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CLOUD COMPUTING - MODULE 1

What is the concept of cloud computing?

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.

Difference between Traditional computing and Cloud Computing?

Traditional Computing	Cloud Computing
It refers to delivery of different services on local server.	It refers to delivery of different services such as data and programs through internet on different servers.
It takes place on physical hard drives and website servers.	It takes place on third-party servers that is hosted by third-party hosting companies.
User can access data only on system in which data is stored.	It is easy to access data anywhere at any time by user.
It does not require any internet connection to access data or information.	It requires fast, reliable and stable internet connection to access information anywhere at any time.
Software in purchased individually for every user and requires to be updated periodically.	Software is offered as an on-demand service (SaaS) that can be accessed through subscription service

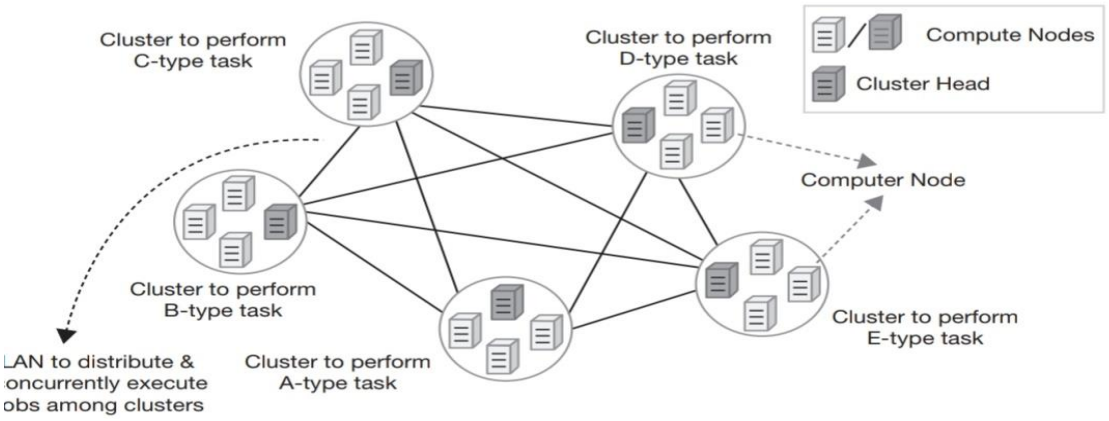
What are the limitations of Traditional computing?

- Administrative overhead
- High maintenance cost
- Time and Space restrictions
- Limited Scalability
- Remote access to system is not available

Cluster Computing

- Computing clusters are made of multiple nodes (computers) connected via network which perform similar tasks.
- execution of a task can be faster as it can be distributed and executed in parallel across multiple machines inside a cluster
- All the nodes of a cluster together give impression of a single system.
- *Each node in a simple cluster is set to perform same task or same set of tasks*
- In each cluster, one computer is assigned the job of controlling the cluster. That particular computer (or node) is known as *cluster head*.
- The head's responsibility in such a simple cluster is to divide and distribute jobs among different nodes in that cluster when matching computing tasks appear.
- In an actual *cluster computing* system, multiple clusters (built to perform different type of functionalities) are linked together through a LAN
- when a particular job appears, the cluster head divides and distributes it among matching clusters (designated for those jobs) for faster execution
- *Computers are clustered together to achieve reliability, greater processing power and produce supercomputer like performance*

- In this computing model, a set of computers were reserved to handle specific type of task to make the system more reliable. If any node fails, other nodes in the cluster can handle the load
- *Cluster computing introduced the concept of resource pooling. The pools were made of homogeneous computing systems.*



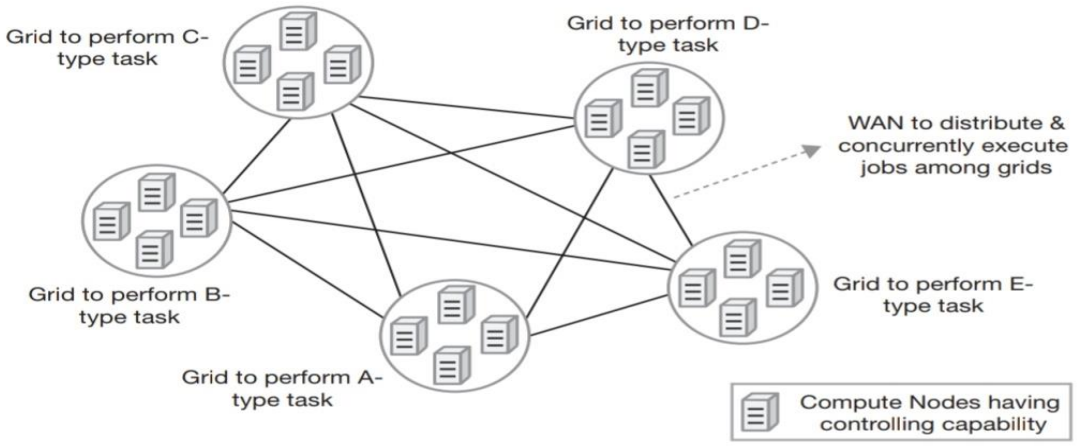
Question: How will we eliminate cluster head problem in cluster computing?

Cluster architecture lead to more powerful and reliable computing systems by creating resource pools, but it raised concerns regarding its dependency on the cluster head. Performance of such system was largely dependent on the efficiency and accessibility of cluster head. Existence of *cluster head* raises possibility for *single point of failure* too. *An advanced computing model called grid computing model was required to eliminate the cluster head problem of cluster computing model.*

Grid Computing

- In the process of finding a solution to this problem, technologists came up with an idea where each node belonging to a cluster would have same priority. It was required that all of them could perform similar functions and no particular node had to be assigned the role of 'head' among them. This new architecture is called a *Grid*.
- Grid computing concept introduced the idea of decentralization of control in distributed computing environment.
- Another important feature introduced by grid computing is that the computing environment could now be built with heterogeneous computing systems, that is, systems with diverse hardware configurations.
- The other major challenge before setting up a large *distributed computing* environment is stablishing co-operation among systems of different administrative domains.
- Computing grid introduced distributed computing environment, made up of heterogeneous systems which could be located at separate administrative domains.
- With grid computing era, computing systems reached a stage where they had acquired the following important characteristics

Large scale: Grid concept promises to deal with computing resources going up to millions.
Geographical distribution: Computing resources could be located at distant places.
Heterogeneity: Computing grid could accommodate resources having different hardware characteristics and using various types of software.
Resource co-ordination: Resources in a grid could coordinate among themselves to generate aggregated computing capabilities.
Pervasive access: Resource failure could be handled by granting access to other available resources.
Unlimited resource addition (scaling): Being a distributed computing model, it allows easy growth of system capacity by adding more resources into an existing system.



Difference between Cluster Computing and Grid Computing?

Characteristics	Cluster Computing	Grid Computing
Ownership	Single	Multiple
System Management	Centralized	Decentralized
User Management	Centralized	Decentralized
Resource Pool Creation	Yes	Yes
Resource Node Type	Homogeneous	Heterogeneous
Resource Scheduling	Centralized	Decentralized
Network Connection Type	LAN	LAN/WAN/MAN
System Architecture	Single System Image	Autonomous, independent nodes
Coupling	Tight	Loose

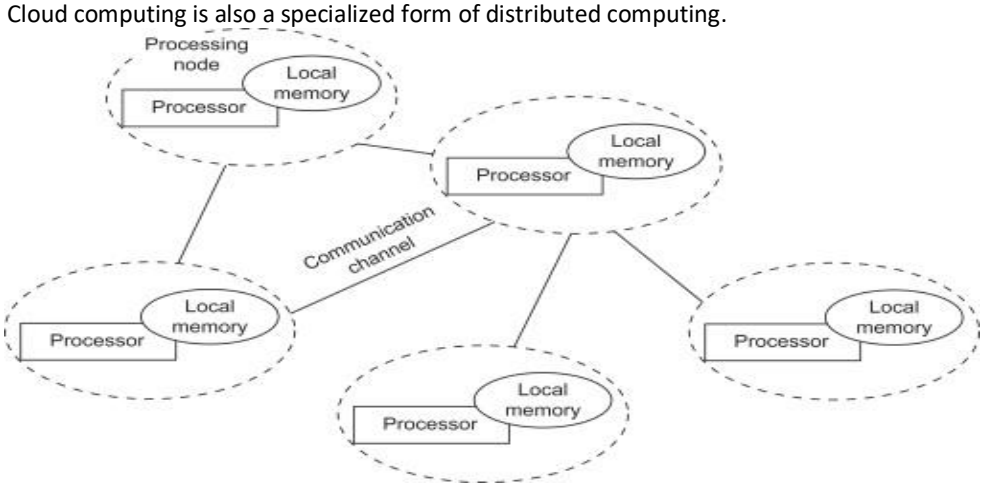
Utility Computing

- In utility computing a service provider makes computing resources and infrastructure management available to the customer as needed & charges them for specific wage rather than flat rate.
- Utility is the packaging of system resources such as computations, storage as a metered service.
- Focused on on-demand computing like computing can be delivered as a utility service much like electricity.
- Utility Computing is the packaging and delivery of computing resources, similar to traditional public utilities like electricity, water, or telephone. The model follows pay-per-use mode of payment and on-demand service facility.
- This sort of computing enabled small business owners to afford high-performance computing facilities, which with their limited budget they could have never dreamed of using.
- One important facilitator behind utility computing idea implementation was the virtualization concept of hardware resources like processor, memory, storage, and network.

Distributed Computing

- **Distributed computing is a model in which components of a software system are shared among multiple computers or nodes. Even though the software components may be spread out across multiple computers in multiple locations, they're run as one system. This is done to improve efficiency and performance.**
- **Distributed computing can increase performance, resilience and scalability, making it a common computing model in database and application design.**

- **Distributed computing networks can be connected as local networks or through WAN if the machines are in a different geographic location.**
- **Processors in distributed computing systems typically run in parallel**.
- Cloud computing is also a specialized form of distributed computing.



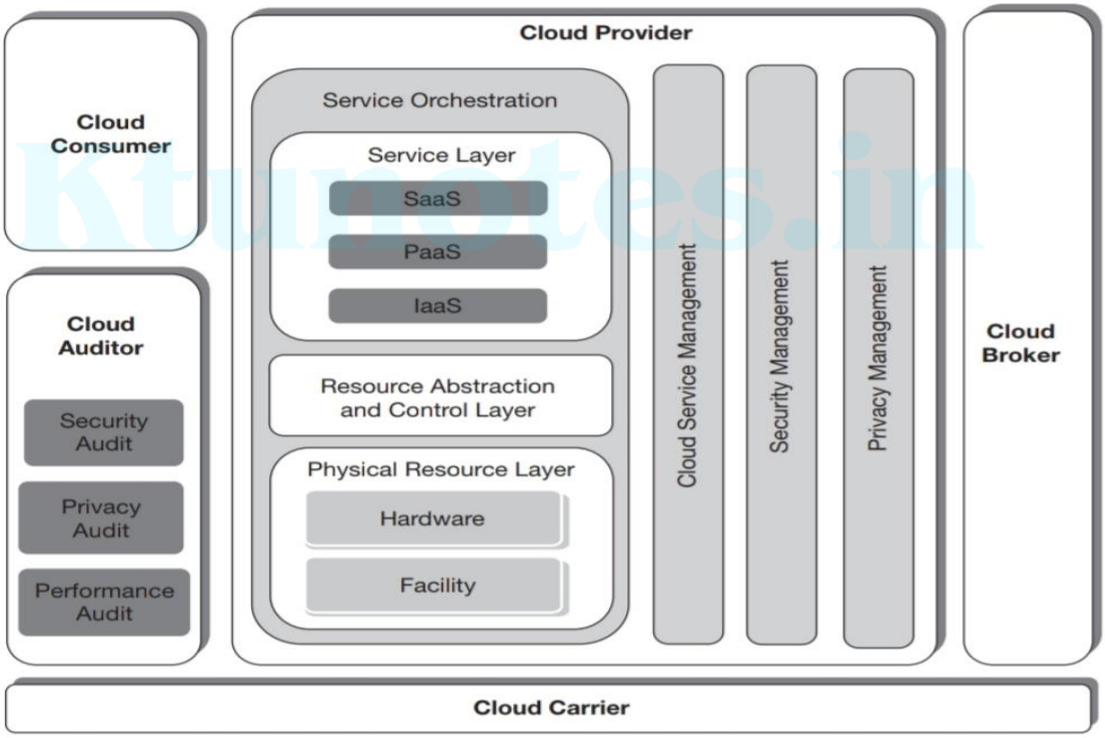
Difference between Cluster, Grid and Cloud Computing

Cluster Computing	Grid Computing	Cloud Computing
A cluster is normally formed with computers of a single location, otherwise the system becomes complex.	Grid is inherently more distributed by its nature. The computers need not to be in the same geographical location.	It allows total distribution of resources like the grids. Hardware resources are maintained in multiple data centers spread across the globe.
Resources are generally prereserved for specific type of task.	Resources are generally prereserved for specific type of task.	Resources are not pre-reserved for specific task. Resource utilization is mainly demand-driven.
Computation job takes place in one administrative domain owned by a single party.	Computation could occur over many administrative domains owned by multiple parties as connected together.	Computing resources of a cloud is usually owned by a single party. But multiple administrative domains can be combined together to perform the job.
It features the centralized task management and scheduling system.	It features the distributed task management and decentralized scheduling	It features the decentralized task management with more dynamic computing infrastructure.
System is not dynamic in nature. Application mobility is not possible.	System is not dynamic in nature. Application mobility is not possible.	It is a dynamic system. Mobility of application is an inherent feature in this system.

NIST Reference Model – Basic Terminologies and Concepts

- The *NIST model* of cloud computing separates cloud computing in two categories. One category is based on the operational or deployment pattern of the cloud and the other one is based on the nature of service that the cloud provides.
- *Cloud modeling based on deployment*: It focusses on the access boundary and location of the cloud establishment. The access boundary defines the purpose of using the cloud to some extent. There are four categories of cloud deployment: public cloud, private cloud, community cloud and hybrid cloud.
- *Cloud modeling based on service delivery*: This model describes the type of computing service that is offered to users by the service provider. There are three prime categories of service delivery models, namely Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS)

- Cloud Consumer: The cloud consumer is the principal *stakeholder* for the cloud computing service. A cloud consumer represents a person or an organization that maintains a business relationship with, and uses the service from a cloud provider. The cloud consumer uses cloud service and may be billed for the service by the provider.
- Cloud Provider: A cloud provider is a person or an organization; it is the entity being responsible for making a service available to interested parties. A Cloud Provider acquires and manages the computing infrastructure required for providing the services.
- Cloud Auditor: The cloud services provided by cloud provider to the cloud consumer must comply to some pre-agreed policies and regulations in terms of performance, security etc. The verification of these agreed conditions can be performed by employing a third-party auditor. The cloud auditor is a party who can conduct independent assessment of cloud services and report it accordingly.
- Cloud Broker: A cloud broker is an entity that manages the use, performance, and delivery of cloud services and negotiates the relationships between cloud providers and cloud consumers. Consumers can avoid the responsibilities of complex tasks by requesting services from brokers instead of consuming services from providers directly.
- Cloud Carrier: Cloud computing services are delivered from cloud provider to cloud consumer either directly or via some cloud broker. Cloud carrier acts as an agent in this delivery process. They are the organizations who provide the connectivity and transport facility of services through their network.



- Service Management: The *Service Management* component of cloud provider takes care of the functions needed for the management and operation of cloud services. There are three modules of cloud service management as business support, provisioning/configuration and portability/interoperability.
- Security & Privacy: *Security management* in the NIST reference architecture refers towards developing a secure and reliable system. It means protecting the system and its information from unauthorized access. *Privacy management* aims to keep personal or sensitive information secret and saves them from revealing out.

- Service Orchestration: Service orchestration refers to the 'composition of system components to support the cloud providers' activities in arrangement, coordination and management of computing resources in order to provide cloud services to cloud consumers. It has 3 layers.
- Service layer: Cloud provider puts interfaces that enables the service consumers to access various computing services. Thus the access interfaces for different types of cloud services (SaaS, PaaS and IaaS) are represented in this layer.
- Resource Abstraction & Control layer: At this layer, the abstraction of physical resources are implemented (through the software). Access to any hardware resources goes through this layer and the layer secures the system by controlling resource allocation and access.
- Physical Resource layer: The *physical resource layer* is the lowest layer in the stack that houses all of the physical computing resources. Hardware resources include computers (with processor and memory components), storage components (hard disks), network entities (routers, firewalls, switches, network links and interfaces) and other physical computing devices. Facilities include includes power supply, ventilation, cooling, communications and other aspects of a physical plant.

Cloud Deployment Models or Types of cloud

1) Public Cloud

- the infrastructure is made available to the general public or a large industry group and is owned by an organization selling cloud services.
- The *public cloud* deployment model provides the widest range of access to consumers among all cloud deployments.
- Anyone who subscribes it gets open access to this cloud facility. The consumer can either be an individual user or a group of people representing some organization or an enterprise.
- Public cloud is also referred as *external cloud* as physical location-wise it remains external or *off-premises* and the consumers can then remotely access the service.
- A public cloud is hosted and managed by some *computing vendors* who establishes data centers to provide the service to consumers.
- Amazon Web Services, Google Cloud, Microsoft Azure and Salesforce.com are some of the popular public clouds.
- Public cloud deployment promotes *multi-tenancy* at its highest degree. Same physical computing resource can be shared among multiple unrelated consumers. This provides major advantages as it becomes possible for a single *cloud vendor* to serve a large number of consumers.

2) Private Cloud

- The *private cloud* deployment does not provide open access to all. It is mainly for organizational use and access to a private cloud deployment is restricted for general public.
- Private cloud is also referred as *internal cloud* since it is built to serve internal purpose of the organizations.
- the infrastructure is operated solely for an organization, It may be managed by the organization or a third party and may exist on or off the premises of the organization.
- For high-security and critical systems, like systems of defense organizations, private cloud is the suggested approach.
- While a public cloud cannot physically reside at any consumer's location (*physical boundary*), private clouds may reside either inside consumer organization's premises (*on-premises*) or outside (*off-premises*) at any neutral location.
- A private cloud may be established and managed by the consumer organization itself or they (the consumer) may outsource the responsibility to some other computing vendor.

3) Community Cloud

- The *community cloud* deployment model allows access to a number of organizations or consumers belonging to a community and the model is built to serve some common and specific purpose.
- It is for the use of some community of people or organizations who share common concerns in business functionalities, security requirements etc.

- Community cloud deployment can be *on-premises* or *off-premises*.
- Physically it may reside on any community member's premises or it may be located in some external location. Like private cloud, this cloud can also be governed by some participating organization(s) (of the community) or can be outsourced to some external computing vendor.
- The goal of community cloud deployment is to provide the benefits of public cloud, like multi-tenancy, pay-per-use billing etc. to its consumers along with added level of privacy and security like the private cloud.
- One familiar example of community cloud is some services launched by government of a country with the purpose of providing cloud services to national agencies. The agencies are consumers in this case belonging to a single community (the government).

4) Hybrid Cloud

- A *hybrid cloud* is generally created by combining private or community deployment with public cloud deployment together.
- This deployment model helps businesses to take advantage of private or community cloud by storing critical applications and data.
- There at the same time, it provides the cost benefit by keeping shared data and applications on the public cloud.
- the hybrid cloud can be formed by combining two elements from a set of five different *cloud deployments* as on-premises private cloud, off-premises private cloud, on-premises community cloud, off-premises community cloud and public cloud, where one among the first four deployments is combined with the last one (public cloud)

Difference between public cloud and private cloud

Public Cloud	Private Cloud
The management is entirely provider's responsibility.	The consumers have important roles to play in management of the cloud.
The consumers have very less control or no control.	The consumers have more control over the environment.
The public cloud deployment often creates concerns regarding security and privacy of data.	It provides more confidence regarding security of data as remains under the control of consumer organization's security boundary.
It is an ideal model for practicing pay-as-you-use philosophy.	It is not an ideal scenario for promoting pay-asyou-use philosophy.
This is more economical as multiple unrelated consumers (tenants) share same infrastructure.	The cost of computing is more in comparison to public cloud.

Cloud Characteristics

Cloud computing has some interesting characteristics that bring benefits to both cloud service con- sumers (CSCs) and cloud service providers (CSPs). These characteristics are:

- No up-front commitments
- On-demand access
- Nice pricing
- Simplified application acceleration and scalability
- Efficient resource allocation
- Energy efficiency
- Seamless creation and use of third-party services

Benefits of Cloud

1. **High Speed – Quick Deployment:** The ability to spin up new cloud computing instances in a matter of seconds reshaped the agility and speed of software development. Developers can easily test new ideas

and design application architecture without the dependency on on-site hardware limitations or slow procurement processes.

2. **Efficiency and Cost Reduction:** By using cloud infrastructure, you don't have to spend huge amounts of money on purchasing and maintaining equipment. This drastically reduces CAPEX costs and Total Cost of Ownership (TCO). You don't have to invest in hardware, facilities, utilities, or building out a large data center to grow your business. You do not even need large IT teams to handle your cloud data center operations, as you can enjoy the expertise of your cloud provider's staff.
3. **Data Security:** Cloud offers many advanced security features that guarantee that data is securely stored and handled. Features like granular permissions and access management via federated roles can restrict access to sensitive data only to the employees that need access to it, and by that reducing the attack surface for malicious actors.
4. **Scalability:** Cloud-based solutions are ideal for businesses with growing or fluctuating bandwidth demands. If your business demands increase, you can easily increase your cloud capacity without having to invest in physical infrastructure. This level of agility can give businesses using cloud computing a real advantage over competitors. This scalability minimizes the risks associated with in-house operational issues and maintenance. Scalability is probably the greatest advantage of the cloud.
5. **Unlimited Storage Capacity:** Related to the scalability benefit above, the cloud has essencially unlimited capacity to store any type of data in various cloud data storage types, depending on the availability, performance and frequency the data has to be accessed. The rule of thumb is that the cost of storage goes up according to the levels of availability of the data, performance and access frequency. Creating and optimizing the cloud cost stucture policy can reduce the cost of cloud storage
6. **Back-up and Restore Data:** The fact that data can be stored in the cloud without capacity constrains also helps with backup and restore purposes. As end-users data changes over time and needs to be tracked for regulations or compliance reasons, older software versions can be stored for later stages, in cases they would be needed for recovery or rollback.
7. **Data Loss Prevention:** Cloud infrastructure can also help you with loss prevention. If you rely on a traditional on-premises approach, all your data will be stored locally, on office computers. Despite your best efforts, computers can malfunction for various reasons — from malware and viruses to age-related hardware deterioration, to simple user error. But, if you upload your data to the cloud, it remains accessible for any computer with an internet connection, even if something happens to your work computer.

Challenges of cloud computing

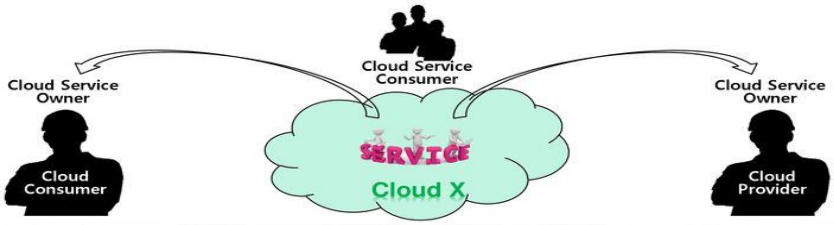
1. Security, Privacy, and Trust: Security and privacy affect the entire cloud computing stack, since there is a massive use of third-party services and infrastructures that are used to host important data or to perform critical operations. In this scenario, the trust toward providers is fundamental to ensure the desired level of privacy for applications hosted in the cloud. Legal and regulatory issues also need attention.
2. Data Lock-In and Standardization: A major concern of cloud computing users is about having their data locked-in by a certain provider. Users may want to move data and applications out from a provider that does not meet their requirements. However, in their current form, cloud computing infrastructures and platforms do not employ standard methods of storing user data and applications. Consequently, they do not interoperate and user data are not portable. The answer to this concern is standardization.
3. Availability, Fault-Tolerance, and Disaster Recovery: It is expected that users will have certain expectations about the service level to be provided once their applications are moved to the cloud. These expectations include availability of the service, its overall performance, and what measures are to be taken when something goes wrong in the system or its components. In summary, users seek for a warranty before they can comfortably move their business to the cloud.
4. Resource Management and Energy-Efficiency: One important challenge faced by providers of cloud computing services is the efficient management of virtualized resource pools. Physical resources such as

CPU cores, disk space, and network bandwidth must be sliced and shared among virtual machines running potentially heterogeneous workloads.

Roles and Boundaries

Roles and Boundaries – 1/2

- **Cloud provider**
  - A organization that provides cloud-based IT resources as-a-service
  - Responsible for making cloud services available to cloud customers under SLA and guaranteeing required management/administrative duties delivered in order to ensure the on-going operation of the overall cloud infrastructure
  - Makes the IT resources (owned or leased) available to other cloud customers for lease
- **Cloud customer**
  - A organization or an individual that signs for a formal contract or arrangement with a cloud provider for IT resource lease
  - Cloud service consumer: consumers of service provided by a cloud consumer
- **Cloud service owner**
  - The individual or organization that legally owns a cloud service
  - = a cloud consumer or a cloud provider depending on who actually provides the service



Roles and Boundaries – 2/2

- **Cloud resource administrator**
  - The individual or organization responsible for administrating a cloud-based IT resource (including cloud service)
  - = (members of) the cloud consumer or cloud provider
  - Cloud resource administrator ≠ cloud service administrator ⇨ cloud resource ≠ cloud service
- **Additional roles** (as supplementary roles defined by NIST Cloud Computing Reference Architecture)
  - **Cloud auditor** : a third-party contractor for independent assessment of cloud environments evaluating security controls, privacy impacts, performance and so on
  - **Cloud broker** : a party responsible for managing and negotiating the usage of cloud service between cloud customers and cloud providers including intermediation, aggregation, arbitrage
  - **Cloud carrier** : the party responsible for providing the wire-level connectivity between cloud consumers and cloud providers – network and telecommunication providers in general
- **Organizational boundary**
  - Physical perimeter that surrounds a set of IT resources that are owned and governed by an organization
- **Trust boundary**
  - A logical perimeter that typically spans beyond physical boundaries to represent the extent to which IT resources are trusted

Cloud Delivery Models

Cloud Delivery Models – 1/3

- **Cloud delivery models**
  - Three basic delivery models: Infrastructure-as-a-Service (**IaaS**), Platform-as-a-Service (**PaaS**), Software-as-a-Service (**SaaS**)
  - Specialized variations: Storage-as-a-Service, Database-as-a-Service, Security-as-a-Service, Testing-as-a-Service, Communication-as-a-Service, Integration-as-a-Service, Process-as-a-Service, etc.
- **Infrastructure-as-a-Service (IaaS)**
  - Provides a self-contained IT environment comprised of infrastructure –centric IT resources that can be accessed and managed via cloud service-based interfaces and tools
  - Offers typically **virtualized** and **packaged** IT resources including hardware, network, connectivity, operating systems and other raw IT resources (vs. traditional hosting with **physical** IT resources)
  - Allows simple up-front runtime scaling and customization of the given infrastructure
  - Provides cloud customers with a high level of control and responsibility over its configuration and utilization
  - Preferred by those cloud customers that want a high level of control over the cloud-based environment with a proper level of administrative ability – delivered without pre-configuration in general
  - IaaS provided by the cloud customer of the other cloud providers – a sort of sub-lease
  - Typical IT resources offered by IaaS environments include:
    - Virtual server : specified by processing power, memory capacity, local storage space
    - Virtual storage : specified by capacity in GB or TB unit generally in large scale with no QoS guarantee
    - Virtual network : specified by bandwidth, QoS
  - Requires cloud customers to configure IT resources for their own after lease

Cloud Delivery Models – 2/3

- **Platform-as-a-Service (PaaS)**
  - Provides a pre-defined "ready-to-use" environment typically comprised of already deployed and configured IT resource
  - Relies on (and is defined by) the usage of a ready-made environment that establishes a set of pre-packaged products and tools used to support the entire delivery lifecycle of custom applications
  - Primary reasons for cloud customers to rely on PaaS include:
    - To extend on-promise environments into the cloud for scalability and economic purpose
    - To substitute the ready-made environment for the entire on-promise environment at once
    - To deploy its own cloud services to be made available to other cloud customers
    - For short-term lease of many different platforms for the purpose of special needs (e.g., software development – No. of OSs × No. of OS versions)
  - Releases cloud customers from the administrative burden of setting up and maintaining the bare infrastructure IT resources at the cost of less control over the underlying IT resources
- **Software-as-a-Service (SaaS)**
  - Provides the lease service of software programs
  - Provides a reusable cloud service widely available (often commercially) to a range of cloud consumers for various purpose and different terms
  - Allows very limited administrative control over a SaaS implementation for cloud customers
  - Can be provided by the cloud consumers of other cloud providers
  - Very practical cloud delivery model for those software programs that are not always in use – e.g., white box testing software (vs. DBMS)

Cloud Delivery Model Comparison

Cloud Delivery Model	Typical Level of Control Granted to Cloud Consumer	Typical Functionality Made Available to Cloud Consumer
SaaS	Usage and usage-related configuration	Access to front-end user-interface
PaaS	Limited administrative	Moderate level of administrative control over IT resources relevant to cloud consumer's usage of platform
IaaS	Full administrative	Full access to virtualized infrastructure-related IT resources and possibly to underlying physical IT resources

Cloud Delivery Model	Common Cloud Consumer Activities	Common Cloud Provider Activities
SaaS	Uses and configures cloud service	▪ Implements, manages and maintains cloud service ▪ Monitors usage by cloud consumers
PaaS	Develops, tests, deploys and manages cloud services and cloud-based solutions	Pre-configures platform and provisions underlying infrastructure, middleware and other needed IT resources as necessary
IaaS	Sets up and configures bare infrastructure, and installs, manages, and monitors any needed software	▪ Provisions and manages the physical processing, storage, networking and hosting required ▪ Monitors usage by cloud consumers