Cloud computing

UNIT-I

(Computing Paradigms)

Computing Paradigms

- ✓The term paradigm conveys a model/method to be followed to accomplish a task.
- ✓Due to the technological advancements, there exist many computing practices being used.
- ✓In this chapter, we look into the various computing paradigms:

  High Performance Computing(HPC).
  Parallel computing,
  Distributed computing
  Cluster computing,
  Grid computing,
  Cloud computing,
  Bio-computing,
  Mobile computing,
  Quantum computing, Optical computing, and Nanocomputing.

High-Performance Computing

- ✓ The term HPC is occasionally used as a synonym for supercomputing.

- ✓ Due to the Technological advances like the Internet of Things (IoT), artificial intelligence (AI), and 3-D imaging, the size and amount of data that organizations have to work with is growing exponentially.

- ✓ Organizations need lightning-fast, highly reliable IT infrastructure to process, store, and analyze massive amounts of data.

HPC is used in to solve complex problems in science and engineering, academic institutions, Government agencies(military) and business.

- ✓ High performance computing (HPC) is the ability to process data and perform complex calculations at high speeds.

- ✓ For Example, identification of DNA patterns, streaming a live sporting event, testing new products, or analyzing stock trends.

High-Performance Computing

HPC cluster:

- ✓ An HPC systems consists of hundreds or thousands of compute servers that are networked together.

(or)

- ✓ In HPC systems, a pool of processors (processor machines or central processing units [CPUs]) connected (networked) with other resources like memory, storage, and input and output devices.

- ✓ HPC solutions have three main components: 1.Compute 2.Network 3.Storage

- ✓ Each server is also called as a node.

- ✓ The nodes in each cluster work in parallel with each other to deliver high performance computing.

- ✓ HPC uses **“ parallel processing”** for running complex applications efficiently, reliably and quickly.

- ✓ The processor **machines can be of homogeneous or heterogeneous type**.

High-Performance Computing

Characteristics of HPC

Performance: Delivers more than a TFLOPS(teraflop 10^{12}) floating-point operations per second.

Reliability: Fault-tolerant design provides greater than 99.9999% availability.

Scalability: enables seamless scalability from terabytes to petabytes by adding capacity in any increment

Lower Cost: computing is provided based on the pay-per usage.

Easy to deploy and manage: on-the-fly replication of storage blocks, computing CPUs and proactive monitoring.

High-Performance Computing

Applications of HPC

Research labs. HPC is used to help scientists find sources of renewable energy, understand the evolution of our universe, and create new products/materials.

Media and entertainment. HPC is used to edit feature films, render mind-blowing special effects, and stream live events around the world.

Oil and gas. To identify where to drill for new wells and to help boost up production from existing wells.

Financial services. to track real-time stock trends and automate trading.

Manufacturing. To design new products, simulate test scenarios, and make sure that parts are kept in stock so that production lines aren't held up.

Healthcare: To research and develop new vaccines, drugs and treatments for disease, improve screening techniques and to make more accurate patient diagnoses.

Meteorology. To predict and track floods/storms and other unusual weather patterns.

Artificial intelligence : in the design of self-driving cars and automated vehicles etc.

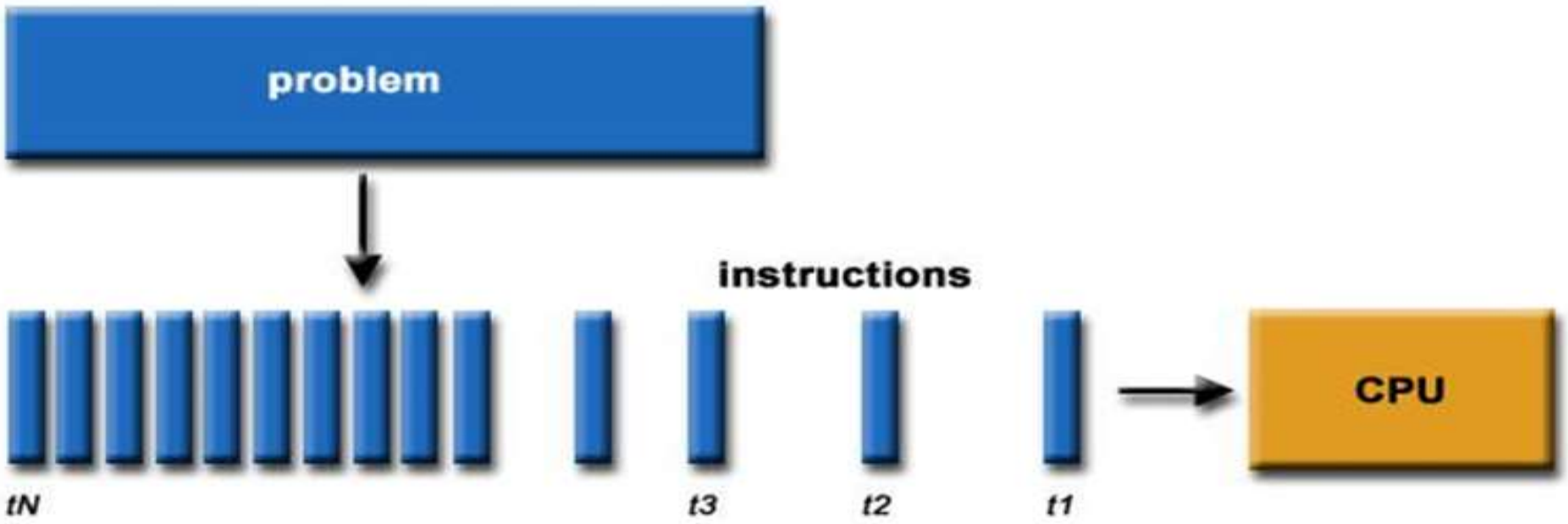
Parallel Computing

- ✓ Parallel computing is also one of the facets of HPC.
- ✓ Parallel computing is a form of computation in which many calculations are carried out simultaneously.
- ✓ operating on the principle that large problems can often be divided into smaller ones, which are then solved concurrently ("in parallel").
- ✓ Here, a set of processors work cooperatively to solve a computational problem.
- ✓ These processor machines or CPUs are mostly of homogeneous type.
- ✓ One can distinguish between conventional (also known as serial or sequential or Von Neumann) computers and parallel computers in the way the applications are executed.

Parallel Computing

In serial or sequential computers, the following apply.

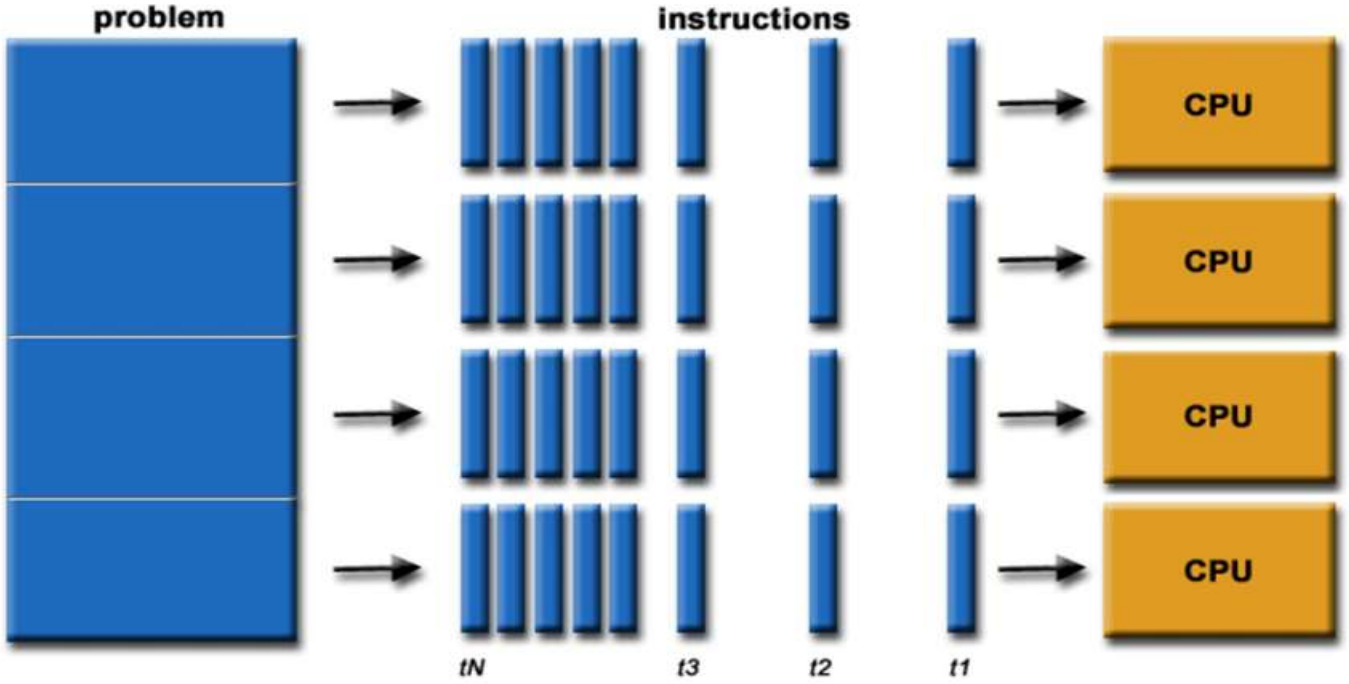
- ❖It runs on a single computer/processor machine having a single CPU.
- ❖A problem is broken down into a discrete series of instructions.
- ❖Instructions are executed one after another.



Parallel Computing

In parallel computing, the following can be applicable:

- ❖It is run using multiple processors (multiple CPUs).
- ❖ A problem is broken down into discrete parts that can be solved concurrently.
- ❖Each part is further broken down into a series of instructions.
- ❖Instructions from each part are executed simultaneously on different processors.
- ❖An overall control/coordination mechanism is employed.



Distributed Computing

- ✓ Distributed computing consists of multiple autonomous computers/ processor machines connected through a network but runs as a single coherent system to the outsider/end-user.
- ✓ nodes can be homogeneous or heterogeneous- in general heterogeneous.
- ✓ The heterogeneity of the distributed system supports any number of possible configurations in the processor machines, such as mainframes, PCs, workstations, and minicomputers.
- ✓ All the nodes shares the resources and co-ordinate each other by using a middle-ware(called distributed OS).
- ✓ All the nodes communicate each other by message-passing to achieve a common goal.
- ✓ The goal of distributed computing is to make such a network work as a single computer.

Examples:

Electronic banking, Internet- which enable users to access, www, email, file-transfer, Airline reservation systems.

Distributed Computing

Benefits of distributed systems

Scalability/Horizontal Scalability

- ✓ It is the ability of the system to be easily expanded by adding more machines as needed, without affecting the existing setup.

Reliability

- ✓ Most distributed systems are **fault-tolerant**.
- ✓ Here, several machines can provide the same services, so that even if one is unavailable (or failed), work does not stop.

Performance

Distributed systems are extremely efficient because work loads can be broken up and sent to multiple machines.

Distributed Computing

Challenges of distributed systems

Scheduling

- ✓ A distributed system has to decide which jobs need to run, when they should run, and where they should run.
- ✓ Improper Schedulers leading to underutilized hardware and unpredictable results.

Latency

- ✓ The more widely your system is distributed, the more latency you can experience with communications.

Observability

- ✓ Monitoring hardware usage metrics for large clusters is a significant challenge.

Distributed Computing

Types of distributed systems

- ✓ Different forms of Hardware and software architectures are used to maintain a distributed system.

- ✓ Generally fall into one of four different basic architecture models:

1.Client-server

2.Three-tier

.

***3.n*-tier**

4.Peer-to-peer

Cluster Computing

- ✓A cluster computing system consists of a set of the same or similar type of processor machines connected using a dedicated network infrastructure(referred to as nodes).

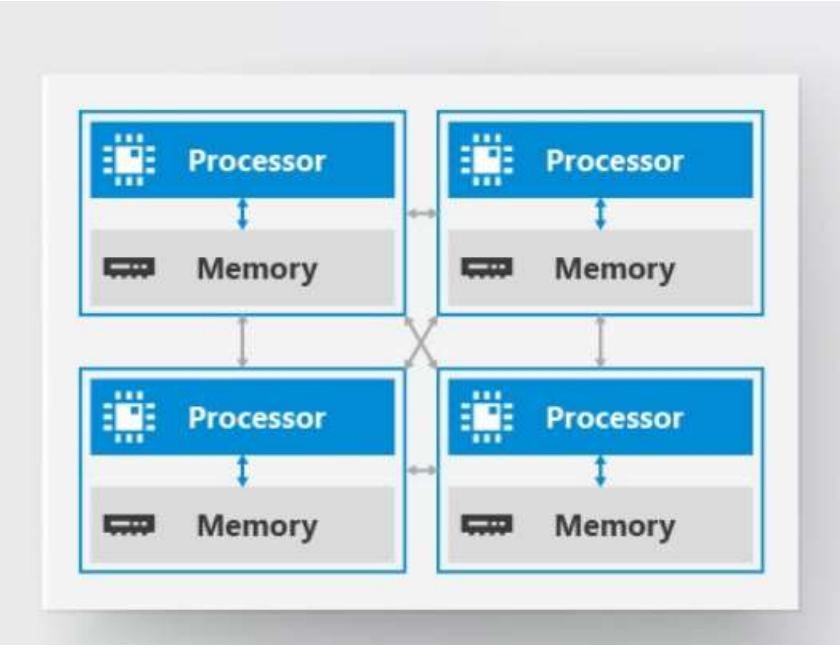
- ✓The individual nodes can work together to solve a problem larger than any computer can easily solve.

- ✓All processor machines share resources such as a common home directory(**a file system directory**).

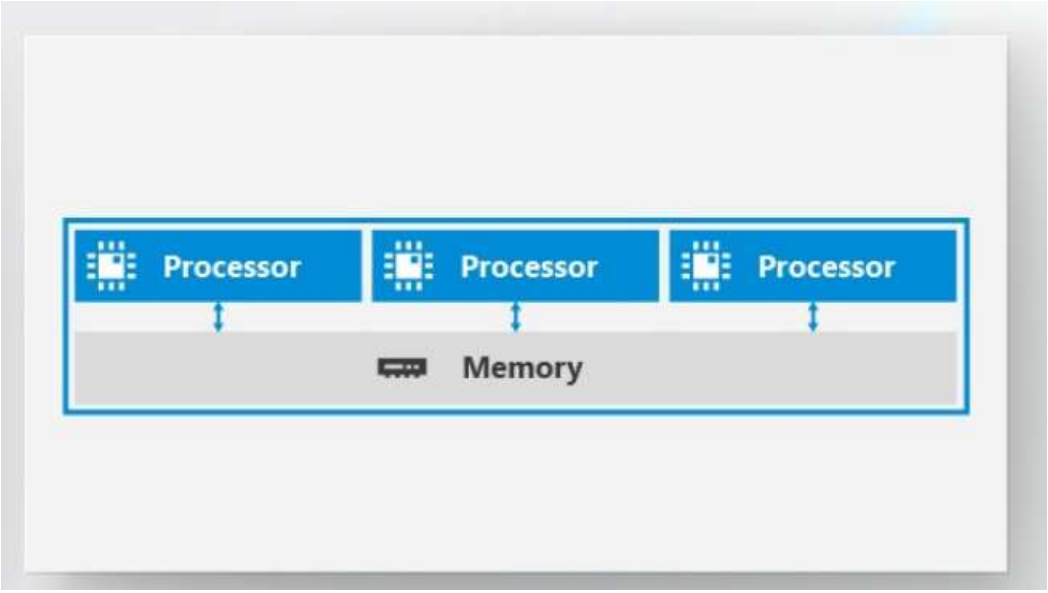
- ✓Nodes need to communicate with one another in order to work cooperatively and meaningfully together to solve the problem in hand.

- ✓All have a software such as a message passing interface (MPI) installed to allow programs to be run across all nodes simultaneously.

Cluster Computing



Cluster computing



Parallel computing

Difference between parallel and cluster computing

Single computer is required	Uses multiple computers
Multiple processors perform multiple operations	Multiple computers perform multiple operations
It may have shared or distributed memory	It have only distributed memory
Processors communicate with each other through bus	Computer communicate with each other through message passing.
Improves the system performance	Improves system scalability, fault tolerance and resource sharing capabilities

Grid Computing

- ✓ The computing resources in most of the organizations are underutilized but are necessary for certain operations.
- ✓ The idea of grid computing is to make use of such nonutilized computing power by the needy organizations, and there by the return on investment (ROI) on computing investments can be increased.
- ✓ Thus, grid computing is a network of computing or processor machines managed with a kind of software such as middleware, in order to access and use the resources remotely.
- ✓ The managing activity of grid resources *through the middleware* is called *grid services.*
- ✓ *grid services* provide access control, security, access to data including digital libraries and databases, and storage facilities.

Grid Computing

Electrical Power Grid vs Grid computing

Electrical Power Grid	Grid Computing
Never worry about where the electricity that we are using comes from	*Never worry* about where the computer power that we are using comes from
The infrastructure that makes this possible is called the *power grid.*	The infrastructure that makes this possible is called the *computing grid.*
The power grid is *pervasive*: electricity is available essentially everywhere, and one can simply access it through a standard wall-mounted socket.	The computing grid is also *pervasive* in the sense that the remote computing resources would be accessible from different platforms
The power grid is a *utility* based.	The grid computing is also a *utility* based

Grid computing is more popular due to the following reasons:

- ✓ Its ability to make use of unused computing power, and thus, it is a cost-effective solution.
- ✓ its a way to solve problems of any using HPC-based System.
- ✓ Enables heterogeneous resources of computers to work cooperatively and collaboratively to solve a scientific problem.

Bio/Biological computing

✓The cutting-edge field of technology-is- Biocomputing

(which is a intersection of biology, engineering, and computer science).

✓The ultimate goal of biocomputing is to mimic some of the biological 'components' of our bodies (like DNA or RNA) — and to use it for our computing needs.

✓Biological computers use biologically derived/ simulated molecules — such as DNA and proteins — to perform digital or real computations.

✓DNA and proteins are nature's building blocks. 1 gram DNA=215 Peta bytes of data.

✓Biocomputing provides the theoretical background and practical tools for scientists to explore proteins and DNA.

✓Thus, the biocomputing scientist works on inventing the order suitable for various applications mimicking biology.

Mobile Computing

- ✓ **Mobile computing** consists of small processing elements (i.e., handheld devices).
- ✓ and the communication between devices is taking place using wireless media.
- ✓ It is a technology that allows-anytime anywhere or everywhere computing.
- ✓ Initially used for Mobile communication for voice applications (Example, cellular System).
- ✓ An extension of this technology is the ability to send and receive data, voice and video using small devices such as smartphones.
- ✓ Mobile computing–based applications are becoming very popular and rapidly evolving (apps).

Limitations: limited computing power and limited usage.

Quantum Computing

- ✓ Manufacturers of computing systems-embed more and more transistors into ICs and thereby doubling the processing power about every 18 months.
- ✓ there is a limit for cramming more and more transistors into smaller(ICs). This problem will have to be overcome by a new quantum computing–based solution.
- ✓ Quantum computing is a rapidly-emerging technology which uses the principles of quantum theory(quantum mechanics) to create a new way of computing to solve complex problems faster.
- ✓ Quantum theory explains the behavior of energy and material on the quantum (atomic and subatomic) level.

Superposition is the ability of a quantum system to be in multiple states simultaneously. The go-to example of superposition is the flip of a coin, which consistently lands as heads or tails—a very binary concept.

Entanglement as a quantum property is taking objects and connecting them by permanently entangling them together. the entanglement of qubits allows quantum computers to solve problems efficiently, finding a solution faster, with many fewer calculations.

Quantum Computing

✓ Quantum computing uses a combination of bits (qubits) to perform specific computational tasks.

✓ Unlike a normal computer bit, which can be either 0 or 1, a qubit can exist in a multidimensional state.

✓ The power of quantum computers grows exponentially with more qubits.

✓ Quantum computers are millions of times faster than even our most powerful supercomputers today.

- In a quantum computer, a number of elemental particles such as electrons/protons can be used.
- Each particle is given a charge or polarization, acting as a representation of 0 and/or 1.
- The behaviour of these particles forms the basis of quantum computing. Each particle is called a quantum bit, or qubit

Optical Computing

- ✓ Optical computing system **uses the photons** in visible light or infrared beams, rather than electric current, to perform digital computations.

- ✓ A **photon** (a particle of light) defined as the smallest discrete amount of electromagnetic radiation.

- ✓ An electric current flows at only about 10% of the speed of light. which limits the rate at which data can be transferred over long distances- **and is one of the factors that led to the evolution of optical fiber.**

- ✓ An optical computer (photonic computer) can perform operations 10 or more times faster than a conventional electronic computer.

Nano Computing

- ✓ Nanocomputing describes computing that uses extremely small, or nanoscale, components.
- ✓ nanocomputing devices are made of semiconductor transistors 100 nanometers or less in length.
- ✓ The **silicon transistors in traditional computers** may be replaced by **transistors based on carbon nanotubes.**

Issues:

- ✓ integration of massive amount of components requires special ICs technology.
- ✓ economically-infeasible.

Note: Researchers are working on all these issues to bring nanocomputing a reality

Introduction to DNA storage

- By 2025 -465 Exha bytes per day-generated by social networking plat-forms
- 1 Exha=1 Million Tera Bytes

- Twitter :500 million tweets per day
- 294 billion mails
- 4 peta bytes facebook
- 400 hours of video per –minute
- In 1965-soviet scientist MS Neeman-published a paper on

DNA can be used for storage

UNIT-2

2.Cloud Computing Fundamentals

2.1.1 Motivation for Cloud Computing

Let us review the scenario of computing prior to the availability of cloud computing:

- The users who are in need of computing are expected to invest money on computing resources such as hardware, software, networking, and storage.

- Users have to buy these computing resources, keep these in their premises, and maintain and make it operational—all these will include cost.

- huge expenditure to the enterprises that require enormous computing power and resources, compared with classical academics and individuals.

- On the other hand, it is easy and handy to get the required computing power and resources from some provider (or supplier) as and when it is needed and pay only for that usage.

- This would result in a reasonable investment, compared to the huge investments.

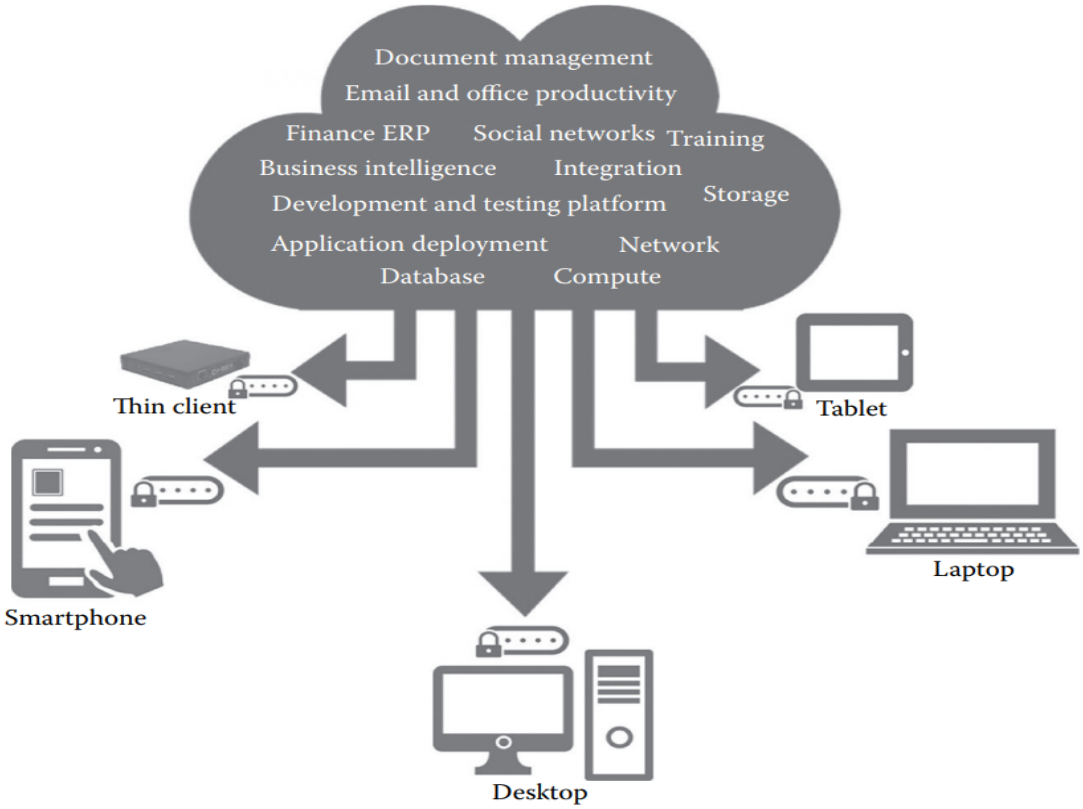
- This phenomenon can be viewed as capital expenditure versus operational expenditure. Capital expenditure requires huge lump sum amount (for investment and maintenance of computing infrastructure) whereas operational expenditure requires (smaller lump sum) for the hiring the resources.

- Therefore, cloud computing is a mechanism of hiring or getting the computing power /services to an organizational or individual needs based on pay and use basis. One can compare this situation with the usage of electricity from its producer-cum-distributor to houses or organizations.

- Thus, one can say as a one-line answer to the need for cloud computing that it eliminates a large computing investment without compromising the use of computing at operational cost.

- Cloud computing is very economical and saves a lot of money.

- Figure shows several cloud computing applications. And the accessibility is through some secure support of connectivity.



- It is a computing solution growing in popularity, especially among individuals and small- and medium-sized companies (SMEs). In the cloud computing model, an organization's core computer power resides offsite and is essentially subscribed to rather than owned.

- Cloud computing encompasses the subscription based or pay-per-use service model of offering computing to end users or customers over the Internet and thereby extending the IT's existing capabilities.

2.1.2 The Need for Cloud Computing

- Convenience (In the past, if we wanted to bring a file, we would have to save it to a Universal Serial Bus (USB) flash drive, external hard drive, or compact disc (CD) and bring that device to a different place. Instead, saving a file to the cloud (e.g., use of cloud application Dropbox(Dropbox is a file hosting service operated by the American company Dropbox, Inc.)) ensures that we will be able to access it with any computer that has an Internet connection.

- Reliable (While using the cloud, losing our data/file is much less likely)
- High Speed – Quick Deployment.
- Automatic Software Updates and Integration.
- Efficiency and Cost Reduction.
- Scalability.
- Collaboration (The cloud also makes it much easier to share a file with friends, making it possible to collaborate over the web).
- Unlimited Storage Capacity.
- Back-up and Restore Data.
- Disaster Recovery.
- Mobility.
- Control.

2.2 Defining Cloud Computing

- The cloud is just a metaphor for the Internet.

- Cloud computing is a means of providing computing services (including **databases, servers, software, and networking**) via the internet, allowing the user to bypass direct management of those systems.

- In the simplest terms, cloud computing means storing, processing and accessing data and programs over the Internet from a remote location or computer instead of our computer's hard drive.

- When we store data on or run a program from the local computer's hard drive, that is called local storage and computing. For it to be considered cloud computing, we need to access our data or programs over the Internet.

- cloud computing can be done anywhere, anytime, and by any device.

2.2.1 NIST Definition of Cloud Computing

- The formal definition of cloud computing comes from the National Institute of Standards and Technology (NIST).

- Many vendors, pundits, and experts refer to NIST, why because both the International Standards Organization (ISO) and the Institute of Electrical and Electronics Engineers (IEEE) back the NIST definition.

- "Cloud computing is a **model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources** (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort.

- also known as the pay-as-you-go or pay-as-per-use model.

- Cloud model is composed of five essential characteristics, three service models, and four deployment models also known as 5-4-3 principles.

Now, let us try to define and understand cloud computing from two other perspectives—as a service and a platform—in the following sections.

2.2.2 Cloud Computing Is a Service

- The simplest thing that any computer does is allow us to store and retrieve information. We can store our family photographs, our favourite songs, or even save movies on it, which is the most basic service offered by cloud computing.

- wide range of services delivered on demand to companies and customers over the internet. For example, from checking email to collaborating on documents, most employees use cloud services throughout the workday. Example: **Flickr:**

- first, it allows us to easily store and access our images no matter where we are or what type of device we are using.

- Second, Flickr lets us share the images. There is no need to burn them to a CD or save them on a flash drive.

- Third, Flickr provides data security.

2.2.3 Cloud Computing Is a Platform

- The basic meaning of the term platform is that it is the support on which applications run or give results to the users.

- For example, Microsoft Windows is a platform. But a platform does not have to be an operating system.

- The World Wide Web (WWW) can be considered as the operating system for all our Internet-based applications.

- Through cloud computing, the web is becoming a platform. Applications such as office 2.0 (which are originally available on desktop computers) are now being converted into web–cloud applications.

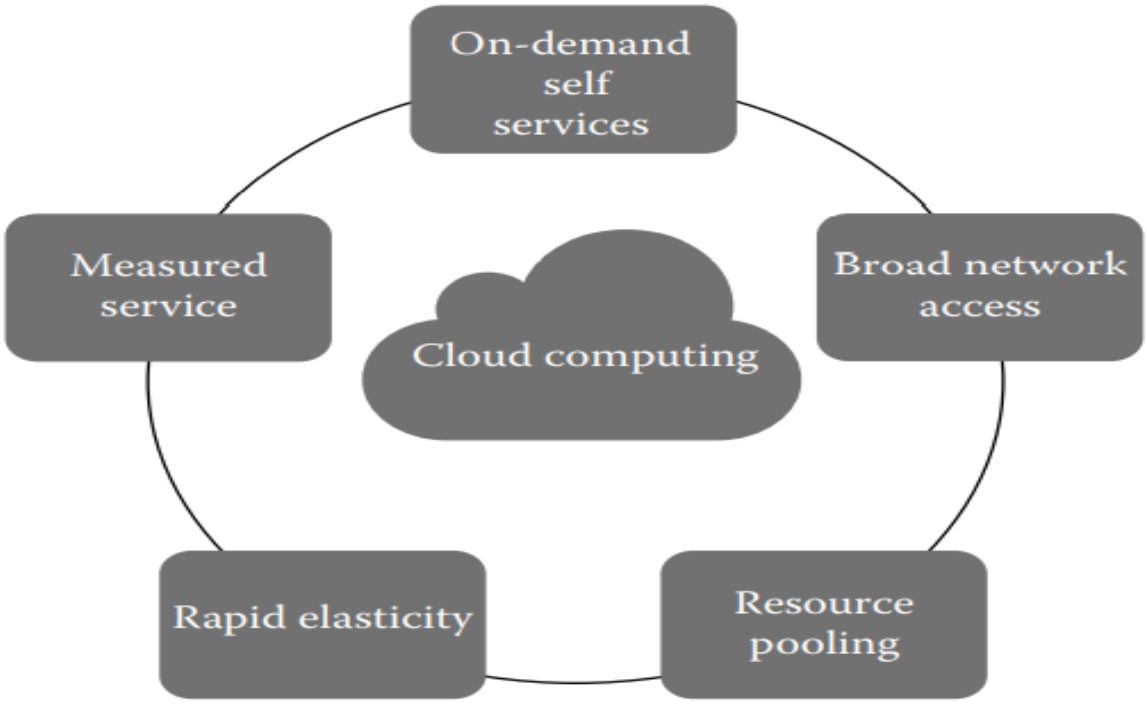
- **Example: office 365**(from Microsoft) **google docs** (from Google) **are** now available on the cloud.

2.3 5-4-3 Principles of Cloud computing

5-4-3 principles suggested by NIST describes (a) the five essential characteristic features that promote cloud computing, (b) the four deployment models (architectural models) of cloud computing for customers and (c) the three important and basic service offering models of cloud computing.

2.3.1 Five Essential Characteristics

Cloud computing has five essential characteristics, which are shown in below Figure.



1. **On-demand self-service:**

✓ Cloud computing provides resources *on demand*, i.e., when the consumer wants it.

✓ This is made possible by *self-service*. Self-service means that the consumer performs all the actions needed to acquire the service (such as server time, network, storage space etc.) himself, without human intervention on the provider's side.

2. **Broad network access:**

✓ Capability of availing services through standard mechanisms that promote to use heterogeneous thin or thick client platforms (e.g., mobile phones, laptops, and personal digital assistants [PDAs]).

3. **Resource pooling:**

- ✓ The provider's computing resources (include storage, processing, memory, and network bandwidth) are pooled to serve multiple consumers **using a multitenant model**, with different physical and virtual resources dynamically assigned and released according to consumer demand.
- ✓ Customer has no knowledge over the exact location of the provided resources but may be able to specify the location at a higher level of abstraction (e.g., country, state, or data centre).

4. **Rapid elasticity:**

- ✓ Capabilities can be elastically provisioned and released in some cases automatically based on demand.
- ✓ The ability to dynamically scale services being provided in direct response to the need of customers for space and other services.

5. **Measured service:**

- ✓ Measured service is a delivery model in which a service provider monitors how much of a particular service each customer consumes within a designated time period.
- ✓ Measured services give the provider insight into resource consumption and provide customers with transparency into how they are billed for the services they consume.
- ✓ Measured services are supported by **metering** capabilities of service consumption. For example, metering for cloud computing resources can be based on how much storage the cloud customer uses, how much processing power they use, how much network bandwidth they consume, the number of active user accounts.

2.3.2 Four Cloud Deployment Models

- ✓ In cloud (Internet) computing-the location from where data and services are acquired and provisioned to its customers— can take various forms.

- ✓ deployment models describe the ways with which the cloud services made available to its customers or can be deployed -based on the organizational structure and the provisioning location.

- ✓ There are four deployment models named private, public, hybrid and community cloud.

1. **Private cloud:**

- ✓ The cloud infrastructure is provisioned for exclusive use by a single organization comprising multiple consumers.
- ✓ It may be owned, managed, and operated by the organization itself or by a third party.
- ✓ and it generally exist on premises.

2. Public cloud:

- ✓ The cloud infrastructure is provisioned for open use by the general public.
- ✓ It may be owned, managed, and operated by any business organization, academic institute, or government organization, or some combination of them.
- ✓ It exists on the premises of the cloud provider.

3. Community cloud:

- ✓ The cloud infrastructure is shared by a **group of several organizations** to share information between them.
- ✓ **Provides service support to a specific community.**
- ✓ It is owned, managed, and operated by one or more organizations in the community or by a third party.
- ✓ It may exist on premise or off premise.
- ✓ **Example:** Our government organization within India may share computing infrastructure in the cloud to manage data. Example: **Education cloud. Meghamala (iit Kharagpur)**
- ✓ Community cloud is **cost effective** because the whole cloud is shared between several organizations or a community.

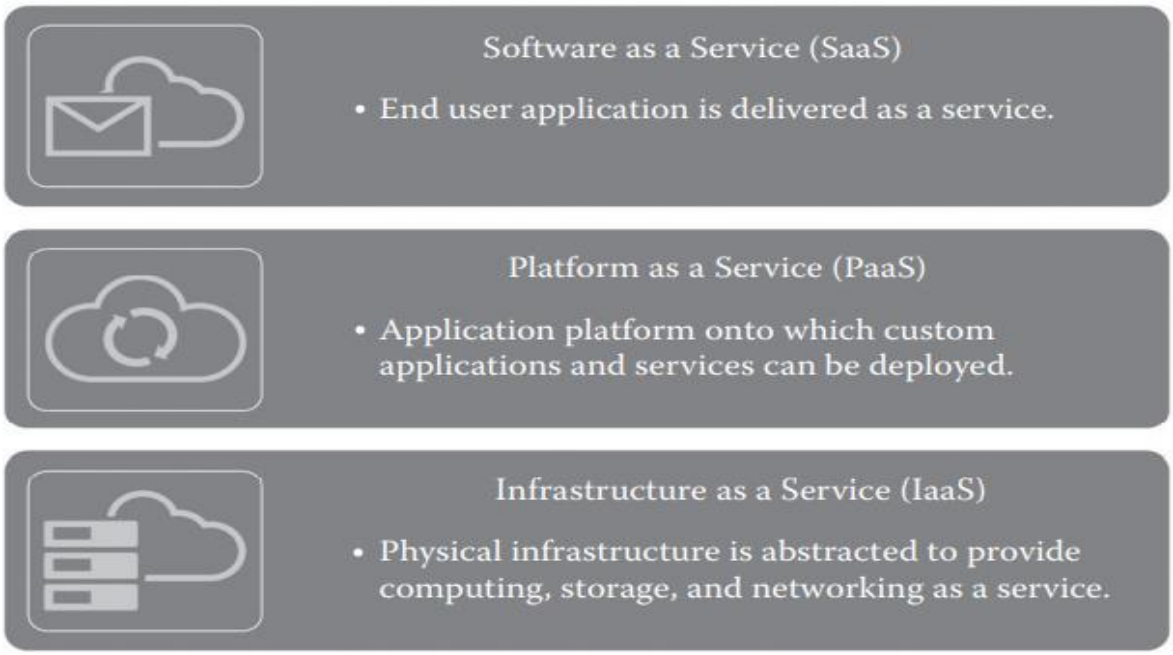
4. Hybrid cloud:

- ✓ The cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public).
- ✓ The distinguishable entities which are bounded together by standardized or proprietary technology that enables **data and application portability** (e.g., cloud bursting for load balancing between clouds).
- ✓ **Cloud bursting is an application configuration** that allows the private cloud to "burst" into the public cloud and access additional computing resources without service interruption. These cloud bursts can be triggered automatically in reaction to high demand of IT infrastructure.

2.3.3 Three Service Offering Models

Cloud computing model offers three kinds of basic services named: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS).

It is also known as the **Service–Platform–Infrastructure (SPI)** model of the cloud and is shown in below Figure.



1. **Software as a Service (SaaS):**

✓ SaaS is a software distribution model in which applications (software) are hosted by a vendor or service provider and made available to customers over the Internet.

✓ The applications are accessible from various client devices through either a client interface, such as a web browser or a program interface.

✓ Typical applications offered as a service include **customer relationship management (CRM)**, **business intelligence analytics tools**, and **online accounting software** etc.

✓ **Example:** Google Apps, Salesforce, Dropbox, Cisco WebEx.

1. **Platform as a Service (PaaS):**
   - ✓ PaaS is a paradigm for delivering operating systems and associated tools and integrated development environments [IDEs] for developing software solutions over the Internet without downloads or installation.

   - ✓ The consumer does not manage or control the underlying cloud infrastructure but has control over the deployed applications and possibly configuration settings for the application-hosting environment.

   - ✓ In other words, it is a packaged and ready-to-run development or operating framework.

   - ✓ Examples of PaaS providers include **Microsoft Azure Services** and **Google App Engine.**

3.Infrastructure as a Service (IaaS)

   - ✓ The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources on a pay-per-use basis.

   - ✓ where he or she is able to deploy and run arbitrary software, which can include operating systems and applications.

   - ✓ The consumer does not manage or control the underlying cloud infrastructure but has control over the operating systems, storage, and deployed applications.

   - ✓ The service provider owns the equipment and is responsible for housing, cooling operation, and maintenance.

   - ✓ **Amazon Web Services (AWS)** is a popular example of a large IaaS provider. Microsoft Azure, Google Compute Engine (GCE), Rackspace, and Cisco Metacloud.

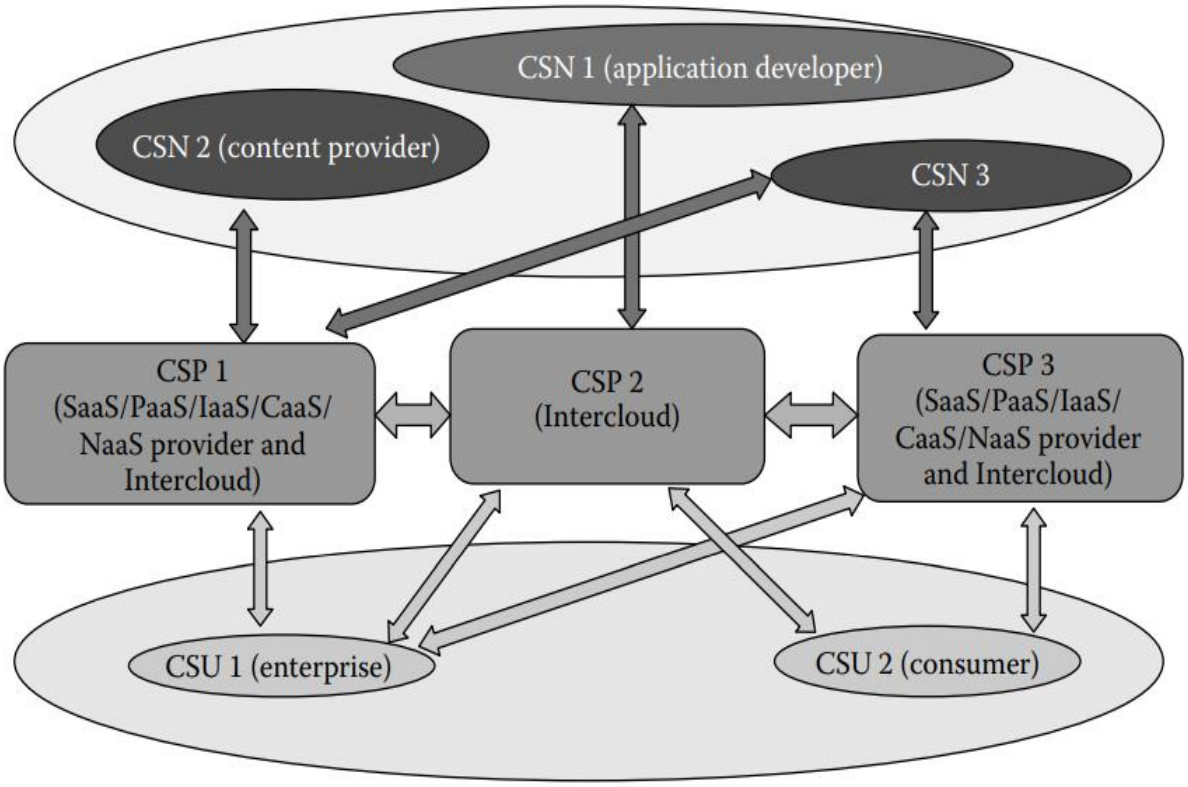
2.4 Cloud Ecosystem

- Cloud ecosystem is a term used to describe the complete environment or system of interdependent components or entities that work together to enable and support the cloud services.

- The cloud computing's ecosystem is a complex environment.

- The traditional elements of cloud computing such as **software (SaaS)**, **hardware (PaaS and/or IaaS)**, other **infrastructure (e.g., network, storage)**, and also **stakeholders** like users, consultants, integrators, partners, third party organizations etc.

- The cloud ecosystem of interacting components and organizations with individuals, together known as the **actors** **who could be responsible for either providing or consuming cloud services.**



Different categories of actors are as follows:

1. **Cloud service users (CSUs):** A consumer (an individual/person), enterprise, a public/government institution or organization that consumes delivered cloud services;

2. **CSPs:** An organization that provides or delivers and manages cloud services, that is, provider of SaaS, PaaS, IaaS, or any allied computing infrastructure.

3. **Cloud service partners (CSNs):**
   - ✓ A person or organization that provides support to the building of a service offered by a CSP.
   - ✓ (e.g., application developer, content, software, hardware or equipment provider, system integrator, and auditor)

2.5. Requirements for Cloud Services

The cloud service offering models require certain features to be exhibited in order to be considered as services.

1. Multitenancy: Multitenancy is an essential characteristic of cloud systems aiming to provide isolation of the different users of the cloud system (tenants) while maximizing resource sharing. Multitenancy is a feature that allows a single instance of an application (say, database system) and leverages the economy of scale to satisfy several users at the same time.

2. Service life cycle management: Cloud services are paid as per usage and can be started and ended at any time. In addition, metering and charging can be done by a proper service life cycle management.

3. Security: The security of each individual service needs to be protected in the multitenant cloud environment.

4. Responsiveness: The cloud ecosystem is expected to enable early detection, diagnosis, and fixing of service-related problems if any to help the customers.

5. Intelligent service deployment: It is expected that the cloud enables efficient use of resources in service deployment, i.e. (maximizing the number of deployed services with minimal resources).

6. Portability: It is expected that a cloud service supports the portability of its features over various underlying resources and CSPs (e.g., VM portability) with limited-service disruption.

7. Interoperability: It is expected to have available well-documented and well-tested specifications that allow heterogeneous systems in cloud environments to work together.

8.Regulatory aspects: There should be a proper regulatory system, including privacy protection.

9. Service availability and quality assurance: CSUs demand for their services end-to-end quality of service (QoS) from CSPs.

10. Service access: A cloud infrastructure is expected to provide CSUs with access to cloud services from any user device.

11. Flexibility: (fast changes in our work- environment) The cloud service can be capable of supporting multiple cloud deployment models and cloud service categories.

12. Accounting and charging: It is expected that a cloud service should support various accounting and charging models and policies.

2.6 Cloud Application

- cloud application is an application program that executes in the cloud.

- Cloud application can exhibit the characteristics of both pure desktop application and a web-based application.

- A desktop application resides entirely on a single device at the user's location and a web application is stored entirely on a remote server and is delivered over the Internet through a browser interface.

- Like a desktop application, cloud applications can provide fast responsiveness and like a web application, it need not permanently reside on the local device, and can be easily updated online.

- A cloud application can be accessed with a web browser on the Internet.

- An example of cloud application is a **web-based e-mail** (e.g., Gmail, Yahoo mail); in this application, the user of the e-mail uses the cloud—all of the emails in their inbox are stored on servers at remote locations at the e-mail service provider.

- another example: **Dropbox** is a cloud storage service that lets us easily store and share files with other people and access files from a mobile device as well.

2.7 Benefits and Drawbacks

Benefits:

1. Reduce spending on technology: It is easy to access data and information with minimal upfront spending in a pay-as-you-go approach.

2. Globalize the workforce: People worldwide can access the cloud with Internet connection.

3. Streamline business processes: It is possible to get more work done in less time with less resource.

4. Reduce capital costs: There is no need to spend huge money on hardware, software, or licensing fees.

5. Pervasive accessibility: Data and applications can be accessed anytime, anywhere, using any smart computing device.

6. Less personnel training is needed: It takes fewer people to do more work on a cloud, with a minimal learning curve on hardware and software issues.

7. Minimize maintenance and licensing software: As there is no too much of on-premise computing resources, maintenance becomes simple.

8.Improved flexibility: It is possible to make fast changes in our work-environment without serious issues at stake.

Drawbacks:

- **Network problems(internet-issues)**
- **Security of data and application**
- **interoperability of applications.**
- **No control on the resources.**

Unit-IV

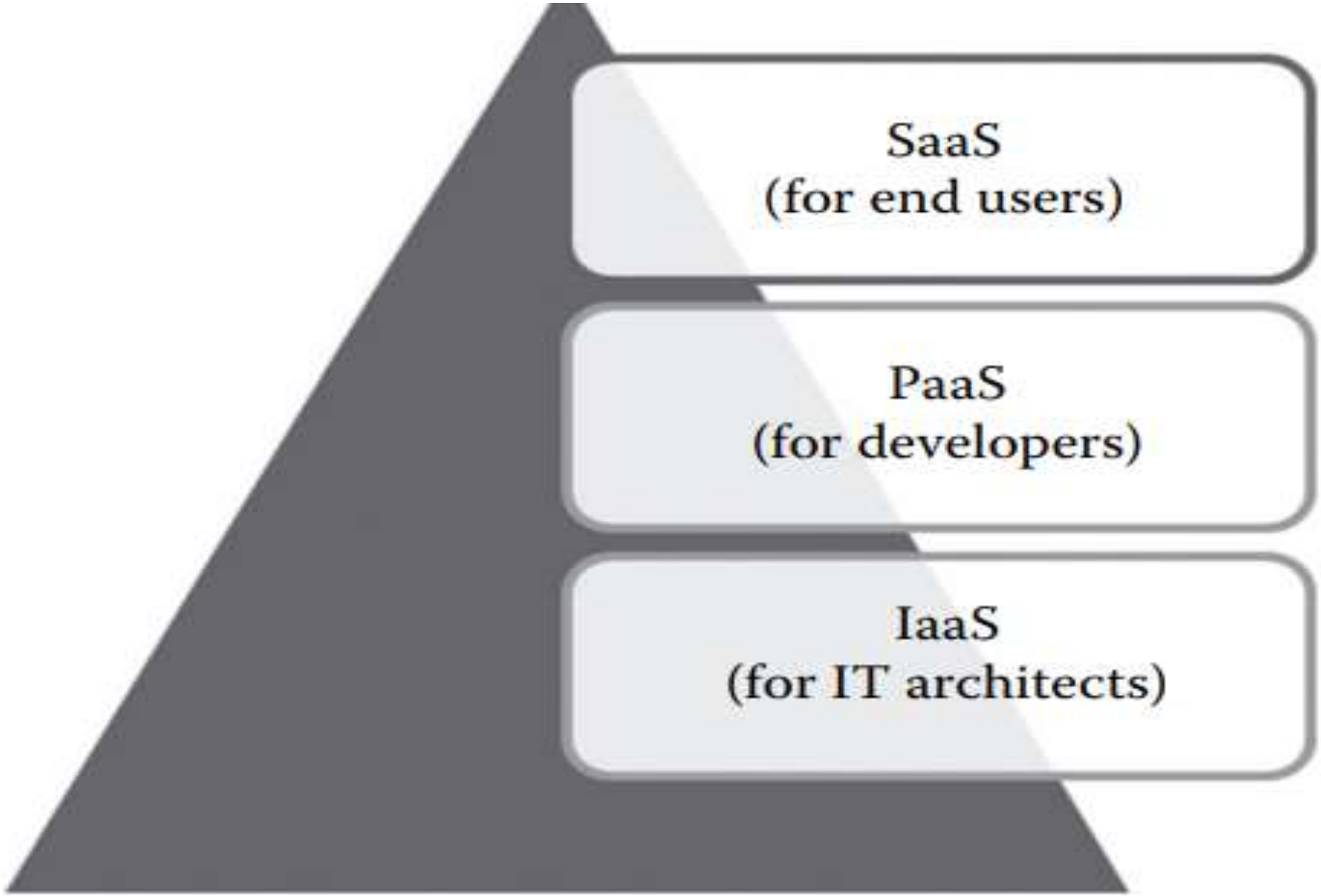
Cloud Service Models

5.1.Introduction:

- ✓Cloud computing is a model that enables the end users to access the shared pool of resources such as compute, network, storage, database, and application as an on-demand service without the need to buy or own it.

- ✓The services are provided and managed by the service provider, reducing the management effort from the end user side.

- ✓The National Institute of Standards and Technology (NIST) defines three basic service models, namely, IaaS, PaaS, and SaaS, as shown in Figure.


SaaS
(for end users)
PaaS
(for developers)
IaaS
(for IT architects)

1.IaaS:

- ✓IaaS providers offer virtual computing resources to the consumers on a payas-you-go basis.
- ✓Here, the underlying infrastructures such as compute, network, and storage are managed by the service provider.
- ✓ Thus, the infrastructure architects are exempted from maintaining the data center or underlying infrastructure.
- ✓The end users are responsible for managing applications that are running on top of the service provider cloud infrastructure.
- ✓The end users can access the services from their devices through web command line interface (CLI) or application programming interfaces (APIs) provided by the service providers.

Some of the popular IaaS providers include:

- ➢ Amazon EC2 ,Google Compute Engine,
- ➢ OpenStack, and Eucalyptus.
- ➢ Alibaba Elastic Compute Service
- ➢ Microsoft Azure Virtual Machines

2.PaaS:

- ✓gives ability to developers to develop and deploy an application on the development platform provided by the service provider.
- ✓ Thus, the developers are exempted from managing the development platform and underlying infrastructure.
- ✓ Here, the developers are responsible for configuring the development environment and managing the deployed application.
- ✓The developers can access the development platform over the Internet through web user interface (UI), and integrated development environments (IDEs).

Some of the popular PaaS providers include:

Google App Engine (platform that enables organizations to build their own applications and supports Node.js, Java, C#, Python and PHP.)

Microsoft Azure Pipelines(enables to build applications with Node.js, Python, Java, PHP, Ruby, C/C++ and of course Microsoft .NET.)

Heroku(Heroku is a container-based PaaS environment),

Engine Yard.

Force.com,

Red Hat OpenShift.

3.SaaS:

- ✓SaaS gives ability to the end users to access an application over the Internet that is hosted and managed by the service provider.
- ✓ Thus, the end users are exempted from managing or controlling an application, the development platform, and the underlying infrastructure.
- ✓The end users can access the services from any thin clients or web browsers.
- ✓ Some of the popular SaaS providers include:

  Saleforce.com,

  Google Apps, and

  Microsoft office 365.

The different cloud service models target different audiences:

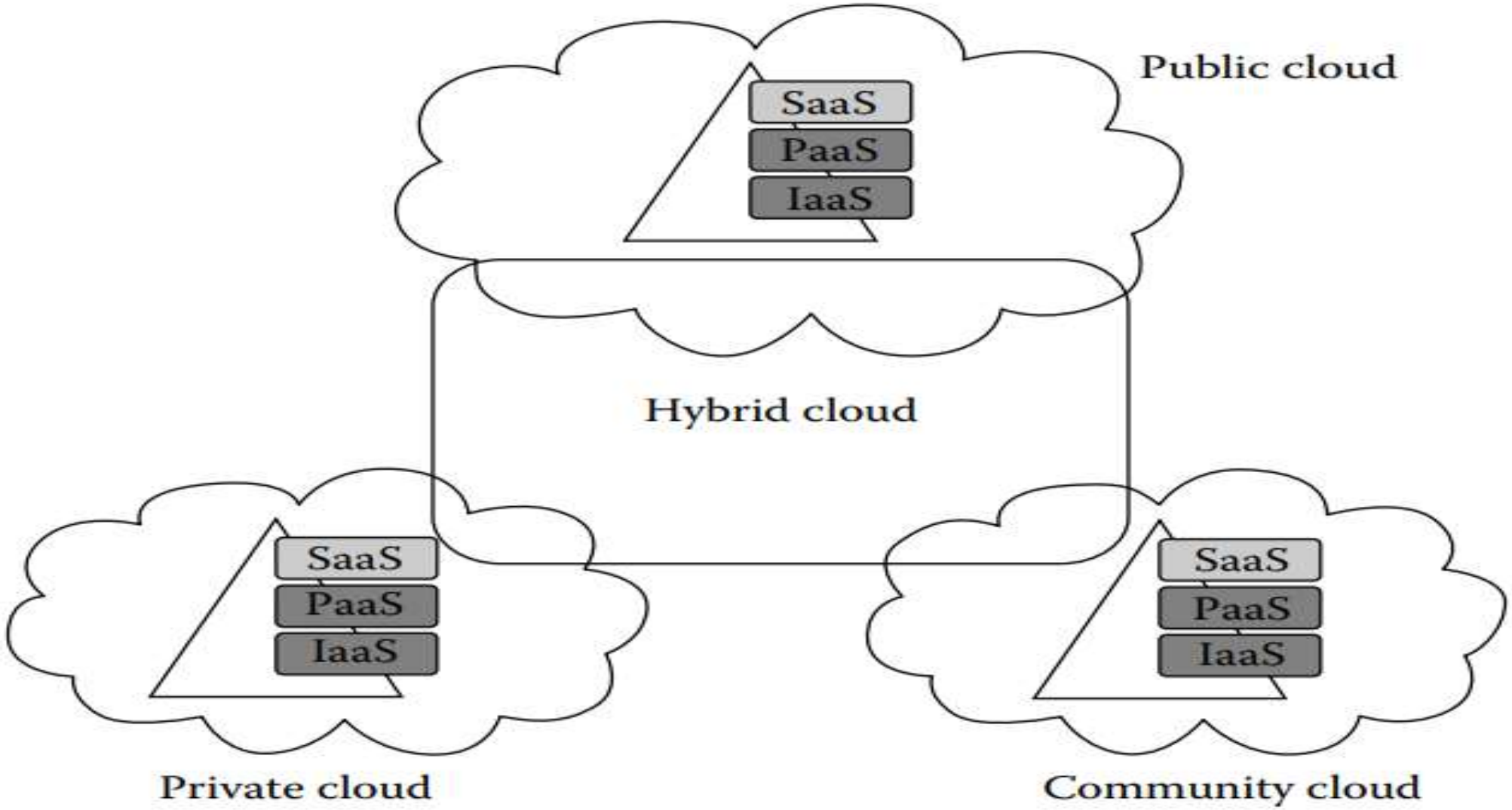
✓ IaaS model targets the information technology (IT) architects

- the primary duties of an IT architect are design and maintain computer networks
- They use computer design s/w to model and test networks.
- Main responsibility is to resolve technical issues if any in the networking operations.

✓ PaaS targets the developers, and

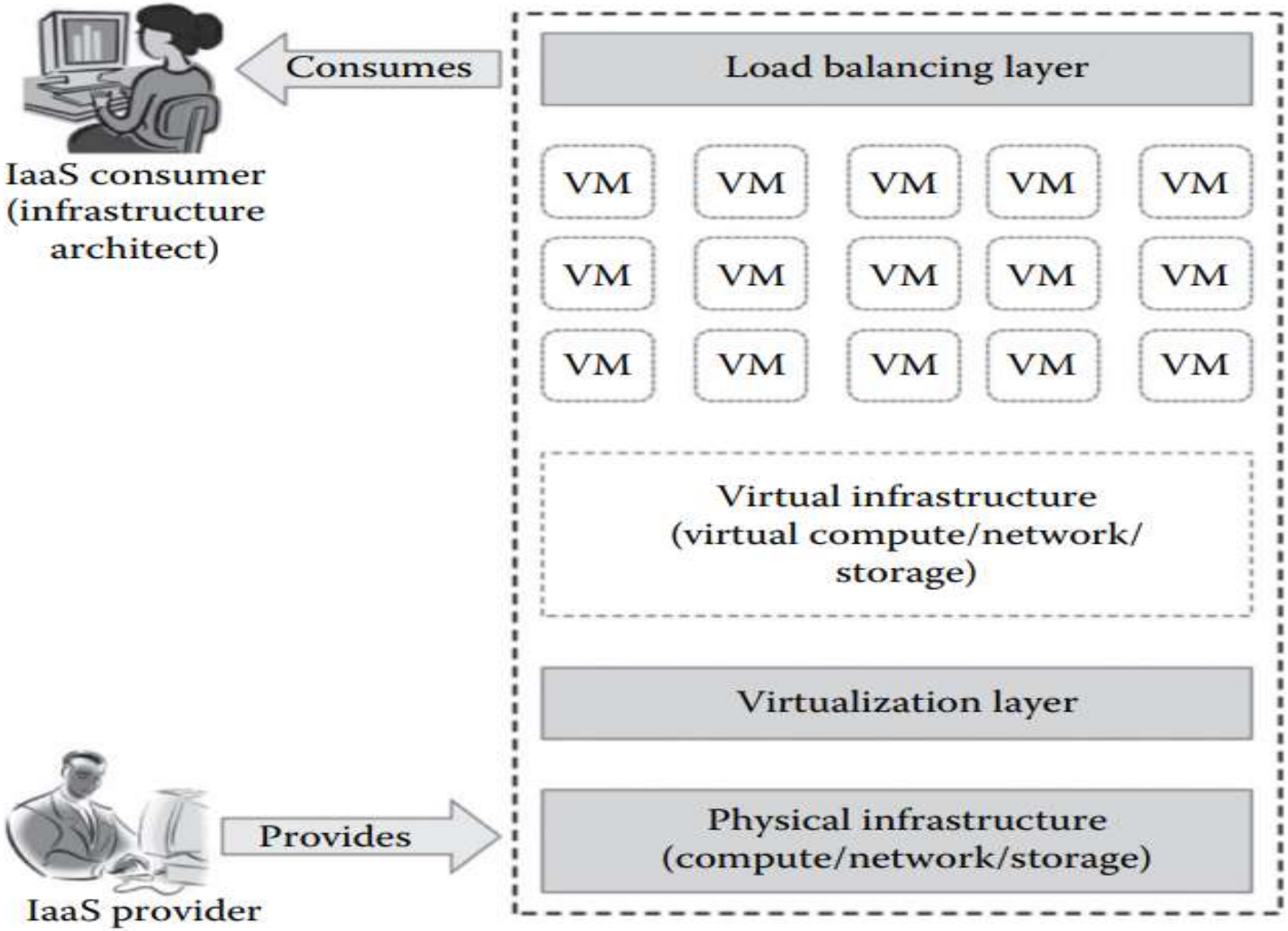
✓ SaaS targets the end users.

Note: **The service models of cloud computing can be deployed and delivered through any one of the cloud deployment models.**



5.2 Infrastructure as a Service

- ✓In traditional data centers, the computing power is **consumed by having physical access** to the infrastructure.
- ✓IaaS changes the way that the compute, storage, and networking resources are consumed.
- ✓IaaS **provides virtual computing, storage, and network resources** by abstracting the physical resources.
- ✓**Virtualization** technology is used to provide the virtual resources.
- ✓The end users or IT architects will use the infrastructure resources in the form of VMs as shown in Figure.


Consumes
IaaS consumer (infrastructure architect)
Load balancing layer
VM
VM
VM
VM
VM
VM
VM
VM
VM
VM
VM
VM
VM
VM
VM
Virtual infrastructure (virtual compute/network/ storage)
Virtualization layer
Physical infrastructure (compute/network/storage)
Provides
IaaS provider

✓The **targeted audience of IaaS is the IT architect**.

✓The IT architect can be provided with virtual infrastructure, network, load balancers, etc.,

✓ The IT architects need not maintain the physical servers as it is maintained by the service providers.

✓Thus, it eliminates /hides the complexity of maintaining physical servers .

A typical IaaS provider may provide the flowing services:

- ✓**1.Compute:** virtual central processing units (CPUs) and virtual main memory for the VMs that are provisioned to the end users.
- ✓**2. Storage:** Provides back-end storage for the VM images. Some of the IaaS providers also provide the back end for storing files.
- ✓**3. Network:** Provides virtual networking components such as virtual router, switch, and bridge for the VMs.
- ✓**4. Load balancers:** provides load balancing capability at the infrastructure layer.

5.2.1 Characteristics of IaaS

- ✓**1. Web access to the resources:** The IaaS model enables the IT users to access infrastructure resources over the Internet(Through any **web browsers/management console).**
- ✓**2. Centralized management:** The resources distributed across different parts can be controlled from a single place/management console.
- ✓**3. Elasticity and dynamic scaling:** IaaS provides elastic services where the usage of resources can be increased or decreased according to the requirements.
- ✓**4. Shared infrastructure:** follows a one-to-many delivery model and allows multiple IT users to share the same physical infrastructure.
- ✓**5. Preconfigured VMs:** providers offer preconfigured VMs with operating systems (OSs), network configuration, etc. The IT users can select any kind of VMs of their choice.
- ✓**6. Metered services:** The services consumed by the IT user will be measured, and the users will be charged by the IaaS providers based on the amount of usage

5.2.2 Suitability of IaaS

- ✓ IaaS reduces the total cost of ownership (TCO). increases the return on investment (ROI) **for start-up companies**.

IaaS can be used in the following situations:

- ✓ **1.Unpredictable spikes in usage:** When there is a significant spike in usage of computing resources, IaaS is the best option for IT industries. In this situation, we cannot add or remove infrastructure immediately according to the demand in a traditional infrastructure.
- ✓ **2. Limited capital investment:** New start-up companies cannot invest more on buying infrastructure for their business needs.
- ✓ **3. Infrastructure on demand:** Some organizations may ***require large infrastructure for a short period of time***. For this purpose, an organization cannot afford to buy more on-premise resources. Instead, they can rent the required infrastructure for a specific period of time.

There are some situations where IaaS may not be the best option.

✓**1. When regulatory compliance does not allow off-premise hosting:** For some companies, its regulation may not allow the application and data to be hosted on third-party off-premise infrastructure.

✓**2. When usage is minimal:** When the usage is minimal and the available on-premise infrastructure itself is capable of satisfying their needs.

✓**3. When better performance is required:** Since the IaaS services are accessed through the Internet, sometimes the performance might be not as expected due to network latency.

✓ **4. When there is a need for more control on physical infrastructure:** Some organizations might require physical control over the underlying infrastructure.

5.2.3 Pros and Cons of IaaS

The following are the benefits provided by IaaS:

1.Pay-as-you-use model: The IaaS services are provided to the customers on a pay-per-use basis. This ensures that the customers are required to pay for what they have used.

2. Reduced TCO: Since IaaS providers allow the IT users to rent the computing resources, they need not buy physical hardware for running their business.

3. Elastic resources: IaaS provides resources based on the current needs. IT users can scale up or scale down the resources whenever they want.

4. Better resource utilization: Resource utilization is the most important criteria to succeed in the IT business. IaaS ensures better resource utilization and provides high ROI for IaaS providers.

5. Supports Green IT: In traditional IT infrastructure, dedicated servers are used for different business needs. Since many servers are used, the power consumption will be high. In IaaS, the need of buying dedicated servers is eliminated as single infrastructure is shared between multiple customers, thus reducing the number of servers to be purchased and hence the power consumption that results in Green IT.

The following are the drawbacks of IaaS:

1. Security issues: Since IaaS uses virtualization as the enabling technology, hypervisors play an important role. There are many attacks that target the hypervisors and then any VMs can be attacked easily. Most of the IaaS providers are not able to provide 100% security to the VMs and the data stored on the VMs.

2. Interoperability issues: There are no common standards followed among the different IaaS providers. It is very difficult to migrate any VM from one IaaS provider to the other.

3. Performance issues: Here, all the distributed servers are connected over the network. Latency of the network plays an important role in deciding the performance. Because of latency issues, sometimes the VM contains issues with its performance.

5.2.4 Summary of IaaS Providers

- ✓ There are many public and private IaaS providers in the market who provides infrastructure services to the end users.
- ✓ The below Table provides the summary of popular infrastructure providers.

TABLE 5.1

Summary of Popular IaaS Providers

Provider	License	Deployment Model	Host OS	Guest OS	Supported Hypervisor(s)
Amazon Web Services	Proprietary	Public	Not available	Red Hat Linux, Windows Server, SuSE Linux, Ubuntu, Fedora, Debian, CentOS, Gentoo Linux, Oracle Linux, and FreeBSD	Xen
Google Compute Engine	Proprietary	Public	Not available	Debian 7 Wheezy, CentOS 6, Red Hat Enterprise Linux, SUSE, Windows Server, CoreOS, FreeBSD, and SELinux	KVM
Microsoft Windows Azure	Proprietary	Public	Not available	Windows Server, CentOS, FreeBSD, openSUSE Linux, and Oracle Enterprise Linux	Windows Azure hypervisor
Eucalyptus	GPLv3	Private and hybrid	Linux	Linux and Windows	Xen, KVM, VMware
Apache CloudStack	Apache 2	Private	Linux	Windows, Linux, and various versions of BSD	KVM, vSphere, XenServer / XCP
OpenNebula	Apache 2	Private, public, and hybrid	CentOS, Debian, and openSUSE	Microsoft Windows and Linux	Xen, KVM, VMware
OpenStack	Apache 2	Private and public	CentOS, Debian, Fedora, RHEL, openSUSE, and Ubuntu	CentOS, Ubuntu, Microsoft Windows, and FreeBSD	libvirt, Hyper-V, VMware, XenServer 6.2, baremetal, docker, Xen, LXC via libvirt

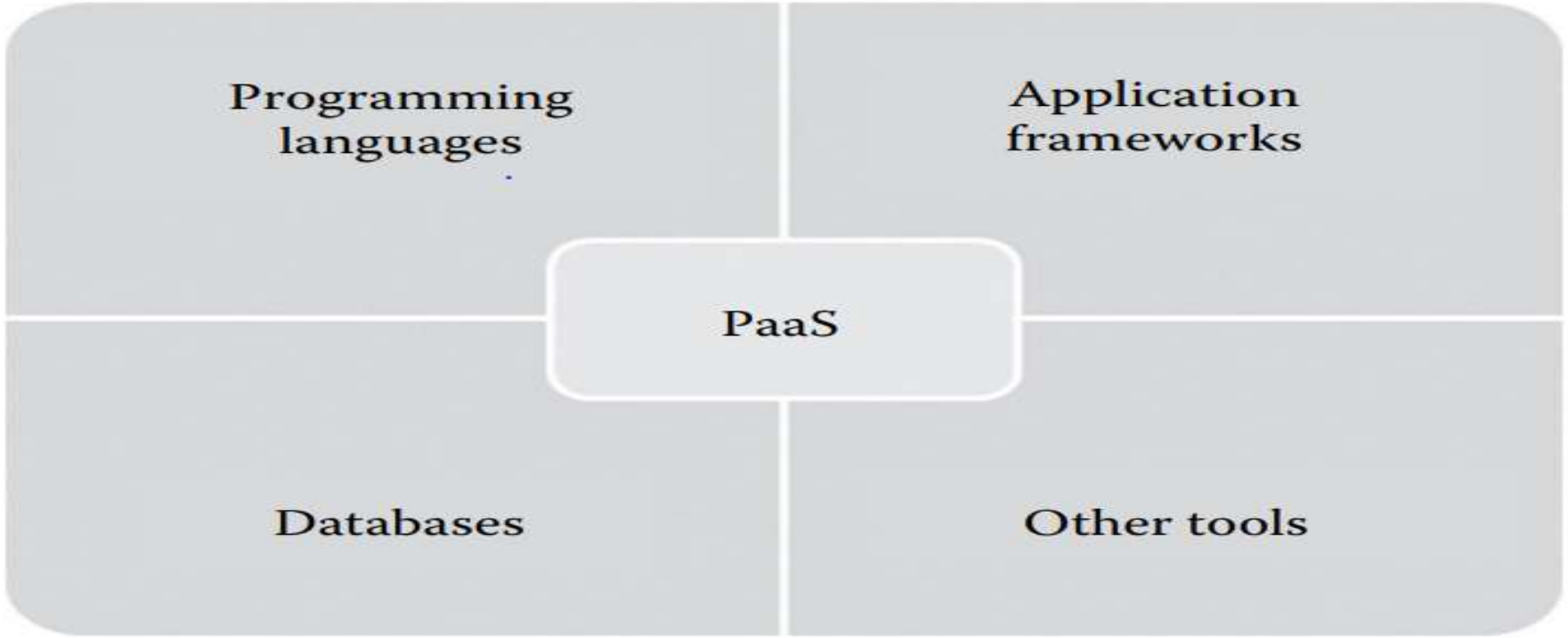
5.3 Platform as a Service

- ✓ PaaS changes the way that the software is developed and deployed.
- ✓ *Providers provide the* ***development Plat-forms*** *from the data center, over the Internet.*
- ✓ In stand-alone application development, the applications will be developed and *delivered as executables. Most* of these are *licensing-based software's*.
- ✓ In traditional application development, the application will be developed locally and will be hosted in the central location.

✓PaaS allows the developers *to develop their application online* and also *allows them to deploy immediately on the same platform*.

Typical PaaS providers may provide:

- programming languages,
- application frameworks,
- databases,
- testing tools, and
- deployment tools.



Services provided by PaaS providers

Note: So it ***reduces the complexity of buying and maintaining different tools*** for developing an application.

1. Programming languages:

- ✓PaaS providers provide a wide variety of programming languages for the developers to develop applications.
- ✓ Some of the popular programming languages provided by PaaS vendors are **Java, Perl, PHP, Python, Ruby, Scala, Clojure, and Go**.

2. Application frameworks:

- ✓PaaS vendors provide application frameworks that simplify the application development.
- ✓Some of the popular application development frameworks include **Node.js**, **Rails**, **Drupal, Joomla, WordPress, Django, Spring**, and **Play.**

3. Database:

- ✓Since every application needs to communicate with the databases, it becomes a must-have tool for every application.
- ✓The popular databases provided by the popular PaaS vendors are **ClearDB**, **PostgreSQL**, **Cloudant**, **Membase**, and **MongoDB.**

4. Other tools: Provide the tools that are ***required to develop, test, and deploy*** an application.

5.3.1 Characteristics of PaaS

1. **All in one:** Providers offer services to develop, test, deploy, host, and maintain applications in the same IDE.

2.Web access to the development platform: Using web UI, any developer can get access to the development platform.

3. Offline access: A developer may not be able to connect to the Internet for a whole day to access the PaaS services. When there is no Internet connectivity, the developers should be allowed to work offline. The developers can develop an application locally and deploy it online whenever they are connected to the Internet.

4. Built-in scalability: PaaS services provide built-in scalability to an application that is developed. This ensures that the application is capable of handling varying loads efficiently. *But It is very difficult to enable the dynamic scalability for any application traditional development platforms.*

5. Collaborative platform: Nowadays, the development team consists of developers who are working from different places. There is a need for a common platform where the developers can collaboratively work together on the same project. Most of the PaaS services provide support for collaborative development.

6. Diverse client tools: To make the development easier, PaaS providers provide a wide variety of client tools to help the developer. The client tools include **CLI**, **web CLI**, **web UI**, **REST API**, and **IDE**.

5.3.2 Suitability of PaaS

Note: Most of the ***start-up SaaS development companies*** and ***independent software vendors (ISVs)*** widely use PaaS in developing an application.

PaaS is a suitable option for the following situations:

1.Collaborative development: Since PaaS services provide a collaborative development environment, it is a suitable option for applications that need collaboration among developers and other third parties to carry out the development process.

2. Automated testing and deployment: Most of the PaaS services offer automated testing and deployment capabilities. Automated testing and building of an application are very useful while developing applications at a very short time frame. *The automated testing tools reduce the time spent in manual testing tools.*

3. Time to market: If the software vendor wants their application to be in the market as soon as possible, then the PaaS services are the best option for the development.

PaaS may not be the best option:

1. **Frequent application migration:** Since there are no common standards followed among PaaS providers, it is very difficult to migrate the application from one PaaS provider to the other.

2. Customization at the infrastructure level: The PaaS users do not have full control over the underlying infrastructure. There are some application development platforms that need some configuration or customization of underlying infrastructure.

3. Flexibility at the platform level: PaaS provides template-based applications where all the different programming languages, databases, and development tools are predefined.

4. Integration with on-premise application: A company might have used PaaS services for some set of applications. For some set of applications, they might have used on-premise platforms. This makes the integration of application hosted in on-premise platform and PaaS platform a difficult job.

5.3.3 Pros and Cons of PaaS:

• PaaS has the following benefits:

✓**1. Quick development and deployment**

✓**2. Reduces TCO**

✓**3.Supports agile software development:**(Nowadays, most of the new-generation applications are developed using agile methodologies The Agile methodology is a way to manage a project by breaking it up into several phases. It involves constant collaboration with stakeholders and continuous improvement at every stage. Continuous collaboration is vital, both with team members and project stakeholders.)

✓**4. Different teams can work together**

✓**5. Ease of use:**(PaaS provides a wide variety of client tools such as CLI, web CLI, web UI, APIs, and IDEs. The developers are free to choose any client tools of their choice.)

✓**6. Less maintenance overhead**

✓**7. Produces scalable applications:**(Most of the applications developed using PaaS services are web applications . These applications require better scalability on the extra load. For handling extra load, the software vendors need to maintain an additional server. It is very difficult for a new start-up company to provide extra servers based on the additional load. But, PaaS services are providing built-in scalability to the application.)

• PaaS has the following drawbacks:

✓**1. Vendor lock-in:** The main reason for vendor lock-in is lack of standards. There are no common standards followed among the different PaaS providers.

✓**2. Security issues:** (Since data are stored in off-premise third-party servers, many developers are afraid to go for PaaS services)

✓**3. Less flexibility:** (Only some of the PaaS providers allow developers to extend the PaaS tools with the custom or new programming languages. Still most of the PaaS providers do not provide flexibility to the developers.)

✓**4. Depends on Internet connection:** **(**Even though some of the providers allow offline access, most of the PaaS providers do not allow offline access. With slow Internet connection, the usability and efficiency of the PaaS platform do not satisfy the developer requirements**)**

TABLE 5.2

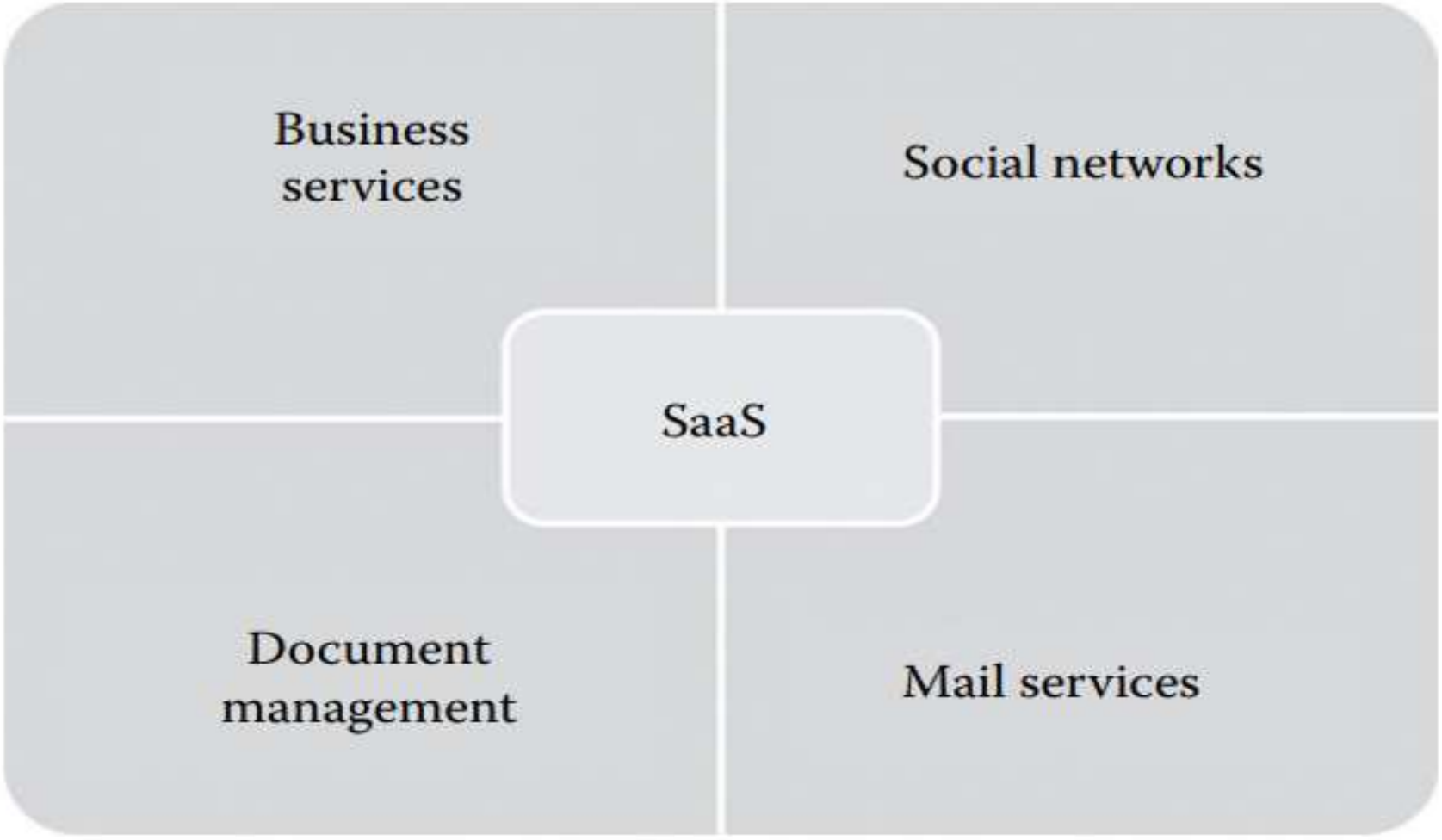
Summary of Popular PaaS Providers

Provider	License	Deployment Model	Supported Languages	Supported Frameworks	Supported Databases	Client Tools
Cloud Foundry	Open source and proprietary	Public	Python, PHP, Java, Groovy, Scala, and Ruby	Spring, Grails, Play, Node.js, Lift, Rails, Sinatra, and Rack	MySQL, PostgreSQL, MongoDB, and Redis	cf. CLI, IDEs, and build tools
Google App Engine	Proprietary	Public	Python, Java, Groovy, JRuby, Scala, Clojure, Go, and PHP	Django, CherryPy, Pyramid, Flask, web2py, and webapp2.	Google Cloud SQL, Datastore, BigTable, and Blobstore	APIs
Heroku	Proprietary	Public	Ruby, Java, Scala, Clojure and Python, PHP, and Perl	Rails, Play, Django, and Node.js.	ClearDB, PostgreSQL, Cloudant, Membase, MongoDB, and Redis	CLI and RESTful API
Microsoft Windows Azure	Proprietary	Public	.Net, PHP, Python, Ruby, and Java	Django, Rails, Drupal, Joomla, WordPress, DotNetNuke, and Node.js	SQL Azure, MySQL, MongoDB, and CouchDB	RESTful API and IDEs
Red Hat OpenShift Online	Proprietary	Public	Java, Ruby, Python, PHP, and Perl	Node.js, Rails, Drupal, Joomla, WordPress, Django, EE6, Spring, Play, Sinatra, Rack, and Zend.	MySQL, PostgreSQL, and MongoDB	Web UI, APIs, CLI, and IDEs
ActiveState Stackato	Proprietary	Private	Java, Perl, PHP, Python, Ruby, Scala, Clojure, and Go	Spring, Node.js, Drupal, Joomla, WordPress, Django, Rails, and Sinatra.	MySQL, PostgreSQL, MongoDB, and Redis	CLI and IDE
Apprenda	Proprietary	Private	.Net and Java	Most of the frameworks form .Net	SQL Server	REST APIs
CloudBees	Proprietary	Private	Java, Groovy, and Scala	Spring, JRails, JRuby, and Grails.	MySQL, PostgreSQL, MongoDB, and CouchDB	API, SDK, and IDEs
Cumulogic	Proprietary	Private	Java, PHP, and Python	Spring and Grails.	MySQL, MongoDB, and Couchbase	RESTful API
Gigaspaces Cloudify	Open source	Private	Any programming language specified by recipe	Rails, Play, and others.	MySQL, MongoDB, Couchbase, Cassandra, and others	CLI, web UI, and REST API

5.4 Software as a Service

- ✓SaaS changes the way the software is delivered to the customers.
- ✓ In the traditional software model, the software is delivered as a license-based product that needs to be installed in the end user device.
- ✓There is no need to install the software to the end user's devices.
- ✓SaaS services can be accessed from any lightweight web browsers on any devices such as laptops, tablets, and smartphones.
- ✓SaaS services can be accessed/ disconnected at any time based on the end user's needs.

A Typical SaaS provider may provide:



A Typical SaaS provider may provide:

1. Business services: Most of the SaaS providers providing a variety of business services that attract start-up companies. *The business services include* ***ERP, CRM, billing, sales, and human resources***.

2.Document management: Since most of the enterprises extensively use electronic documents, *most of the SaaS providers started providing services that are used to create, manage, and track electronic documents.*

3. Social networks: Since social networking sites are extensively used by the general public, many social networking service providers adopted SaaS for their sustainability. ***Note:*** *Since the number of users of the social networking sites is increasing exponentially, cloud computing is the perfect match for handling the variable load.*

4. Mail services: E-mail services are currently used by many people. The future growth in e-mail usage is unpredictable. To handle the unpredictable number of users and the load on e-mail services, *most of the e-mail providers started offering their services as SaaS services.*

5.4.1 Characteristics of SaaS

1.One to many: a single instance of the application can be shared by customers.

2. Web access: It allows the end user to access the application from any location if the device is connected to the Internet.

3. Centralized management: Since SaaS services are hosted and managed from the central location, management of the application becomes easier. Normally, providers will perform the automatic updates on applications.

4.Multidevice support: SaaS services can be accessed from any end user devices such as *desktops, laptops, tablets, smartphones, and thin clients.*

5. Better scalability: Since most of the SaaS services leverage PaaS and IaaS for its development and deployment, it ensures a better scalability than the traditional software. The dynamic scaling of underlying cloud resources makes SaaS applications work efficiently even with varying loads.

6. High availability: SaaS services ensure the 99.99% availability.

7. API integration: SaaS services have the capability of integrating with other service through standard APIs.

5.4.2 Suitability of SaaS

SaaS applications are the best option for the following:

1.On-demand software: The licensing-based software model requires buying full packaged software and increases cost. If the end users are looking for on-demand software rather than the licensing-based full-term software, then the SaaS model is the best option.

2. Software for start-up companies: Since SaaS services do not require high-end infrastructure for accessing, it is a suitable option for start-up companies that can reduce the initial expenditure on buying high-end hardware.

3. Software compatible with multiple devices: Some of the applications like word processors or mail services need better accessibility from different devices. The SaaS applications are adaptable with almost all the devices.

4. Software with varying loads: We cannot predict the load on popular applications such as social networking sites. The user may connect or disconnect from applications anytime. It is very difficult to handle varying loads with the traditional infrastructure. With the dynamic scaling capabilities, SaaS applications can handle varying loads efficiently.

The SaaS delivery model is not the best option for the applications mentioned in the following:

1.Real-time applications: Since SaaS applications depend on Internet connectivity, it may not work better with low Internet speed. ***Real-time applications require fast processing of data that may not be possible with the SaaS applications*** because of the dependency on high-speed Internet connectivity and latency issues.

2. Applications with confidential data: Data security, data governance, and data compliance are always issues with SaaS applications. Since data are stored with third-party service providers, there is no surety that our data will be safe.

3. Better on-premise application: if our on-premise applications fulfill all the requirements of the organization,then migrating to the SaaS model may not be the best option.

5.4.3 Pros and Cons of SaaS

- ✓ **1.No client-side installation:** SaaS services do not require client-side installation of the software.
- ✓ **2. Cost savings:** Since SaaS services follow pay-as-you-go billing and most of the SaaS providers offer different subscription plans to benefit different customers.
- ✓ **3. Less maintenance:** eliminate the overhead of maintaining the software from the client side.
- ✓ **4. Ease of access:** SaaS services can be accessed from any devices if it is connected to the Internet. It is adaptable to all the devices as it uses the responsive web UI.
- ✓ **5. Dynamic scaling:** SaaS services are popularly known for elastic dynamic scaling. It is very difficult for on-premise software to provide dynamic scaling capability as it requires additional hardware.
- ✓ **6. Disaster recovery:** With proper backup and recovery mechanisms, replicas are maintained for every SaaS services. It eliminates the problem of single point of failure.
- ✓ **7. Multitenancy:** Multitenancy is the ability given to the end users to share a single instance of the application.

The following are the major problems with SaaS services:

1. **Security:** Security is the major concern in migrating to SaaS application. Since the SaaS application is shared between many end users, there is a possibility of data leakage. Here, the data are stored in the service provider data center. We cannot simply trust some third-party service provider confidential data.

2. **Connectivity requirements:** SaaS applications require Internet connectivity for accessing it. Sometimes, the end user's Internet connectivity might be very slow. In such situations, the user cannot access the services with ease.

3. **Loss of control:** Since the data are stored in a third-party and off premise location, the end user does not have any control over the data.

5.4.4 Summary of SaaS Providers

Summary of Popular SaaS Providers

Provider	Services Provided
Salseforce.com	On-demand CRM solutions
Google Apps	Gmail, Google Calendar, Talk, Docs, and Sites
Microsoft Office 356	Online office suite, software, plus services
NetSuite	ERP, accounting, order management, inventory, CRM, professional services automation (PSA), and e-commerce applications
Concur	Integrated travel and expense management solutions
GoToMeeting	Online meeting, desktop sharing, and video-conferencing software
Constant Contact	E-mail marketing, social-media marketing, online survey, event marketing, digital storefronts, and local deals tools
Workday, Inc.	Human capital management, payroll, and financial management
Oracle CRM	CRM applications
Intacct	Financial management and accounting software solutions

Cloud Service Providers

The main objective of this chapter is to provide an overview of different cloud service providers. After reading this chapter, you will Know about

- Know cloud services offered by the companies
- Understand open source/proprietary tools offered by the companies
- Understand the architecture and features of different tools.

- Subsequent sections talk about companies like Amazon, Microsoft, Google, EMC, Salesforce, and IBM that provide various tools and services in order to give cloud support.
- It also gives an idea of tools and technologies adapted by companies in order to provide services to the users. Amazon, Microsoft, Google, Yahoo, EMC, Salesforce, Oracle, IBM, and many more companies provide various tools and services in order to give cloud support for their customers.

11.2 EMC (EMC-*Corporation* until 2016) is an American multinational corporation. EMC was acquired by Dell in 2016 then renamed as **dell EMC**.

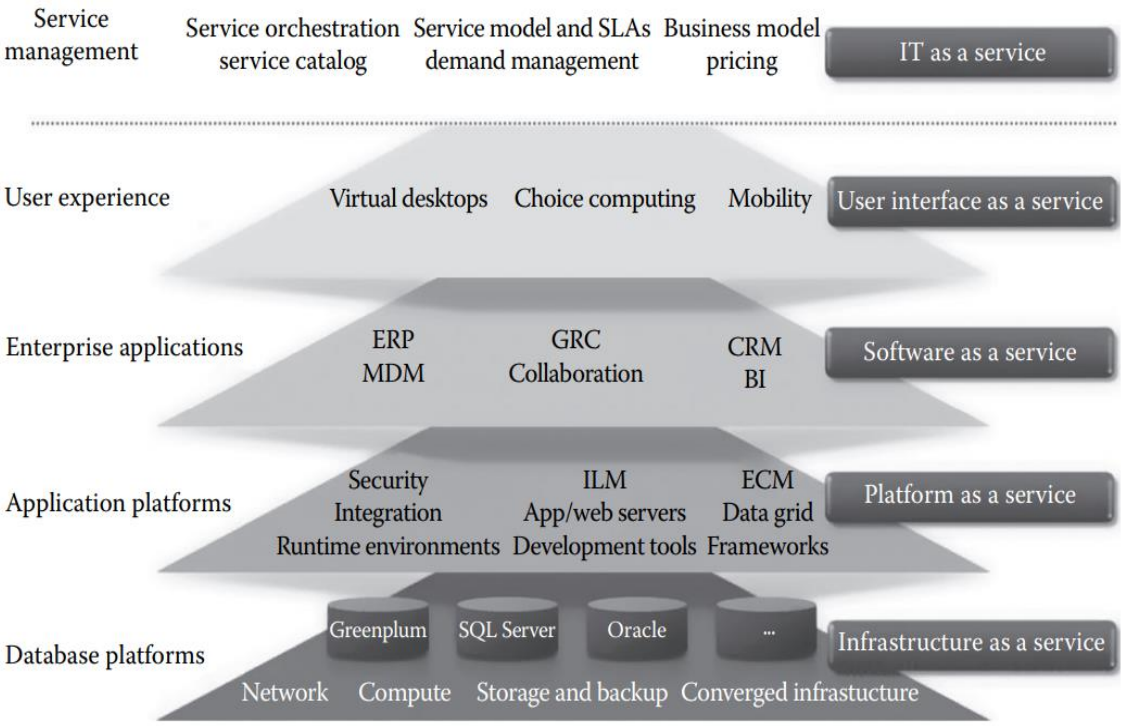
- Dell EMC provides **data-storage**, **information security**, **virtualization**, **analytics**, **cloud computing** and other products and services to their clients.

- Which enable organizations to store, manage, protect, and analyse data.

11.2.1 EMC IT:(Information Technology as a Service (ITaaS)):

- EMC is Offering Information Technology as a Service (ITaaS) reduces the energy consumption through resource sharing.

- ***EMC IT*** provides its business process units with IaaS, PaaS, and SaaS which is shown in below figure.



1. **IaaS**: under IaaS EMC offers the infrastructure components such as network, storage, computing, and operating systems individually or as integrated services.

2. **PaaS**: EMC IT offers application platforms (application development, Enterprise Content Management as a Service, Information Cycle Management as a Service and database platforms (Oracle Database as a Service, SQL Server as a Service, Greenplum as a Service.

3. **SaaS:** EMC IT brought together several existing business solutions under the unified architecture named as **Business Intelligence as a Service**. It also offers Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM) as a Service.

4. **User Interface as a Service (UIaaS)** provisions user and interface experience, rather than provisioning the actual device used.

11.2.2 Captiva Cloud Toolkit:

- EMC offers a tool called ***Captiva Cloud Toolkit***.

- EMC Captiva Cloud Toolkit is a Software Development Kit (SDK) comprised of modules that help web application developers to quickly add ***scanning and imaging functionality*** directly to their web-based business applications.

- **Using Captiva Cloud Toolkit, developers can quickly create a scan-enabled web-based business application in as early as 1 week.** It is ideal for document capture vendors.

- Enables developers to rapidly add scanning functionality to web-based applications through industry standards.

Note: There are few modules which are most commonly used in many of the applications. A few of these modules are as follows:

1. **Scan:** Scanning is *importing activity of documents* into Captiva from a scanner. Scanning is the entry point to Captiva where one can import any kind of document like pdf, tiff, and jpg.

2. **MDW:** *Multi Directory Watch* is another entry point to Captiva. MDW can be pointed to any folder/repository from where Captiva could import documents directly.

3. **IE:** Image enhancement is a kind of filter or repairing tool for images that are not clear. It enhances the image quality, so it could be processed easily through Captiva.

4. **Index:** Indexing is a data capturing activity in Captiva through which one can capture key data from various fields. For example, if bank form is being processed, the A/C no.

5. **Export:** Export is the exit point of Captiva where images/data are sent to various repositories like file, net, document, or data.

6. **Multi:** Multi is the last process in Captiva to delete batches that have gone through all modules and exported value successfully.

11.3 Google

- Google is one among the leading cloud providers that offer secure storage of user's data.
- It provides google cloud platform (**GCP)**, **compute engine**, **app engine, cloud print, cloud connect**, and many more features s that are scalable, reliable, as well as secure.
- Software infrastructures such as **MapReduce**, **BigTable**, and **Dremel** are the innovations for industrial development.
- Google offers many of these services for free or at a minimum cost making it user friendly.

11.3.1 Google Cloud Platform (GCP):

- **Google Cloud Platform** (**GCP**), offered by Google, is a suite of cloud computing services that runs on the google datacentres, for its end-user such as Google Search, Gmail, Google Drive, and YouTube.
- Google Cloud Platform enables developers to build, test, and deploy applications on Google's highly scalable and reliable infrastructure.
- The cloud platform offers a fully managed platform as well as flexible virtual machines allowing the user to choose as per the requirements.
- Google also provides easy integration of user's application within the cloud platform.
- Applications hosted on the cloud platform can automatically scale up to handle the most demanding workloads and scale down when traffic subsides.
- **GCP** includes **virtual machines, block storage, NoSQL datastore, and big data analytics**.
-

11.3.2 Cloud Storage:

Google Cloud Storage is a RESTful online file storage web service(**api**) for storing and accessing one's data on Google's infrastructure.

Google Cloud Storage is safe and secure. Data are protected through redundant storage at multiple physical locations.

The following are the few tools for Google Cloud Storage:

- ✓ ***Google Developers Console*** is a web application where one can perform simple storage management tasks on the Google Cloud Storage system.

- ✓ ***gsutil*** is a Python application that lets the user access Google Cloud Storage from the command line.

11.3.3 Google Cloud Connect:

- ✓ Google Cloud Connect is a feature provided by Google Cloud by integrating cloud and the application programming interface (API) for Microsoft Office.

- ✓ After installing a plug-in for the Microsoft Office suite of programs, one can save files to the cloud. The cloud copy of the file becomes the master document that everyone uses.

- ✓ Google Cloud Connect assigns each file a unique URL that can be shared to let others view the document.

- ✓ If changes are made to the document, those changes will show up for everyone else viewing it.

- ✓ When multiple people make changes to the same section of a document, Cloud Connect give's chance to the user to choose which set of changes to keep.

- ✓ When the user uploads a document to Google Cloud Connect, the service inserts some metadata into the file.

11.3.4 Google Cloud Print:

- ✓ Google Cloud Print is a service that extends the printer's function to any device that can connect to the Internet.

- ✓ To use Google Cloud Print, the user needs to have a free Google profile, an app, a program, or a website that incorporates the Google Cloud Print feature.

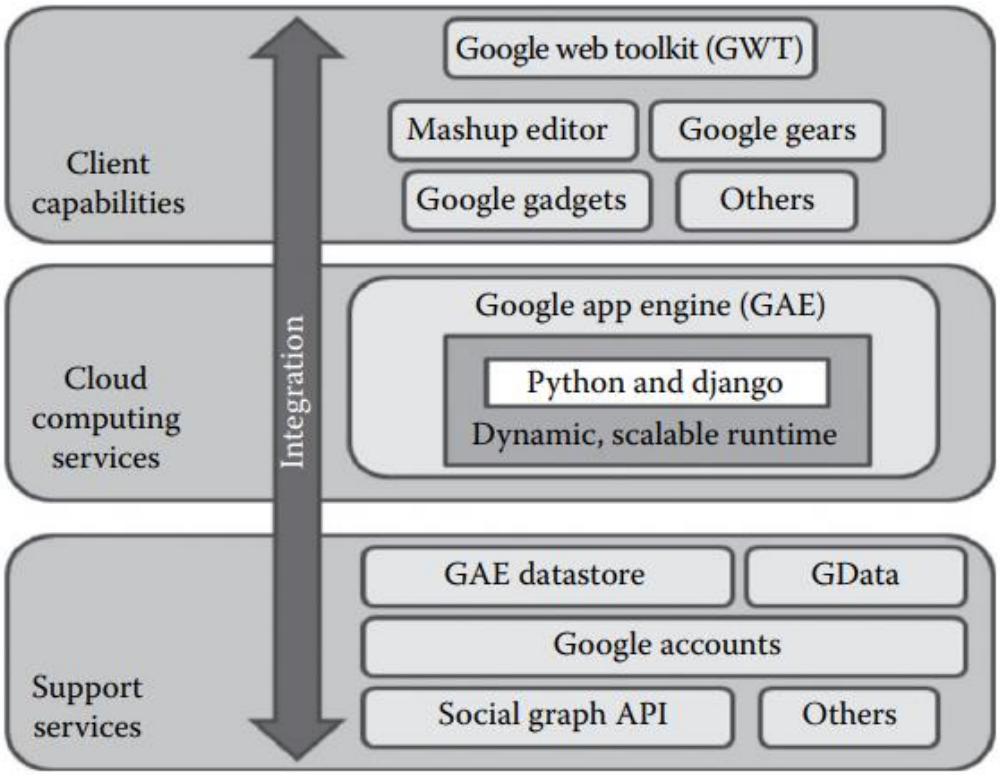
- ✓ When Google Cloud Print is used through an app or website, the print request goes through the Google servers. Google routes the request to the appropriate printer associated with the user's Google account.

11.3.5 Google App Engine

- ✓ Google App Engine lets the user run web applications on Google's infrastructure.

- ✓ App Engine applications are easy to build, easy to maintain, and easy to scale as traffic and data storage needs grow.

- ✓ With App Engine, there are no servers to maintain: Just upload the application, and it is ready to serve users.
- ✓ Below Figure shows the different modules in Google App Engine. Integration of cloud computing services with support services and client capabilities is shown in the diagram.



Google App Engine supports several programming languages. With App Engine's Java runtime environment, one can build one's app using standard Java technologies, including the JVM, the Java servlets, and the Java programming language—or any other language. App Engine also features a Python runtime environment, which includes a fast Python interpreter and the Python standard library. App Engine also features a PHP runtime, with native support for Google Cloud SQL and Google Cloud Storage that works just like using a local MySQL instance and doing local file writes.

GCP:

In the year 2008,Google announced a preview release of App Engine, a developer tool that allowed customers to run their web applications on Google infrastructure.

Major services of Google Cloud Platform include:

- Computing and hosting
- Storage and database
- Networking
- Big Data
- Machine learning
- IOT