UNIT-1: Distributed Systems

What is Computing:

The process of utilizing computer technology to complete a task. Computing may involve computer hardware and/or software, but must involve some form of a computer system.

Computing includes:

- Designing
- Developing and
- Building hardware and software systems
- Processing
- Structuring and managing various kinds of information
- Doing scientific research on and with computers
- Entertainment Media.

In the world of technology where every tasks are performed with help of computers, these computers have become one part of human life. Computing is nothing but process of completing a task by using this computer technology and it may involve computer hardware and/or software. But computing uses some form of computer system to manage, process, and communicate information. After getting some idea about computing now lets understand about **computing environments**.

Computing Environments :
When a problem is solved by the computer, during that computer uses many devices, arranged in different ways and which work together to solve problems. This constitutes a computing environment where various number of computer devices arranged in different ways to solve different types of problems in different ways. In different computing environments computer devices are arranged in different ways and they exchange information in between them to process and solve problem. One computing environment consists of many computers other computational devices, software and networks that to support processing and sharing information and solving task.

19 Key Trends in Cloud Computing

With access to on-demand computing power, highly scalable platforms and a more flexible approach to IT spending, the cloud has gone from emerging technology to an indispensable IT resource. Below we outline 19 trends, grouped into five categories, that are shaping the future of cloud computing.

Cloud Delivery Models

Cloud services can be delivered in a variety of ways. The delivery model a company chooses to use varies based on its functionality requirements and the maturity of its IT and data governance needs. While public software-as-a-service (SaaS) solutions remain the largest market segment, vendors increasingly offer solutions that cater to a wide range of customers and requirements.

1. **SaaS:** Software-as-a-service (SaaS) applications deliver software over the internet that users access via a browser. The vendor manages the hardware, database, security and infrastructure, while users typically have some ability to configure the software to their needs. In the business context, these applications are often departmental. For example, customer relationship management for sales, service and marketing, HR software for HR.

2. **PaaS:** Platform-as-a-service (PaaS) cloud solutions provide developers with the software and operating systems they need to build cloud-based applications, be it a mobile app for better inventory tracking or a consumer-facing social media platform. Companies are also beginning to use PaaS cloud systems for their network security, since they can easily be customized to suit specific security requirements. Spending on PaaS cloud services is forecast to reach $71.5 million in 2022, up 54% from 2020, according to Gartner.

3. **Multicloud:** Certain businesses want to distribute internal computer processing and storage requirements across multiple cloud platforms and applications, often from different vendors, based on their needs. It's common for them to choose different cloud providers for different functions, like ERP, security and marketing technology

4. **Private cloud:** A private cloud is a cloud computing model where services are provided over private infrastructure for the use of a single business, typically managed by that same business. Businesses choose private clouds to gain the benefits of cloud services through vendors without incurring the costs of building out and maintaining the cloud infrastructure themselves.

5. **Hybrid cloud:** Many companies opt for a hybrid cloud model that combines public cloud services with the deployment of a private cloud, which is dedicated to a single business. This is especially true of organizations that collect sensitive data or operate in highly regulated industries like insurance, where data privacy is essential. The global hybrid cloud market is expected to be worth $145 billion in 2026, up more than 180% from $51 billion in 2020.

6. **Serverless:** Serverless computing is a form of cloud computing that lets businesses access IT infrastructure on-demand, without the capital investment and need to manage the infrastructure themselves. The difference

between generic cloud computing and serverless is based on how resources are allocated

Category 2: Smarter Working with the Cloud
The cloud has emerged as more than a vehicle for computing power. Cloud storage and platforms also drive more efficient working practices, time and cost savings and innovation, helping companies modernize the way they work.

7. **Machine learning and artificial intelligence:** Cloud-based artificial intelligence (AI) technologies, including machine learning, are helping businesses draw additional value from the ever-growing volumes of data they collect. From logistics companies analyzing the efficiency of their transportation networks to ecommerce brands testing the performance of their websites in real time.Companies that don't have the budget or talent to build AI infrastructure of their own — and many don't — can still take advantage of it by running systems from cloud service providers.

8. **Automation:** Automation is a key driver of cloud adoption, particularly when it comes to improving the efficiency of business operations. With their data and systems centralized on the cloud, companies can automate many of their internal processes, be it the consolidation of data from different locations or the creation of business intelligence dashboards. Today, many organizations are looking to tighten connections between different pieces of software with the aim of better managing their growing cloud footprints and ensuring that solutions from different vendors work together seamlessly.

9. **Delegation of IT ops:** As more vendors launch solutions that can be hosted on external servers, some businesses will elect to outsource portions of their IT operations to third parties. Rather than hiring dedicated teams to build, manage and maintain their systems, companies can cut their operating costs and focus on the core product or service.

Category 3: Compliance and Security Trends
IT security and data compliance are major concerns for businesses and customers alike, and today's cloud solutions have evolved to address these concerns. Vendors have imbued their offerings with leading data controls and defenses that reduce the risk of human error when managing sensitive data.

10. **Complexity of compliance:** With companies collecting more data from a growing number of sources and governments enacting data protection regulations such as the General Data Protection Regulation (GDPR) and California Consumer Privacy Act (CCPA), compliance has become a priority for companies. Cloud storage and applications improve access to business data, which gives companies added control over how the information is managed. Data governance is now a core consideration for all IT investments, particularly when implementing solutions that will handle sensitive financial data or other personal information about customers.

11. **Better cloud security:** IT security threats are on the rise. The number of global ransomware attacks, for example, whereby cybercriminals steal a company's data and hold it hostage until they are paid a ransom grew by

almost five times in 2020. Leading cloud providers back up their solutions with best-in-class IT security practices, mitigating much of the threat.

12. **SASE:** With employees accessing more services and data from their own devices, which sit outside their companies' IT networks, businesses are rethinking their approach to security and risk management. Secure Access Service Edge (SASE), a term coined by Gartner, is a cloud-based approach to IT security that caters to the changing nature of work. Companies with a SASE architecture benefit from network security services such as secure gateways, firewalls, zero-trust network access and more, all based in the cloud.

13. **Cloud-based disaster recovery:** Disaster recovery has been moving to the cloud, with 20% more companies expected to move on-premises disaster recovery to the public cloud by the end of 2021, per Forrester. While similar to traditional disaster recovery, cloud-based disaster recovery backs up a company's data on an external cloud server and is generally more cost- and time-efficient, with the added bonus of being managed by an external provider. What's more, businesses can add, change and remove data from these external systems as they see fit without having to scale their own IT infrastructure. It's also common for businesses to rely on cloud-based disaster recovery for critical servers and applications, such as large databases or ERP systems.

Category 4: Innovation and Application Development

As companies look to differentiate themselves by quickly launching new products and services, cloud-based platforms are evolving to support their development needs at a record pace. From purpose-built coding environments to decentralized data storage, cloud computing has opened the door to new possibilities in application development.

14. **Containers and Kubernetes:** Containers offer businesses a dedicated, cloud-based space where they can build, test and deploy new applications. This allows developers to focus on the details of their applications and IT teams to focus on deploying and managing solutions as they are developed, making the entire process quicker and more efficient. Of 1,324 IT professionals surveyed in a 2020 Cloud Native Computing Foundation report, 92% said they are running containers in their production environments.

    Kubernetes is an open-source container orchestration solution that simplifies the process of deploying and managing applications developed in containers. In addition to automated scaling of applications based on customer demand, the software also monitors the performance of new services so businesses can address issues proactively. The same study found 91% of respondents use Kubernetes, primarily in production.

15. **Edge computing:** This form of cloud computing brings data processing — collection, storage and analysis — closer to the sources generating the data, rather than a centralized cloud. This reduces latency and powers the use of edge devices. Edge computing is the driving force behind smart devices, such as smartphones, smartwatches and smart cars, and the interconnection of all

the data generated by these technologies. Gartner predicts 75% of business-generated data will be created and processed outside of a centralized cloud by 2025.

16. **Cloud native:** Cloud-native applications allow businesses to build and deliver new software to their customers more quickly than traditional monolithic cloud applications, which run on a single hardware or software hub. Instead, cloud-native applications are built as a network of distributed containers and microservices. That means multiple teams can work on new features at the same time, accelerating the pace of innovation.

Category 5: Cloud-Based Operating Models

In addition to supporting more efficient technology operations, cloud computing has led to increased collaboration between employees across teams, departments and geographies.

17. **Collaboration:** Remote work is not a new phenomenon, but it has become far more common recently and the rise of cloud collaboration platforms has made the approach more viable. Secure networks, conferencing and communication platforms have become must-haves for modern organizations. Adroit Market Research predicts that the enterprise collaboration market could reach $45 billion by 2025, as more employees opt for real-time communication.

18. **Virtual cloud desktops:** A virtual cloud desktop, also known as desktop-as-a-service, delivers the entire desktop operating system and software applications as a cloud-based service directly to a laptop, desktop or other device. Companies only pay for the time their staff spend logged in to their devices, and they don't have to pay for hardware upgrades. Virtual cloud desktops can also be scaled instantly, which means companies always have the licenses and devices they need to support their growing workforce. The global market for virtual cloud desktops is predicted to reach $10.2 billion by 2023, growing at a compound annual growth rate of 16.5% since 2017, according to Allied Market Research.

19. **Cloud costs:** The upfront costs of cloud computing are much lower than those that come with buying and setting up on-premises IT infrastructure and systems. The same applies to having to maintain and upgrade hardware and software, along with the cost of staff charged with those duties. However, that's not to imply migrating to the cloud is always an inexpensive proposition. If not managed properly, the variable cost nature of the cloud may potentially exceed budget and increase total costs over the long run.

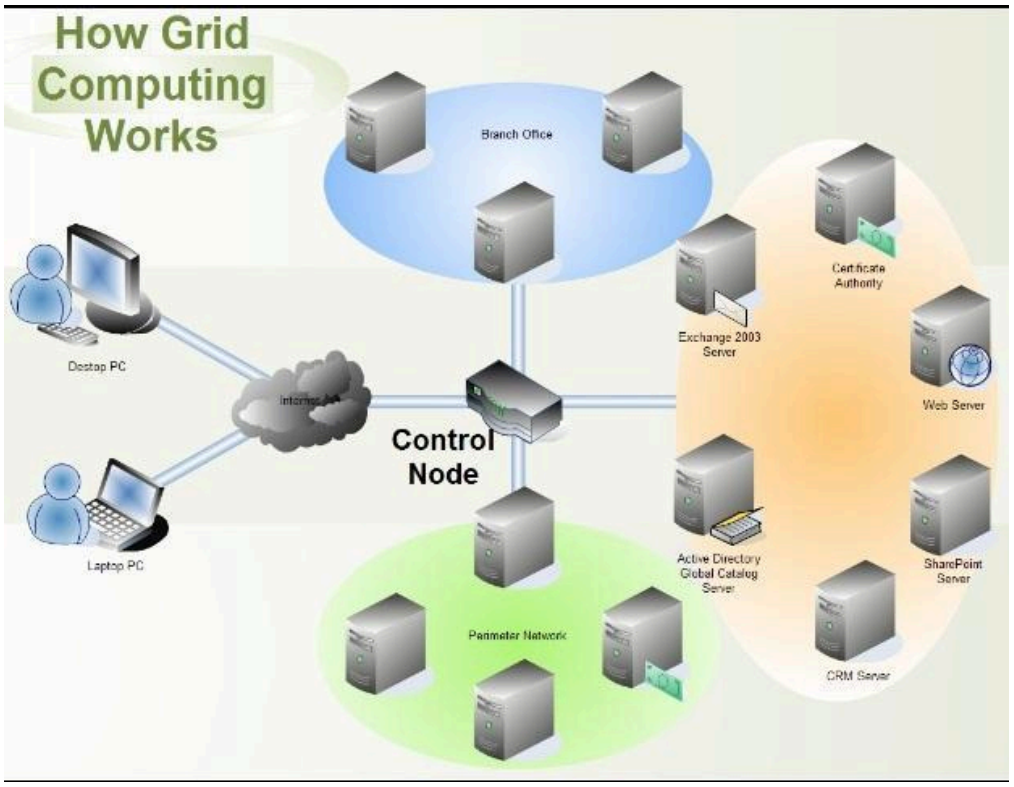
What is Grid Computing – Definition

Grid computing is a group of computers physically connected (over a network or with Internet) to perform a dedicated tasks together, such as analyzing e-commerce data and solve a complex problem. **Grids are a form of "super virtual computer"** that solve a particular application.The grid size may vary from small to large enterprises network.

A *computing grid* is constructed with the help of grid middle ware software that allows them to communicate. middle ware is used to translates one node information passed stored or processed information to another into a recognizable format. **It is the form of "distributed computing" or "peer-to-peer computing".**

'Grid computing' is distinguished from the cluster computing, because in Grid computing each node has heterogeneous and geographically dispersed (such as a WAN) and its own resource manager and perform a different task and are loosely connected by the Internet or low-speed networks, but in cluster computing resources are managed in a single location (Like a LAN).

Grid Computing



The **grid computing model** is a special kind of cost-effective distributed computing.In distributed computing, resources are shared by same network computers.In grid computing architecture, every computer in network turning into a powerful supercomputer that access to enormous processing power,memory and data storage capacity.

Grid computing solve Challenging problems such as earthquake simulation and weather modeling. Grids computing is a way of using resources optimally inside an organization.

*Grid architecture can also be used for load balancing and and redundant network connections.*This Model use parallel processing software that divide a program among the many thousand computers and Collect and combine the results into a single solution.For the security reasons,grid computing is restricted within the same organization.

Grid computing can be used in a large Networks where thousands of machines sit idle at any given moment. Even when a user is reading, it constitutes idle time. These idle power of computers can be used for large computational problems, these technique is running in the background that is known as **cycle-scavenging**.

SETI@home (“SETI at home”) is an another example of grid computing project created by the Berkeley SETI Research Center at Space Sciences Laboratory in University of California, Berkeley. In the SETI Research Center thousands of machines searching for signs of extraterrestrial intelligence.

What is Cluster Computing? – Definition

Cluster computing or *High-Performance computing* frameworks is a form of computing in which bunch of computers (often called nodes) that are connected through a LAN (local area network) so that, they behave like a single machine. A computer cluster help to solve complex operations more efficiently with much faster processing speed, better data integrity than a single computer and they only used for mission-critical applications.

The Clustering methods have identified as- HPC IAAS, HPC PAAS, that are more expensive and difficult to setup and maintain than a single computer.

A computer cluster defined as the addition of processes for delivering large-scale processing to reduce downtime and larger storage capacity as compared to other desktop workstation or computer.

Some of the critical Applications of Cluster Computers are Google Search Engine, Petroleum Reservoir Simulation, Earthquake Simulation, Weather Forecasting.

Cluster Can be classified into two category Open and Close Cluster.

Open Cluster: All nodes in Open Cluster are needed IPs, and that are accessible through internet/web,that cause more security concern.
Close Cluster: On the other hand Close Cluster are hide behind the gateway node and provide better security.

Types of Cluster computing

1. **Load-balancing clusters**: As the name implies, This system is used to distribute workload across multiple computers. That system

distributes the processing load as possible across a cluster of computers.
2. **High availability (HA) clusters**: A high availability clusters (HA cluster) are the bunch of computers that can reliably utilise for

redundant operations in the event of nodes failure in Cluster computing.
3. **High performance (HP) clusters**: This computer networking methodology use supercomputers and Cluster computing to solve advanced computation problems.

Advantages of using Cluster computing

1. **Cost efficiency**: In a Cluster computing Cost efficiency is the ratio of cost to output, that is the connecting group of the computer as computer cluster much cheaper as compared to mainframe computers.
2. **Processing speed**: The Processing speed of computer cluster is the same as a mainframe computer.
3. **Expandability**: The best benefit of Cluster Computing is that it can be expanded easily by adding the additional desktop workstation to the system.
4. **High availability of resources**: If any node fails in a computer cluster, another node within the cluster continue to provide uninterrupted processing. When a mainframe system fails, the entire system fails.

What is a Distributed Computing System? –

A **Distributed computing** is a model of computation that is firmly related to **Distributed Systems**, refers to as multiple computer systems located at different places linked together over a network and use to solve higher level computation without having to use an expensive supercomputer. Distributed system is called, When collection of various computers seems a single coherent system to its client, then it is called *distributed system*.

According to the definitions; All the computers are tied together in a network either a Local Area Network (LAN) or Wide Area Network (WAN), communicating with each other so that different portions of a Distributed applications run on different computers from any geographical location. Every node on the Distributed computing is autonomous machines (do not physically share memory or processors but thereby sharing resources such as printers and databases).

Distributed Systems have broken down into two parts: the front end and the back end. The front end, the part of the application that the user interacts with to determine what information she wants to examine and how to organise it, runs on

the user's computer. The back end, the part of the application that finds and sorts the requested information, runs on a central computer somewhere else. This type of distributed computing also referred to as "client-server architecture," splits up the functioning of applications across some separate computers.

Grid computing is a based on distributed architecture and is the form of "distributed computing" or "peer-to-peer computing"that involving large numbers of computers physically connected to solve a complex problem.

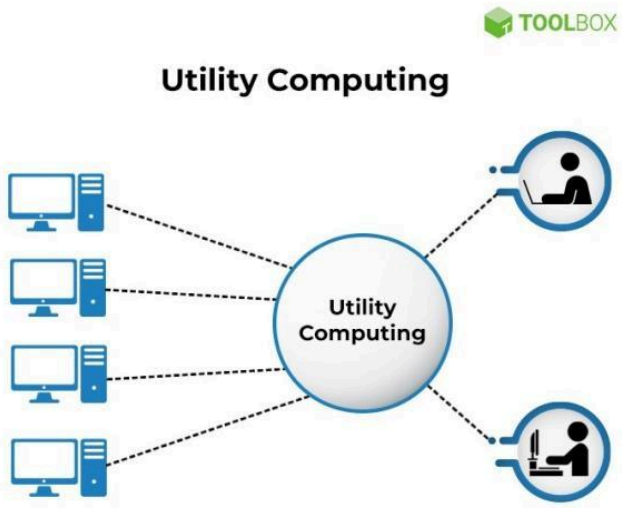
Standalone applications are traditional applications(or 3-tier old systems) that run on a single system; distributed applications run on multiple systems simultaneously. Traditional applications need to be installed on every system and make it hard to maintain. However, In Distributed computing, applications run on both simultaneously. With distributed computing, if a workstation that goes down, another workstation can resume the jobs.

The advantages of distributed computing increased the speed with "absolute performance" and lower cost with more reliability than a non-distributed system. It is currently quite popular, and many businesses are converting to it as we speak.

Extremely well-known example of distributed systems and applications of distributed computing used in SETI@Home project of the University of California Berkley, Telecommunication networks, Telephone networks and cellular networks, Computer networks such as the Internet, Wireless sensor networks, Routing algorithms.

What Is Utility Computing?

Utility computing is a service provisioning model that offers computing resources such as hardware, software, and network bandwidth to clients as and when they require them on an on-demand basis. The service provider charges only as per the consumption of the services, rather than a fixed charge or a flat rate.



Utility computing is a subset of cloud computing, allowing users to scale up and down based on their needs. Clients, users, or businesses acquire amenities such as

data storage space, computing capabilities, applications services, virtual servers, or even hardware rentals such as CPUs, monitors, and input devices.

The utility computing model is based on conventional utilities and originates from the process of making IT resources as easily available as traditional public utilities such as electricity, gas, water, and telephone services. For example, a consumer pays his electricity bill as per the number of units consumed, nothing more and nothing less. Similarly, utility computing works on the same concept, which is a pay-per-use model.

The service provider owns and manages the computing solutions and infrastructure, and the client subscribes to the same and is charged in a metered manner without any upfront cost. The concept of utility computing is simple—it provides processing power when you need it, where you need it, and at the cost of how much you use it.

What is Cloud Computing?

Cloud Computing Definition is that it is a shared pool of configurable computing resource (eg. networks, servers, storage, applications, and services) network on demand over the internet. Cloud computing literally, is the use of remote servers (usually accessible via the Internet) to process or store information. Access is usually using a Web browser. Save files on a server via the Internet is one example.

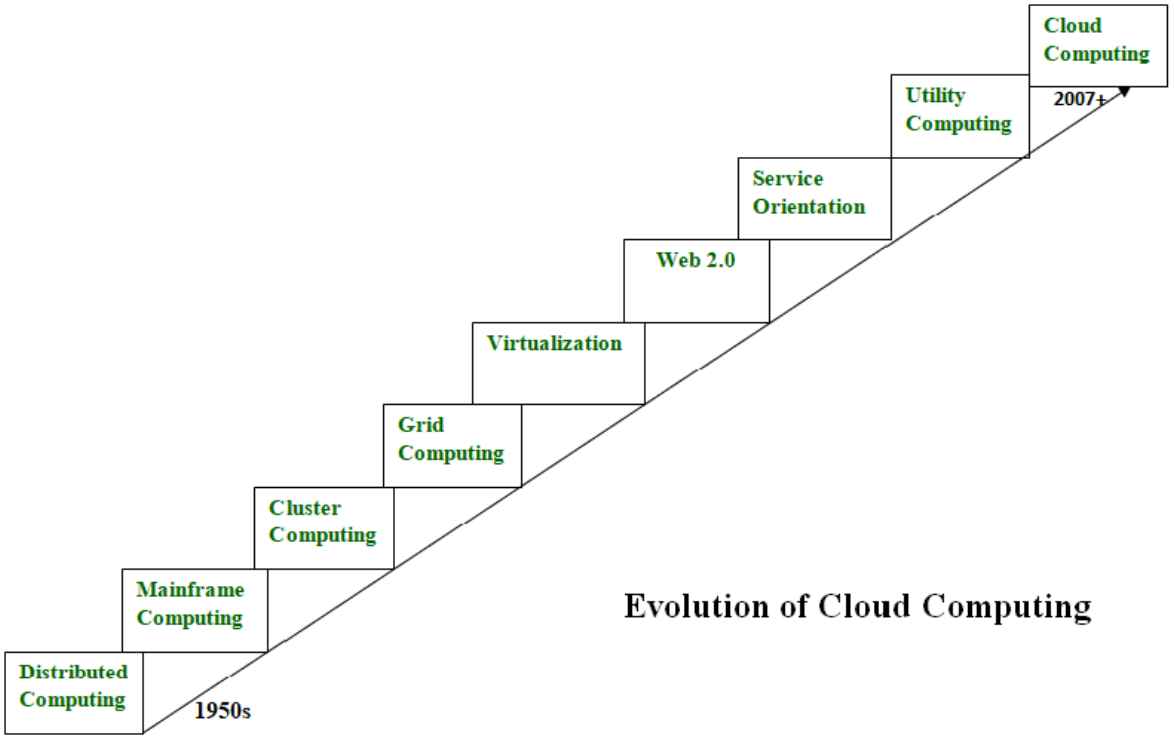
Cloud computing is the best solution to manage your applications yourself; it is a shared multi-tenant platform that is supported. When using an application running in the cloud, you simply connect to it, customize it and use it.

Today, Millions of us are happy to use a variety of applications in the cloud, such as applications of CRM, HR, accounting, and even business applications.These applications based in the cloud can be operational in a few days is not possible with traditional enterprise software. They are cheap because you do not have to invest in hardware and software,or to spend money for the configuration and maintenance of complex layers of technology or to finance facilities to run them. And they are more scalable, more secure and reliable than most applications. In addition, upgrades are

supported, so that your applications automatically benefit from all the improvements of safety and performance available, as well as new features.

Evolution of Cloud Computing

Cloud computing is all about renting computing services. This idea first came in the 1950s. In making cloud computing what it is today, five technologies played a vital role. These are distributed systems and its peripherals, virtualization, web 2.0, service orientation, and utility computing.



- **Distributed Systems:**
  It is a composition of multiple independent systems but all of them are depicted as a single entity to the users. The purpose of distributed systems is to share resources and also use them effectively and efficiently. Distributed systems possess characteristics such as scalability, concurrency, continuous availability, heterogeneity, and independence in failures. But the main problem with this system was that all the systems were required to be present at the same geographical location. Thus to solve this problem, distributed computing led to three more types of computing and they were-Mainframe computing, cluster computing, and grid computing.

- **Mainframe computing:**
  Mainframes which first came into existence in 1951 are highly powerful and reliable computing machines. These are responsible for handling large data such as massive input-output operations. Even today these are used for bulk processing tasks such as online transactions etc. These systems have almost no downtime with high fault tolerance. After distributed computing, these increased the processing capabilities of the system. But these were very expensive. To reduce this cost, cluster computing came as an alternative to mainframe technology.

- **Cluster computing:**
  In 1980s, cluster computing came as an alternative to mainframe computing. Each machine in the cluster was connected to each other by a network with high bandwidth. These were way cheaper than those mainframe systems. These were equally capable of high computations. Also, new nodes could easily be added to the cluster if it was required. Thus, the problem of the cost was solved to some

extent but the problem related to geographical restrictions still pertained. To solve this, the concept of grid computing was introduced.

- **Grid computing:**
  In 1990s, the concept of grid computing was introduced. It means that different systems were placed at entirely different geographical locations and these all were connected via the internet. These systems belonged to different organizations and thus the grid consisted of heterogeneous nodes. Although it solved some problems but new problems emerged as the distance between the nodes increased. The main problem which was encountered was the low availability of high bandwidth connectivity and with it other network associated issues. Thus. cloud computing is often referred to as “Successor of grid computing”.

- **Virtualization:**
  It was introduced nearly 40 years back. It refers to the process of creating a virtual layer over the hardware which allows the user to run multiple instances simultaneously on the hardware. It is a key technology used in cloud computing. It is the base on which major cloud computing services such as Amazon EC2, VMware vCloud, etc work on. Hardware virtualization is still one of the most common types of virtualization.

- **Web 2.0:**
  It is the interface through which the cloud computing services interact with the clients. It is because of Web 2.0 that we have interactive and dynamic web pages. It also increases flexibility among web pages. Popular examples of web 2.0 include Google Maps, Facebook, Twitter, etc. Needless to say, social media is possible because of this technology only. In gained major popularity in 2004.

- **Service orientation:**
  It acts as a reference model for cloud computing. It supports low-cost, flexible, and evolvable applications. Two important concepts were introduced in this computing model. These were Quality of Service (QoS) which also includes the SLA (Service Level Agreement) and Software as a Service (SaaS).

- **Utility computing:**
  It is a computing model that defines service provisioning techniques for services such as compute services along with other major services such as storage, infrastructure, etc which are provisioned on a pay-per-use basis.

Thus, the above technologies contributed to the making of cloud computing.

Types of Cloud Computing

Public cloud: This type of infrastructure is accessible to a wide audience and belongs to aprovider of “cloud services.”

Private cloud: The cloud infrastructure works for one organization. It can be managed by the company itself (internal Private Cloud). In the latter case, the infrastructure is dedicated to the company and accessible via secure VPN-type networks.

The Cloud Community: The infrastructure is shared by several organizations that have common interests (e.gsafety requirements, compliance …). As private cloud, it can be managed by the organizations them selves or by third parties.

Hybrid cloud: Infrastructure consists of two or more clouds (private, Community or Public), which remain unique entities but are bound together by standardized or proprietary technology, enabling data portability or applications.

Cloud Computing Benefits and Limitations

The Benefits of Cloud Computing (Cloud Computing)

Cost Reduction: Cloud computing is seen as an incremental investment, companies can save money in the long term by obtaining resources.

Storage increase: instead of purchasing large amounts of storage before the need, organizations can increase storage incrementally, requesting additional disk space on the service provider when the need is recognized.

Resource pooling: in the IT industry, this feature is also known as Multi-tenancy, where many users / clients share a type and varied level of resources.

Highly automated: As the software and hardware requirements are hosted on a cloud provider, IT departments sites no longer have to worry about keeping the things-to-date and available.

Greater mobility: Once the information is stored in the cloud, access it is quite simple, just you have an Internet connection, regardless of where they are located.

Change the IT focus: Once the responsibility of the computing environment has, essentially shifted to the cloud provider, IT departments can now focus more on the organization's needs and the development of strategic applications and tactics and not on operational needs of the day-to-day.

Towards Green IT: By releasing the physical space, virtualization of applications and servers contributes to the reduction of equipment as well as the need for air conditioning, consequently, less energy waste.

Keep updated things: Similar to change the IT focus, this benefit is because of the new demands of providers cloud services, ie, the focus of providers is to monitor and maintain the most recent tools and techniques for the contractor.

Quick elasticity: this characteristic has to do with the fundamental aspects of Cloud flexibility and elasticity. For example, the web shops carry a standard amount of transactions during the year, but it is necessary to increase near Christmas time. And of course these stores do not want to pay for that capacity at peak during the rest of the year.

Measurement service: which means services monitored, controlled and reported. This feature allows a model of pay-per-use service, or pay for use. It has similarities with the concept of telephone service packages where you pay a standard signature to basic levels, and paid extra for the additional service, without changing the contract.

The limitations of Cloud Computing (Cloud Computing)

The various problem areas for cloud computing environments are:

Security: As the data are no longer in their own organization, security becomes a major issue and questions must be answered, such as: Data is protected as adequate? There is a hacker-proof system? Can you meet the requirements regulations and government for privacy? How do you discover the leak information? Note also that corporate governance is always very concerned about the data that is stored outside the organization.

Location and Data Privacy: Where the data is stored? How data is stored? The provider has adequate security for data in places where they are stored?

Internet addiction: Since the cloud features are not available on the local network, you have to worry about the availability of the Internet. If you lose access to the Internet out, what that happens to your cloud computing environment? If your service provider increasing period unavailability, what you do with your employees and customers? What do you do in case of increased latency or delays the answers?

Levels of availability and service: Most organizations are familiar with the agreements service levels. The service level agreement specifies the amount of service capacity that someone has to provide, along with the penalties for not providing this level of service. How you can be sure that the cloud service provider

has sufficient resources to maintain a service level agreement you signed with them?