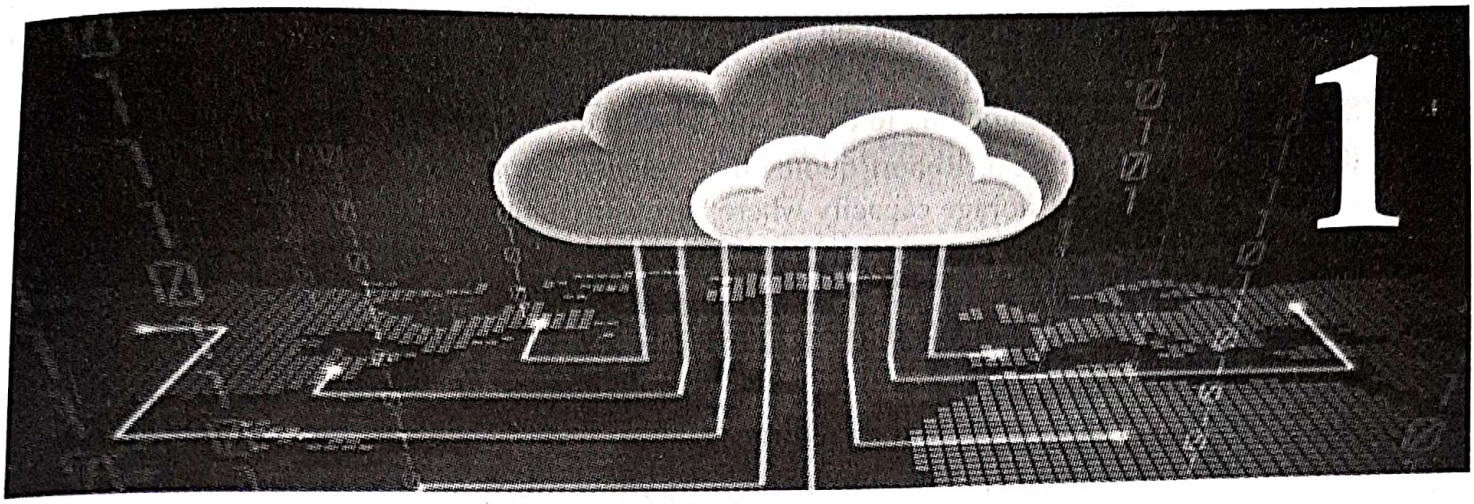


1

Introduction to Cloud Computing

1.1 INTRODUCTION

Cloud computing has spawned start-ups in different new industry verticals. It has forced the existing conglomerates to acclimatize and adapt quickly to survive in the innovative environment. It is a set of approaches that can help organizations quickly, effectively add and subtract resources in almost real time. Cloud computing is a business and economic model. It is the next stage in the evolution of Internet.

But still cloud computing is in its infancy stage. **The term 'cloud' in cloud computing refers to the means through which everything—from computing power to computing infrastructure, applications, business processes to personal collaboration—can be delivered to you as a service wherever and whenever you need [6].** A cloud is a group of interconnected network servers or PCs that may be private or public. The data and the applications served by cloud are accessible to a group of users through the network. But the cloud infrastructure and technology are not-visible to the end-users. Cloud services include the software delivery, infrastructure and storage over Internet based on the end-users demand. It assembles large networks of virtualized services. ***Hardware services*** like compute services, storage and network and ***infrastructure services*** like web server, databases, message queuing systems, monitoring systems etc. Cloud computing is like a fluid that can expand and contract depending on the customers/ business needs. That is, the users can add or remove the resources as per their needs. **Also understand here that this makes cloud computing elastic.** Also we can do this either manually or using some automated tools.

Cloud computing is shifting computing from the physical hardware and locally managed software-enabled platforms to virtualized cloud-hosted services. Cloud providers like Microsoft Azure, Amazon Web Services (AWS), Rackspace, GoGrid etc. give users the option to deploy their application over a pool of virtually infinite resources with practically no money expenditure. It is the elasticity, cost effectiveness and large availability of resources that force, motivate and encourage these companies to shift from enterprise applications to cloud computing.

In a **recent survey** conducted by different organizations:-

- Gartner Research, 2014, it is observed that cloud computing would be $150 billion business.
- AMI partners and SMEs (Small and Medium Enterprise) are expected to spend more than $100 billion on cloud computing.

- IDC recently predicted that spending on public cloud hosted applications will grow from $16.5 billion to over $55 billion in 2014.
- Software companies are flocking to cloud now to reap the ultimate benefits of cloud.
- Recent McKinsey and Co. Report quotes that "clouds are hardware-based services offering compute, network and storage capacity where hardware management is highly abstracted from the buyer, buyers incur infrastructure costs as variable OPEX and infrastructure capacity is highly elastic."
- In another report from University of California Berkeley, the key features of cloud computing are as follows-
  - The illusion of infinite computing resources.
  - The elimination of an up-front commitment by cloud users.
  - The ability to pay for use...as needed..."

Principle: ***To offer computing, storage and software "as-a-service".***

Several researchers have given different definitions of cloud but the basic implication is same. Some of them are as follows:-

"Cloud Computing is a paradigm in which information is permanently stored in servers on the Internet and cached temporarily on clients that include desktops, entertainment centres, table computers, notebooks, wall computers, handhelds, sensors, monitors etc."

[Carl Hewitt, IEEE 2008]

Or

"It is information processing model in which centrally administered computing capabilities is delivered as services, on an as-needed basis, across the network to a variety of user-facing devices."

[Brian et al. 2014]

Or

"It 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."

[NIST, USA, 800-145]

Or

"It is an umbrella term to describe a category of sophisticated on-demand computing services initially offered by commercial providers like Amazon, Google and Microsoft."

Or

"It denotes a model on which a computing infrastructure is viewed as a 'cloud' from which businesses and individuals access applications from anywhere in the world on demand."

Or

"Cloud is a parallel and distributed computing system consisting of a collection on 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."

Or

"Clouds are a large pool of easily usable and accessible virtualized resources (such as hardware, development platforms and/or services). These resources can be dynamically reconfigured to adjust to a variable load (scale), allowing also for an optimum resource utilization. This pool of resources is typically exploited by a pay-per-use model in which guarantees are offered by the Infrastructure Provider by means of customized Service Level Agreements."

[Vaquero et al.]

Or

"Data centre hardware and software that provides services".

[Armbrust et al.]

Or

"Cloud is more often used to refer to IT infrastructure deployed on an Infrastructure as a Service provider data center."

[Sotomayor et al.]

The following equation makes it more clearer:-

Hardware (like virtualization of hardware, multi-core chips)

+ Internet Technologies (like web services, SOA, web 3.0)

+ Systems Management (like autonomic computing)

+ Distributed Computing.(like grid computing, utility computing)

We shall be studying these a bit later.

Actors (players) of Cloud Computing

Three players make the world of cloud computing possible:-

1. Vendors.
2. Partners.
3. Business leaders.

Vendors that provide applications and enabling technology, infrastructure, hardware and integration.

Partners of these vendors that create these cloud services for the users/customers.

Business leaders who use or evaluate these cloud computing services.

The point is that the cloud services should enable **multi-tenancy** i.e. different companies should be able to share the same available resources—online. *Cloud computing cuts down the space, time, power and cost extensively.* **For example,** cloud services like Facebook or LinkedIn and collaboration tools like video conferencing, document management and webinars etc. are affecting business functioning a lot.

Not only raw computing and storages but it also offers software services of different types like APIs (Application Programming Interfaces) and development tools that allow software web developers to develop scalable projects. **Please note that the ultimate goal is to run the everyday I.T. infrastructure in the cloud. Also note that it is possible to define this umbrella term 'cloud computing' as**

"The cloud services that are made available to the users on demand via Internet from a cloud computing provider's servers like Microsoft Azure."

[Rajiv, 2016]

1.2 OVERVIEW OF PARALLEL COMPUTING

The term parallel computing is different from cloud computing. **Parallel computing means running several computers, may be kept in one room, but they are made to solve one problem only.** Such architectures are called as **advanced computer architectures** and computers are known as **parallel computers or supercomputers.** These computers use parallel programming constructs and hence are also called as **parallel computers. For example,** CRAY-XMP, CRAY-YMP, PARAGON, PARAM, JUGENE and so on. On the other hand, cloud computing refers to the use of available resources on Internet in a time and cost effective way. This is possible due to sharing of the resources. So, cloud provides software as a service, infrastructure as a service and platform as a service. We will be discussing about this a bit later.

1.3 GRID COMPUTING

Let us first of see the definition of grid computing as given in Wikipedia (a free online encyclopedia):-

"Grid computing is a form of distributed computing whereby a "super and virtual computer" is composed of a cluster of networked, loosely-coupled computers, acting in concert to perform very large tasks. This technology has been applied to computationally-intensive scientific, mathematical and academic problems through volunteer computing and it is used in commercial enterprises for such diverse applications as drug discovery, economic forecasting, seismic analysis and back-office data processing in support of e-commerce and web services."

Grids are more loosely coupled, heterogeneous and geographically dispersed [7].

According to [6], grid computing is a step beyond distributed processing, involving large number of networked computers that are harnessed to solve a common problem. Clouds are usually organized as a computer grid.

According to Carl Kesselman and Ian Foster, grid computing is a cluster of computers that were geographically distributed but worked together to perform a common task. **Please understand that in grid computing a cluster of loosely coupled computers work together to solve a single problem that involves massive amounts of numerical calculations and compute cycles.** The concept is just similar to that of an *electronic grid* where we could connect and use the power at any time. Grid computing uses *grid-controlling software* that divides the work into smaller pieces and assigns each piece to a pool of thousands of computers. Then later on the controlling unit (CU) assembles the results to build the output. So, just as we have electronic grids to harness electric power, similarly we have grid computing to harness the power of computer that is free otherwise.

For example, SETI- Search for Extraterrestrial Intelligence is a grid computing system. People all over the world share idle CPU cycles of their computers to the SETI project.

1.4 DISTRIBUTED COMPUTING AND ITS VARIANTS-MANETS, PEER-TO-PEER, CLOUD

It refers to the different tasks that are distributed among separate nodes in the network. It includes:-

- Grid Computing.
- Peer-to-peer architecture.
- Client-server architecture.

We have already seen what is a grid computing? Let us now compare peer-to-peer architecture and cloud.

Peer-to-Peer (P2P) Architectures Compared to Cloud

In peer-to-peer network of hosts, resource sharing, processing and communications control are fully **decentralized.** Each *host acts as a server* (provider) of some services. But it depends on the other nodes within the network for other services. All clients are same on the network. On one hand, **cloud computing** is elastic and scalable in terms of resource sharing. On the other hand, **peer-to-peer** architectures are cheaper and simpler to manage.

Cloud computing needs heavy initial money investment and good technology expertise while peer-to-peer deployments have a limited extensibility property.

Client-Server Architecture Compared to Cloud

Client-server architecture is a form of distributed computing wherein the clients depend on the number of servers that will provide them the services. So, its scalability involves more cost (processing power cost, management costs and administrative costs). On the other hand, cloud saves cost, time and manpower. All resources are shared by the customer now. There is no additional cost involved as it is there in client-server architectures. **Also note that in client-server deployments, a minimum of one server is a must.** Hence, more costs are involved. Cloud is, therefore, cheaper.

MANETS

Adhoc networks are formed as and when an immediate requirement of setting up a network in an area arises. They are defined as the category of wireless networks that use multihop transmission. They are capable of operating without any support from the existing infrastructure. Barring natural disasters, in rural areas, adhoc networks can be set easily. MANETS stands for Mobile Adhoc Networks. According to the **routing strategy**, the routing protocols can be classified as *table-driven and source-initiated protocols.* On the other hand, based on the **network structure**, they can be classified as *flat-routing, hierarchical routing and geographical position assisted routing protocols.*

Table-driven / Proactive Protocols: The table-driven protocols are also called as proactive protocols because they maintain the routing information even before it is needed. In this protocol, each and every node in the network maintains routing information to every other node in the network. In general, routing information is kept in the routing tables and is periodically updated as the network topology changes. Many of these routing protocols come from the link-state routing. **Also note that these protocols are not suitable for larger networks as they need to maintain node entries for each and every node in the routing table of every node.** This causes more overhead in the routing table leading to consumption of more bandwidth.

For example, Fisheye State Routing Protocol (FSR), Optimized Link State Routing Protocol (OLSR).

Also there are some on-demand routing protocols/ reactive protocols.

On-demand routing protocols/ reactive protocols: They are also called as reactive protocols because they don't maintain routing information or routing activity as the network nodes if there is no communication. If a node wants to send a packet to another node then this protocol searches for the route in an on-demand manner and establishes the connection in order to transmit and receive packet. The route discovery occurs by flooding the route request packets throughout the network.

For example, Dynamic Source Routing (DSR), Ad-hoc On-demand Distance Vector (AODV) Routing.

MANETS may also use **Hierarchical State Routing (HSR) protocols.** This protocol maintains a hierarchical topology where elected cluster heads at the lowest level become members of the next higher level. On the higher level, super clusters are formed. **Please understand that the nodes which want to communicate to a node outside of their cluster ask their cluster head to forward their packet to the next level, until a cluster head of the other node is in the same cluster. Then the packet travels down to the destination node. Also note that HSR proposes to cluster nodes in a logical way rather than in a geographical way.**

Also they can use **Zone Routing Protocols (ZRP). They are also known as hybrid reactive/ proactive routing protocol.** As the name implies, ZRP is based on the concept of zones. *A routing zone is defined for each node separately and the zones of neighbouring nodes overlap.* **The routing zone has a radius expressed in hops.** So, the zone includes the nodes whose distance from the node in question is at most **hops. Please note that the number of nodes in the routing zone can be regulated by adjusting the transmission power of the nodes. Also note that lowering the power reduces the number of nodes within direct reach and vice versa.** The number of neighbouring nodes should be sufficient to provide adequate reach ability and redundancy. On the other hand, a too large coverage results in many zone members and the update traffic becomes excessive.

MANETS may also use geographic position assisted routing. In includes protocol like Location-Aided Routing (LAR) and Distance Routing Effect Algorithm for Mobility (DREAM) protocols.

MANETS is a collection of mobile nodes with no pre-established or fixed architecture. Network nodes act as routers by relaying each other's packets. It is a wireless network in which nodes communicate through single hop or multihop paths. MANETS have dynamic topologies, B.W. constraints, variable capacity links and self-organized behaviour.

1.5 INTRODUCTION TO AUTONOMIC COMPUTING

Let us first of all define what are autonomic systems? The term autonomic is derived from the concept of biology only. We say autonomous systems are those that monitor changes that affect the body and are based on human autonomic nervous systems. Say, if you touch a hot plate or anything hot, then suddenly you remove your hands from there. This is so because our nerves then send messages to the brain to immediately remove the hands. This is done automatically. So, such systems are **self-managing.** In the field of computer science also we have the concept of **autonomic computing.** Such systems should be able to handle events autonomously like malicious attacks, hardware and software faults, power shutdowns, software updates and so on. IBM introduced this concept with the following features:-

Features of autonomic systems:-

1. **Self Awareness** i.e. they know themselves very well.
2. **Self Configuring:** It should be able to configure and reconfigure itself under varying conditions.
3. **Self Optimizing:** It should be able to optimize itself to improve its execution.
4. **Self Healing:** It should be able to detect and correct problems and to continue functioning as it is.
5. **Self Protecting:** It should be able to protect itself from both internal and external attacks of security.
6. **Open Systems:** It should be developed using standard and open protocols and interfaces.

Please note that the basic concept of autonomic systems is their self-management. Also note that the objective of autonomous self-healing process is to keep the elements working as per their design specifications.

In nutshell, we can say that *"it is a set of self-managing, self-healing, self-configuration, self-optimization and self-protection features of distributed computing resources that operate on the basis of a set of pre-defined policies."*

1.6 HISTORICAL DEVELOPMENT AND EVOLUTION OF CLOUD COMPUTING

History of Cloud

Initially cloud computing was thought of, being **public only.** So, it was named as **public cloud**. But due to security reasons, we shifted from public clouds to **private clouds.** The focus was to make **cloud more secure** and yet to provide the same services and resource sharing. Then cloud infrastructures naturally evolved to what is known as **hybrid cloud.** Hybrid clouds can be explained with the help of an equation also:-

Hybrid Cloud = Public Cloud + Private Cloud

This means that now you can take the benefits of both internal network storage as well as public data cloud that can be accessed from anywhere in the world using Internet. Using broadband services along with the cloud the companies can connect to larger networks to make use of available resources. There is no need of a huge computer now to handle complex tasks like database indexing.

Evolution of Cloud

In 1960s,

(a) Joseph Licklider, a Professor at MIT, described the idea of cloud computing and resource sharing.

(b) Professor, John McCarthy, at MIT and Stanford focussed on the concepts of time-sharing, computing power and applications being used and sold as a utility and online social networking.

(c) In 1966, Douglas F Parkhill, published a book on The Challenge of Computer Utility" wherein he described the utility-like features of cloud computing like dynamic provisioning, illusion of infinite supply and being always online.

In 1970s,

(a) In 1979, Dun and Bradstreet, bought National CSS that sold time-sharing concept.

(b) Even BBN Technologies, founded by MIT, in 1970s, marketed time-sharing.

In 1980s,

(a) In 1985, DEC also introduced VAX clusters where several VAX machines were grouped together for resource sharing.

(b) In 1980, Tim-Berbers-Lee, worked on hypertext and is known as the **father of Internet** today.

Note: All these advancements were pre-cloud phases of cloud development.

In 1990s,

(a) Ian Foster and Carl Kesselman wrote a book entitled 'The Grid: Blueprint for a New Computing Infrastructure'. They explain the concepts of grid computing that can work cohesively for computationally intensive tasks.

(b) In 1998, the Data Protection Act of UK, had a very long-term impact on cloud computing. This act covered data collection, protection and sharing in a multi-tenant environment.

(c) In 1999, Salesforce.com, who happens to be a pioneer in software-as-a Service (SaaS) CRM, made it operational.

(d) In mid 1990s, Yahoo too offered cloud-based email services.

(e) Again in 1990s, server virtualization was introduced (based on 8086 Microprocessors). This became the base/foundation for cloud resource sharing.

(f) In 1998, VMware was founded by Mendel et al. at University of California.

In 2000s,

(a) In 2001, SIIA (Software and Information Industry Association) used an acronym SaaS and compared it with ASP (Application Service Provider).

(b) In 2002, Amazon launched its web services to permit users to integrate their website with Amazon's online content. This later became IaaS, EC2 (Elastic Compute Cloud) and S3 (Storage-as – a-Service). They actually introduced pay-per-use pricing and very soon it became standard with other companies too.

(c) In 2003, Nicholas Carr, published a research paper in Harvard Business Review named as ' IT doesn't Matter" wherein he described that corporate will start purchasing IT resources as and when needed from external resources only.

(d) In 2008, Gartner quotes cloud computing as an emerging technology that is still in its infancy stage.

1.7 VISION OF CLOUD COMPUTING

Cloud computing can save money and time. This is the major goal of cloud. Big companies who provide their customers with cloud services also provide SLAs i.e. SERVICE LEVEL AGREEMENTS.

We define SLA as a contract in which the service providing companies agree on a specified level of service (or uptime). An SLA gives the potential customers a sort of confidence to them to use cloud computing services. A system administrator has a role here. It should ensure that this uptime is constant. This they can easily achieve because of the redundancy of cloud computing. Several SLAs promote an uptime level of 99.999% but cannot always provide for data redundancy to be at that level. This problem can be solved by making sure that the data integrity is written into this SLA agreement itself to prevent any kind of confusion.

1.8 PROPERTIES AND CHARACTERISTICS OF CLOUD COMPUTING

Some of the key characteristics of cloud computing are as follows:-

1. Cloud service providers like MS-AZURE, AMAZON WEB SERVICE (AWS), IBM, GOOGLE, provide **on-demand self-services.** Cloud includes a set of approaches that can help organizations quickly, effectively add and subtract resources in almost real time.
2. Cloud services can be used even on mobile phones. So, they have a **broader network access.**
3. Resources like memory, network bandwidth and virtual machines can be easily **shared** now, according to Gartner, pooling like this with resources builds economies to larger extent. The cloud also focuses on maximizing the effectiveness of the shared resources. **Please understand that cloud resources are usually not only shared by multiple users bit are also dynamically reallocated per demand.** This can work for allocating resources to users.

Also note that with cloud computing, multiple users can access a single server to retrieve and update their data without purchasing licenses for different applications.

4. **Cloud is elastic.** This means that if needed you can scale-in or scale-out resources easily.
5. It is possible to **measure, manage and control** the cloud computing resource practices. Cloud works on **"pay-as-you-go" principle** just as our electricity meters work. So, you are charged only for the time you are using cloud services.
6. **Multi-tenancy** is another feature of cloud. It refers to different companies sharing the same underlying resources.
7. Cloud adopts features from SOA – Service-oriented Architecture that can help the user break these problems into services that can be then integrated to provide a solution. **Please note that cloud computing provides all of its resources as services and makes use of the well-established standards.**
8. Cloud computing is a **marketing term. It refers to a model of network computing where a program or application runs on a connected server or servers rather than on a local computing device like a PC, tablet or smart phone.**
9. Like a traditional *client-server model or legacy mainframe computing*, a user connects with a server to perform a task. The difference with **cloud computing** is that the computing process may run on one or many connected computers at the same time, utilizing the concept of **virtualization.**
10. Cloud computing is NOT a quick fix solution. It requires a lot of thinking before implementing it in an organization.
11. It requires a strong foundation of best practices in software development, software architecture and service management foundations.
12. It is user-centric, task-centric, document-centric, powerful, accessible, intelligent and programmable.
13. Cloud computing is not network computing. Nor it is traditional outsourcing.
14. It should facilitate a shift from the remote data to the current data, from applications to the tasks and from computer to the user, with the objective of accessing from any place and sharing it with anyone. Authorized users have instant access.
15. Cloud when used with IT will be more beneficial than when used in isolation.

1.9 REFERENCE MODEL OF CLOUD COMPUTING

There are three major models of cloud computing services and they are known as Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS) and Infrastructure-as-a-Service (IaaS). These cloud services may be offered in a public, private or hybrid network [NIST]. Some of the cloud vendors include-*MS Azure, Amazon, IBM, Oracle Cloud, Salesforce and Google.*

For example, Windows Azure is a Microsoft's cloud-based application platform for developing, managing and hosting applications off-site. MS AZURE consists of several components like cloud operating system itself, SQL Azure (that provides databases services in the cloud) and .NET services. **Please note that Azure runs on computers that are physically located in Microsoft data centres.** We shall be discussing these data centres a bit later.

Let us now compare the three service models in a tabular form (see Table 1.1):-

Table 1.1: Cloud Computing Service Models

Model	Explanations	Examples
IaaS	Customer gets resources like processing power, storage, network bandwidth, CPU and power. Once the user gets the infrastructure, he controls the OS, data, applications, services, host-based security etc.	AWS-Amazon Web Services, RackSpace, GoGrid, Verizon, IBM, AT &T.
PaaS	Customer is provided the hardware infrastructure, network and operating system to form a hosting environment. User can install his applications and activate services from the hosting environment.	MS AZURE, Google App Engine, Force.com, Informatica-on-demand, Keynote Systems, Caspio, Tibco and WaveMaker.
SaaS	Customer/user is provided an access to an application. He has no control over the hardware, network, security or OS.	SalesForce.com, Google, MS, Ramco and Zoho.

We will discuss about these in detail in the next chapter.

However, cloud services are typically made available via public, private or hybrid cloud. Let us define these and compare them first.

I. **Public Cloud / External Cloud:** In general, it offers services over the Internet and are owned and operated by a cloud provider. For example, email services, social networking sites etc. are all aimed at general public. **Please remember the following points regarding public clouds (or external clouds):-**

1. It offers services to the users on the principle of pay-by-use (explained earlier).
2. They are run by third parties as they need a huge investment to build.
3. In this model, applications from different customers are mixed together on storage systems, cloud servers and other infrastructures within the cloud.
4. The customers can choose a location to deploy the application. This mitigates latency, risks, time and costs for the users.
5. Data control and security are important tasks here.
6. Public cloud is always larger than an organization's private cloud as it provides the ability to scale-up, down and to transfer the risks of an infrastructure from an organization to the cloud provider.
7. It is a better choice if the standardized workload for application is used by several people, or you need to test and develop application code or if you have SaaS applications from cloud vendor. Also it may be a choice if you need incremental capacity i.e. to add compute capacity at peak times or if you are using collaboration projects or even if you are doing an adhoc software development.

8. In this type of cloud, the service providers charge the companies according to their usage.
9. **Please understand that here resources are owned or hosted by the cloud service providers (company) and the services are sold to other companies.** That is,

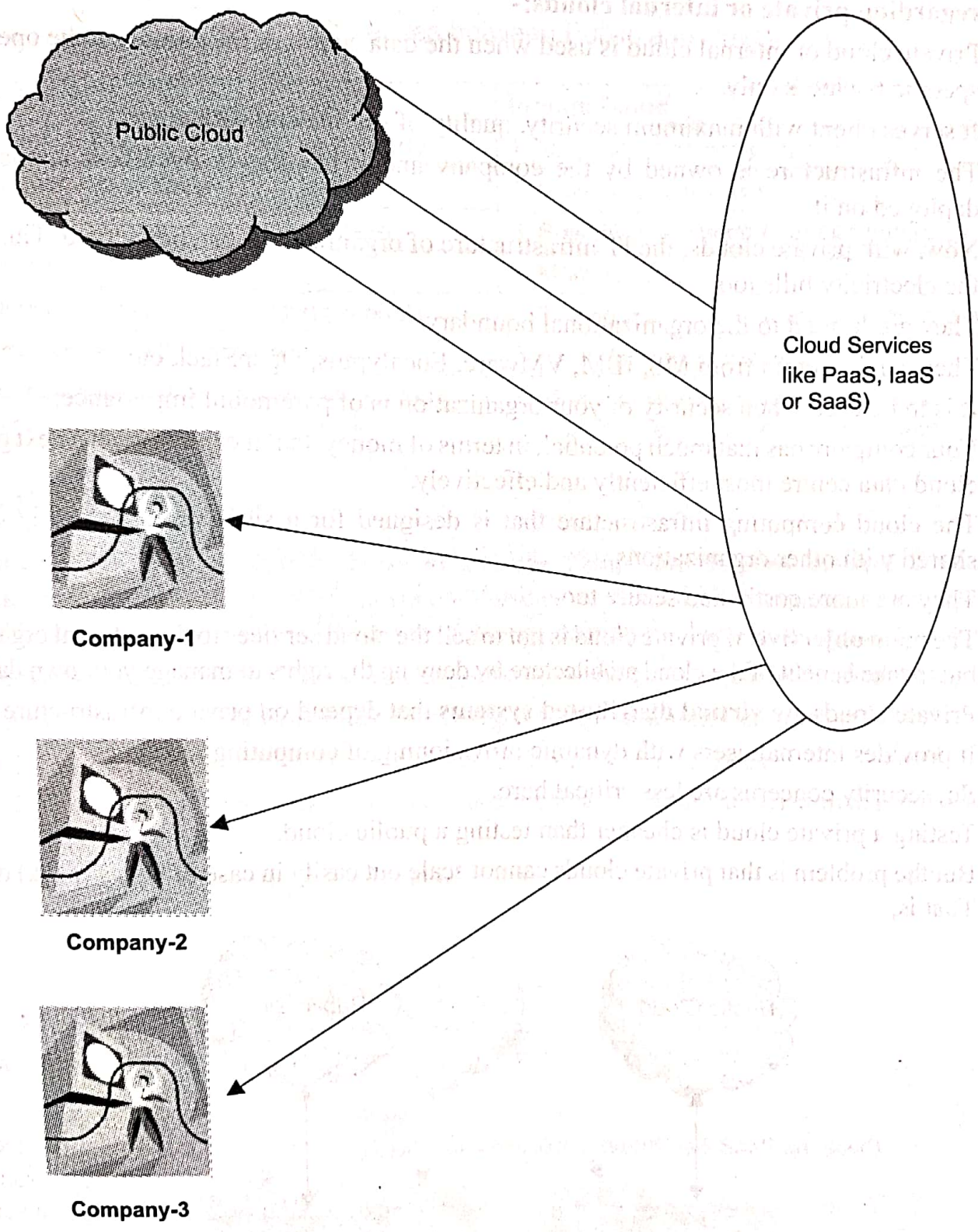


Figure 1.1: Public Cloud

10. No direct connectivity is provided by public cloud service providers like Amazon AWS, MS and Google.

II. Private Cloud / Internal Cloud: Just as public cloud can be thought of as Internet, similarly private cloud can be thought of as the intranet. Please remember the following points regarding private or internal clouds:-

1. Private cloud or internal cloud is used when the data centre of the cloud is to be operated for a specific business only.
2. It serves client with maximum security, quality of service and data control.
3. The infrastructure is owned by the company and it has power over how applications are deployed on it.
4. Now, with private clouds, the IT infrastructure of organizations can be merged. This mitigates the electricity bills too.
5. They are limited to the organizational boundary.
6. They can be set up from MS, IBM, VMware, Eucalyptus, OpenStack etc.
7. It is to be used when security of your organization is of paramount importance.
8. Your company has that much potential, in terms of money, that it can run even a next generation cloud data centre most efficiently and effectively.
9. The cloud computing infrastructure that is designed for a single company only cannot be shared with other organizations.
10. They are more costly and secure too.
11. The main **objective** of private cloud is not to sell the cloud services to the external organizations but to take benefit of the cloud architecture by denying the rights to manage your own data centre.
12. Private clouds are **virtual distributed systems** that depend on private infrastructure only.
13. It provides internal users with dynamic provisioning of computing resources.
14. So, security concerns are less critical here.
15. Testing a private cloud is cheaper than testing a public cloud.
16. But the problem is that private clouds cannot scale out easily in case of heavy (peak) demands. That is,

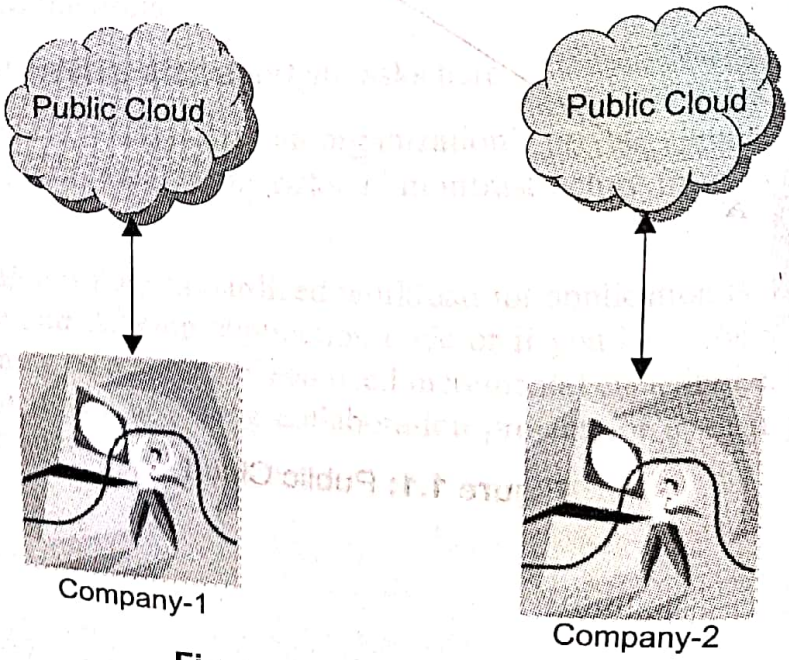


Figure 1.2: Private Clouds

To cope with all these problems, the only solution is to combine both public and private clouds to get a hybrid cloud.

But before we discuss further about hybrid clouds, let us tabulate the differences between public and private clouds first.

Table 1.2: Differences between Public and Private Clouds

Public Cloud	Private Cloud
1. Its owner is the cloud provider or 3rd party.	1. Its owner is an organization only.
2. It involves lesser costs.	2. It involves more costs.
3. Scalability is on demand and unlimited.	3. Scalability is limited to the infrastructure installed.
4. Lesser security.	4. More security.
5. Testing it is difficult as everything is public.	5. Testing them is easier as it is a private cloud.
6. Performance is difficult to obtain.	6. Its performance is guaranteed.
7. Less management and control is needed as it works on the concept of virtualization.	7. More management and control is needed as it has a higher level of control over resources.

Variant of Private Cloud

Community cloud is a type /variant of Private Cloud but it goes beyond a business or an organization. It is implemented when several businesses have similar requirements and perspective to share. They are accessible to members of a particular community but are not available to general public.

For example, branches of educational organizations and government, military and industry suppliers.

Just keep in mind the following points regarding community clouds:-

1. They are needed when there is a necessity for general services.
2. By creating virtual machines from the machines that are under-utilized, a community cloud can be established.
3. This is shown in figure 1.3. That is,

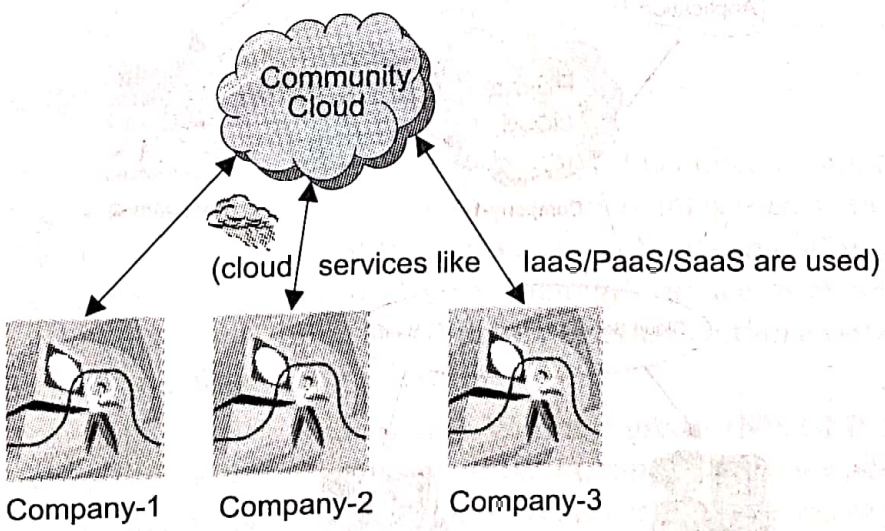


Figure 1.3: Community Cloud

Let us now study hybrid clouds.

Hybrid Clouds/ Mixed Clouds: The focus was to make **cloud more secure** and yet to provide the same services and resource sharing. Then cloud infrastructures naturally evolved to what is known as **hybrid cloud.** Hybrid/mixed clouds can be explained with the help of an equation also:-

Hybrid Cloud = Public Cloud + Private Cloud

This means that now you can take the benefits of both internal network storage as well as public data cloud that can be accessed from anywhere in the world using Internet. Using broadband services along with the cloud the companies can connect to larger networks to make use of available resources. There is no need of a huge computer now to handle complex tasks like database indexing. **Please remember the following points regarding hybrid clouds:-**

1. Better scalability and reliability as it allows companies to move from public to private clouds.
2. Better sharing of resources on demand.
3. It is an approach of extending the infrastructure beyond the organizational firewall with more security.
4. More important applications are stored on hybrid but lesser important applications and data are stored on a public cloud.
5. **An example** of hybrid usage is like a patient's record or some financial matters that cannot be put on public cloud servers as it is sensitive information. They can make use of hybrid clouds.
6. This type of cloud is used during **cloud bursting.** In this case, an organization generally uses its own computing infrastructure but in case of higher load requirements, the company can access clouds. **Please understand that this means that the company using hybrid cloud can manage an internal cloud/ private cloud for its general usage and it can migrate the entire application to the public cloud during heavy peak hours.**
7. This can be shown diagrammatically also as in figure 1.4.

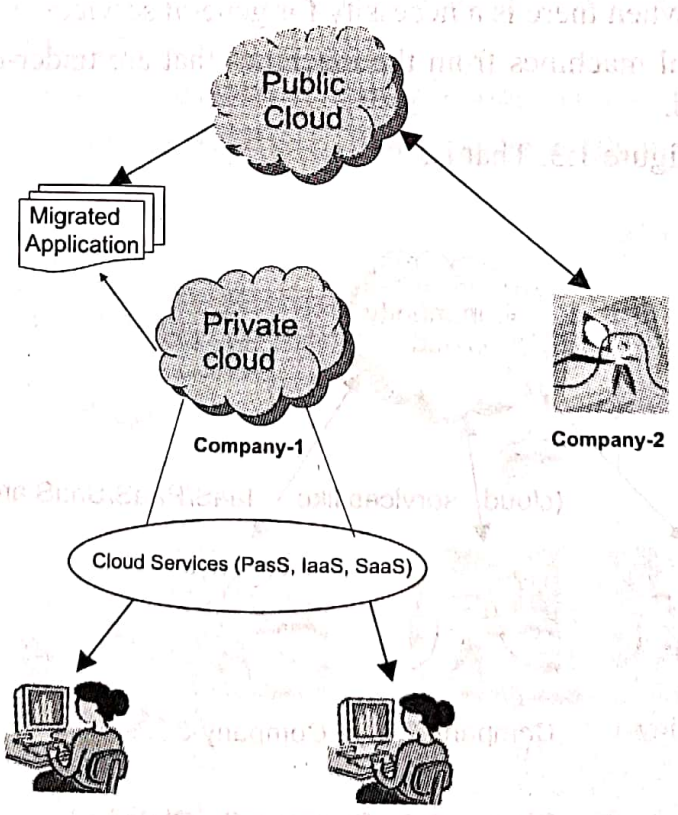


Figure 1.4: Hybrid Clouds

8. The purpose is to lease public cloud services when private cloud capacity is not sufficient.
9. B. Sotomayor et al. quotes that "a hybrid cloud takes shape when a private cloud is supplemented with computing capacity from public clouds. **And this method of temporarily renting a capacity to handle spikes in load is known as cloud bursting."**
10. We can combine either private cloud with public cloud or even public with the community clouds.
11. Let us now compare public cloud and community clouds:-

Table 1.3: Public Cloud versus Community Cloud

Public Cloud	Community Cloud
1. Any user who signs up can use a public cloud.	1. Only users within a particular industry segment/ group can use it. These users have common objectives.
2. It uses pay-per-usage model which is expensive.	2. It is more expensive as the site is customized for use by the company group.
3. Security is less.	3. More secure as limited users have accounts.
4. The provider is not known to the consumer.	4. The provider is not known to the consumer.
5. No objective of compliance to regulations by an organization.	5. Objective is to have a compliance to regulations by an organization.

12. Similarly, we can compare a private cloud and a hybrid cloud:-

Table 1.4: Private Cloud versus Hybrid Cloud

Private Cloud	Hybrid Cloud
1. It is fully set-up by a company.	1. It uses the resources of a public provider on a pay-per-use model.
2. Performance is limited.	2. More scalable and elastic as it can use public resources to meet load spikes.
3. Lesser flexible.	3. More flexible as it can develop and test services on a public cloud and later deploy then on a private cloud.
4. It is costlier.	4. It is cheaper.

1.10 CLOUD COMPUTING ENVIRONMENTS

As per DELL's report 2012, cloud is not just a technology only. It is rather a corporate strategy based on business outcomes. The real benefit of cloud comes when it is integrated with IT and leveraged across all environments. **Please understand that the service consultants should work to understand the business and help customers to plan, build, deploy, manage and access clouds that meet their specific needs. Also note that need is to create virtualization or visualization environments, develop and implement the application on cloud platforms.**

The NIST Cloud Computing Standards Roadmap Working group (NIST-SP 500-292 std.), an agency of the US Department of Commerce, has surveyed the existing standards landscape for security, portability and inter-operability standards/ models/ studies/ use cases etc., relevant to cloud computing.

The overview of the Reference Architecture of cloud lists five major actors: Cloud Consumer, Cloud Provider, Cloud Broker, Cloud Auditor and Cloud Carrier

[Source: NIST Executive Summary]

We have already seen the role of cloud provider. But a cloud auditor has the job of security and privacy audit. A cloud broker has the job of service intermediation, service aggregation

NIST also indentifies three deployment models-public cloud, private cloud and hybrid clouds. The main differences between each are based on how exclusive the computing services and resources are made to a cloud consumer.

1.11 CLOUD SERVICES REQUIREMENTS

We list some of the best practices that every successful cloud computing platform should follow:-

1. **Better Security:** Providing best security at every level.
2. **Better Transparency:** Providing transparent, real-time, accurate service performance and information.
3. **True Multi-tenancy:** Deliver maximum scalability and performance to customers with a true multi-tenant architecture.
4. **Proven Scale:** Support millions of users with proven scalability.
5. **Better Performance:** Deliver consistent, high speed performance globally.
6. **Better Disaster Recovery:** Protect customer data by running the service on multiple geographically dispersed data centres with extensive back-up, data archive and failover capabilities.
7. **Better Availability:** Equip world-class facilities with proven high-availability infrastructure and application software.
8. **Resource Reservation:** Cloud should assure that at the needed time the resources or the services will be positively available to the customer.
9. **Self-Service portal:** cloud should offer a self-service facility to its customers. Just as in Mc D. If there is no one to serve you a pizza then you opt for self-service. Similarly, the cloud users should be able to manage using a **web-based self-service portal.**
10. **Dynamic Resource Allocations:** It should be possible by the cloud to do resource distribution and re-distributions easily. This dynamic resource allocation and de-allocations will illustrate the efficiency of SaaS (Software-as-a-Service).
11. The *resource distribution and actual cloud utilization* must be reported in an **accounting database.**
12. *Dynamic* workload management, resource automation and metering of these resources are also the desired essentials of cloud.

1.12 CLOUD AND DYNAMIC INFRASTRUCTURE

We define dynamic infrastructure as **an information technology paradigm concerning the design of data centres so that the underlying hardware and software can respond dynamically to changing levels of demand in more fundamental and efficient ways than before.** *This paradigm is also known as Infrastructure 2.0 and Next Generation Data Centre.*

Principle (of Dynamic Infrastructures): **"To leverage pooled IT resources to provide flexible IT capacity, enabling seamless, real-time allocation of IT resources in line with demand from business processes".**

And this is achieved by using server virtualization technology to pool computing resources wherever possible and allocating these resources on-demand using automated tools. This provides load balancing as it avoids under-utilization of resources too.

For example, Flex Frame for SAP is a server-level Dynamic Infrastructure.

Eg2. Flex Frame for Oracle Solutions by Fujitsu Siemens Computers.

Fujitsu defines that **Dynamic Infrastructures enable customers to assign IT resources dynamically to services as required and to choose sourcing models which best fit their businesses. This brings IT flexibility and efficiency to the next level.**

IBM defines **that a Dynamic Infrastructure integrates business and IT assets and aligns them with the overall goals of the business while taking a smarter, new and more streamlined approach to helping improve service, reduce cost and manage risk.**

The approach of these is to dynamically assign servers to applications on demand, levelling peaks and enabling companies to maximize the benefit from their IT investments (ROI-Return-on-Investment). **Please note that if an enterprise switches to Dynamic Infrastructures then it also reduces costs, improves quality-of-service and make more important use of energy by reducing the number of standby or under-utilized machines in their data centres. Also note that these Dynamic Infrastructures provide for failover from a smaller pool of spare machines.** By reducing redundant capacity, organizations are enabled to make more efficient use of their IT budgets and devote greater proportions of their budget to physical and virtual production servers.

Dynamic Infrastructures may also be used to provide security and data protection when workloads are moved during migrations, provisioning, enhancing performance or building c0-location facilities.

Benefits of Dynamic Infrastructures:-

- Enhancing performance.
- Scalability.
- System availability and uptime.
- Better server utilizations.
- Performing routine maintenance of physical or virtual systems.
- Mitigating interruption to business operations.
- Reducing IT costs.
- Providing business continuity.

For networking companies, Infrastructure 2.0 **refers to the ability of networks to keep up with the movement and scale requirements of new enterprise IT initiatives, like virtualization and cloud computing.** As per the reports of big companies like Cisco, F5 Networks, and Infoblox, network automation and connectivity intelligence between networks, applications and endpoints will be required to reap the full benefits of virtualization and cloud computing. This needs network management and infrastructure to consolidate, enabling higher levels of dynamic control and connectivity between networks, systems and endpoints.

Uses of Dynamic Infrastructures

Dynamic Infrastructures make use of the intelligence gained across the network. By design, every dynamic infrastructure is service-oriented. It can use alternative sourcing approaches also like cloud computing to deliver new services with agility and speed.

Applications of Dynamic Infrastructures

1. Transportation companies can optimize their vehicle's routes leveraging GPS and traffic information.
2. Technology systems can be optimized for energy efficiency, managing spikes in demand and ensuring disaster recovery readiness.
3. Utility companies can reduce energy with a 'smart grid'.

Gartner et al. reports that:-

1. Virtualized applications can reduce the cost of testing, packaging and supporting an application by 60% and that they reduced overall TCO by 5% to 7% in our model.
2. **Green issues** are the primary driver in 10% of current data centre outsourcing and hosting initiatives. **Cost reduction initiatives** are a driver of 47% of the time and are now aligned well with **green goals.** Also **combining these two means** that at least 57% of data centre outsourcing and hosting initiatives are driven by green.
3. Also it reports that by 2013, more than 50% of midsize organizations and more than 75% of large enterprises will implement layered recovery architectures.

1.13 CLOUD ADOPTION

No doubt, a company can adopt cloud as it has many benefits but at the same time it has some drawbacks also. Why organizations are today moving towards cloud computing? Some of the benefits of this movement are as follows:-

1. Reduced organizational cost (as pay-as-you-go model is used).
2. Better storages.
3. More automation.
4. Better flexibility.
5. Better mobility.
6. Better IT personnel usage.
7. More security.
8. Better investment.
9. Better service.
10. No need of software installations.
11. Shorter deployment times needed now.
12. Better CRM-Customer Relationship Management.

Cloud allows businesses and people to avail the services and information available from any place at any time as long as the system is in the network. Practically speaking, we all use different types of cloud services in different ways in our daily life. **For example,** Gmails, Pandora (music website) etc.

Cloud should be innovative too for the cloud actors, as discussed earlier also. Cloud adoption follows a life cycle:-

Phase-1: (Evaluation) Evaluate cloud challenges, prospects and its impact on the markets.

Phase-2: (Plan) Build up a cloud strategy, develop and implement security measures, plan about which service to implement in a company (out of SaaS, IaaS or PaaS).

Phase-3: (Adopt) After planning, we can think of cloud adoption keeping in mind the cloud deployment architectures and identify the servers to understand its implementation.

Phase-4: (Optimize) Deliver online lessons after every cloud deployments in an organization. Draw timeline charts and locate skilled people before you deploy a cloud.

Please understand that the selection of cloud computing strategies for an organization are very critical issues. The question is to see that if a company adopts a cloud technology then will it give any value to the present business? How much of efforts and risks involved on clouds implementation? Can we implement cloud on only few selected area of business? How can we control the shifting of an organization from present technology to cloud computing? **Also understand that the answer to this is that the organization should make a decision to implement cloud on the basis of three factors i.e. scalability, availability, cost and convenience.** The term CLOUD DATA CENTER (CDC) is also in the cloud computing literature. This CDC may be an internal, external or federated provider of infrastructure, platform or software services.

However, an optimal decision cannot be always established for all cases. This is so because the types of resources (infrastructure, storage, software) obtained from a CDC depend on the size of the organization, understanding of IT impact on business, workloads, flexibility and available money and resources for testing. The objective is to have scalability-driven, availability-driven, market-driven and convenience-driven strategy.

1.14 ISSUES AND CHALLENGES IN CLOUD COMPUTING

Some of the major cloud issues and challenges are as follows:-

1. **Cloud security** is of paramount importance today. It is so because data is shared on cloud and this makes the data as well as the information more vulnerable to cyber cloud attacks. *Ambrust et al. quote that current cloud offerings are essentially public...exposing the system to more attacks."*
2. Not having **better quality services** in cloud can make organizations decline.
3. Cloud should provide a **better inter-operability and portability** as industry heavily needs it.
4. **Resource sharing and complex data** on net needs sufficient bandwidth. More costs are involved. And this is not acceptable to many companies.
5. Cloud is very much regular in failures. **Cloud Reliability means a failure-free operation of the cloud.** And this happens to be a very big issue.
6. **Parallel data access** by multiple customers at all times and mix of hardware types will make the data protection in any cloud very complex. *Data must be made redundant/ duplicated/ replicated and stored at different locations* and that it should be easily accessible. But having data redundancy means also having a check on data location, latency, user workload, backup, report generations, application testing etc. Thus, it is not an easy task.
7. **Cloud disaster recovery** is very significant when we evaluate cloud providers.
8. An issue also arises when you **back up the cloud data.** Like if you download data on your pen drives, you need to pay for the bandwidth. Another issue arises that you need to save the data as a better place where security is more.
9. **Data recovery** to a cloud-based service site is tough, slow and error prone. This happens more if you upload a large amount of data to the cloud over a WAN connection.

10. Consumers of cloud services are not aware of where the primary or replicated **data copies reside**. The user data is usually distributed across many data-centres. Also a company's cloud data may not reside within the operating or registered country.
11. **Service reliability** is also a bigger challenge like hardware and software components being heterogeneous, connectivity over multi-vendor WAN, user-friendliness etc.
12. Several users work simultaneously on different data sets in the cloud. So, the data is split or fragmented into many pieces and stored in various storage locations. This is called as **data fragmentation.** This data spreading leads to inefficiency and reduces the Read/Write performances.
13. **Data integration** is itself a challenge as the data that has been distributed at different data-centres cannot be easily integrated.
14. Cloud data can be accessed only when both the user and the services are online. This needs bandwidth which further depends on the amount of workload.
15. Data transformation is also an issue. **The process of converting cloud data's format into a format that can be easily used by other cloud applications is known as data transformation.** This is an issue because the transformed data may not be compatible with different environments. Also data transformation creates multiple copies and managing these is a big issue.
16. Cloud standardization is also an issue today. *The Cloud Computing Interoperability Forum (CCIF) was formed by companies like Intel, Sun and Cisco, in order to enable a global cloud computing ecosystem whereby organizations are able to seamlessly work together for the purposes for wider industry option of cloud computing technology."* As another standard organization, *Unified Cloud Interface (UCI)* was formed by CCIF that aims *to create a standard programmatic point of access to an entire cloud infrastructure. Also, in Open Virtual Format (OVF) the aim is in packing and distribution of software to be run on Virtual Machines so that virtual appliances can be made portable.* Thus, efficient management of cloud service providers means efficient management of virtualized resource pools. **Please understand that the multi-dimensional nature of virtual machines complicates the process of finding a good mapping of virtual machines onto available physical hosts while maximizing user utility.** Management of this data is also an issue.
17. Data centres also consume huge amount of electricity. *As per the report published by HP, "100 server racks can consume 1.3 MW of power and another 1.3 MW are required by the cooling system. This costs US dollars 2.6 million per year."* Besides this monetary cost, data centres also impact the environments in terms of CO_2 emissions from the cooling systems.
18. The need is to optimize application performance, so, dynamic resource management can also improve utilization and thus **reduce energy consumption in data centres.** And this can be achieved by consolidating workload onto smaller number of servers and turning off idle resources.

1.15 ADVANTAGES AND DISADVANTAGES OF CLOUD COMPUTING

Let us first of all see the **advantages** of cloud computing:-

1. **Resource Management:** When you deploy your application and services to the Cloud, It provides the necessary virtual machines, network bandwidth and other infrastructure resources. **Please understand that if machines go down for hardware updates or**

because of unexpected failures, cloud locates new virtual machines for your application automatically. Because you will *only pay for what you use*, so you can start with a smaller investment. Doing so avoids incurring the typical upfront costs required for an on-premises deployment. This can be especially useful for smaller companies. *In an on-premises scenario*, small organizations might not have the data centre space, IT skills or hardware skills necessary to deploy their applications successfully. **For example,** the automatic infrastructure services that Microsoft Azure provides offer a low barrier of entry for application deployment and management.

2. **Dynamic Scaling: The process of scaling-out and scaling back your application depending on resource requirements is known as dynamic scaling.** It is also known as **elastic scaling.** With cloud services, you create roles that work together to implement your application logic. **For example,** one web role could host the ASP.NET front-end of your application. One or more worker roles could perform necessary background tasks. **One or more virtual machines hosting each role are called as role instances.** Requests are load balanced across these instances. **Please understand that in this scenario, as resource demands increase, you can provision new role instances to handle the load. Also note that when demand decreases, you can remove these instances so that you don't have to pay for unnecessary computing power.** There are also options for automatically scaling up and down based on pre-defined rules and policies. This is very different from an on-premises deployment where you must over-provision hardware to anticipate peak demands if you want more control over automatic scaling than he platform provides. *It is also possible to scale-out websites and virtual machines.* If your application requires fluctuating or unpredictable demands for computing resources, cloud like MS AZURE allows you to easily adjust your resource utilization to match the load.
3. **High Availability and Durability:** Cloud vendors like MS AZURE, provides a platform for applications that can reliably store and access server data through its storage services. Cloud applications like MS AZURE have MS AZURE-SQL DATABASE for the same purpose. It ensures high availability of compute resources. For websites, you can meet the requirements of Service Level Agreement (SLA) with only a single instance. **Please note that for cloud services and virtual machines, you can meet the SLA requirements by having at least two instances per role or machine type. For virtual machines,** the instances must be interchangeable and load balanced. It is the cloud vendor like MS AZURE that monitors the actual hardware that hosts these virtual machines and instances. **Also note that vendor like MS AZURE is able to respond quickly to hardware restarts or failures by deploying new instances or moving application code and processing to other working hardware.** The cloud vendors like AZURE ensures high availability and durability for data stored by one of its storage services. MS AZURE storage services *replicate all data to at least three different servers. By default,* this storage also replicates to a secondary MS AZURE region. Similarly, MS AZURE SQL DATABASE replicates all data to guarantee availability and durability.
4. **Highly Available Services:** Say, there is an online store that is deployed in MS AZURE. **Note that as this online store is a revenue generator, so it is important and critical to stay it running.** To achieve this objective, AZURE data centre performs service monitoring and automatic instance management. The online store must also stay responsive to customer demand. The **elastic scaling ability of MS AZURE accomplishes this. During peak shopping times, new instances can come online to handle the increased usage.** Also, the online store must not lose orders. **Please understand that both MS AZURE and AZURE SQL DATABASE provide highly available and durable storage options to hold the order**

details and state throughout the order life cycle. For the highest level of availability, you can deploy the same application to multiple MS AZURE **regions. Also note that it is possible to design a service that remains available even if an entire MS AZURE region experiences a temporary failure.** Doing this requires proper synchronization architecture and procedures for routing users.

5. **Periodic Workloads:** Some applications like a demo or a utility application that you want to make available only for several days or weeks. They need not be run continuously. MS AZURE allows you to easily create, deploy and share that application. **Note that once this purpose is achieved, you can remove the application and you are charged only for the time it was deployed.**

   Case Study: *Consider a big company that runs complex data analysis of sales numbers at the end of each month. Although processing-intensive, the total time required to complete analysis is at most two days. In an on-premises scenario, the server required for this work would be under-utilized for the majority of the month. In MS AZURE, the business would pay only for the time the analysis application is running in the cloud. Assume that the application architecture is designed for parallel processing. The scale out features of MS AZURE would allow the company to create large numbers of worker role instances or virtual machines. Working together these can complete more complex work in less time. In this case study, you should use code or scripting to automatically deploy the application at the appropriate time every month.*

   Note: Remove the deployment as just suspending the application is not sufficient, as this will avoid charges for compute time.

6. **Unpredictable Growth:** All businesses have a goal of rapid and sustainable growth. But growth is not easy to achieve if traditional on-premises model is used. If you do not meet the expected growth even after spending huge dollars then it means you have spent on maintaining underutilized hardware and infrastructure. But if growth happens more quickly than expected, you might be unable to handle the load. This results in lost business and poor customer experience. For smaller companies, there might not even be enough initial capital to prepare for or keep up with rapid growth. **For example,** say there is a small sports news portal (specialized part of website) that makes money from advertising. **Here, the amount of revenue is directly proportional to the amount of traffic that the site generates.** In this case, initial capital for the venture is limited. Also a company does not have the money required to set up and run its own data-centre. But by designing the website to run on MS AZURE, the company can easily deploy its solution as an ASP.NET application. The application will use MS AZURE SQL DATABASE for relational data and blob storage for pictures and videos. **Please understand that if the popularity of the website grows dramatically, the company can increase the number of web role instances for its front-end. The company can also increase the size of the AZURE SQL DATABASE service.** The blob storage has an in-built scalability features within MS AZURE. **Also understand that if business decreases, the company can remove any unnecessary instances.** *Also because its revenue is proportional to the traffic on the site, MS AZURE helps the company to start small, grow fast and reduce risk.* If you use MS AZURE in your company, then you have full control to find out how you can manage your computing costs. You can decide to implement **automatic scaling** through the use of the AUTOSCALE feature or through the use AUTOSCALING APPLICATION BLOCK. This can add or remove instances based on custom rules (pre-determined amount).

For example, you might have 8 instances during business hours and 4 instances during non-business hours. *You can also keep the number of instances constant and only increase them manually through the web portal as demand increases over time.* MS AZURE provides you the flexibility to make the decisions that are right for your business.

7. **Workload Spikes:** This workload pattern also works on the principle of **elastic scale,** as explained earlier. Re-consider the example of sports news portal once again. Now, even as its business is steadily growing, **there is still a possibility of temporary spikes or bursts of activity. For example,** assume that another popular news outlet refers to the site. **This means that the number of visitors to the site could dramatically increase in a single day.**

   Example 2, consider a service that processes daily reports at the end of the day. When the business day closes, each office sends in a report that the company headquarters processes. **Please note that because the process is only active a few hours each day, it is also a candidate for elastic scaling and deployment. Also note that MS AZURE is suitable for temporarily scaling out an application to handle load spikes and then scaling back after the event has passed.**

8. **Infrastructure Offloading:** It has been observed that most of the cloud scenarios make use of elastic scaling of MS AZURE. Also, even applications that show steady workload patterns will do a significant cost savings using MS AZURE cloud services. **Please note that it is difficult and costlier to manage your own data-centre as it is costlier in terms of energy, people, skills, hardware, software licensing and facilities. Also note that it is difficult to understand how costs are tied to individual applications.** MS AZURE, however, makes those costs to minimum and more and more transparent too.

   For example, MS AZURE VIRTUAL MACHINES (VM) and VIRTUAL NETWORK (VN) provide an easier method of *migrating on-premises servers and networks to the cloud. But transitioning on-premises applications to cloud services or websites also alleviates the pressure on the on-premises data-centre. MS AZURE and not these data centres are actually responsible for providing the required computing and storage resources for those applications. also MS AZURE provides a pricing calculator for understanding specific costs. It also provides a TOTAL COST OF OWNERSHIP (TCO) calculator for estimating the overall cost reduction that cloud occur by adopting MS AZURE.*

9. Resource management, dynamic scaling and high availability and durability are some of the main advantages of running applications in cloud.
10. To ensure the highest levels of availability, for managing unpredictable growth and for handling workload spikes, MS AZURE is preferred.
11. Quick service, safe and secure service, multiple user access, development environment and unlimited storage are some of its benefits.
12. Lesser operational issues, more reliability, more flexibility, innovative and easier communication among teams and customers.

Let us now see the **disadvantages** of cloud computing:-

1. Cloud services are more complex than traditional services.
2. Cloud based software may not be a silver bullet for customers using them or companies who are deploying them.
3. A company that uses cloud and its services will certainly rely on technology. So, cloud is technology-based technology and if technology fails somewhere then cloud will also fail.

4. Data on cloud is quite insecure and needs to be tested extensively.
5. Since data on cloud is made redundant, so there is a need of redundancy tool.
6. There is no physical back-up.
7. On one hand cloud has increased the business opportunities while on the other hand it has disrupted several, well-established IT businesses.
8. Transitions to the cloud services must be cautious and calculated.
9. For critical applications, factors like data security, compliance, availability and performance are also to be considered.
10. Standards for cloud deployment are still in their infancy stage. This makes portability from one provider to another quite complex and unpredictable.
11. The cloud environment itself requires a strong foundation of best practices in software development, software architecture and service management foundations.
12. Cloud uses data centres that consume large amounts of electricity. As per the HP report, 100 server racks can consume 1.3MW of power and another 1.3MW are required by the cooling system. This costs $2.6 million per year. Also these data centres impact the environment in terms of CO_2 emissions from the cooling systems. Thus, the need is to minimize energy consumption in data centres.

1.16 APPLICATIONS OF CLOUD COMPUTING

Cloud computing has several applications in IT today. Some of them are as follows:-

1. Cloud can be used with web and mobile applications easily as these applications are easily scalable.
2. Cloud testing can be done by using constantly configured resources, lower expenditure and lesser release cycles.
3. Gaming applications can be easily implemented in clouds.
4. ECG analysis can be easily done in clouds.
5. To study protein structures.
6. For satellite image processing.
7. Cloud takes CRM (Customer Relationship Management) and ERP (Enterprise Resource Planning) to next level.
8. Social networking is very common now-a-days. So, social cloud architecture is presented in literature now. In social cloud, services can be mapped to particular users through Facebook identification.

SUMMARY

Cloud computing has deep ramifications in almost every field now. Cloud Engineering is not far now. Cloud analysis, Cloud design, Cloud coding, Cloud testing and Cloud maintenance are all the current hot branches of cloud. Mobile cloud computing, cloud security and cloud energy efficiency are some of the potential areas of research today. The researches in cloud computing field has changed the way IT services are invented, developed, scaled and maintained. *Information and services* may be programmatically aggregated. Both act as building blocks of complex compositions called as **service mashups.** Many service providers like Amazon, Facebook and Google have made their service APIs

public by using standard protocols like SOAP and REST. So, a fully functional web application can be developed easily just by gluing pieces with few LOC (Lines of Code).

MULTIPLE CHOICE QUESTIONS [MCQs]

1. In cloud computing,
   (a) Grid Computing is only used.
   (b) The computing process may run on one or many connected computers at the same time, utilizing the concept of virtualization.
   (c) It is just a client-server model.
   (d) None of the above.
2. The main advantages of cloud computing are-
   (a) Shared resources.
   (b) Improved Manageability.
   (c) Standardisation.
   (d) All of the above.
3. Which of the following is a cloud-based application platform for developing, managing and hosting applications off-site-
   (a) Solaris.
   (b) Linux.
   (c) Windows Azure.
   (d) None of the above.
4. Combining together of information and services on the web programmatically so as to form complex compositions are known as-
   (a) Service mashups.
   (b) Data mashups.
   (c) Information mashups.
   (d) None of the above.
5. Systems that rely on monitoring probes and sensors and do self-management are known as-
   (a) Automatic systems.
   (b) Autonomic systems.
   (c) Atmospheric systems.
   (d) None of the above.
6. A combination of public and private clouds is known as-
   (a) Community Cloud.
   (b) Private Cloud.
   (c) Hybrid Cloud.
   (d) None of the above.
7. A kind of private cloud that goes beyond a business or an organization is known as-
   (a) Hybrid Cloud.
   (b) Community Cloud.
   (c) Mobile Cloud.
   (d) None of the above.

8. The Mean Time Between Failures (MTBF) is basically governed by the-
   (a) Number of logical nodes.
   (b) Number of physical nodes.
   (c) Number of logical and physical nodes.
   (d) None of the above.
9. An approach that declares that the infrastructure is capable of supporting the resource demands is known as-
   (a) Project Planning.
   (b) Capacity Planning.
   (c) System Planning.
   (d) None of the above.
10. AWS stands for-
   (a) Amazon Wide Software.
   (b) Amazon Web Service.
   (c) Amazon Web Site.
   (d) None of the above.
11. Cloud uses which model for resource utilization-
   (a) Pay-by-use.
   (b) See-by-use.
   (c) Play-by-use.
   (d) None of the above.
12. A binding contract where service companies agree on a specified level of service (uptime) is known as-
   (a) Service Level Agreements.
   (b) Software Level Agreements.
   (c) Software Requirements Specification.
   (d) None of the above.
13. The main role of system administrator is-
   (a) To make sure that the uptime is constant.
   (b) To make sure that both front-end and back-end work.
   (c) To gives rights and privileges to users.
   (d) None of the above.
14. Three service models as defined by NIST are-
   (a) SAAS, BAAS, PAAS.
   (b) SAAS, PAAS, IAAS.
   (c) AAS, PAAS, LAAS.
   (d) None of the above.
15. Grid computing, peer-to-peer architecture and client-server architecture are some forms of-
   (a) Autonomic computing.
   (b) Cluster.
   (c) Distributed computing.
   (d) HPC (high performance computing).

16. A situation in which an organization uses its own computing infrastructure is known as-
    (a) Cloud bursting.
    (b) Cloud showering.
    (c) Cloud computing.
    (d) None of the above.
17. A web interface that allows customers to access virtual machines is-
    (a) Amazon EC2.
    (b) Amazon MC2.
    (c) Amazon PC2.
    (d) None of the above.
18. The cloud operating system built on top of Microsoft data centre's infrastructure is-
    (a) MS AZURE.
    (b) AWS.
    (c) SALESFORCE.COM.
    (d) None of the above.
19. A relational database service hosted on MS AZURE is-
    (a) SQL Azure.
    (b) SQL SERVER.
    (c) SQL QUERY.
    (d) None of the above.
20. The idea of being able to utilize reusable components across a provider's network is a-
    (a) Service.
    (b) Software.
    (c) Hardware.
    (d) None of the above.

ANSWERS

1. *b*	**2.** *d*	**3.** *c*	**4.** *a*
5. *b*	**6.** *c*	**7.** *b*	**8.** *b*
9. *b*	**10.** *b*	**11.** *a*	**12.** *a*
13. *a*	**14.** *b*	**15.** *c*	**16.** *c*
17. *a*	**18.** *a*	**19.** *a*	**20.** *a*

CONCEPTUAL SHORT QUESTIONS WITH ANSWERS

Q1. Define what is a duty cycle in cloud computing?

Ans. 1 As we know that cloud data centres are having several servers. This increases the energy consumptions. These servers are designed to be overloaded and overdesigned for better reliability. They must support redundancy, error-correcting RAM, parity disk drives, (n + 1) power supplies and so on. All this needs energy to cool and power it, light the data centre, provide security etc. **And this concept of purposely overdesigning a true server for a constant reliable operation is known as duty cycle.**

Q2. What is Eucalyptus?

Ans. 2 Eucalyptus is open source software that implements Amazon Web Services compatible cloud which is cost-effective, flexible and secure. Eucalyptus is an acronym for '*Elastic Utility Computing Architecture for Linking Your Programs to Useful Systems*'. Its development started in 2003, at Rice University in US as a research project. In 2014, it was acquired by HP. They had their own cloud offerings with the name HPE Helion banner. Now both have combined as **HPE Helion Eucalyptus.** It can be easily deployed in existing IT infrastructures to enjoy the benefits of both public and private cloud models. **Eucalyptus** provides an Infrastructure as a Service (IaaS). The main benefit is that it provides easy and secure deployment. The private cloud is deployed in the premises of the enterprise. It can be accessed by the users over the intranet. So, vital data remains secure from outside intrusions. It also provides AWS (Amazon Web Services) APIs. Thus, at any time, consumers can easily migrate or load balance their sensitive data into the Amazon public cloud. So, they need not worry about the elasticity of their network.

Q3. Name some companies that offer cloud service development.

Ans. 3 Some of the companies offering cloud services are as follows:-

(a) Amazon.
(b) Google App Engine.
(c) IBM.
(d) Salesforce.com
(e) MS AZURE.

Q4. Mention some cloud services development tools.

Ans. 4. Some of the cloud services development tools are as follows:-

(a) Mosso.
(b) Nirvanix.
(c) Skytap.
(d) StrikeIron.
(e) 3tera.
(f) 10gen.
(g) Cohesive Flexible Technologies.
(h) Joyent.

Q5. List some issues associated with cloud.

Ans. 5 Some of the issues associated with cloud are as follows:-

(a) Technical issues.
(b) Business model issues.
(c) Internet issues.
(d) Security issues.
(e) Compatibility issues.
(f) Social issues.

Q6. What is a Blog?

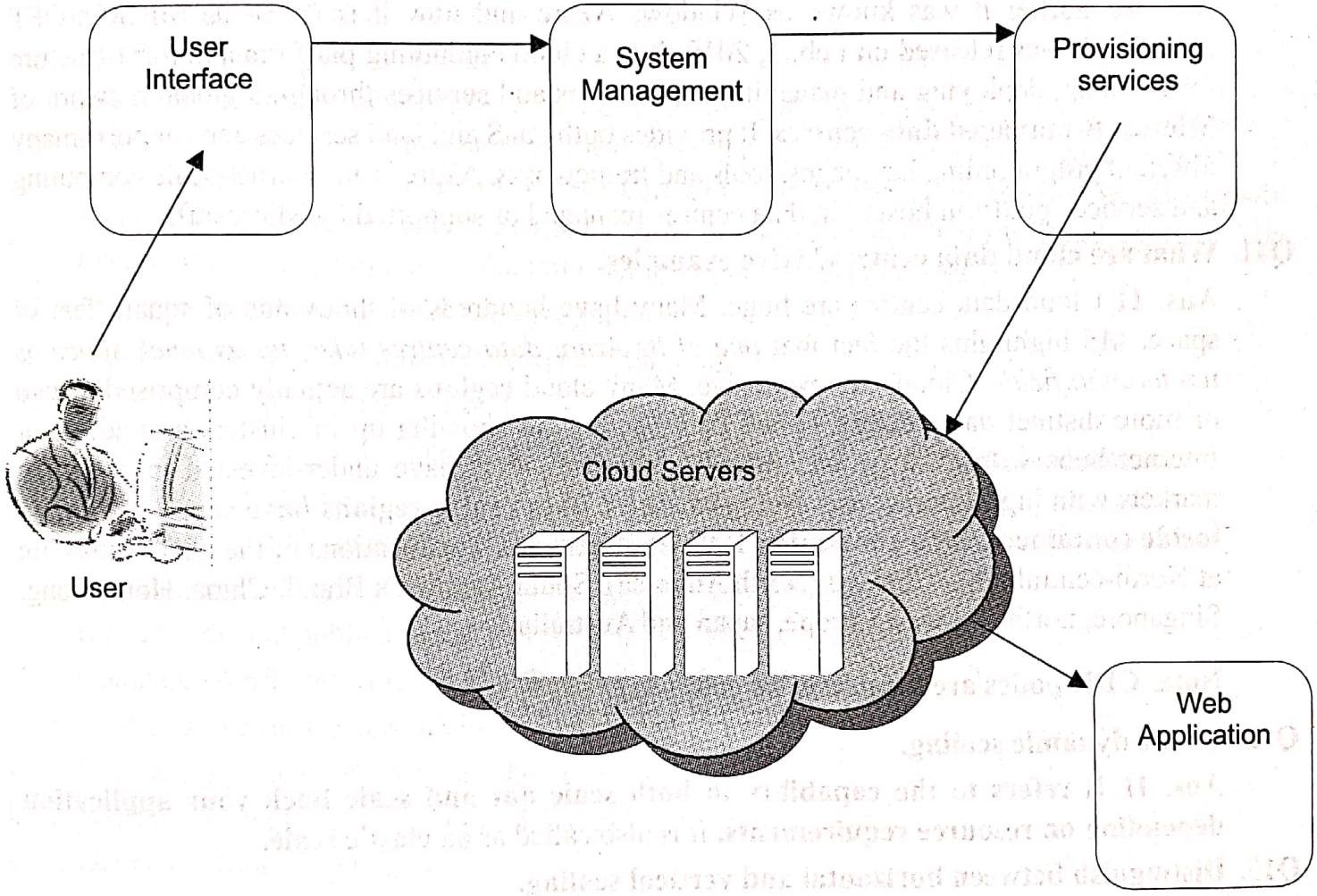
Ans. 6 A blog is a personal journal put up on the net/ web log. It focuses on one topic and does not require much formatting. It is simple to create. As each blog has its own URL, it is

an easy way of adding new URLs which increase a site's popularity with search engines. A blog is an ideal vehicle for advertising your business and its products. The syndication that is built into the blog management means that the advertisement could reach a wide audience. So, the blog will attract visitors to your site who wouldn't otherwise find it. If we use blogs as an e-marketing tool then they should be updated regularly.

To create a blog, go to www.blogger.com that is owned by Google.

Q7. With a neat diagram, show the cloud architecture.

Ans. 7 The cloud architecture is as follows:-



Q8. Explain VMM (Virtual Machine Monitor) platform- VMWare ESXi.

Ans. 8 VMWare is a company that provides a set of tools ranging from server and desktop virtualization to high-level management tools. ESXi is a VMM from VMWare. VMM or hypervisor mediates access to the physical hardware that presents to each guest OS, a virtual machine (VM) that is a set of virtual platform interfaces. ESXi is a bare metal hypervisor i.e. it installs directly on physical server whereas others may require a host OS too. It provides advanced virtualization techniques of processor, memory and I/O.

Q9. What is the basic concept behind virtualization?

Ans. 9 Using virtualization, one or more physical servers can be configured and partitioned into multiple independent **virtual servers,** all functioning independently and appearing to the user to be a single physical device. **Please note that such 'virtual servers' do not physically exist and can therefore be moved around and scaled-up or down on the fly without affecting the end user. Also note that the computing resources have now become 'granular'.** This provides end-user and operator benefits including on-demand self-service,

broad access across multiple devices, resource pooling, rapid elasticity and service metering capability. Any individual user who has permission to access the server can use the server's processing power to run an application, store data or perform any other computing task. *Therefore, instead of using a PC every time to run an application, the individual can now run the application from anywhere in the world, as the server provides the processing power to the application and the server is also connected to a network via Internet or other connection platforms to be accessed from anywhere. This has become possible due to increased computer processing power available to human mankind.*

Q10. What is MS AZURE?

Ans. 10 Earlier it was known as Windows Azure and now it is called as MICROSOFT AZURE. It was released on Feb. 1, 2010. It is a cloud computing platform and infrastructure for building, deploying and managing applications and services through a global network of **Microsoft-managed data centres.** It provides both PaaS and IaaS services and supports many different programming languages, tools and frameworks. Azure is an Internet-scale computing and services platform hosted in data centres managed or supported by Microsoft.

Q11. What are cloud data centres? Give examples.

Ans. 11 Cloud data centres are huge. Many have hundreds of thousands of square feet of space. MS highlights the fact that *one of its Azure data centres takes up as much space as ten football fields.* Clouds are expensive. Many cloud **regions** are actually comprised of two or more distinct data centres. Cloud data centres are showing up in clusters around major Internet hubs with existing. In nutshell, cloud providers have under-invested in emerging markets with high Internet use. **Note that some data centre regions have servers grouped inside containers, each containing 1800-2500 servers.** The locations of the data centres are at North-central US – Chicago (North America), South America's Brazil, China, Hong Kong, Singapore, north and west Europe, Japan and Australia.

Note: CDN nodes are located in 24 countries.

Q12. Define dynamic scaling.

Ans. 11 It refers to the capability to both scale out and scale back your application depending on resource requirements. It is also called as an **elastic scale.**

Q13. Distinguish between horizontal and vertical scaling.

Ans. 12 The process of combining several independent computers as one to offer more processing power is known as horizontal scaling. This type of scaling implies several instances of an operating system existing on individual servers. On the other hand, **the process of adding resources like storage, processors etc. to expand the processing capability is known as vertical scaling.** This type of scaling makes use of a single instance of an OS.

Q14. Cloud computing architecture consists of front end and back end. Explain.

Ans. 13 The front end is the side that the client sees and back end is the cloud section of a system. But a cloud infrastructure consists of storage, network and computing components.