Jaipur Engineering College & Research Centre, Jaipur

Notes

Cloud Computing

[6CS4-06]

Prepared By:
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VISION AND MISSION OF INSTITUTE

VISION

To become renowned centre of outcome based learning and work towards academic, professional, cultural and social enrichments of the lives of individual and communities"

MISSION

M1. Focus on evaluation of learning outcomes and motivate students to inculcate research aptitude by project based learning.

M2. Identify areas of focus and provide platform to gain knowledge and solutions based on informed perception of Indian, regional and global needs.

M3. Offer opportunities for interaction between academia and industry.

M4. Develop human potential to its fullest extent so that intellectually capable and imaginatively gifted leaders can emerge in a range of professions.

VISION AND MISSION OF DEPARTMENT

VISION

To become renowned Centre of excellence in computer science and engineering and make competent engineers & professionals with high ethical values prepared for lifelong learning.

MISSION

M1: To impart outcome based education for emerging technologies in the field of computer science and engineering.

M2: To provide opportunities for interaction between academia and industry.

M3: To provide platform for lifelong learning by accepting the change in technologies

M4: To develop aptitude of fulfilling social responsibilities.

COURSE OUTCOMES

CO1: Implement the cloud computing architecture i.e, the model, types of clouds, various service models and programming concepts.

CO2: Acquire knowledge about the recent trends in area of cloud computing like Hadoop, programming of Google app engine and virtualization technology and resource management.

CO3: Identify the various threats related to cloud and as well as disaster recovery related to same.

CO4: Analyze the cloud platforms in IT industry and various case studies on the industries providing cloud services.

Program Outcomes (PO)

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Educational Objectives (PEO)

1. To provide students with the fundamentals of Engineering Sciences with more emphasis in Computer Science & Engineering by way of analyzing and exploiting Engineering challenge

2. To train students with good scientific and engineering knowledge so as to comprehend, analyze, design, and create novel products and solutions for the real life problems.

3. To inculcate professional and ethical attitude, effective communication skills, teamwork skills, multidisciplinary approach, entrepreneurial thinking and an ability to relate engineering issues with social issues.

4. To provide students with an academic environment aware of excellence, leadership, written ethical codes and guidelines, and the self-motivated life-long learning needed for a successful professional career.

5. To prepare students to excel in Industry and Higher education by Educating Students along with High moral values and Knowledge.

MAPPING CO-PO

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	2	2	2	1	2	2	3
CO2	3	3	3	3	3	2	2	2	1	2	2	3
CO3	3	3	3	3	2	2	2	2	2	2	2	3
CO4	3	3	3	3	2	2	2	2	2	2	2	3

PSO

PSO1: Ability to interpret and analyze network specific and cyber security issues, automation in real word environment.

PSO2: Ability to Design and Develop Mobile and Web-based applications under realistic constraints.

SYLLABUS

UNIT 1: Introduction: Objective, scope and outcome of the course.

UNIT 2: Introduction: Objective, scope and outcome of the course. Introduction Cloud Computing: Nutshell of cloud computing, Enabling Technology, Historical development, Vision, feature Characteristics and components of Cloud Computing. Challenges, Risks and Approaches of Migration into Cloud. Ethical Issue in Cloud Computing, Evaluating the Cloud's Business Impact and economics, Future of the cloud. Networking Support for Cloud Computing. Ubiquitous Cloud and the Internet of Things.

UNIT 3: Cloud Computing Architecture: Cloud Reference Model, Layer and Types of Clouds, Services models, Data centre Design and interconnection Network, Architectural design of Compute and Storage Clouds. Cloud Programming and Software: Fractures of cloud programming, Parallel and distributed programming paradigms-Map Reduce, Hadoop, High level Language for Cloud. Programming of Google App engine.

UNIT 4: Virtualization Technology: Definition, Understanding and Benefits of Virtualization. Implementation Level of Virtualization, Virtualization Structure/Tools and Mechanisms, Hypervisor VMware, KVM, Xen. Virtualization: of CPU, Memory, I/O Devices, Virtual Cluster and Resources Management, Virtualization of Server, Desktop, Network, and Virtualization of data-centre.

UNIT 5: Securing the Cloud: Cloud Information security fundamentals, Cloud security services, Design principles, Policy Implementation, Cloud Computing Security Challenges, Cloud Computing Security Architecture . Legal issues in cloud Computing. Data Security in Cloud: Business Continuity and Disaster Recovery , Risk Mitigation , Understanding and Identification of Threats in Cloud, SLA-Service Level Agreements, Trust Management

UNIT 6: Cloud Platforms in Industry: Amazon web services , Google AppEngine, Microsoft Azure Design, Aneka: Cloud Application Platform -Integration of Private and Public Clouds Cloud applications: Protein structure prediction, Data Analysis, Satellite Image Processing, CRM

Unit 1: Introduction to Cloud Computing

Unit 1 -Introduction:

Introduction Cloud Computing: Nutshell of cloud computing, Enabling Technology, Historical development, Vision, feature Characteristics and components of Cloud Computing. Challenges, Risks and Approaches of Migration into Cloud. Ethical Issue in Cloud Computing, Evaluating the Cloud's Business Impact and economics, Future of the cloud. Networking Support for Cloud Computing. Ubiquitous Cloud and the Internet of Things

Introduction:

- Cloud Computing means "Storing of data online rather than on your home computer that means you are using cloud computing services".
- If you are an organization and you want to use an online invoicing service instead of updating the in-house one you have been using for many years that online invoicing service is a "cloud computing" service.
- Cloud computing: Cloud computing refers to the delivery of computing resources over the Internet. Instead of keeping data on your own hard drive or updating applications for your needs.
- You can also use a service over the internet at any location to store your information but doing this also give rise to certain type of privacy implications.
- In this chapter we have defined about the introductory part of the cloud computing. We discuss about the history, vision, characteristics, components & future of the cloud computing. As well also discussed about the approaches to follow for migration into cloud, Ethical issues, Networking support for the cloud computing.

Cloud Computing:

Many people within IT organizations view that cloud computing have changed their computing world because of the flexibility it gives them by providing services and applications to apply in it.Cloud computing is defined as:

Cloud computing is the computer technology that can attach together the processing power of many inter-networked computers while covering the structure that is behind it.

The term "**cloud**" refers to the hiding nature of this technology's framework: the system works for users but in real they have no idea about the inherent complexities that the system utilizes. They do not realize that there is a massive amount of data being pushed globally in real time to make these applications work for them and the scale of which is simply amazing.

The idea of connecting to the cloud is familiar among technologists today because it has become a popular buzzword among the technology media. The only thing users need to be concerned about is the terminal that they are using and whether it is connected to the internet or not so that they can have access to the tools that the cloud can provide.

Cloud Computing is unknown to many people as they don't know much about the information technology industry of today's. As industry now a days is done with a cloud computing environment or is moving towards that end.

A slow migration towards it has been going on from several years, mainly due to the infrastructure and support costs of the standalone hardware.

Fig 1.1: Cloud Computing Model

The following definition of cloud computing has been developed by the U.S. National Institute of Standards and Technology (NIST):

"Cloud computing is a model for enabling 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 or service provider interaction. This cloud model promotes availability and is composed of five essential characteristics, three service models, and four deployment models".

Cloud computing is a technological advancement that focuses on the way we design computing

systems, develop applications, and leverage existing services for building software. It is based on the concept of *dynamic provisioning*, which is applied not only to services but also to compute capability, storage, networking, and information technology (IT) infrastructure in general. Resources are made available through the Internet and offered on a *pay-per-use* basis from cloud computing vendors. Today, anyone with a credit card can subscribe to cloud services and deploy and configure servers for an application in hours, growing and shrinking the infrastructure serving its application according to the demand, and paying only for the time these resources have been used.

This chapter provides a brief overview of the cloud computing phenomenon by presenting its vision, discussing its core features, and tracking the technological developments that have made it possible. The chapter also introduces some key cloud computing technologies as well as some insights into development of cloud computing environments.

Cloud computing at a glance

In 1969, Leonard Kleinrock, one of the chief scientists of the original Advanced Research Projects Agency Network (ARPANET), which seeded the Internet, said:

As of now, computer networks are still in their infancy, but as they grow up and become sophisticated, we will probably see the spread of 'computer utilities' which, like present electric and telephone utilities, will service individual homes and offices across the country.

This vision of computing utilities based on a service-provisioning model anticipated the massive transformation of the entire computing industry in the 21st century, whereby computing services will be readily available on demand, just as other utility services such as water, electricity, telephone, and gas are available in today's society. Similarly, users (consumers) need to pay providers only when they access the computing services. In addition, consumers no longer need to invest heavily or encounter difficulties in building and maintaining complex IT infrastructure. In such a model, users access services based on their requirements without regard to where the services are hosted. This model has been referred to as *utility computing* or, recently (since 2007), as *cloud computing*. The latter term often denotes the infrastructure as a "cloud" from which businesses and users can access applications as services from anywhere in the world and on demand. Hence, cloud computing can be classified as a new paradigm for the dynamic provisioning of computing services supported by state-of-the-art data centers employing virtualization technologies for consolidation and effective utilization of resources.

Cloud computing allows renting infrastructure, runtime environments, and services on a pay-per-

use basis. This principle finds several practical applications and then gives different images of cloud computing to different people. Chief information and technology officers of large enterprises see opportunities for scaling their infrastructure on demand and sizing it according to their business needs. End users leveraging cloud computing services can access their documents and data anytime, anywhere, and from any device connected to the Internet. Many other points of view exist.[1] One of the most diffuse views of cloud computing can be summarized as follows:

*I don't care where my servers are, who manages them, where my documents are stored, or where my applications are hosted. I just want them always available and access them from any device connected through Internet. And I am willing to pay for this service for as a long as I need it.*The concept expressed above has strong similarities to the way we use other services, such as water and electricity. In other words, cloud computing turns IT services into *utilities*. Such a delivery model is made possible by the effective composition of several technologies, which have reached the appropriate maturity level. *Web 2.0* technologies play a central role in making cloud computing an attractive opportunity for building computing systems. They have transformed the Internet into a rich application and service delivery platform, mature enough to serve complex needs. *Service orientation* allows cloud computing to deliver its capabilities with familiar abstractions, while *virtualization* confers on cloud computing the necessary degree of customization, control, and flexibility for building production and enterprise systems.

Besides being an extremely flexible environment for building new systems and applications, cloud computing also provides an opportunity for integrating additional capacity or new features into existing systems. The use of dynamically provisioned IT resources constitutes a more attractive opportunity than buying additional infrastructure and software, the sizing of which can be difficult to estimate and the needs of which are limited in time. This is one of the most important advantages of cloud computing, which has made it a popular phenomenon. With the wide deployment of cloud computing systems, the foundation technologies and systems enabling them are becoming consolidated and standardized. This is a fundamental step in the realization of the long-term vision for cloud computing, which provides an open environment where computing, storage, and other services are traded as computing utilities.

Defining Cloud

Cloud computing has become a popular buzzword; it has been widely used to refer to different technologies, services, and concepts. It is often associated with virtualized infrastructure or

hardware on demand, utility computing, IT outsourcing, platform and software as a service, and many other things that now are the focus of the IT industry. Figure 1.2 depicts the plethora of different notions included in current definitions of cloud computing.

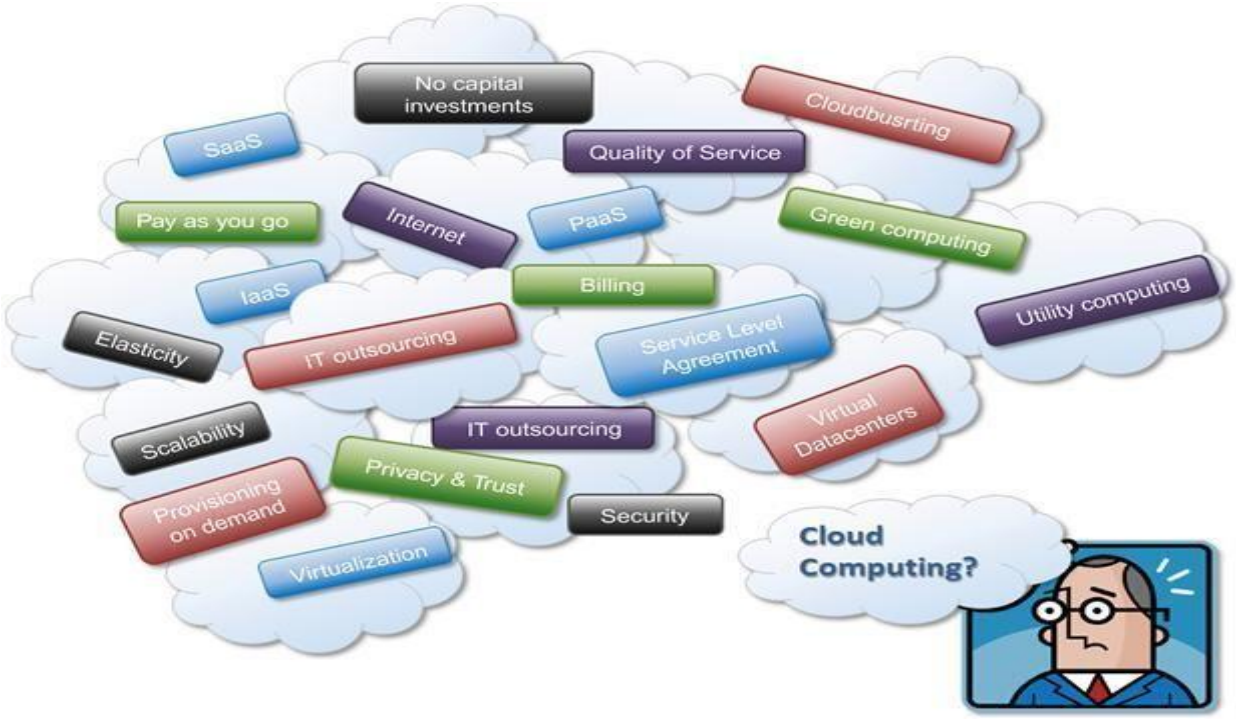


Fig 1.2 Cloud computing technologies, concepts, and ideas.

The term *cloud* has historically been used in the telecommunications industry as an abstraction of the network in system diagrams. It then became the symbol of the most popular computer network: the Internet. This meaning also applies to *cloud computing*, which refers to an Internet-centric way of computing. The Internet plays a fundamental role in cloud computing, since it represents either the medium or the platform through which many cloud computing services are delivered and made accessible. This aspect is also reflected in the definition given by Armbrust et al.:

Cloud computing refers to both the applications delivered as services over the Internet and the hardware and system software in the datacenters that provide those services.

This definition describes cloud computing as a phenomenon touching on the entire stack: from the underlying hardware to the high-level software services and applications. It introduces the concept of *everything as a service*, mostly referred as *XaaS*,[2] where the different components of a system—IT infrastructure, development platforms, databases, and so on—can be delivered,

measured, and consequently priced as a service. This new approach significantly influences not only the way that we build software but also the way we deploy it, make it accessible, and design our IT infrastructure, and even the way companies allocate the costs for IT needs. The approach fostered by cloud computing is global: it covers both the needs of a single user hosting documents in the cloud and the ones of a CIO deciding to deploy part of or the entire corporate IT infrastructure in the public cloud. This notion of multiple parties using a shared cloud computing environment is highlighted in a definition proposed by the U.S. National Institute of Standards and Technology (NIST):

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 or service provider interaction.

Another important aspect of cloud computing is its utility-oriented approach. More than any other trend in distributed computing, cloud computing focuses on delivering services with a given pricing model, in most cases a "pay-per-use" strategy. It makes it possible to access online storage, rent virtual hardware, or use development platforms and pay only for their effective usage, with no or minimal up-front costs. All these operations can be performed and billed simply by entering the credit card details and accessing the exposed services through a Web browser. This helps us provide a different and more practical characterization of cloud computing. According to Reese, we can define three criteria to discriminate whether a service is delivered in the cloud computing style:

• The service is accessible via a Web browser (nonproprietary) or a Web services application programming interface (API).

• Zero capital expenditure is necessary to get started.

• You pay only for what you use as you use it.

Even though many cloud computing services are freely available for single users, enterprise-class services are delivered according a specific pricing scheme. In this case users subscribe to the service and establish with the service provider a service-level agreement (SLA) defining the quality-of-service parameters under which the service is delivered. The utility-oriented nature of cloud computing is clearly expressed by Buyya et al. [30]:

A cloud is a type of parallel and distributed system consisting of a collection of interconnected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources based on service-level agreements established through negotiation between the service provider and consumers.

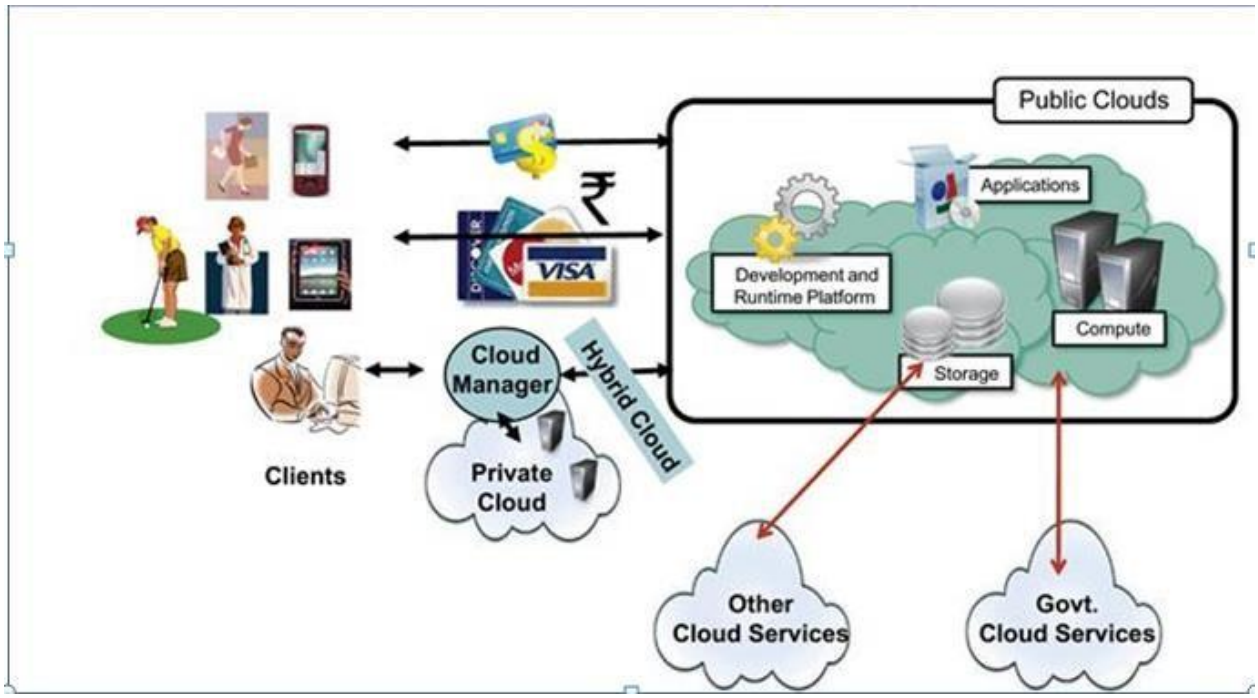


Fig 1.3 A bird's-eye view of cloud computing.

Nutshell of Cloud Computing:

When we are consuming some product in the home or organization, we care neither how that product is produced nor how it comes in market. This is possible because we think that production process of that product is virtualized, whether it is available in market from a different organizations working together on the grid of the machines. When extended to information technologies, this concept means delivering useful functions while hiding their internal process. Computing it to be considered fully virtualized must allow computers to be built from distributed components such as processing, storage, data, and software resources.

Technologies such as cluster, grid, parallel and cloud computing are all aimed at allowing access to large amounts of computing power in a fully virtualized manner by aggregating resources and offering a single system view.

Cloud computing has been defined as the on-demand computing services which was initially offered by the cloud service providers such as IBM, Amazon, Google, and Microsoft. It provides a model on which a computing infrastructure which is known as "cloud" from which businesses and individuals access applications from anywhere in the world on demand by paying charges as their uses basis. The main principle behind this model is offering software, Platform and Infrastructure "as a service."

According to Dr. Rajkumar Buyya of CLOUDS Laboratory, University of Melbourne, Australia Cloud Computing : "Cloud is a parallel and distributed computing system consisting of a collection of inter-connected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources based on service-level agreements (SLA) established through negotiation between the service provider and consumers."

Enabling Technology:

Key technologies that enabled cloud computing are virtualization, Web service and service-oriented architecture, service flows and workflows, and Web 2.0 and mash up. The brief discussion of all is given below:

- **Virtualization**

  The advantage of cloud computing is the ability to virtualize and sharing resources among different applications with the objective for better server utilization. In non-cloud computing three independent platforms (SAAS, PAAS & IAAS) exist for three different applications running on its own server. In the cloud servers can be shared or virtualized for operating systems and applications resulting in fewer servers.

- **Web Service and Service Oriented Architecture**

  Web Services and Service Oriented Architecture (SOA) represent the base technologies for cloud computing. Cloud services are typically designed as Web services, which follow industry standards including WSDL, SOAP, and UDDI. A Service Oriented Architecture organizes and manages Web services inside clouds. A SOA also includes a set of cloud services, which are available on various distributed platforms.

- **Service Flow and Workflows**

  The concept of service flow and workflow refers to an integrated view of service based activities provided in clouds. Workflows have become one of the important areas of research in the field of database and information systems.

- **Web 2.0 and Mashup**

  Web 2.0 is a new concept that refers to the use of Web technology and Web design to enhance creativity, information sharing, and association among users. On the other hand, Mashup is a web application that combines data from more than one source into a single integrated storage tool. Both technologies are very beneficial for cloud computing. The components in this architecture are dynamic in nature. The components closer to the user are smaller in nature and more reusable.

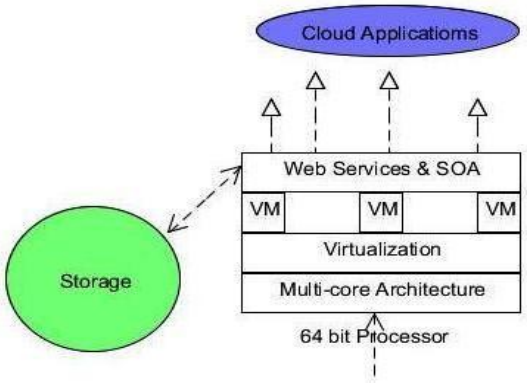


Fig 1.4: Enabling Technologies

History of Cloud Computing:

- The term cloud was used to represent the Internet early in the year 1994. In which servers were connected externally to the cloud.
- A reference to cloud computing in its modern sense was found in 1996. The popularization of the term can be traced to 2006 when Amazon.com introduced the Elastic Compute Cloud

The 1950s

- The first concept of cloud computing was introduced in 1950s.
- In 1950s, large-scale mainframe computers became available in academia and corporations accessible via thin clients/terminal computers often referred to as "static terminals" because they were used for communications but had no internal processing capacities.
- To make more efficient use of costly mainframes a practice evolved that allowed multiple users to share both the physical access to the computer from multiple terminals as well as the

CPU time which eliminated periods of silence on the mainframe. The practice of sharing CPU time on a mainframe became known in the industry as time-sharing.

- During the mid-70s, time-sharing was popularly known as RJE (Remote Job Entry) and this classification was mostly associated with large vendors such as IBM.

The 1990s

- In the 1990s telecommunications companies began offering virtual private network (VPN) services with comparable quality of service but at a lower cost.
- By switching traffic as they saw fit to balance server use they could use overall network bandwidth more effectively.
- They began to use the cloud symbol to denote the separation point between the provider's responsibilities and user's responsibilities.
- Cloud computing extends this boundary to cover all servers as well as the network infrastructure.

Since year 2000

- In early 2008 Eucalyptus became the first open-source, AWS API-compatible platform for deploying private clouds.
- In early 2008 OpenNebula introduced RESERVOIR European Commission-funded project by hosting Cloud concept in it and became the first open-source software for deploying private and hybrid clouds for the federation.
- By mid-2008 Gartner shape the relationship among consumers of IT services those who use IT services and those who sell them and observed that organizations are switching from company owned hardware and software assets to per-use service-based models so that the projected shift to computing will result in dramatic growth in IT products in some areas and significant reductions in other areas.
- In July 2010 Rackspace Hosting and NASA jointly launched an open-source cloud-software initiative known as OpenStack. The OpenStack project intended to help organizations offer cloud-computing services running on standard hardware.
- On 1st March 2011 IBM announced the IBM SmartCloud framework to support Smarter Planet.
- On 7th June 2012 Oracle announced the Oracle Cloud. While aspects of the Oracle Cloud are

still in development, this cloud offering is posed to be the first to provide users with access to an integrated set of IT solutions, including the Applications (SaaS), Platform (PaaS), and Infrastructure (IaaS) layers.

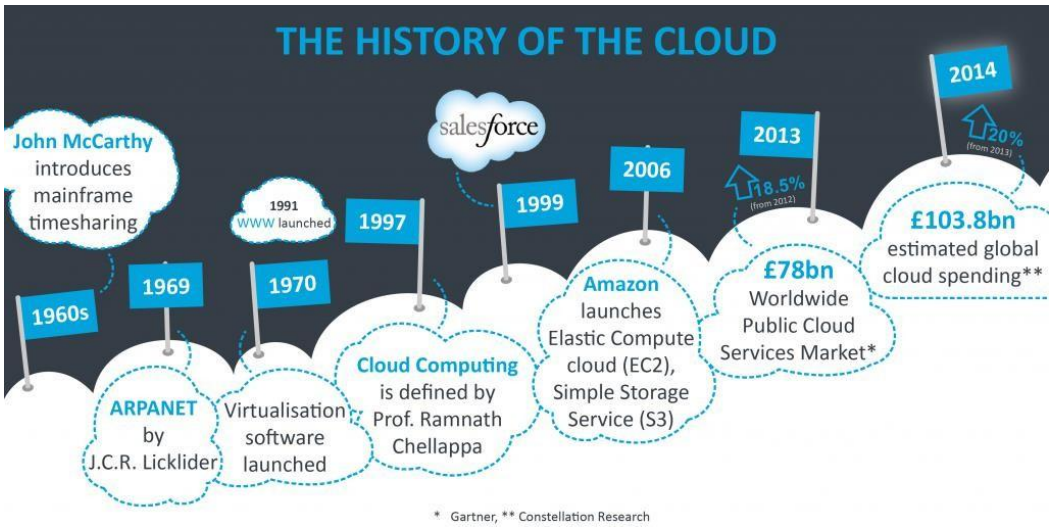


Fig 1.5: History of cloud Computing

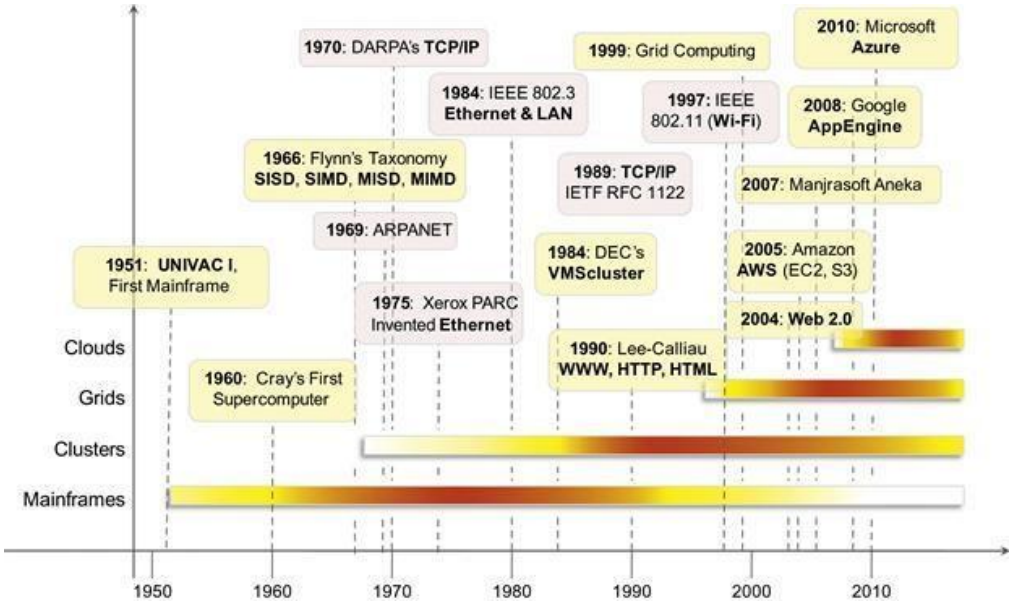


Fig 1.6: The evolution of distributed computing technologies, 1950s–2010s.

The Vision of Cloud Computing

Cloud computing allows anyone with a credit card to provision virtual hardware, runtime environments, and services. These are used for as long as needed, with no up-front commitments required. The entire stack of a computing system is transformed into a collection of utilities, which can be provisioned and composed together to deploy systems in hours rather than days and with virtually no maintenance costs. This opportunity, initially met with skepticism, has now become a practice across several application domains and business sectors (see Fig 1.7). The demand has fast-tracked technical development and enriched the set of services offered, which have also become more sophisticated and cheaper.

Fig 1.7: Cloud computing vision.

Despite its evolution, the use of cloud computing is often limited to a single service at a time or, more commonly, a set of related services offered by the same vendor. Previously, the lack of effective standardization efforts made it difficult to move hosted services from one vendor to another. The long-term vision of cloud computing is that IT services are traded as utilities in an open market, without technological and legal barriers. In this cloud marketplace, cloud service providers and consumers, trading cloud services as utilities, play a central role.

Many of the technological elements contributing to this vision already exist. Different stakeholders leverage clouds for a variety of services. The need for ubiquitous storage and

compute power on demand is the most common reason to consider cloud computing. A scalable runtime for applications is an attractive option for application and system developers that do not have infrastructure or cannot afford any further expansion of existing infrastructure. The capability for Web-based access to documents and their processing using sophisticated applications is one of the appealing factors for end users.

In all these cases, the discovery of such services is mostly done by human intervention: a person (or a team of people) looks over the Internet to identify offerings that meet his or her needs. We imagine that in the near future it will be possible to find the solution that matches our needs by simply entering our request in a global digital market that trades cloud computing services. The existence of such a market will enable the automation of the discovery process and its integration into existing software systems, thus allowing users to transparently leverage cloud resources in their applications and systems. The existence of a global platform for trading cloud services will also help service providers become more visible and therefore potentially increase their revenue.

A global cloud market also reduces the barriers between service consumers and providers: it is no longer necessary to belong to only one of these two categories. For example, a cloud provider might become a consumer of a competitor service in order to fulfill its own promises to customers.

These are all possibilities that are introduced with the establishment of a global cloud computing marketplace and by defining effective standards for the unified representation of cloud services as well as the interaction among different cloud technologies. A considerable shift toward cloud computing has already been registered, and its rapid adoption facilitates its consolidation. Moreover, by concentrating the core capabilities of cloud computing into large datacenters, it is possible to reduce or remove the need for any technical infrastructure on the service consumer side. This approach provides opportunities for optimizing datacenter facilities and fully utilizing their capabilities to serve multiple users. This consolidation model will reduce the waste of energy and carbon emissions, thus contributing to a greener IT on one end and increasing revenue on the other end.

In other words the vision of cloud computing can be understood by the following-

- Cloud computing allows to provision virtual hardware, runtime environments, and services.
- The entire stack of a computing system is transformed into a collection of utilities, which can be provisioned and composed together to deploy systems in hours rather than days and

virtually with no maintenance costs.

- Despite its evolution, the use of cloud computing is often limited to a single service at a time or, more commonly a set of related services offered by the same vendor.
- Previously the lack of effective standardization efforts made it difficult to move hosted services from one vendor to another.
- The long-term vision of cloud computing is that IT services are traded as utilities in an open market, without technological and legal barriers. In this cloud marketplace, cloud service providers and consumers, trading cloud services as utilities, play a vital role.
- The need for ubiquitous storage and compute power on demand is the most common reason to consider cloud computing. A scalable runtime for applications is an attractive option for application and system developers that do not have infrastructure or cannot afford any further expansion of existing infrastructure.
- The discovery of such services is done by human intervention: a person or a team of people who looks over the internet to identify offerings that meet his or her needs.
- We imagine that in the near future it will be possible to find the solution that matches our needs by simply entering our request in a global digital market that trades cloud computing services.
- The existence of such market will enable the automation of the discovery process and its integration into existing software systems, thus allowing users to transparently leverage cloud resources in their applications and systems.
- The existence of a global platform for trading cloud services will also help service providers become more visible and therefore potentially increase their revenue.
- A global cloud market also reduces the barriers between service consumers and providers.
- By concentrating the core capabilities of cloud computing into large datacenters, it is possible to reduce or remove the need for any technical infrastructure on the service consumer side.
- This approach provides opportunities for optimizing datacenter facilities and fully utilizing their capabilities to serve multiple users.
- This consolidation model will reduce the waste of energy and carbon emissions, thus contributing to a greener IT on one end and increasing revenue on the other end.

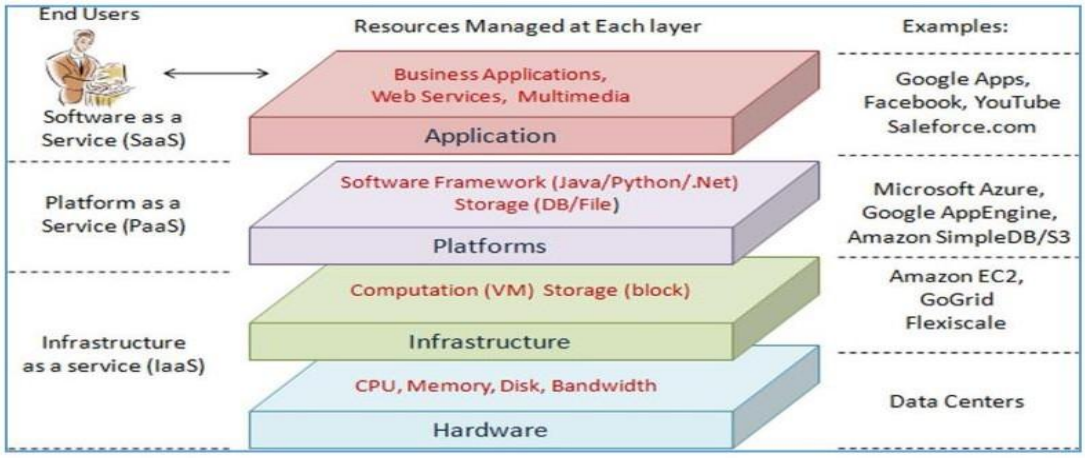


Figure 1: A layered model of Cloud Computing

Features:

Cloud computing brings a number of new features compared to other computing paradigms. There are briefly described here:

- **Scalability and on-demand services**

  Cloud computing provides resources and services for users on demand. The resources are scalable over several data centers.

- **User-centric interface**

  Cloud interfaces are location independent and can be accesses by well-established interfaces such as Web services and Internet browsers.

- **Guaranteed Quality of Service (QoS)**

  Cloud computing can guarantee QoS for users in terms of hardware/CPU performance, bandwidth, and memory capacity.

- **Autonomous system**

  The cloud computing systems are autonomous systems managed transparently by users. However software and data inside clouds can be automatically reconfigured and consolidated to a simple platform depending on user's needs.

- **Pricing**

  Cloud computing does not require up-from investment. No capital expenditure is required. Users pay for services and capacity as they need them.

Characteristics of Cloud Computing:

1. Resources Pooling

It means that the **Cloud provider** pulled the computing resources to provide services to multiple customers with the help of a multi-tenant model. There are different physical and virtual resources assigned and reassigned which depends on the demand of the customer. The customer generally has no control or information over the location of the provided resources but is able to specify location at a higher level of abstraction

2. On-Demand Self-Service

It is one of the important and valuable features of Cloud Computing as the user can continuously monitor the server uptime, capabilities, and allotted network storage. With this feature, the user can also monitor the computing capabilities.

3. Easy Maintenance

The servers are easily maintained and the downtime is very low and even in some cases, there is no downtime. Cloud Computing comes up with an update every time by gradually making it better. The updates are more compatible with the devices and perform faster than older ones along with the bugs which are fixed.

4. Large Network Access

The user can access the data of the cloud or upload the data to the cloud from anywhere just with the help of a device and an internet connection. These capabilities are available all over the network and accessed with the help of internet.

5. Availability

The capabilities of the Cloud can be modified as per the use and can be extended a lot. It analyzes the storage usage and allows the user to buy extra **Cloud storage** if needed for a very small amount.

6. Automatic System

Cloud computing automatically analyzes the data needed and supports a metering capability at some level of services. We can monitor, control, and report the usage. It will provide transparency for the host as well as the customer.

7. Economical

It is the one-time investment as the company (host) has to buy the storage and a small part of it can be provided to the many companies which save the host from monthly or yearly costs. Only the amount which is spent is on the basic maintenance and a few more expenses which are very less.

8. Security

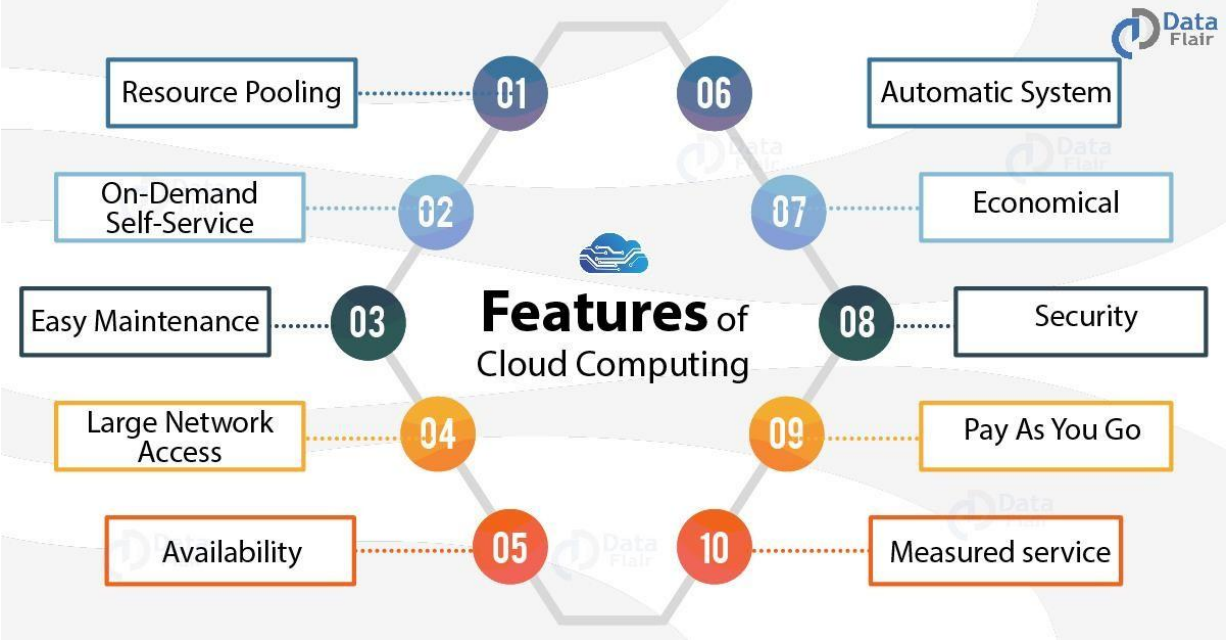
Cloud Security, is one of the best features of cloud computing. It creates a snapshot of the data stored so that the data may not get lost even if one of the servers gets damaged. The data is stored within the storage devices, which cannot be hacked and utilized by any other person. The storage service is quick and reliable.

9. Pay as you go

In cloud computing, the user has to pay only for the service or the space they have utilized. Thereis no hidden or extra charge which is to be paid. The service is economical and most of the time some space is allotted for free.

10. Measured Service

Cloud Computing resources used to monitor and the company uses it for recording. This resource utilization is analyzed by supporting charge-per-use capabilities. This means that the resource usages which can be either virtual server instances that are running in the cloud are getting monitored measured and reported by the service provider. The model pay as you go is variable based on actual consumption of the manufacturing organization.



Components of Cloud Computing:

Successful implementation of cloud computing requires proper implementation of certain components. Without any of these components cloud computing will not be possible. The Components of the Cloud Computing are as such:

- **The Clients**
  - The hardware components, the application and anything else developed for cloud computing will be used in the client.
  - The client could come in two types:
    - The hardware component
    - The combination of software and hardware components.

- **The Services**
  - One of the main reasons cloud computing become popular is due to the adoption of businesses as the easier way to implement.
  - Cloud computing is all about processes and the services launched through cloud computing always has to deal with processes with an expected output.
  - The optimization on services is based on two things: the proper development of the

application and the end user. Sometimes the service could be used by the user wherein their experience is greatly affected by their gadget.

- **The Applications**
  - This service is often all the same as the application.
  - Although the application is entirely different because it is the application that decide the service is acknowledged.
  - This is where software developers have to focus in terms of ensuring the application will work as expected.
  - Optimization of the application is based the actual coding of developers. Through extensive testing on load handling, security and functionality, the application could work as expected.

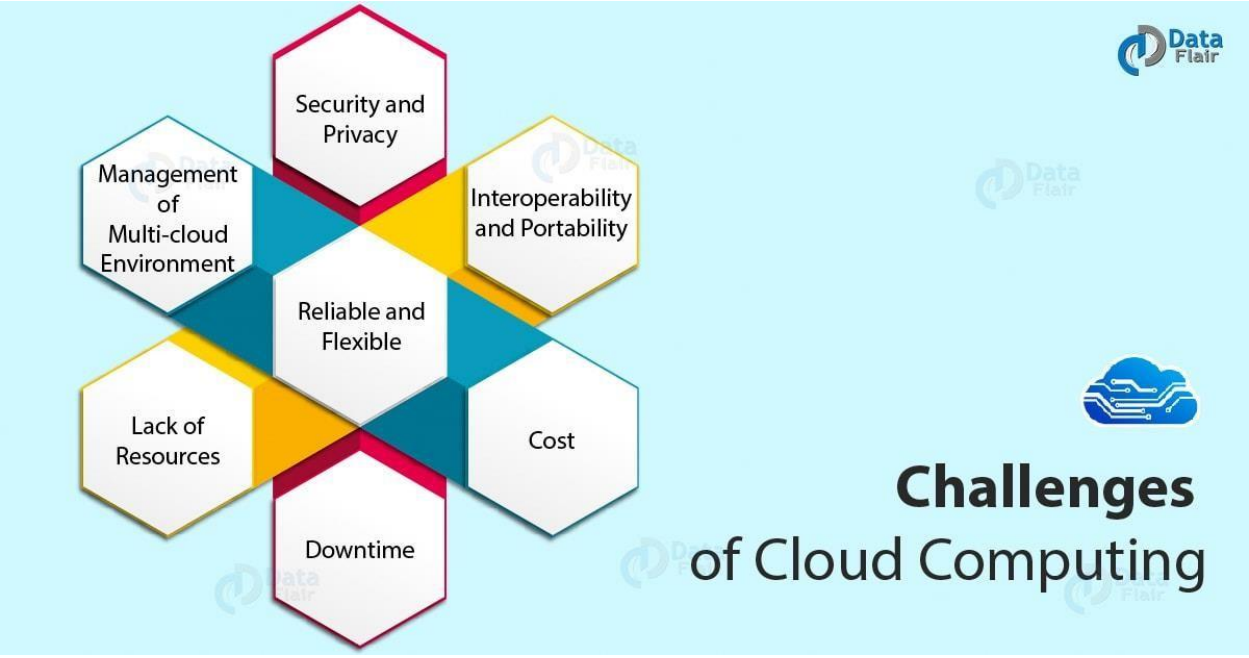
- **The Platform – SAAS, PAAS or IAAS**
  - In regular websites or applications that don't deal with cloud computing, the application is directly connected to the server.
  - In cloud computing the application is still launched to another application called the platform. The platform usually coded by using the programming language such as Ajax, JAVA, Python or Ruby on Rails.
  - At this point those who opted to seek cloud computing providers will have to follow the set that could be run in the platform
- **The Storage**
  - Everything that the application knows and the functions that could be provided by service are possible through storage.
  - The storage holds applicable data and information on function on how they will be implemented.
  - Optimization on storage is based on how the storage facility protected from different attacks and availability of back-up.

- Computing is always about consistency and availability of service which will naturally require the storage to be available all the time.

- **The Infrastructure**
  - Every function, service and the ability of storage to provide the needed data is only possible through optimized infrastructure.
  - This could be considered as the platform behind the storage as the infrastructure helps the storage deal with load problems.
  - The infrastructure is a platform wherein it weights the ability of the storage against the number of requests. The infrastructure has the ability to make some changes by load balancing and even management.

Challenges:

Cloud computing provides a number of benefits and advantages over the previous computing paradigms and many organizations are adopting it. However, there are still a number of challenges which are briefly described below.



The Cloud Computing is getting implemented in almost all companies as the companies are in need to store the data. A tremendous amount of data generate and store by the companies. So there are lots of security issues faced by them. To improve the cloud computing management the companies can include establishment to simplify and automate the process.

i. Security and Privacy of Cloud

The data store in the cloud must secure and provide full confidentiality. The customers rely on the cloud provider so much. This means that the cloud provider should take necessary security measures to secure the data of the customers. Securities are also the responsibility of the customer as they should provide a strong password, should not share the password with anyone, and regularly change the password when we did. If the data is outside the firewall there may be some issues which can eliminate by the cloud provider. Hacking and malware are also one of the major problems as it can affect multiple customers. Hacking can lead to data loss; disrupt the encrypted file system and many other problems.

ii. Interoperability and Portability

The customer must be provided with the services of migration in and out of the cloud. There should be no bond period as it can create a hindrance for the customers. The cloud should have the ability to provide facilities on the premises. One of the Cloud challenges is remote access which can eliminate by the cloud provider so that the customer can access the cloud from anywhere security.

iii. Reliable and Flexible

Reliability and flexibility are also one of the challenges of cloud customers and it can eliminate in a way that the data provided to the cloud should not leak and the host should provide the reliability to the customers. To eliminate this challenge the services provided by the third party should be monitored and supervision should be done on performance, robustness and business dependency.

iv. Cost

Cloud computing is affordable but modifying the cloud to the customer's demand can be sometimes expensive. Moreover, it can cause hindrance to the small-scale organization is modifying the cloud as per their demand can sometimes cost more. In addition, transferring of data from the Cloud to the premises can also sometimes be costly.

v. Downtime

Downtime is the common challenges of cloud computing as no cloud provider guarantees a

platform that is free from downtime. Internet connection also plays an important role as if a company has an untrustworthy internet connection then there may be a problem as they can face downtime.

vi. Lack of resources

Lack of resources and expertise is also one of the major challenges faced by the cloud industry and many companies are hoping to overcome this challenge by hiring more workers which are more experienced. These workers will not only help to eliminate the challenges of the companies but also they will train existing staff to benefit the company. Today many IT workers are working to boost the cloud computing expertise and CEO of the company is finding it difficult as the workers are not much skilled. It believes that workers with knowledge of the latest development and the technologies related to it will become more valuable in business.

vii. Management of Multi-Cloud Environment

Companies nowadays do not use a single cloud instead they are using multiple clouds. On an average company are using 4.8 different public and private clouds due to which their management is hindered. When a company uses multi-cloud there are so many complexities faced by the IT team. This Cloud challenge can eliminate by training employees, utilization of proper tools, and doing research.

Risks and Approaches of Migration into Cloud:

Migration into the cloud is implemented in phases or in stages. A structured and process-oriented approach to migration into a cloud has several advantages of capturing within itself the best practices to many migration projects. Migration into cloud is a difficult and unclear subject of not much interest for academics. The industry practitioners have not done so much effort across the industry to combine a top revenue earner and a long standing customer pain.

The Seven-Step Model of Migration into the Cloud for understanding and leveraging the cloud computing service offerings in the enterprise context. The seven steps in the model of migration into the cloud are:

- Conduct Cloud Migration Valuations
- Separate the Dependencies
- Map the Messaging & Environment
- Re-architect & Implement the lost functionalities

- Control Cloud functionalities & features
- Test the Migration
- Repeat and Optimize

The process of the seven-step migration into the cloud is given in the figure below:

Fig 1.3: Seven Step Model

In the cloud migration firstly the assessment has to be done for the cost in the cloud migration, functionality & database needed and after that the isolation of the environment and dependencies has to be checked out for the cloud after that the mapping has to be done between all the libraries as per the cloud environment. Now the new analysis performed on the new design for getting the new use-cases. In the augment step of migration process the security & bandwidth requirement used to be calculated. Now test the whole new cloud developed by the organization as per there need for checking whether it is working proper or not? In the optimize step the proper working of the cloud has been maintained by using the concept of ROI.

The workings of all the seven steps are as such:

Assess	Isolate	Map	Re-Architect	Augment	Test	Optimize
Cloudonomics	Runtime Environment	Messages mapping	Approximate lost functionality using cloud runtime support API	Exploit additional cloud features	Expand Test Cases and Test Automation	Optimize
Migration Costs	Licensing	Mapping Environment	New Use cases	Seek Low cost extension	Run Proof of concepts	Significantly satisfy cloudonomics of migration
Recurring Costs	Libraries Dependency	Mapping Libraries & runtime approximation	Analysis	Auto-scaling	Test Migration strategy	Optimize compliance with standards and governance
Database Data segmentation	Application Dependency		Design	Storage	Test new test cases due to cost augmentation	Deliver best migration ROI
Database Migration	Latencies Bottlenecks			Bandwidth	Test for Production Loads	Develop Roadmap for leveraging new cloud

						features
Functionality Migration	Performance Bottlenecks			Security		
NFR Support	Architectural Dependencies					

This is just a subset of our Seven-step Migration Model and is very specific and proprietary to cloud offering by many organizations in the market.

Risks:

The biggest risk to any cloud migration project is how effectively the migration risks are identified and moderated. In the Seven-Step Model of Migration into the Cloud the process step of testing and validating includes efforts to identify the key migration risks.

Migration risks in migrating into the cloud fall under two broad categories:

- The general migration risks
- The security-related migration risks

The several risks are there in the migration into the cloud including:

- Performance, monitoring and tuning essentially by identifying all possible production level deviants
- The business continuity and disaster recovery in the world of cloud computing service
- The compliance with standards and governance issues
- The IP and licensing issues
- The quality of service (QoS) parameters as well as the corresponding SLAs committed to the ownership, transfer, and storage of data in the application
- The portability and interoperability issues.

On the security basis cloud migration risks are visible at various levels of the enterprise application as applicable on the cloud in addition to issues of trust and issues of privacy. There are several legal compliances that a migration strategy and implementation has to fulfill including obtaining the right execution logs as well as retaining the rights to all audit tracks at a detailed level which currently may not be fully available.

Ethical Issues in Cloud Computing:

Cloud computing has mainly the following Ethical issues on the basis of market trends:

- The control is give up to third-party services like unauthorized access, data corruption, infrastructure failure, and service unavailability.
- The data is stored on multiple sites administered by several organizations.
- Multiple services interoperate across the network.

The complex structure of cloud services make it difficult to determine who is responsible in case something undesirable happens and therefore no one can be held responsible for undesirable. This is called problem of many hands.

Identity fraud and theft are made possible by the unauthorized access to personal data in circulation. New forms of distribution using social networks also position a danger to cloud computing.

Privacy is affected by cultural differences as some cultures favor privacy and other cultures emphasize community. So this leads to an uncertainty. Many undesirable wonders in cloud computing will only appear.

The need for rules and regulations for the control of cloud computing is noticeable. Explicit attention to ethics must be paid by governmental organizations providing research funding for cloud computing.

Private companies are less constrained by ethics lapse and governance arrangements are more helpful for profit generation.

Accountability is a necessary element of cloud computing. Suitable information about how data is handled within the cloud and about allocation of responsibility are key elements for enforcing ethics rules in cloud computing. Recorded evidence allows us to assign responsibility but there can be tension between privacy and accountability and it is important to find what is being recorded and who has access to the records.

Evaluating the Cloud's Business Impact and Economics:

The Cloud Computing has benefited all sectors of the Business present in the market. The impact will be fairly categorical in certain sectors of the Business present mainly in the society. The Cloud is most advantageous to the Government. Now the some main sectors of the business which are benefited by the cloud computing are as such:

- Government
- Healthcare
- Education
- Small and Medium Enterprises

Government

- Governments can use the Cloud to bridge the communication gap with those citizens that reside in remote parts of the country.
- The Cloud could also be used to increase inter-operability between various government agencies, reduce redundancy, track & monitor the effectiveness of government schemes.
- Computing resources shared between Central and State governments would result in reducing costs by leveraging existing infrastructure.
- Transparency in Government can be achieved at a faster pace through the adoption of Cloud.

Healthcare

- The Cloud is a paradigm shift in the use of Healthcare Information over the internet which enables stakeholders to focus more on their core competencies.
- In the case of the Healthcare industry it would provide for the seamless management and access to Electronic Health Records (EHRs) of patients. This would facilitate the provisioning of healthcare products and services to patients located in remote areas and those that have limited access to quality medical services.
- The use of the Cloud could possibly result in consolidation of IT assets for Healthcare service providers. The creation of an integrated Healthcare ecosystem would help the providers of healthcare services make available the best of services to patients.

Education

- The Cloud would prove to be the catalysts that will enable the sector overcome barriers such as the challenges of high cost, limited reach and quality.

- The Education sector which has already embraced the use of the Cloud for email services could now consider moving critical applications such as Virtual Learning Environment (VLE), Learning Management Systems (LMS) and Student Information System (SIS) into the Cloud.
- The Cloud could make the Education system more collaborative and innovative with unique resources readily available to all students. This could change the way in which education is delivered and financed.

Small and Medium Enterprises (SMEs)

- SMEs have been largely unable to take advantage of IT systems and solutions due to the high upfront costs of sourcing and deploying the same. Consequently they are known to face issues in the management of their supply chains, financials, inventories, customer relationships, and human resources.
- The Cloud reduces the cost burden of using IT for SMEs especially because Cloud services provided access to on a usage based pricing model. Other benefits like scalability, flexibility and On-Demand service are highly attractive proposition to this user group.

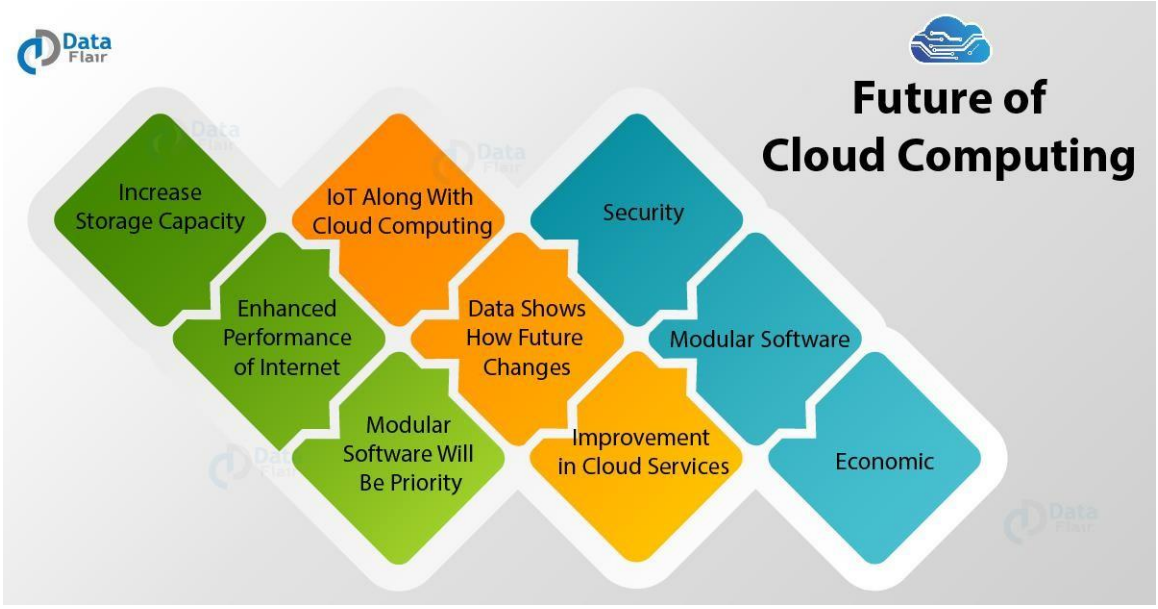
Future of the Cloud:

The cloud computing is growing in the market as more startups continue to go public. The top five cloud predictions for the computing in the coming years are as such:

- **More application availability on the cloud**
  - With most new software being built for cloud from the outset and it is predicted that by 2018 around 48 million will be available on the cloud (e.g. Global Technology Outlook, Cloud 2014 & etc.).
  - About 56 percent of enterprises consider cloud to be a strategic differentiator, and approximately 58 percent of enterprises spend more than 10 percent of their annual budgets on cloud services.
- **Increased growth in the market for cloud**
  - The cloud is accelerating globally. The enterprises were increasingly relying on cloud to develop market and sell products manage supply chains and more.
  - The worldwide market of the software as a service (SaaS) would grow amazingly yearly growth rate of 20.2 percent. With this kind of expected growth, it is no wonder that many

companies are rebranding.

- **More hybrid cloud adoption**
  - It is estimated that about 50 percent of the enterprises would have hybrid clouds by 2017. More and more companies are adopting cloud computing daily.
  - It would be very difficult to move everything wholesale to the cloud because of the complexity of today's environments. The hybrid cloud a mix of on and off premises offers a combination of strengths allowing organizations to achieve the performance of on-premises.
- **Increased development for the cloud**
  - More than millions of software developers worldwide developing for the cloud today. As cloud continues to be adopted, more developers will develop for the cloud.
  - Regarding the growth of these IT services, 20 percent of all application revenue in 2016 will be generated by SaaS.
  - There will be an increase in third-party, commercial and enterprise developers and contributors to cloud application ecosystems, marketplaces and application programming interface (API) exchanges.
- **More innovation because of cloud**
  - Increased competition in the cloud space will give way to better products, services and innovation.
  - When a vendor establishes a new product or service than its pace of innovation drops. This occurs because companies need to help their clients adopt the new innovative offering.



Networking Support for cloud computing:

The cloud computing is an anywhere any time service access to a broad set of applications and services to be delivered over the network to multiple customers.

- These services are essentially offered through interfaces available within the clouds rather than spread over the single computers connected through the Internet.
- Cloud infrastructures are used to provide high degree of abstraction and has the potential to introduce unpredictable performance behaviors. In fact while sharing the resources available on a large distributed infrastructure can average out the variability of individual workloads and it is extremely difficult to predict the exact performance characteristics of your application at any particular time. As in any shared infrastructure varying individual workloads, resource demands and network load conditions can result in unpredictable performance behavior of the combined applications.
- Cloud computing enables users and applications to store all their data on the network which is handling and moving large volumes of data within the cloud or between the users and the cloud may become a challenging issue.
- Cloud-service providers must guarantee that data are processed automatically and transferred transparently when and where they are needed.

Integrating an accurate network into the cloud is to support these types of services which would make the cloud more flexible and also increase the efficient use of the available resources and

communication infrastructure.

- The network architecture which is building the foundation for cloud computing concept used to consists of interconnected server farms within the data centers and a high-speed transport network providing connectivity to remote and backup sites.
- High-speed connections from the backbone of the cloud network are required to run at highest bandwidth with lowest transmission delay and in general according to a properly defined QoS degree.
- Cloud computing resources can be made accessible through the public Internet, private high performance networks, and also through a hybrid mixing of the two.
- Providers and users of cloud services must understand the performance, redundancy, and cost associated with Cloud model. Some will only require the basic capabilities available on the public internet or traditional public connection services. Other services may also require the enforcing of specific network performance constraints.

Ubiquitous Cloud and the Internet of Things:

The Ubiquitous Cloud means that the availability of the data of cloud anywhere at any time. As the data over the cloud can be assessed easily from anywhere in the world at any time is known as Ubiquitous Cloud Computing. And the cloud platform where data is stored and which is providing service at any place at any time is known as Ubiquitous cloud.

The concept of the Internet of Things (IoT) was introduced in 1999 at MIT. The IoT refers to the networked interconnection of everyday objects, tools, devices or computers. One can view the IoT as a wireless network of sensors that interconnect all things in their daily life. These things can be large or small and can vary with respect to time and place. The idea is to tag every object using RFID or a related sensor or electronic technology such as GPS.

- With the introduction of the IPv6 protocol the 2128 IP addresses become available to distinguish all the objects on Earth including all computers and universal devices. The IoT researchers have estimated that every human being will be surrounded by objects. For this the IoT needs to be designed to track static or moving objects simultaneously. The IoT demands universal addressability of all of the objects or things.
- All objects and devices are instrumented, interconnected and interacted with each other intelligently. Three communication patterns are as s:uch
    - H2H (human-to-human)

- H2T (human-to-thing)
- T2T (thing-to-thing)

The idea is to connect things including human and machine objects at any time and any place intelligently with low cost at any place or at any time.

- The dynamic connections will grow exponentially into a new dynamic network called Internet of Things. The IoT is still in its beginning stage of development. Many prototype for IoTs with restricted areas of coverage are under experimentation at the time.
- Cloud computing scholars believe to use the cloud and future Internet technologies together to support fast, efficient and intelligent interactions among humans and machines or any other object on Earth.

Internet of things

The Internet of Things refers to the ever-growing network of physical objects that feature an IP address for internet connectivity, and the communication that occurs between these objects and other Internet-enabled devices and systems. oT (Internet of Things) is an advanced automation and analytics system which exploits networking, sensing, big data, and artificial intelligence technology to deliver complete systems for a product or service. These systems allow greater transparency, control, and performance when applied to any industry or system.

IoT systems have applications across industries through their unique flexibility and ability to be suitable in any environment. They enhance data collection, automation, operations, and much more through smart devices and powerful enabling technology.

This tutorial aims to provide you with a thorough introduction to IoT. It introduces the key concepts of IoT, necessary in using and deploying IoT systems.

The Internet of Things(IoT) can be defined as a network of physical objects or people called "things" that are embedded with software, electronics, network, and sensors which allows these objects to collect and exchange data.

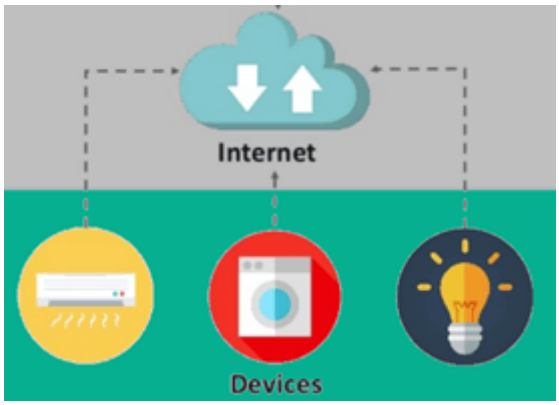
The goal of IoT is to extend to internet connectivity from standard devices like computer, mobile, tablet to relatively dumb devices like a toaster. IoT makes virtually everything "smart," by improving aspects of our life with the power of data collection, AI algorithm, and networks.

The thing in IoT can also be a person with a diabetes monitor implant, an animal with tracking devices, etc.

History of IOT

- 1970- The actual idea of connected devices was proposed
- 1990- John Romkey created a toaster which could be turned on/off over the Internet
- 1995- Siemens introduced the first cellular module built for M2M
- 1999- The term "Internet of Things" was used by Kevin Ashton during his work at P&G which became widely accepted
- 2004 - The term was mentioned in famous publications like the Guardian, Boston Globe, and Scientific American
- 2005-UN's International Telecommunications Union (ITU) published its first report on this topic.
- 2008- The Internet of Things was born
- 2011- Gartner, the market research company, include "The Internet of Things" technology in their research

How IOT works?



How IoT Works

The entire IOT process starts with the devices themselves like smartphones, smartwatches, electronic appliances like TV, Washing Machine which helps you to communicate with the IOT platform.

Fundamental components of an IoT system:

1) Sensors/Devices: Sensors or devices are a key component that helps you to collect live data from the surrounding environment. All this data may have various levels of complexities. It could be a simple temperature monitoring sensor, or it may be in the form of the video feed.

A device may have various types of sensors which performs multiple tasks **apart** from sensing. Example, A mobile phone is a device which has multiple sensors like GPS, camera but your smartphone is not able to sense these things.

2) Connectivity: All the collected data is sent to a cloud infrastructure. The sensors should be connected to the cloud using various mediums of communications. These communication mediums include mobile or satellite networks, Bluetooth, WI-FI, WAN, etc.

3) Data Processing: Once that data is collected, and it gets to the cloud, the software performs processing on the gathered data. This process can be just checking the temperature, reading on devices like AC or heaters. However, it can sometimes also be very complex like identifying

objects, using computer vision on video.

4)User Interface: The information needs to be available to the end-user in some way which can be achieved by triggering alarms on their phones or sending them notification through email or text message. The user sometimes might need an interface which actively checks their IOT system. For example, the user has a camera installed in his home. He wants to access video recording and all the feeds with the help of a web server.

However, it's not always one-way communication. Depending on the IoT application and complexity of the system, the user may also be able to perform an action which may create cascading effects.

For example, if a user detects any changes in the temperature of the refrigerator, with the help of IOT technology the user should able to adjust the temperature with the help of their mobile phone.

IoT Applications

IoT solutions are widely used in numerous companies across industries. Some most common IoT applications are given below:

Application type	**Description**
Smart Thermostats	Helps you to save resource on heating bills by knowing your usage patterns.
Connected Cars	IOT helps automobile companies handle billing, parking, insurance, and other related stuff automatically.
Activity Trackers	Helps you to capture heart rate pattern, calorie expenditure, activity levels, and skin temperature on your wrist.
Smart Outlets	Remotely turn any device on or off. It also allows you to track a device's energy level and get custom notifications directly into your smartphone.
Parking Sensors	IOT technology helps users to identify the real-time availability of parking spaces on their phone.
Connect Health	The concept of a connected health care system facilitates real-time health monitoring and patient care. It helps in improved medical decision-making based on patient data.
Smart City	Smart city offers all types of use cases which include traffic management to water distribution, waste management, etc.

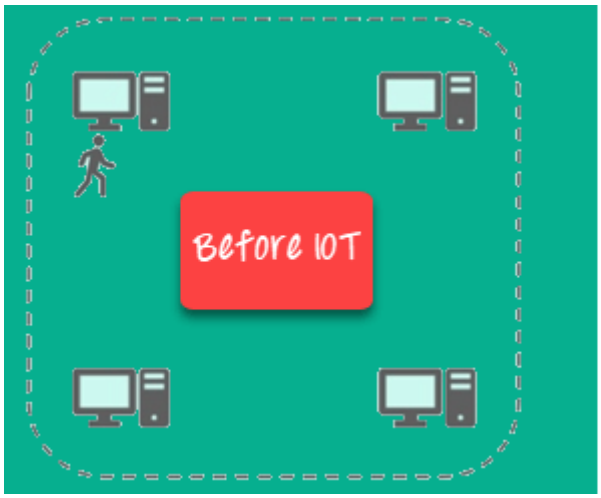
Smart home	Smart home encapsulates the connectivity inside your homes. It includes smoke detectors, home appliances, light bulbs, windows, door locks, etc.
Smart supply chain	Helps you in real time tracking of goods while they are on the road, or getting suppliers to exchange inventory information.

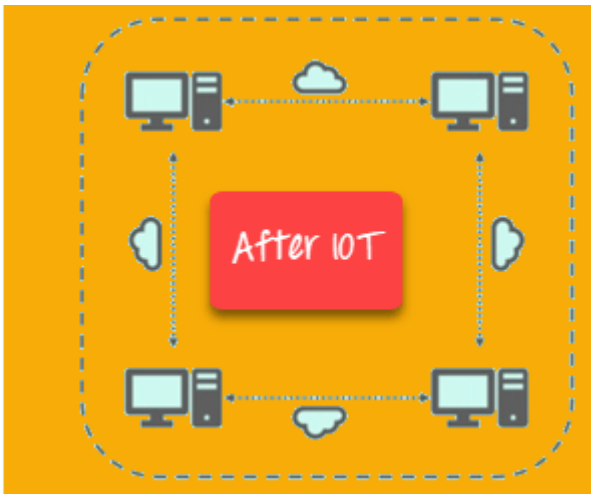
Challenges of IoT

At present IoT is faced with many challenges, such as:

- Insufficient testing and updating
- Concern regarding data security and privacy
- Software complexity
- Data volumes and interpretation
- Integration with AI and automation
- Devices require a constant power supply which is difficult
- Interaction and short-range communication

Advantages of IoT





Key benefits of IoT technology are as follows:

- **Technical Optimization:** IoT technology helps a lot in improving technologies and making them better. Example, with IoT, a manufacturer is able to collect data from various car sensors. The manufacturer analyzes them to improve its design and make them more efficient.
- **Improved Data Collection:** Traditional data collection has its limitations and its design for passive use. IoT facilitates immediate action on data.
- **Reduced Waste:** IoT offers real-time information leading to effective decision making & management of resources. For example, if a manufacturer finds an issue in multiple car engines, he can track the manufacturing plan of those engines and solves this issue with the manufacturing belt.
- **Improved Customer Engagement:** IoT allows you to improve customer experience by detecting problems and improving the process.

Disadvantages IOT

- **Security:** IoT technology creates an ecosystem of connected devices. However, during this process, the system may offer little authentication control despite sufficient security measures.
- **Privacy:** The use of IOT, exposes a substantial amount of personal data, in extreme detail, without the user's active participation. This creates lots of privacy issues.
- **Flexibility:** There is a huge concern regarding the flexibility of an IoT system. It is mainly regarding integrating with another system as there are many diverse systems involved in the process.
- **Complexity:** The design of the IOT system is also quite complicated. Moreover, it's deployment and maintenance also not very easy.
- **Compliance:** IOT has its own set of rules and regulations. However, because of its complexity, the task of compliance is quite challenging.

IOT Best Practices

- Design products for reliability and security
- Use strong authentication and security protocols
- Disable non-essential services
- Ensure Internet-managed, and IoT management hubs & services are secured
- Energy efficient algorithms should be designed for the system to be active longer.

Summary

- The Internet of Things (IoT) is a network of physical objects or people called "things" that are embedded with software, electronics, network, and sensors which allows these objects to collect and exchange data.
- The actual idea of connected devices was proposed in 1970
- Four Key components of IoT framework are 1) Sensors/Devices, 2) Connectivity, 3) Data Processing, 4) User Interface
- Various applications of IoT are Smart Thermostats, Connected Cars, Activity Trackers, Smart Outlets, Connect Health, etc
- Technical Optimization, Improve Data Collection, Reduced Waste, Improved Customer Engagement are key benefits of IoT
- Security, Privacy, Complexity, Compliance, are key challenges of IoT