cloud-based secure environment that is protected by powerful firewalls and under the supervision of an organization's IT department.
- The private cloud gives greater flexibility of control over cloud resources.


On premise Private cloud
Enterprise P
Cloud Service Provider
Externally hosted Private cloud
Enterprise P
Cloud Service Provider
Dedicated for Enterprise P

Advantages of the Private Cloud Model

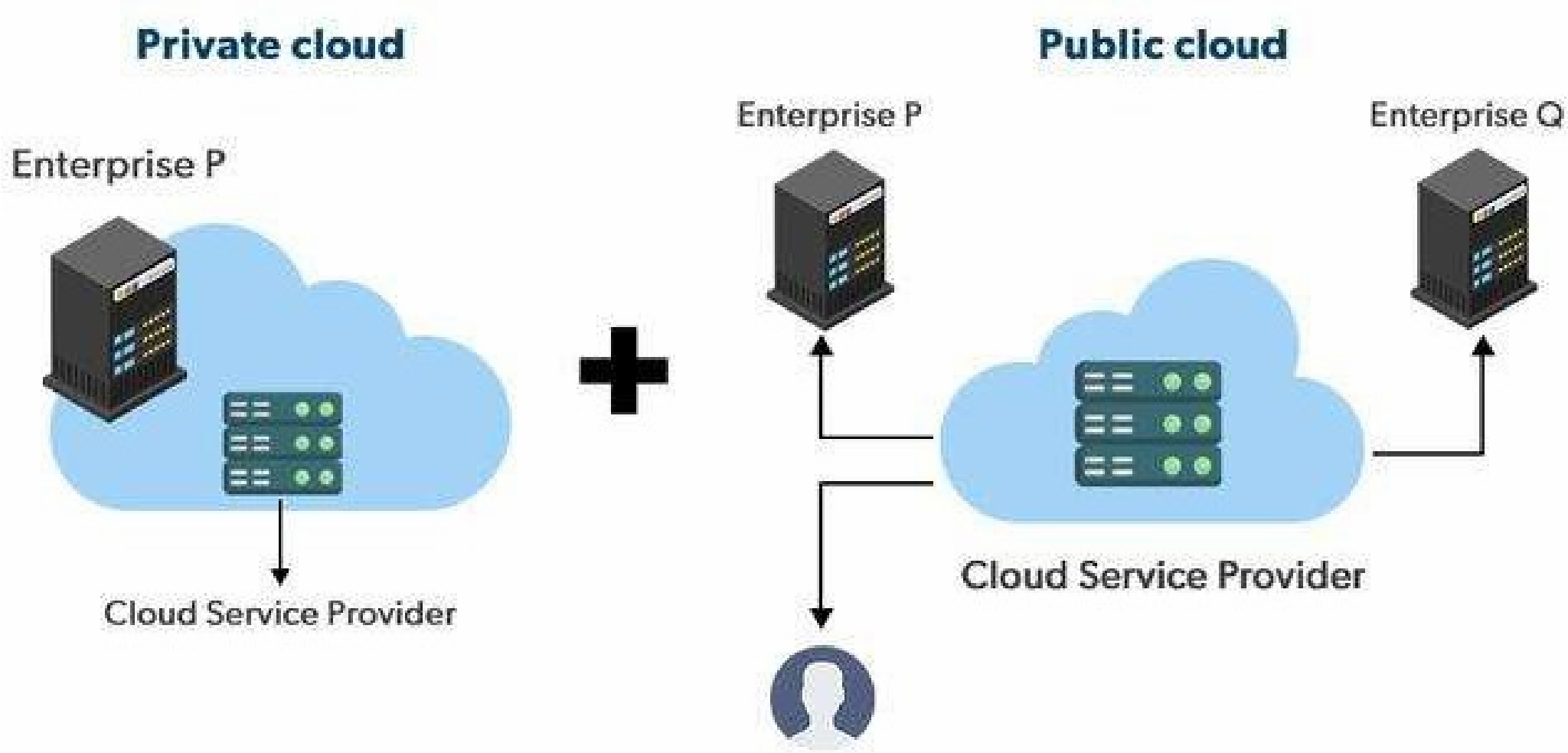
- **Better Control:** You are the sole owner of the property. You gain complete command over service integration, IT operations, policies, and user behavior.
- **Data Security and Privacy:** It's suitable for storing corporate information to which only authorized staff have access. By segmenting resources 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

- By bridging the public and private worlds with a layer of proprietary software, hybrid cloud computing gives the best of both worlds.
- With a hybrid solution, you may host the app in a safe environment while taking advantage of the public cloud's cost savings.
- Organizations can move data and applications between different clouds using a combination of two or more cloud deployment methods, depending on their needs.


Private cloud
Enterprise P
Cloud Service Provider
Public cloud
Enterprise P
Enterprise Q
Cloud Service Provider

Advantages of the Hybrid Cloud Model

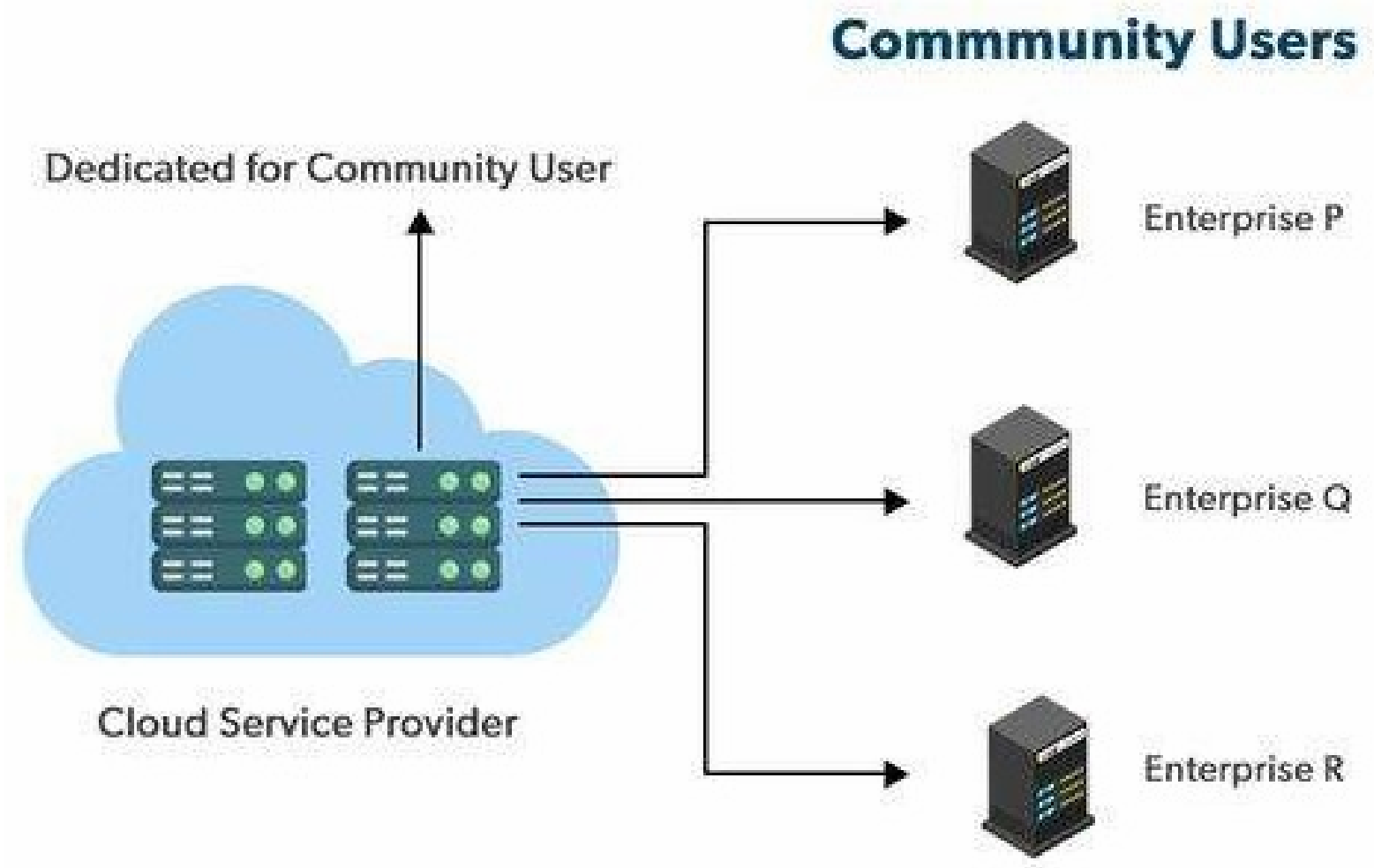
- **Flexibility and control:** Businesses with more flexibility can design personalized solutions that meet their particular needs.
- **Cost:** Because public clouds provide scalability, you'll only be responsible for paying for the extra capacity if you require it.
- **Security:** Because data is properly 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

- It allows systems and services to be accessible by a group of organizations.
- It is a distributed system that is created by integrating the services of different clouds to address the specific needs of a community, industry, or business.
- The infrastructure of the community could be shared between the organization which has shared concerns or tasks.
- It is generally managed by a third party or by the combination of one or more organizations in the community.


Commmunity Users
Dedicated for Community User
Enterprise P
Enterprise Q
Enterprise R
Cloud Service Provider

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.

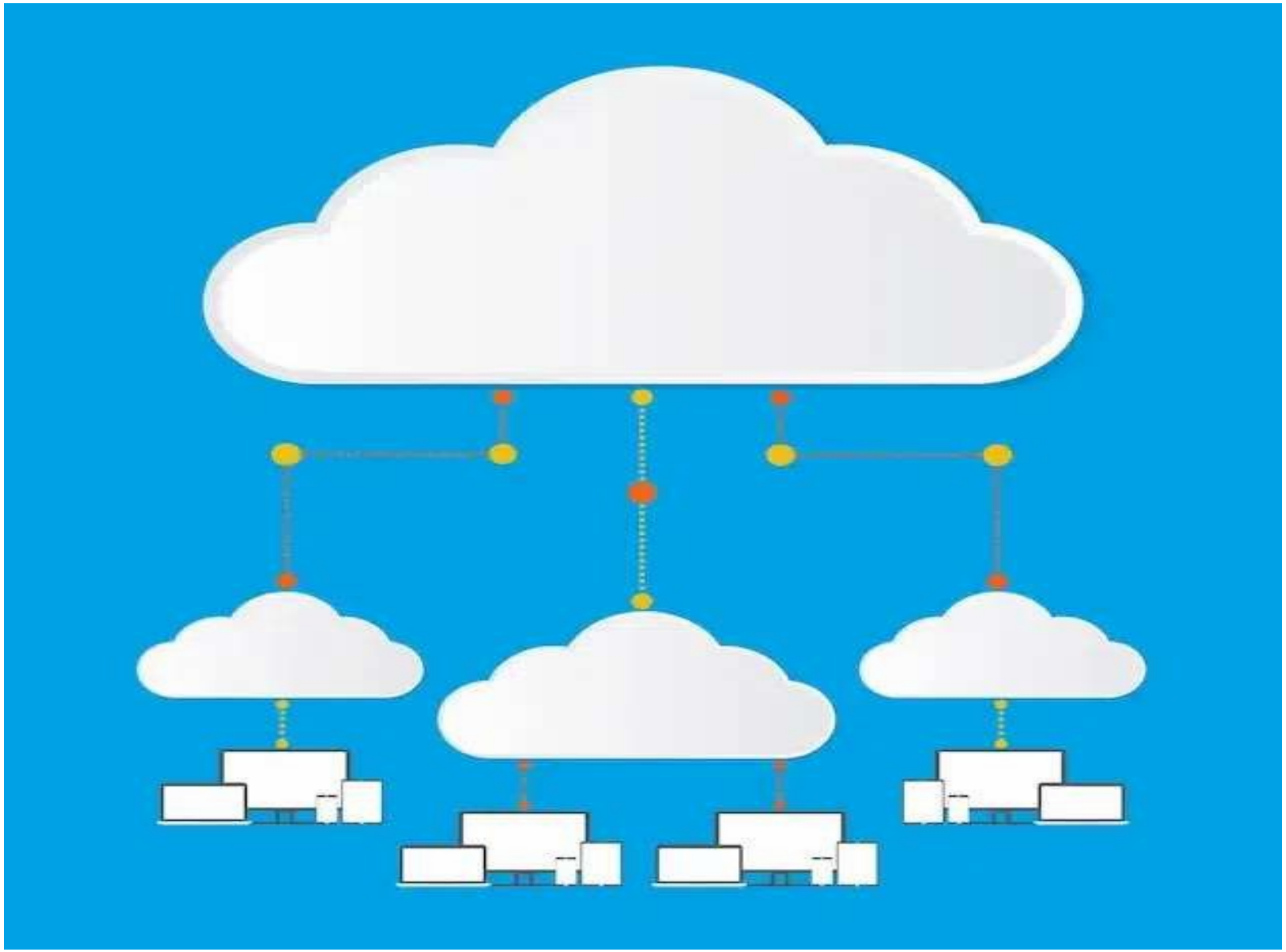
Disadvantages of the Community Cloud Model

- **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

- We’re talking about employing multiple cloud providers at the same time under this paradigm, as the name implies.
- It’s similar to the hybrid cloud deployment approach, which combines public and private cloud resources.
- Instead of merging private and public clouds, multi-cloud uses many public clouds.
- Although public cloud providers provide numerous tools to improve the reliability of their services, mishaps still occur.
- It’s quite rare that two distinct clouds would have an incident at the same moment.
- As a result, multi-cloud deployment improves the high availability of your services even more.



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.

Overall Analysis of Cloud Deployment Models

Factors	Public Cloud	Private Cloud	Community Cloud	Hybrid Cloud
Initial Setup	Easy	Complex, requires a professional team to setup	Complex, requires a professional team to setup	Complex, requires a professional team to setup
Scalability and Flexibility	High	High	Fixed	High
Cost-Comparison	Cost-Effective	Costly	Distributed cost among members	Between public and private cloud
Reliability	Low	Low	High	High
Data Security	Low	High	High	High
Data Privacy	Low	High	High	High

Cloud Computing Vendors

- **1. Amazon Web Services (AWS)**

Launched in 2006, AWS is the best cloud service provider **leading in the market**.

It becomes a major player in AI, database, machine learning, 5G cloud, multi-cloud and serverless deployments.

AWS operates in **20 geographical regions** across the world.

The company reported a revenue of **9 billion dollars** in Q3 2019.

- AWS offers **175 fully-featured services** to meet any kind of business requirements. These services are database storage, computing power, networking and many more

- You can virtually host any applications, including networks like firewall, DNS, Load balancing, or even you can have your virtual private cloud.

- AWS applications are scalable, flexible, reliable, secure and trustworthy.

- Easy sign-up and fast deployment. The best thing is there is no upfront cost and you pay for what you use. It also offers a FREE tier for some of their popular services.

Top Companies using Amazon Web Services (AWS)

- Netflix
- Spotify
- Airbnb
- Uber
- Peloton
- Expedia
- Pinterest
- Samsung
- Sony
- Novartis

2. Microsoft Azure

Microsoft Azure was launched in 2010 as Windows Azure, and later in 2014, it was renamed, Microsoft Azure.

It was launched years after the release of AWS and Google cloud but still, it is the fastest-growing cloud and giving tough competition to AWS and other cloud service providers.

There is a five-year partnership between Microsoft and **Disney**.

In this partnership, the new method will be developed to move production content to the cloud. Azure has **54 data centers** regions across the world available in **140 countries**.

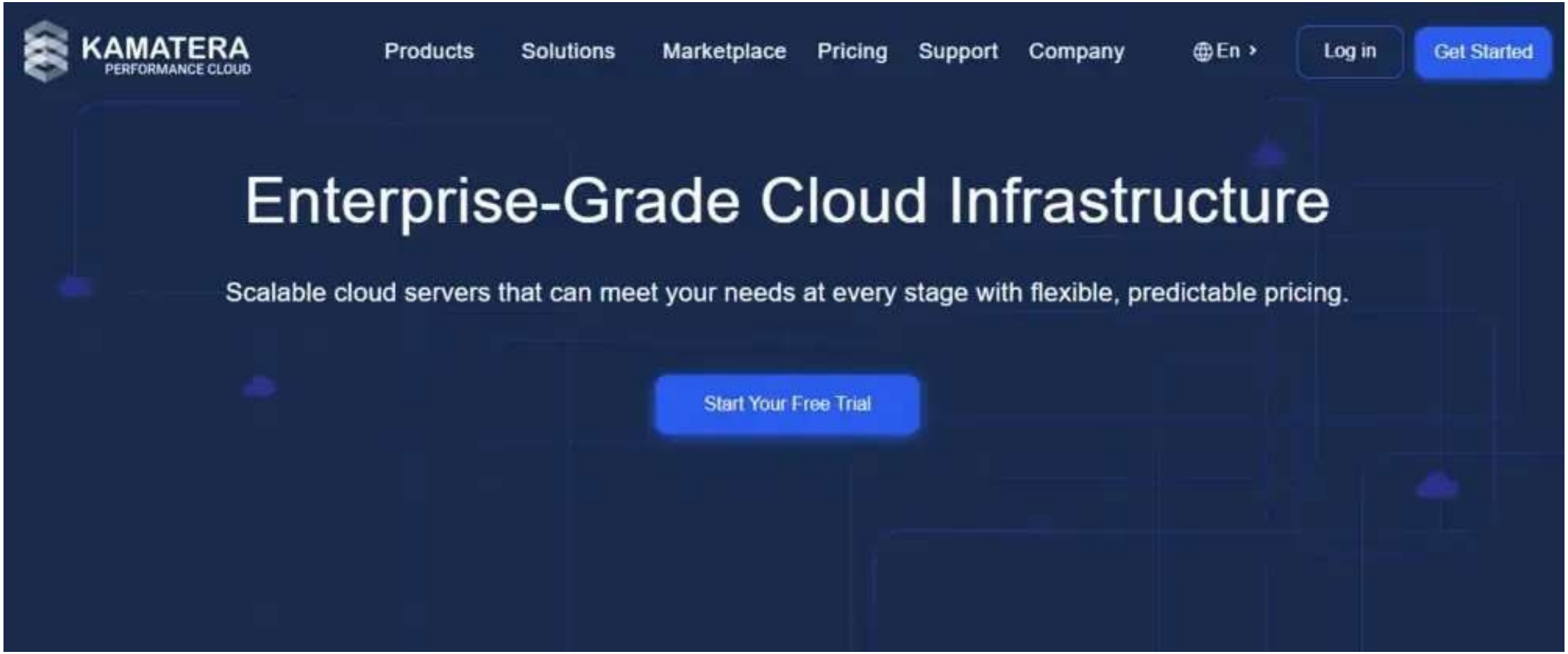
- Azure offers hundreds of services including **AI + Machine Learning**, **Analytics,** Blockchain, Compute, Containers, Databases, Developer Tools, DevOps, Identity, Integration, Internet of Things, Management, Media, Microsoft Azure Stack, Migration, Mixed Reality, Mobile, Networking, Security, Storage, Web, and Windows Virtual Desktop.

- Microsoft Azure is available with public or private cloud service or hybrid cloud service consists of both private and public.
- Scalability, consistency, security, flexibility, and cost-effectiveness.
- Azure supports various operating systems, databases, tools, programming languages and frameworks.
- It’s easier for users to move their application or framework without any hassle and recoding them again.
- 24/7 cooperative team paying attention to their customers. A free trial version of Microsoft Azure is available for 30 days.

Top Companies using Microsoft Azure

- Walmart
- Macy’s
- The Home Depot
- Starbucks
- Coca-Cola
- Bank of America
- JPMorgan Chase
- Citigroup
- Fidelity Investments
- Standard Chartered

3. Kamatera


KAMATERA
PERFORMANCE CLOUD
Products
Solutions
Marketplace
Pricing
Support
Company
En
Log in
Get Started
Enterprise-Grade Cloud Infrastructure
Scalable cloud servers that can meet your needs at every stage with flexible, predictable pricing.
Start Your Free Trial

- Allows users to adjust server configurations, CPU, RAM, and storage in real-time.
- Highly reliable with **99.95% up-time guaranteed.**
- Allows you to only pay for the resources you use, with no upfront investment or hidden fees.
- Lets you scale your cloud resources to match changing business needs.
- **24/7 Technical Support** is offered. A dedicated team available round-the-clock for troubleshooting and assistance.
- Kamatera **operates in 24 cities** across 4 continents and has recently expanded to Singapore, Tokyo, and Sydney.
- Supports multiple operating systems, databases, and applications for seamless cloud deployment.
- **Kamatera offers a 30-day free trial of up to $100.**

Top Companies using Kamatera

- Xero
- Redfin
- CivicFlus
- CoSchedule
- MarketMuse
- AirCail
- Veeqo
- Foirt of Rertal
- Raken

Oracle Cloud

Oracle Cloud is an **ERP(Enterprise Resource Planning)** based cloud service that helps you to build, deploy, and manage workloads in the cloud or on-premises. Oracle has approximately **4, 30, 000** huge numbers of clients around the world. The total revenue generated by Oracle was around **6.81 billion dollars** in 2019.

- Oracle IaaS offerings are Compute, Storage, Networking, Governance, Database, Load Balancing, DNS Monitoring, Ravello, and FastConnect.IaaS help to run any kind of workload of an Enterprise.

- Oracle PaaS offerings are Data Management, Application Development, Integration, Business Analytics, Security, Management, and Content and Enterprise. PaaS helps developers to develop, connect, secure and share data across the applications.

- Oracle SaaS offerings are CX, HCM, ERP, SCM, EPM, IoT, Analytics, Data, and Blockchain Applications. SaaS provides a complete data-driven and secure cloud environment.

- The best thing about this cloud services provider is its **chatbot** option which can help customers 24/7 whenever they face difficulties.
- Data analytics by users that help decision-makers in planning for the company's financial condition.
- Secure and better visibility to unsanctioned apps and protects against sophisticated cyberattacks.
- Payment according to the usage.

Top Companies using Oracle Cloud

- Labcorp
- Diebold Nixdorf
- CVS Health
- Universal Studios
- Zurich
- UnitedHealth Group
- Hitachi
- Ahold Delhaize
- Bank of America

IBM Cloud (Kyndryl)

- Developed by IBM, this cloud service offers another set of solutions to the users to deploy their applications on the cloud. It offers IaaS, SaaS, and PaaS services via **public, private, hybrid and multi-cloud** models.
- IBM generated **5.3 billion dollars** of revenues according to Q3 2019 which is 6.4 percent higher than the previous quarter.
- IBM cloud offers approximately 170 products and services to meet the customer's business demands.
- IBM's best bets come in the form of the **Internet of Things, Cognitive Computing and Blockchain**.
- Recently IBM has **Red Hat**, for the delivery of hybrid solutions efficiently.
- The cloud service is helping home appliance manufacturers, retailers, and medical supply businesses.

- Computer Network, Storage, Cloud Packs, Management, Security, Database, Analytics, AI, IoT, Mobile, Dev Tools, Blockchain, Integration, Migration, Private Cloud, and VMware are some services offered by IBM cloud.
- Freedom to select and unite the desired tools, data models and delivery models in designing/creating the next-generation services or applications.
- Users can manage their applications in many coding languages such as Java, Python, Swift, Php, etc.
- IBM AI helps with its multifunctional ability such as text to speech, detecting language, machine learning, classification of natural language, etc.
- Costs depends on the usage but free in its lite mode with free access to more than 40 services by IBM Cloud.
- You can incorporate **highly performing cloud communications and services** into your IT environment with the help of **IBM Bluemix** Cloud platform.

Top Companies using IBM Cloud (Kyndryl)

- City Furniture, Inc.
- Chevron Phillips Chemical (CPChem)
- Carrefour Belgium
- Canadian Malartic
- Bord Gáis Energy
- Blue NAP Americas
- Bank of Ayudhya Public Company Ltd (Krungsri)
- Arizona Department of Transportation

VMware

VMware is a comprehensive cloud management platform. It helps you to manage a hybrid environment running anything from traditional to container workloads. The tools also allow you to maximize the profits of your organization.

Features:

- Enterprise-ready Hybrid Cloud Management Platform
- Offers Private & Public Clouds
- Comprehensive reporting and analytics which improve the capacity of forecasting & planning
- Offers additional integrations with 3rd parties and custom applications, and tools.

Provides flexible, Agile services

Google Cloud Platform

Google Cloud is a set of solution and products which includes GCP & G suite.
It helps you to solve all kind of business challenges with ease.

Features:

1) Allows you to scale with open, flexible technology
2) Solve issues with accessible AI & data analytics
3) Eliminate the need for installing costly servers
4) Allows you to transform your business with a full suite of cloud-based services