Cloud Computing

Introduction

Chapter 1

Outline

Introduction: Example

- Company with 20 employees perform different jobs such as accounting, taxation, etc.
  - To do all this work, need computers services for databases, software, backup system, servers, network to keep themselves connected, and also they need to be connected to their clients.
- Company needs an IT employee to install this set up, troubleshoot the problems, and maintain the safety and security of data.
- As the company grows, they needs more employees, more space to accommodate people and data, and more data to secure, hence resulting in more risks and threats.
  - needs a large set up of IT infrastructure which will considerably result in spending a huge amount of money

Introduction: Example

- To get rid of IT problems, the idea of cloud computing arose.
  - Company can use store all data at a safe and secure place named as cloud
  - which can access with the help of a web browser at anytime from anywhere
  - needs to pay only for those resources that they have used
  - reduces a large amount of expenditure to a low amount by reducing the IT infrastructure cost

Introduction: Cloud Computing

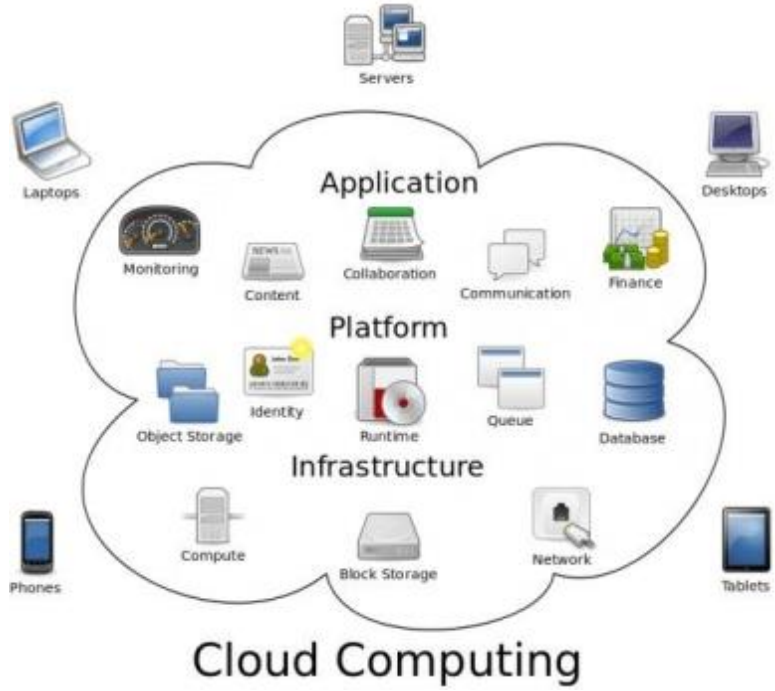
Cloud refers to servers (Data center hardware and software) that are accessed over the internet located remotely

Any activity that uses computer to manage process and communicate information

It is the on-demanded availability of computer system resource and computing power without direct active management by the users

Cloud Computing

According to National Institute of Standards and Technology's (NIST), "Cloud computing is a model for enabling ubiquitous, convenient, and on demand network access to a shared pool of configurable resources that can be rapidly provisioned and released with minimal management effort or service provider interaction."



Examples:

1. While using e-mail: data → stored on the cloud server of the email providers and not on our computer.
   - Can access our e-mails from any devices connected to the internet
2. All pictures and videos that we post on Facebook get stored on the cloud system of Facebook.
3. Videos that we watch on YouTube are stored on the cloud system.
   - Can watch them anytime and anywhere
4. All digital photos stored on sites like Picasa and Flickr are actually stored on the cloud servers of these sites.
5. Google Docs is also an example of a cloud service. Users can upload documents, spreadsheets, and presentations to Google's data servers and edit them using the Google application.

Characteristics of cloud computing

1. **On-demand self-service**
   - All computing services like storage, applications, networking, etc. can be accessed whenever required and without any interaction with service providers.
   - Users or organizations can use the web self-service portal to access the required resources.
2. **Broad network access**
   - All computing resources offered by cloud servers are available over the network and users can access them from anywhere and at anytime with the help of their devices and internet connection.
3. **Resource pooling**
   - To serve multiple customers, service providers create a pool of resources.
   - This pool should be large and flexible enough to meet all the requirements of multiple clients.
   - These resources can be assigned and reassigned on the customer's demand.

Characteristics of cloud computing

4. **Rapid elasticity**
   - Cloud computing services can be elastically provisioned or released.
   - Cloud computing has the ability to assign resources when they are in need by the customers and remove them when they don't need them.
   - The usage, capacity, and cost can be scaled up or down automatically with no additional contract or penalty.
5. **Measured service**
   - Cloud computing is based on the pay-per-use principle ,i.e., charged for the resources that users use.
   - A cloud system leverages a metering capability to measure the resources used.
   - Measurement helps service provider to allocating resources to the customers in the best possible way
   - Cost is variable and is based on the consumption of resources.

Advantages of cloud computing

1. **Economical**
   - No need to buy and maintain expensive IT infrastructure
   - Moving to cloud computing provides access to various computing resources at a low cost.
   - There are no administrative, operational, and upfront costs.
2. **Universal access**
   - Cloud computing enables you to work and gain access from anywhere and any computer or device with just an internet connection.
3. **Scaling**
   - A business can scale (increase or decrease) performance, functionalities, and resources of cloud computing as per the requirements.

Advantages of cloud computing

4. **Collaboration**
   - Cloud environments enables better collaboration across teams: developers, QA, operations, security and product architects are all exposed to the same infrastructure and can operate simultaneously without stepping on each other toes.
5. **Ensures backup and recovery of data**
   - In cloud systems, various copies of data are maintained by service providers on different machines/nodes so as to provide universal access and recovery of data in case any failure occurs at any data center or the data from one machine gets lost.
   - The feature of cloud storage provides you with the facility of automatic data backups and access from any device at any time and any place.
6. **Reliability**
   - In cloud systems, the data are stored in multiple nodes. When one or some nodes fails, the whole system can still work fine

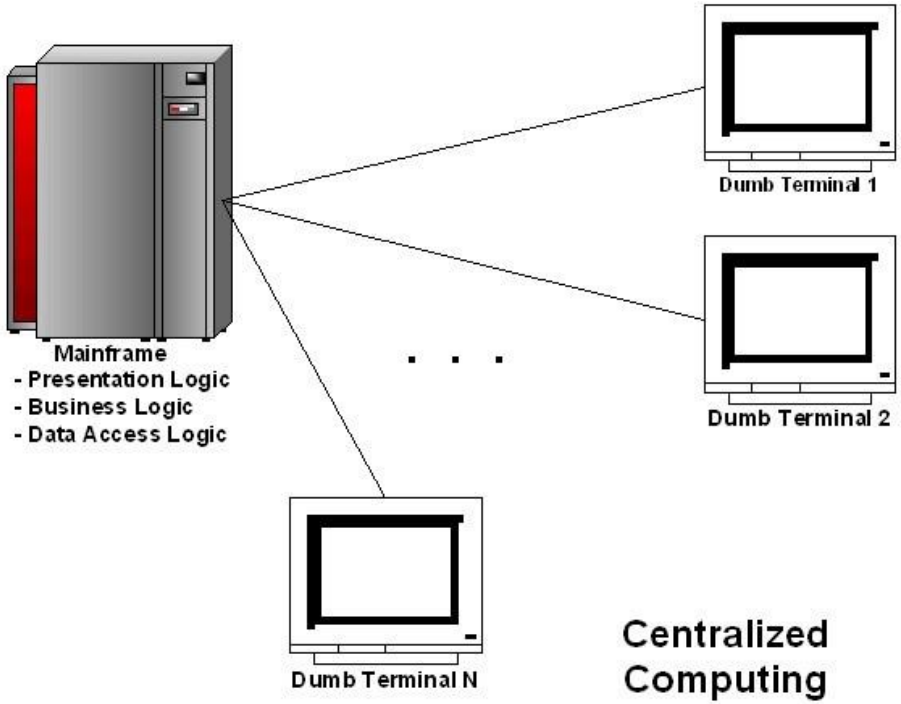
Emergence of Cloud Computing

The underlying concept of cloud computing dates back to the 1950s

1. Centralized Computing
2. Distributed Computing
3. Grid Computing
4. Cluster Computing
5. Utility Computing
6. Cloud Computing

Centralized Computing

- Early computing was performed on a single processor: Uni-processor Computing or Centralized Computing
- It is similar to a client/servers architecture where one or more client PCs are directly connected to a central server



Centralized Computing

Major Drawback: Difficult to solve computational or large scale problem

Centralized Computing

Major Drawback: Difficult to solve computational or large scale problem

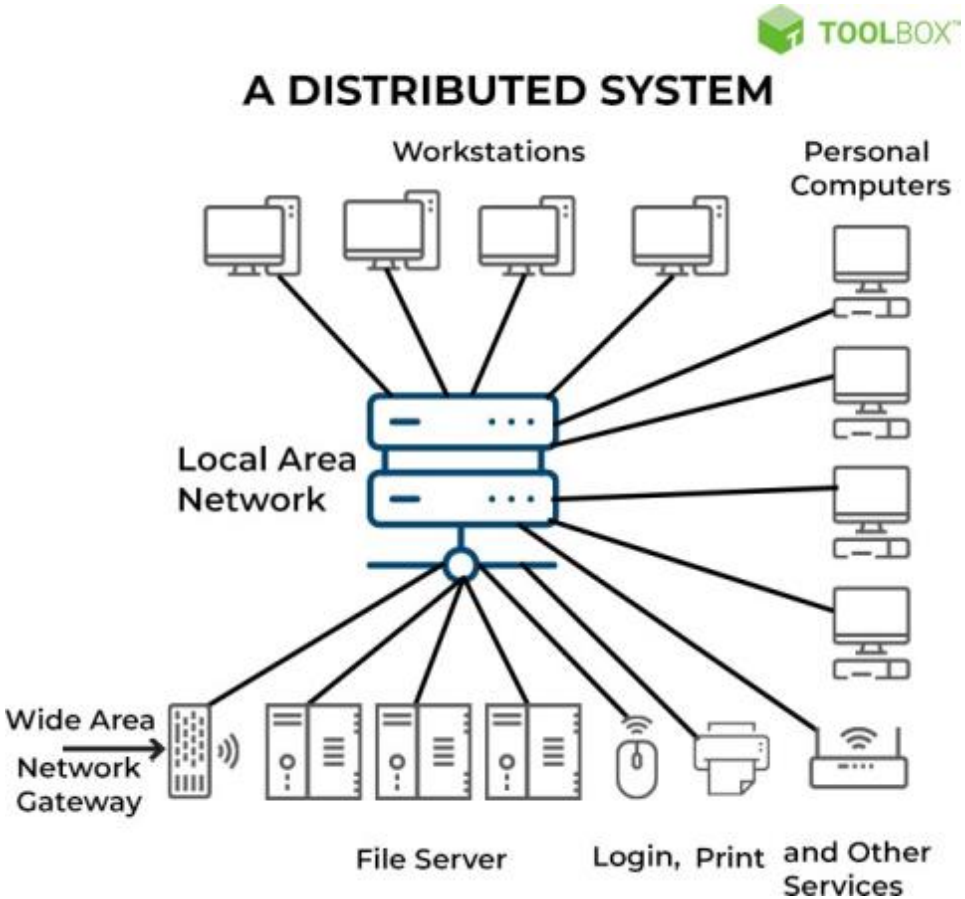
Solution

Use multiple computers to **solve large scale problem** over internet

Distributed Computing

- Refers to multiple computer systems work on single problem
- A single problem is divided into many parts, and each part is solved by different computers.
- Each computer provides a service with its own local memory
- As long as the computers are networked, they can communicate with each other to **solve the problem** by passing message.
- The ultimate goal of distributed computing is to maximize performance by connecting **users** and **IT resources** in a cost-effective, transparent and reliable manner.

Distributed Computing



Characteristics of Distributed Computing

1. **Fault tolerance:** When one or some nodes (computer) fails, the whole system can still work fine
2. **Resource sharing:** Each user can share the computing power and storage resource in the system with other users
3. **Load Sharing:** Dispatching several task to each nodes can help share loading to the whole system
4. **Easy to expand:** Extra node can easily add to the system
5. **Higher performance:** can obtained using parallel computing (subset of distributed computing)

Why Distributed Computing

1. Nature of application
2. Performance
   - Computational intensive: Consume a lots of time on computing
     - E.g: Computation of Pi
   - Data intensive: Deals with a large size of files
     - E.g: Facebook, Google
3. Robustness: No single point of failure (Fault tolerable)

- Internet or Intranet
- ATM machines
- Telecommunication networks
- Email

Grid Computing

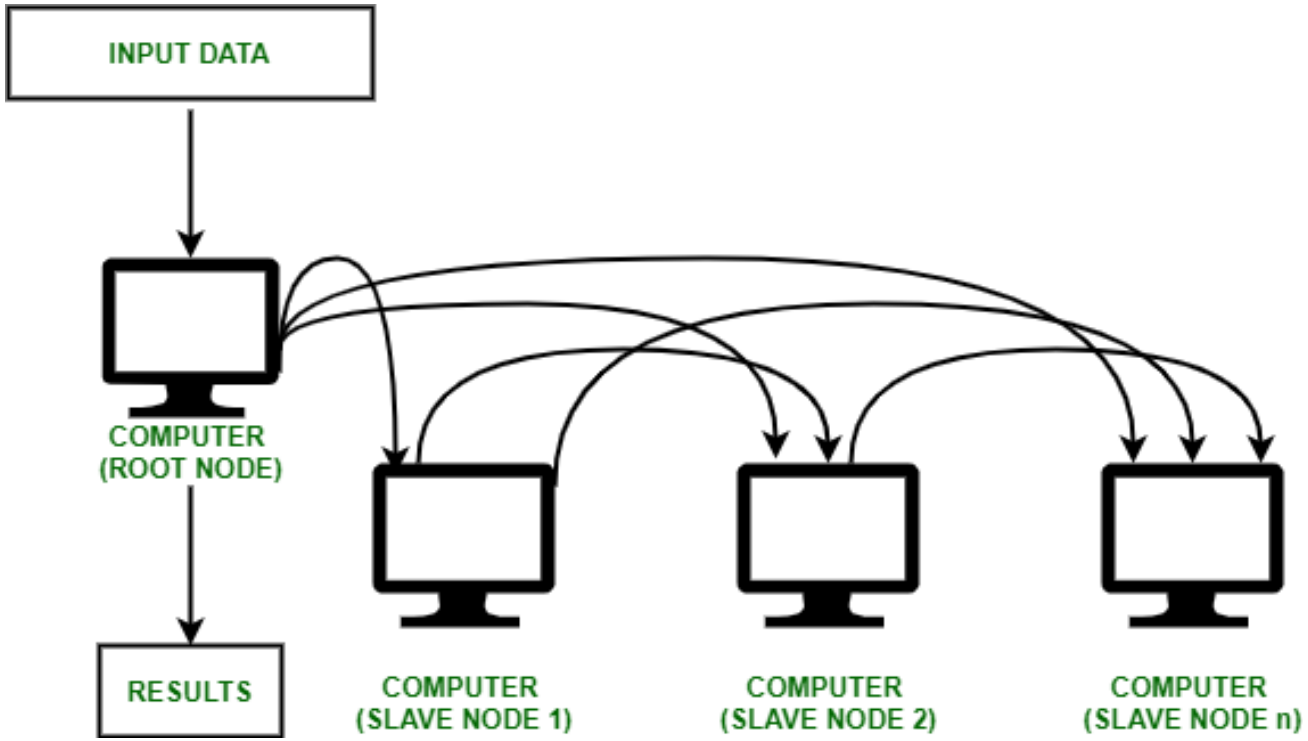
- Enable the virtualization of distributed computing and data resources such as processing, network bandwidth and storage capacity to create a single system
- It grants users and applications seamless access to vast IT infrastructure
- Provide consistent and inexpensive access to computational capabilities

NOTE! Primary paradigms of cloud computing

Cluster Computing

- Type of parallel or distributed computer system which consists of a collection of **inter-connected computers** working together as a single integrated computing resource
- Usually deployed to improve speed and reliability over that provided by a single computer
- Key components of a cluster include:
  - multiple computer
  - operating system
  - high performance interconnect
  - middleware
  - parallel programming environment
  - application
- Each computer that is linked to the network is known as a node.

Cluster Computing



Utility Computing

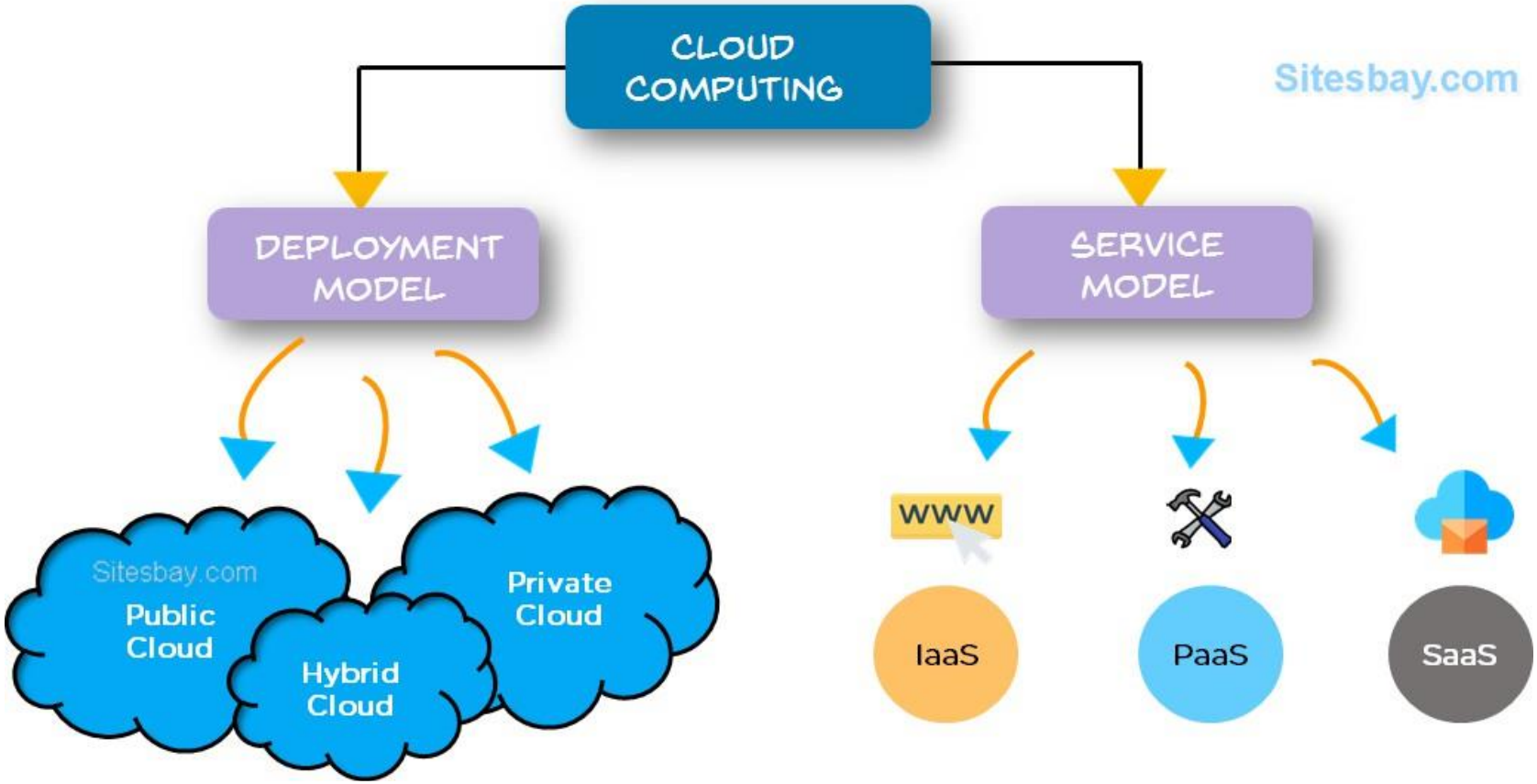
- Utility computing is a service provisioning model where a provider makes computing resources, infrastructure management and technical services available to customers as they need them.
- The provider then charges the customer for the amount of services they use rather than a flat-rate fee. Pay as you use or metered services

  NOTE! Paradigm shift of computing to Pay as you use
- Utility model seeks to maximize efficient resource use, minimize associated costs or both.

Utility computing benefits

1. Pay for use
2. Data center virtualization and provisioning
3. Solves resource utilization problem
4. Outsourcing
5. Web services Delivery
6. Automation

Types of Cloud Computing



Deployment Model

- Cloud deployment model represents a specific type of cloud environment, primarily distinguished by ownership, size, and access
- Type of deployment model:
  1. Public cloud
  2. Private cloud
  3. Hybrid cloud

Public Cloud

- Provision of computing services over the **public internet** by a third-party provider , i.e., Cloud service provider
  - available to anyone who wants to use them and can be free or paid to use
- Public Cloud provides a shared platform that is accessible to the general public through an Internet connection.
  - same storage is being used by multiple users at the same time, i.e., multitenancy
- Public cloud is owned, managed, and operated by businesses, universities, government organizations, or a combination of them.
- Examples: Amazon , Microsoft Azure, IBM's Blue Cloud, Sun Cloud, and Google Cloud are examples of the public cloud.

Public Cloud

1. **Low Cost:** shares the same resources with a large number of consumers
2. **Location Independent:** services are offered through the internet
3. **Scalability and reliability:** offers scalable (easy to add and remove) and reliable (24×7 available) services to the users at an affordable cost

1. **Low Security:** less secure because resources are shared publicly
2. **Performance:** depends upon the speed of internet connectivity
3. **Less customizable:** less customizable than the private cloud

Private Cloud

- Cloud that is **privately** *owned, managed, and operated* by the business or organization
- Not open to the public and is exclusively owned by one business or organization
  - also known as **internal** or **corporate** cloud
- Infrastructures and services in a private cloud can be accessed only **within the organization**
  - An organization that is using a private cloud is solely responsible for its management, maintenance, and regular updates
- Servers can be physically located on organization's premise or can be hosted by third party service providers
- Examples: Dell, Microsoft, Apache, and Open Stack

Private Cloud

1. **Customizable:** more control over their resources and hardware than public clouds
2. **Security** & **privacy:** greater range of security as data is protected behind a firewall
3. **Improved performance:** offers better performance with improved speed and space capacity

1. **High cost:** set up and maintain hardware resources are costly
2. **Restricted area of operations:** accessible within the organization, so the area of operations is limited
3. **Limited scalability:** scaled only within the capacity of internal hosted resources

Hybrid Cloud

- Hybrid cloud is a combination of **public** and **private** security clouds
- By merging the benefits of private and public cloud services:
  - a hybrid cloud provides the **private cloud's** security and the **public cloud's** speed to the organization or business
- **Main aim** to combine these cloud: is to create a unified, automated, and well-managed computing environment
- In the Hybrid cloud:
  - **non-critical activities** performed by public cloud
  - **critical activities** performed by private cloud
  - Mainly, a hybrid cloud is used in finance, healthcare, and Universities
  - Examples: Amazon, Microsoft, Google, Cisco, IBM, and NetApp

Hybrid Cloud

Advantages

1. **Flexible and secure:** provides flexible resources (**public cloud**) and secure resources (**private cloud**)
2. **Cost effective:** costs less than the private cloud. Also helps organizations to save costs for both infrastructure and application support
3. **Optimize Workload Resources:** Process complex workloads in the public cloud where additional capacity is low-cost and easy to access, but keep your simpler workloads in private cloud infrastructure

Disadvantages

1. **Networking issues:** becomes complex because of the private and the public cloud
2. **Infrastructure Compatibility:** due to dual-levels of infrastructure, a private cloud controls the company, and a public cloud does not

Deployment Model

Services Model

- A specific, pre-packaged combination of IT resources offered by a **cloud provider**
- Type of cloud services/ delivery model:
  1. Software-as-a-Service (SaaS)
  2. Platform-as-a-Service (PaaS)
  3. Infrastructure-as-a-Service (IaaS)

Software-as-a-Service (SaaS)

- Way of delivering service and application over the internet
  - also known as "on-demand software"
  - E.g: Dropbox (shared files), gmail (service as sent or received email)
- Works on shared model, i.e., multitenancy environment
  - Eg: Google drive, Office 365, Google play

Characteristics of SaaS

- Hosted and maintenance by cloud service provider
- Users are not responsible for hardware and software updates
- Updates are applied automatically
- The services are purchased on the pay-as-per-use basis
- On demand availability
- Easily scalable as per need
- Work on shared model

Benefits of SaaS

- Easy to Accessible: SaaS application must be easily accessible from anywhere at any time, across operating systems
- Efficient use of software license
- Multi-tenancy
- Centralized management

Issues of SaaS

- **Limited customization**: Most SaaS applications offer little in the way of customization from the vendor
- **Browser based risks**: If user visited malicious website and malicious code get attached to the browser. If same browser access SaaS on cloud. SaaS application may get infected by the malicious code
- **Network dependence**: SaaS model is based on web delivery, if your internet service fails, you will lose access to your software or data
- **Portability Issues**: If user want to transfer SaaS application move from one SaaS cloud to another SaaS cloud

Saas

SaaS model basically provides the following services to the end user:

- Applications: Packaged software
- Platform: OS and Middleware
- Infrastructure: Servers, storage, network, security

Application of SaaS

Provider	Services
Salesforce.com	On-demand Customer Relation Management (CRM)
Microsoft Office 365	Online office suite
Google Apps	Gmail, Google Calendar, Docs, and sites
Go To Meeting	Online meeting and video-conferencing software
Constant Contact	E-mail marketing, online survey, and event marketing
Oracle CRM	CRM applications
Workday, Inc	Human capital management, payroll

Platform-as-a-Service (PaaS)

- Allows organizations to build, run and manage applications without the IT infrastructure
- Allows programmers to easily create, test, run, and deploy web applications on the runtime environment
- PaaS delivers a framework for developers and IT architects to create web or mobile apps that are scalable, without worrying about setting up or managing the underlying infrastructure of servers, storage, network, and databases needed for development

Characteristics of PaaS

- Secured and scalable web services
- Easy workflow and approval process
- Easy integration with other applications on the same cloud

Benefits of PaaS

- **Cost**: Customers do not need to pruchase hardware and software
- **Scalability**: PaaS can be seen as a great scalability solution, as it delivers an environment with highly scalable spaces, tools, and resources
- **Availability & Mobility**: PaaS makes it possible to centralize team communication in a single environment, forming a unified communication structure (without losing sync, even if they are in different locations). This can help solve problems faster and bring agility to the company's activities.
- **Boosts productivity**: PaaS allows you to develop and implement new applications without the need to spend time creating your own work environment. This can speed up the application development, testing, and delivery cycle.
- Updates are applied automatically
- Less administrative overhead

Issues of PaaS

- **Security risk**: The provider's cloud database houses all of the application data. Since the provider can see private and sensitive information, this raises concerns about confidentiality
- **Integration problems**: Every PaaS provider has a unique integration method, similar to compatibility. Merging two PaaS products is not possible

PaaS

- PaaS model comprises of the following services:
  - Platform: OS and Middleware
  - Infrastructure: Servers, Storage, Network, Security
- Examples of PaaS include Google App Engine, Microsoft Azure, Red Hat's OpenShift Platform, and OpenStack

Infrastructure-as-a-Service (IaaS)

- Cloud service model which provides pay-as-you-go or pay-per-use access to all computing resources like storage, database, servers and networking
- Users don't have to deal with expenses incurred in buying and maintaining physical servers and other data center resources.
- Businesses and organizations rely on the vendor's infrastructure to build software applications on their own platforms.
- IaaS model provides the following services to businesses or organizations:
  - Servers
  - Storage
  - Network
  - Security
- Examples are Amazon Web Services (AWS) and Google Compute Engine (GCE)

Benefits of IaaS

- **Scalability:** Allows customers/organizations to easily scale their infrastructure up or down as their needs change. Customers can quickly add or remove computing resources, such as servers, storage, and networking, based on demand.
- **Cost-effectiveness:** More cost-effective than owning and maintaining physical infrastructure since customers only pay for the resources they use.
- **Flexibility:** Provides organizations with a high degree of flexibility since they have complete control over their virtualized infrastructure. Organizations can configure their infrastructure to meet their specific needs and requirements.
- **Security:** IaaS providers are responsible for ensuring the security of their infrastructure, induding physical security, network security, and data security.

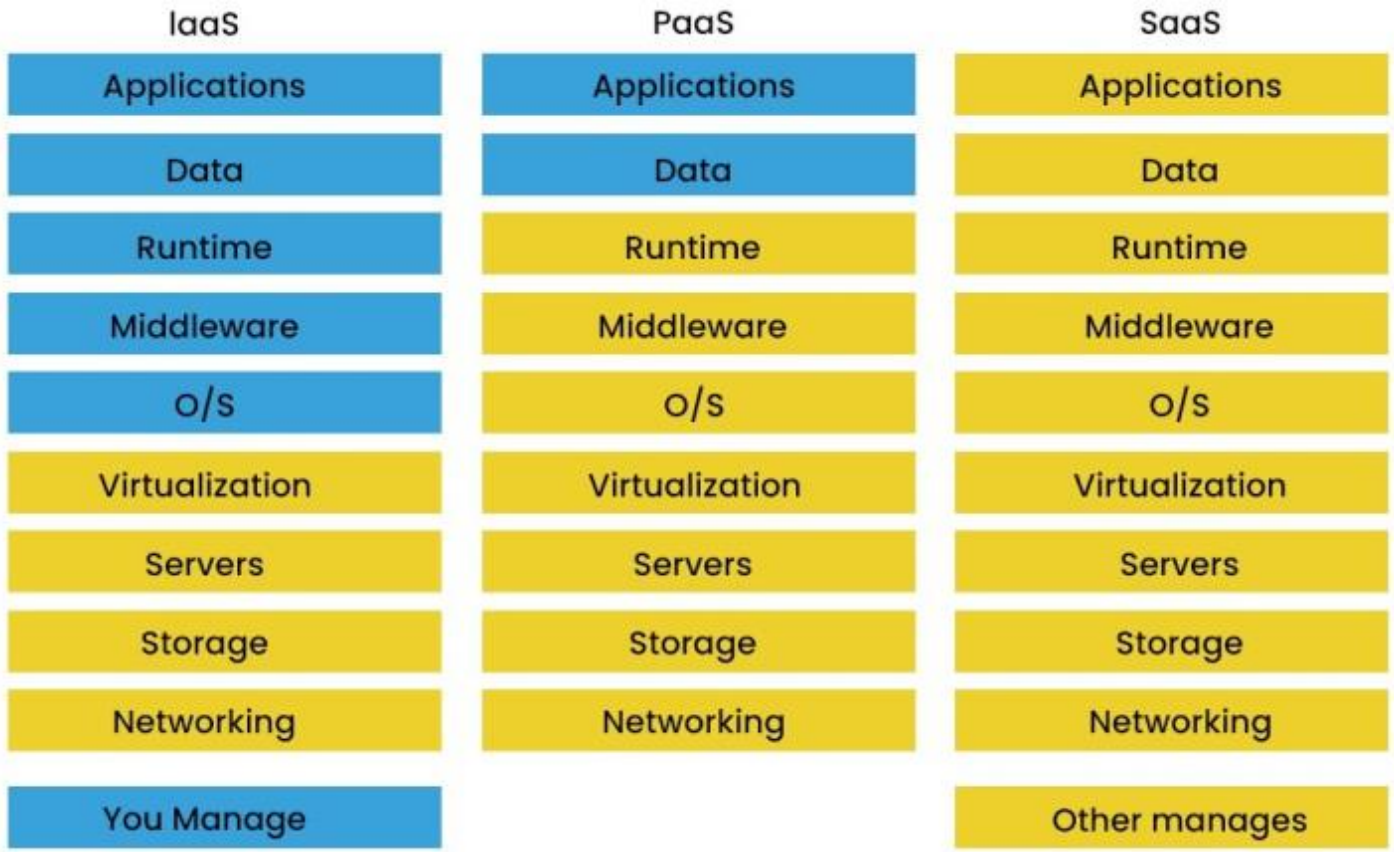
Benefits of IaaS

- **Reliability:** IaaS providers typically offer high levels of reliability, with guaranteed uptime and availability.
- **Disaster recovery:** IaaS providers typically offer disaster recovery and backup services, which can help organizations quickly recover from outages and data loss.
- **Rapid deployment:** Allows organizations to quickly deploy new infrastructure and applications without the need for long lead times associated with physical infrastructure.

Issues of IaaS

- **Compliance:** Compliance with regulatory requirements can be a challenge when using IaaS. The cloud provider must comply with regulations such as HIPAA, PCI-DSS, and GDPR.
- **Scalability:** IaaS is designed to be highly scalable. However, scaling up and down can be a complex process, and customers must plan accordingly.
- **Availability:** IaaS providers must ensure that their infrastructure is highly available. However, downtime can occur due to hardware failure or other issues. Customers must ensure that their applications are architected for high availability.
- **Performance:** Performance can be an issue with IaaS if the infrastructure is not properly configured. Customers must ensure that the infrastructure is configured for optimal performance.

Service Model



How can customers select IaaS, PaaS or SaaS service models in cloud computing?

Some key considerations for selecting IaaS, PaaS, or SaaS:

- **Flexibility**
  1. **IaaS:** most flexibility since it allows customers to have complete control over their virtualized infrastructure
  2. **PaaS:** higher level of abstraction, where the cloud provider manages the underlying infrastructure, and customers focus on application development
  3. **SaaS:** least flexibility, as the customer, only has control over configuring the application
- **Technical expertise**
  1. **IaaS:** requires the most technical expertise since customers are responsible for managing the virtualized infrastructure
  2. **PaaS:** requires less technical expertise, as customers only need to focus on application development
  3. **SaaS:** requires the least technical expertise, as customers only need to configure the application

How can customers select IaaS, PaaS or SaaS service models in cloud computing?

- **Time to market**
  1. **IaaS:** take more time market, as customer have to focus on infrastructure management along with application development
  2. **PaaS:** faster time to market than IaaS, as customers can focus on application development
  3. **SaaS:** fastest time to market, as customers can quickly configure and start using the application
- **Customization**
  1. **IaaS:** most customization since customers have complete control over the infrastructure
  2. **PaaS:** some customization options, but customers are limited by the platform's capabilities
  3. **SaaS:** least customization, as customers can only configure the application

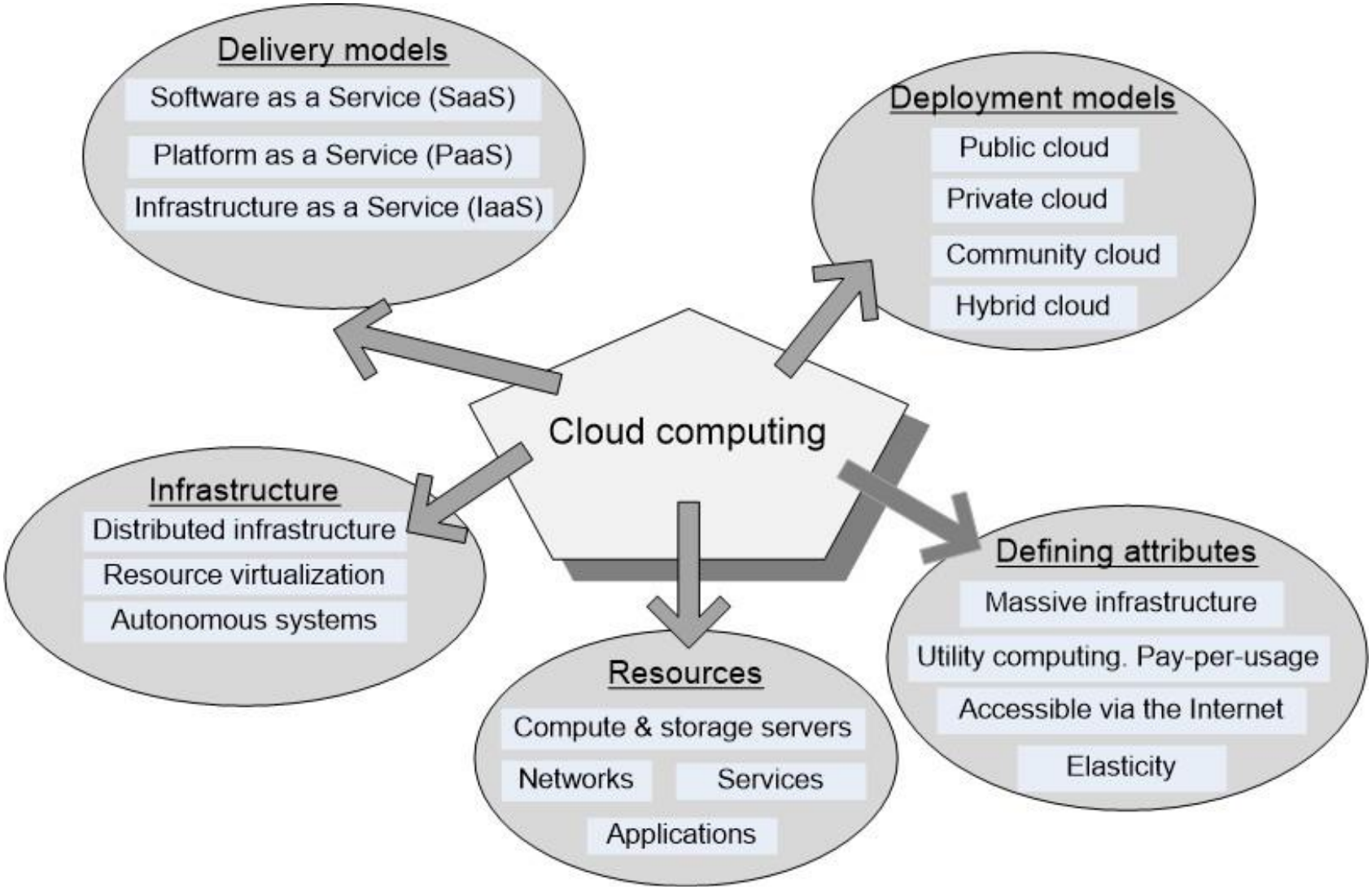
How can customers select IaaS, PaaS or SaaS service models in cloud computing?

Some key considerations for selecting IaaS, PaaS, or SaaS:

- **Cost**
  1. **IaaS:** more cost-effective for customers who have the technical expertise to manage the infrastructure effectively
  2. **PaaS:** more cost-effective for customers who want to focus on application development without the overhead of managing the infrastructure
  3. **SaaS:** most cost-effective for customers who want to quickly start using an application without investing in infrastructure or development.
- **Compliance**
  1. **IaaS:** provides the most control over compliance requirements, but customers are responsible for ensuring compliance
  2. **PaaS and SaaS:** providers may offer compliance certifications, but customers must ensure that their use of the service meets regulatory requirements.

Why cloud computing could be successful when other paradigms have failed?

- It exploits recent advances in software, networking, storage, and processor technologies promoted by the same companies that provide cloud services.
- It is focused on enterprise computing; its adoption by industrial organizations, financial institutions, government
  - could have a huge impact on the economy
- A cloud consists of a homogeneous set of hardware and software resources.
- The resources are in a single administrative domain
  - Security, resource management, fault-tolerance, and quality of service are less challenging than in a heterogeneous environment with resources in multiple administrative domains


Delivery models
Software as a Service (SaaS)
Platform as a Service (PaaS)
Infrastructure as a Service (IaaS)
Deployment models
Public cloud
Private cloud
Community cloud
Hybrid cloud
Cloud computing
Infrastructure
Distributed infrastructure
Resource virtualization
Autonomous systems
Defining attributes
Massive infrastructure
Utility computing. Pay-per-usage
Accessible via the Internet
Elasticity
Resources
Compute & storage servers
Networks
Services
Applications

Challenges for cloud computing

- Availability of service: what happens when the service provider cannot deliver?
- Diversity of services, data organization, user interfaces available at different service providers limit user mobility
  - once a customer is hooked to one provider it is hard to move to another
- Data confidentiality and auditability, a serious problem
- Data transfer bottleneck: many applications are data-intensive
- Performance unpredictability, one of the consequences of resource sharing
  - How to use resource virtualization and performance isolation for QoS guarantees?
  - How to support elasticity, the ability to scale up and down quickly?
- Resource management: are self-organization and self-management the solution?
- Security and confidentiality: major concern

Addressing these challenges provides good research opportunities!!

Ethical issues in cloud computing

Paradigm shift with implications on computing ethics:

- control by third party
  - Risks: Unauthorized access, Data corruption, Infrastructure failure, and service unavailability
- The data is stored on multiple sites administered by several organizations
  - difficult to identify the source of the problem and the entity causing it
- Multiple services interoperate across the network
  - impossible to identify fraud due to lack of traceability
- Vendor lock-in
  - can be difficult to switch to a different provider
  - Organizations being locked into a particular vendor and limit their flexibility
- Transparency and accountability
  - can be challenging for organizations to get a complete picture of how cloud providers are handling their data
  - often a lack of transparency in the way cloud providers operate, which raises concerns about accountability