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Internal Assessment Test 1 – Dec. 2022

Sub:	**Cloud Computing**							**Sub Code:**	**20MCA342**
Date:	**27/12//2022**	**Duration:**	**90 min's**	**Max Marks:**	**50**	**Sem:**	**III**	**Branch:**	**MCA**

Note : Answer FIVE FULL Questions, choosing ONE full question from each Module

		MARKS	OBE CO	OBE RBT
	PART I			
1	Briefly summarize the Cloud Computing Reference Model.	[10]	CO1	L1
	OR			
2	Discuss RPC and how it enables interprocess communication.	[10]	CO2	L2
	PART II			
3	What is cloud? List and explain characteristics and benefits of cloud computing.	[10]	CO1	L1
	OR			
4	Discuss examples of distributed framework	[10]	CO2	L2
	PART III			
5	What are the major distributed computing technologies that led to cloud computing?	[10]	CO1	L1
	OR			
6	Compare the characteristics of parallel and distributed system. Draw and explain the layered view of distributed system	[10]	CO2	L3
	PART IV			
7	Discuss the cloud deployment model and cloud system across all market segments	[10]	CO1	L1
	OR			
8	Discuss the most important model for message-based communication.	[10]	CO2	L2
	PARTV			
9	Discuss the vision and era of cloud computing	[10]	CO1	L2
	OR			
10	Explain the system architectural styles.	[10]	CO2	L2

Q1) Briefly summarize the Cloud Computing Reference Model.

A fundamental characteristic of cloud computing is the capability to deliver, on demand, a variety of IT services that are quite diverse from each other. This variety creates different perceptions of what cloud computing is among users. Despite this lack of uniformity, it is possible to classify cloud computing services offerings into three major categories: Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS), and Software-as-a-Service (SaaS).

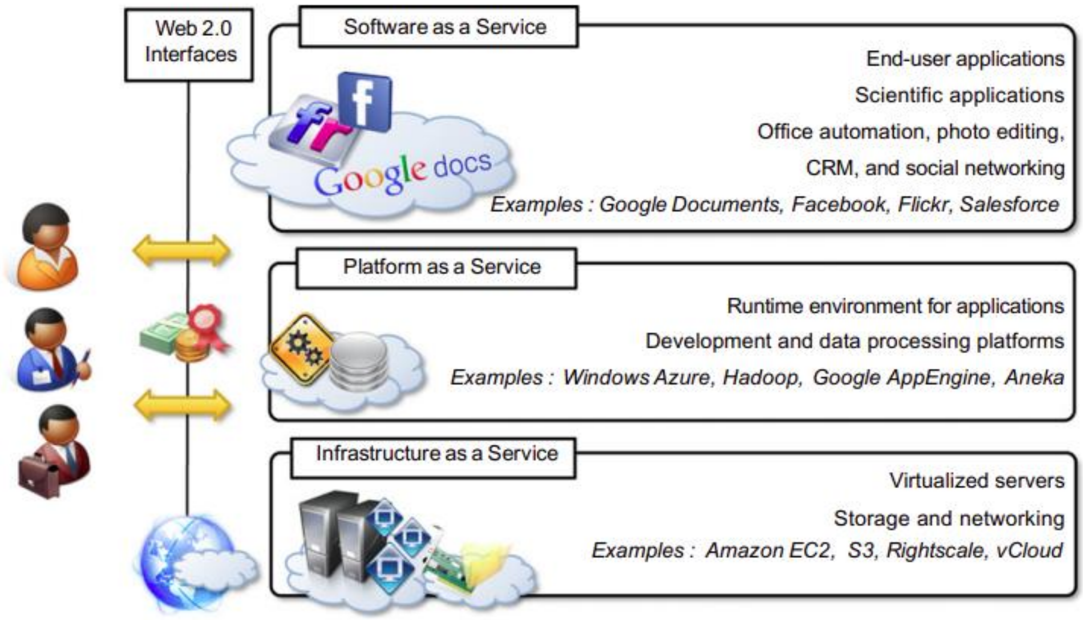


FIGURE 1.5

The Cloud Computing Reference Model.

At the base of the stack, **Infrastructure-as-a-Service** solutions deliver infrastructure on demand in the form of virtual hardware, storage, and networking. Virtual hardware is utilized to provide compute on demand in the form of virtual machine instances. These are created at users' request on the provider's infrastructure, and users are given tools and interfaces to configure the software stack installed in the virtual machine. The pricing model is usually defined in terms of dollars per hour, where the hourly cost is influenced by the characteristics of the virtual hardware. Virtual storage is delivered in the form of raw disk space or object store.. Virtual networking identifies the collection of services that manage the networking among virtual instances and their connectivity to the Internet or private networks.

Platform-as-a-Service solutions are the next step in the stack. They deliver scalable and elastic runtime environments on demand and host the execution of applications. These services are backed by a core middleware platform that is responsible for creating the abstract environment where applications are deployed and executed. It is the responsibility of the service provider to provide scalability and to manage fault tolerance, while users are requested to focus on the logic of the application developed by leveraging the provider's APIs and libraries. This approach increases the level of abstraction at which cloud computing is leveraged but also constrains the user in a more controlled environment.

At the top of the stack, **Software-as-a-Service** solutions provide applications and services on demand. Most of the common functionalities of desktop applications—such as office automation, document management, photo editing, and customer relationship management (CRM) software—are replicated on the provider's infrastructure and made more scalable and accessible through a browser on demand. These applications are shared across multiple users whose interaction is isolated from the other users. The SaaS layer is also the area of social networking Websites, which leverage cloud-based infrastructures to sustain the load generated by their popularity.

Each layer provides a different service to users. IaaS solutions are sought by users who want to leverage cloud computing from building dynamically scalable computing systems requiring a specific software stack. IaaS services are therefore used to develop scalable Websites or for background processing. PaaS solutions provide scalable programming platforms for developing applications and are more appropriate when new systems have to be developed. SaaS solutions target mostly end users who want to benefit from the elastic scalability of the cloud without doing any software development, installation, configuration, and maintenance. This solution is appropriate when there are existing SaaS services that fit users needs (such as email, document management, CRM, etc.) and a minimum level of customization is needed.

Q2) Discuss RPC and how it enables interprocess communication.

RPC is the fundamental abstraction enabling the execution of procedures on client's request. RPC allows extending the concept of a procedure call beyond the boundaries of a process and a single memory address space. The called procedure and calling procedure may be on the same system or they may be on different systems in a network. Figure 2.14 illustrates the major components that enable an RPC system. The system is based on a client/server model. The server process maintains a registry of all the available procedures that can be remotely invoked and listens for requests from clients that specify which procedure to invoke, together with the values of the parameters required by the procedure. RPC maintains the synchronous pattern that is natural in IPC and function calls. Therefore, the calling process thread remains blocked until the procedure on the server process has completed its execution and the result (if any) is returned to the client.

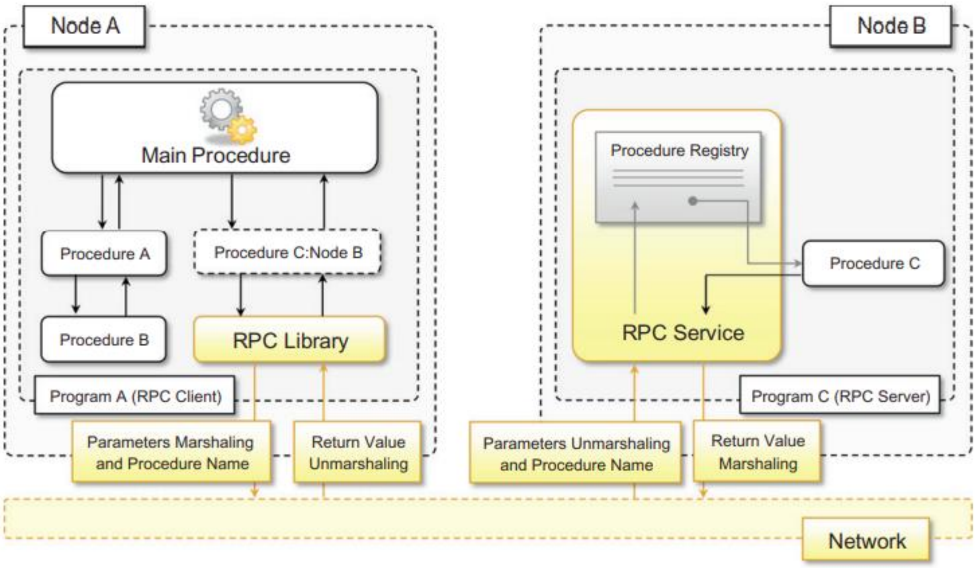


FIGURE 2.14
The RPC reference model.

An important aspect of RPC is marshaling, which identifies the process of converting parameter and return values into a form that is more suitable to be transported over a network through a sequence of bytes. The term unmarshaling refers to the opposite procedure. Marshaling and unmarshaling are performed by the RPC runtime infrastructure, and the client and server user code does not necessarily have to perform these tasks. The RPC runtime, on the other hand, is not only responsible for parameter packing and unpacking but also for handling the request-reply interaction that happens between the client and the server process in a completely transparent manner. Therefore, developing a system leveraging RPC for IPC consists of the following steps:
• Design and implementation of the server procedures that will be exposed for remote invocation.
• Registration of remote procedures with the RPC server on the node where they will be made available. • Design and implementation of the client code that invokes the remote procedure(s).

Each RPC implementation generally provides client and server application programming interfaces (APIs) that facilitate the use of this simple and powerful abstraction. An important observation has to be made concerning the passing of parameters and return values. Since the server and the client processes are in two separate address spaces, the use of parameters passed by references or pointers is not suitable in this scenario, because once unmarshaled these will refer to a memory location that is not accessible from within the server process. Second, in user-defined parameters and return value types, it is necessary to ensure that the RPC runtime is able to marshal them.

This is generally possible, especially when user-defined types are composed of simple types, for which marshaling is naturally provided. RPC has been a dominant technology for IPC for quite a long time, and several programming languages and environments support this interaction pattern in the form of libraries and additional packages. For instance, RPyC is an RPC implementation for Python. There also exist platformindependent solutions such as XML-RPC and JSON-RPC, which provide RPC facilities over XML and JSON, respectively. Thrift [113] is the framework developed at Facebook for enabling a transparent cross-language RPC model. Currently, the term RPC implementations encompass a variety of solutions including frameworks such distributed object programming (CORBA, DCOM, Java RMI, and .NET Remoting) and Web services that evolved from the original RPC concept.

Q3) what is cloud? List and explain characteristics and benefits of cloud computing?

The term cloud has historically been used in the telecommunications industry as an abstraction of the network in system diagrams. It then became the symbol of the most popular computer network: the Internet. This meaning also applies to cloud computing, which refers to an Internet-centric way of computing.
The Internet plays a fundamental role in cloud computing, since it represents either the medium or the platform through which many cloud computing services are delivered and made accessible. This aspect is also reflected in the definition given by Armbrust et al. [28]:

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

This definition describes cloud computing as a phenomenon touching on the entire stack: from the underlying hardware to the high-level software services and applications. It introduces the concept of everything as a service, mostly referred as XaaS, 2 where the different components of a system—IT infrastructure, development platforms, databases, and so on—can be delivered, measured, and consequently priced as a service
This notion of multiple parties using a shared cloud computing environment is highlighted in a definition proposed by the U.S. National Institute of Standards and Technology (NIST):

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

According to Reese [29], we can define three criteria to discriminate whether a service is delivered in the cloud computing style:

- ***The service is accessible via a Web browser (nonproprietary) or a Web services application programming interface (API).***
- ***Zero capital expenditure is necessary to get started.***
- ***You pay only for what you use as you use it.***

The utility-oriented nature of cloud computing is clearly expressed by Buyya et al. [30]:

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

Cloud computing has some interesting characteristics that bring benefits to both cloud service consumers (CSCs) and cloud service providers (CSPs). These characteristics are:

- No up-front commitments
- On-demand access

- Nice pricing
- Simplified application acceleration and scalability
- Efficient resource allocation
- Energy efficiency
- Seamless creation and use of third-party services

Q4) Discuss examples of distributed framework

Common object request broker architecture (CORBA)

CORBA is a specification introduced by the Object Management Group (OMG) for providing cross-platform and cross-language interoperability among distributed components. The specification was originally designed to provide an interoperation standard that could be effectively used at the industrial level. The current release of the CORBA specification is version 3.0 and currently the technology is not very popular, mostly because the development phase is a considerably complex task and the interoperability among components developed in different languages has never reached the proposed level of transparency. A fundamental component in the CORBA architecture is the *Object Request Broker (ORB)*, which acts as a central object bus. A CORBA object registers with the ORB the interface it is exposing, and clients can obtain a reference to that interface and invoke methods on it. The ORB is responsible for returning the reference to the client and managing all the low-level operations required to perform the remote method invocation. To simplify cross-platform interoperability, interfaces are defined in *Interface Definition Language (IDL)*, which provides a platform-independent specification of a component. An IDL specification is then translated into a *stub-skeleton* pair by specific CORBA compilers that generate the required client (stub) and server (skeleton) components in a specific programming language. These templates are completed with an appropriate implementation in the selected programming language. This allows CORBA components to be used across different runtime environment by simply using the stub and the skeleton that match the development language used. A specification meant to be used at the industry level, CORBA provides interoperability among different implementations of its runtime. In particular, at the lowest-level ORB implementations communicate with each other using the *Internet Inter-ORB Protocol (IIOP)*, which standardizes the interactions of different ORB implementations. Moreover, CORBA provides an additional level of abstraction and separates the ORB, which mostly deals with the networking among nodes, from the *Portable Object Adapter (POA)*, which is the runtime environment in which the skeletons are hosted and managed. Again, the interface of these two layers is clearly defined, thus giving more freedom and allowing different implementations to work together seamlessly.

Distributed component object model (DCOM/COM+)

DCOM, later integrated and evolved into COM+, is the solution provided by Microsoft for distributed object programming before the introduction of .NET technology. DCOM introduces a set of features allowing the use of COM components beyond the process boundaries. A COM object identifies a component that encapsulates a set of coherent and related operations; it was designed to be easily plugged into another application to leverage the features exposed through its interface. To support interoperability, COM standardizes a binary format, thus allowing the use of COM objects across different programming languages. DCOM enables such capabilities in a distributed environment by adding the required IPC support. The architecture of DCOM is quite similar to CORBA but simpler, since it does not aim to foster the same level of interoperability; its implementation is monopolized by Microsoft, which provides a single runtime environment. A DCOM server object can expose several interfaces, each representing a different behavior of the object. To invoke the methods exposed by the interface, clients obtain a pointer to that interface and use it as though it were a pointer to an object in the client's address space. The DCOM runtime is responsible for performing all the operations required to create this illusion. This technology provides a reasonable level of interoperability among Microsoft-based environments, and there are third-party implementations that allow the use of DCOM, even in Unix-based environments. Currently, even if still used in industry, this technology is no longer popular and has been replaced by other approaches, such as .NET Remoting and Web Services.

Java remote method invocation (RMI)

Java RMI is a standard technology provided by Java for enabling RPC among distributed Java objects. RMI defines an infrastructure allowing the invocation of methods on objects that are located on different Java Virtual Machines (JVMs) residing either on the local node or on a remote one. As with CORBA, RMI is based on the *stub-skeleton* concept. Developers define an interface extending *java.rmi.Remote* that defines the contract for IPC. Java allows only publishing interfaces while it relies on actual types for the server and client part implementation. A class implementing the previous interface represents the *skeleton* component that will be made accessible beyond the JVM boundaries. The *stub* is generated from the skeleton class definition using the *rmic* command-line tool. Once the *stub-skeleton* pair is prepared, an instance of the skeleton is registered with the RMI registry that maps URIs, through which instances can be reached, to the corresponding objects. The RMI registry is a separate component that keeps track of all the instances that can be reached on a node. Clients contact the RMI registry and specify a URI, in the form *rmi://host:port/serviceName*, to obtain a reference to the corresponding object. The RMI runtime will automatically retrieve the class information for the stub component paired with the skeleton mapped with the given URI and return an instance of it properly configured to interact with the remote object. In the client code, all the services provided by the skeleton are accessed by invoking the methods defined in the remote interface. RMI provides a quite transparent interaction pattern. Once the development and deployment phases are completed and a reference to a remote object is obtained, the client code interacts with it as though it were a local instance, and RMI performs all the required operations to enable the IPC. Moreover, RMI also allows customizing the security that has to be applied for remote objects. This is done by leveraging the standard Java security infrastructure, which allows specifying policies defining the permissions attributed to the JVM hosting the remote object.

.NET remoting

Remoting is the technology allowing for IPC among .NET applications. It provides developers with a uniform platform for accessing remote objects from within any application developed in any of the languages supported by .NET. With respect to other distributed object technologies, Remoting is a fully customizable architecture that allows developers to control the transport protocols used to exchange information between the proxy and the remote object, the serialization format used to encode data, the lifetime of remote objects, and the server management of remote objects. Despite its modular and fully customizable architecture, Remoting allows a transparent interaction pattern with objects residing on different application domains. An application domain represents an isolated execution environment that can be accessible only through Remoting channels. A single process can host multiple application domains and must have at least one.

Q5) What are the major distributed computing technologies that led to cloud computing?

Three major milestones have led to cloud computing: mainframe computing cluster computing, and grid computing.

- Mainframes. These were the first examples of large computational facilities leveraging multiple processing units. Mainframes were powerful, highly reliable computers specialized for large data movement and massive input/output (I/O) operations. They were mostly used by large organizations for bulk data processing tasks such as online transactions, enterprise resource planning, and other operations involving the processing of significant amounts of data. One of the most attractive features of mainframes was the ability to be highly reliable computers that were "always on" and capable of tolerating failures transparently. No system shutdown was required to replace failed components, and the system could work without interruption. Now their popularity and deployments have reduced, but evolved versions of such systems are still in use for transaction processing (such as online banking, airline ticket booking, supermarket and telcos, and government services).

- Clusters. Cluster computing started as a low-cost alternative to the use of mainframes and supercomputers. The technology advancement that created faster and more powerful mainframes and supercomputers eventually generated an increased availability of cheap commodity machines as a side effect. These machines could then be connected by a high-bandwidth network and controlled by specific software tools that manage them as a single system. Starting in the 1980s, clusters become the standard technology for parallel and high-performance computing. Built by commodity machines, they were cheaper than mainframes and made high-performance computing available to a large number of groups, including universities and small research labs. One of the attractive features of clusters was that the computational power of commodity machines could be leveraged to solve problems that were previously manageable only on expensive supercomputers. Moreover, clusters could be easily extended if more computational power was required.
- Grid computing appeared in the early 1990s as an evolution of cluster computing. In an analogy to the power grid, grid computing proposed a new approach to access large computational power, huge storage facilities, and a variety of services. Users can "consume" resources in the same way as they use other utilities such as power, gas, and water. Grids initially developed as aggregations of geographically dispersed clusters by means of Internet connections. These clusters belonged to different organizations, and arrangements were made among them to share the computational power. Different from a "large cluster," a computing grid was a dynamic aggregation of heterogeneous computing nodes, and its scale was nationwide or even worldwide. Several developments made possible the diffusion of computing grids: (a) clusters became quite common resources; (b) they were often underutilized; (c) new problems were requiring computational power that went beyond the capability of single clusters; and (d) the improvements in networking and the diffusion of the Internet made possible long-distance, high-bandwidth connectivity. All these elements led to the development of grids, which now serve a multitude of users across the world

Q6) Compare the characteristics of parallel and distributed system. Draw and explain the layered view of distributed system

Parallel Computing	Distributed Computing
Many operations are performed simultaneously.	System components are located at different locations.
Single computer is required.	Uses multiple computers.
Multiple processors perform multiple operations.	Multiple computers perform multiple operations.
It may have shared or distributed memory.	It have only distributed memory.
Processors communicate with each other through bus.	Computer communicate with each other through message passing.
Improves the system performance.	Improves system scalability, fault tolerance and resource sharing capabilities.

A distributed system is the result of the interaction of several components that traverse the entire computing stack from hardware to software. It emerges from the collaboration of several elements that—by working together—give users the illusion of a single coherent system

Below figure provides an overview of the different layers that are involved in providing the services of a distributed system.

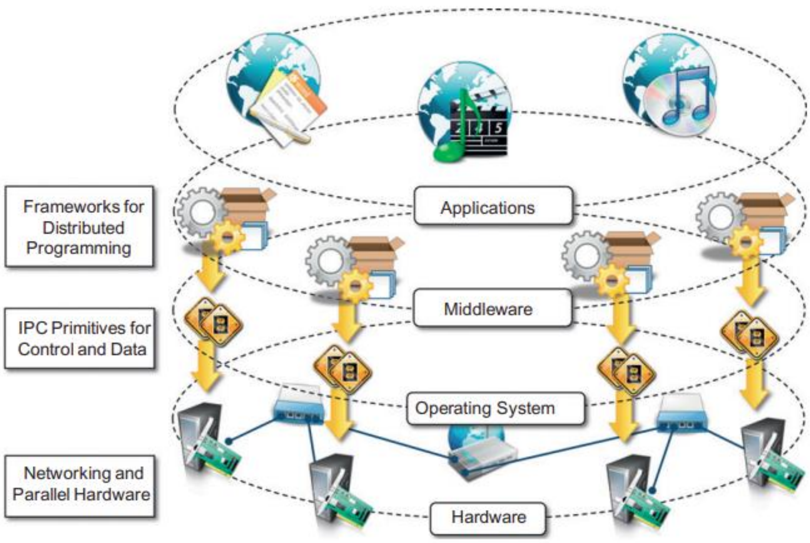


FIGURE 2.10

A layered view of a distributed system.

- At the very bottom layer, computer and network hardware constitute the physical infrastructure; these components are directly managed by the operating system, which provides the basic services for interprocess communication (IPC), process scheduling and management, and resource management in terms of file system and local devices. Taken together these two layers become the platform on top of which specialized software is deployed to turn a set of networked computers into a distributed system
- The middleware layer leverages such services to build a uniform environment for the development and deployment of distributed applications. By relying on the services offered by the operating system, the middleware develops its own protocols, data formats, and programming language or frameworks for the development of distributed applications. All of them constitute a uniform interface to distributed application developers that is completely independent from the underlying operating system and hides all the heterogeneities of the bottom layers.
- The top of the distributed system stack is represented by the applications and services designed and developed to use the middleware. These can serve several purposes and often expose their features in the form of graphical user interfaces (GUIs) accessible locally or through the Internet via a Web browser.

Figure 2.11 shows an example of how the general reference architecture of a distributed system is contextualized in the case of a cloud computing system.

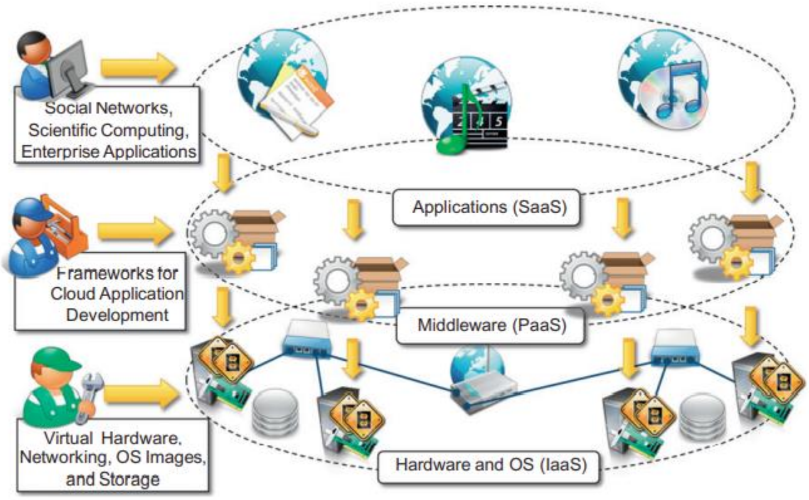


FIGURE 2.11

A cloud computing distributed system.

- Hardware and operating system layers make up the bare-bone infrastructure of one or more datacenters, where racks of servers are deployed and connected together through high-speed connectivity. This infrastructure is managed by the operating system, which provides the basic capability of machine and network management.
- The core logic is then implemented in the middleware that manages the virtualization layer, which is deployed on the physical infrastructure in order to maximize its utilization and provide a customizable runtime environment for applications.
- The middleware provides different facilities to application developers according to the type of services sold to customers. These facilities, offered through Web 2.0-compliant interfaces, range from virtual infrastructure building and deployment to application development and runtime environment

Q7) Discuss the cloud deployment model and cloud system across all market segments

Cloud computing is helping enterprises, governments, public and private institutions, and research organizations shape more effective and demand-driven computing systems. Access to, as well as integration of, cloud computing resources and systems is now as easy as performing a credit card transaction over the Internet. Practical examples of such systems exist across all market segments:

- **Large enterprises** can offload some of their activities to cloud-based systems. Ex., the New York Times has converted its digital library of past editions into a Web-friendly format using AWS
- **Small enterprises** and start-ups can afford to translate their ideas into business results more quickly, without excessive up-front costs. Ex. Animoto is a company that creates videos out of images, music, and video fragments submitted by users. Animoto does not own a single server and bases its computing infrastructure entirely on Amazon Web Services, which are sized on demand according to the overall workload to be processed.
- **System developers** can concentrate on the business logic rather than dealing with the complexity of infrastructure management and scalability. Ex. Little Fluffy Toys is a company in London that has developed a widget providing users with information about nearby bicycle rental services. The company has managed to back the widget’s computing needs on GoogleAppEngine and be on the market in only one week.

- **End users** can have their documents accessible from everywhere and any device. Ex.Apple iCloud is a service that allows users to have their documents stored in the Cloud and access them from any device users connect to it.

Cloud Deployment Models

The three major models for deploying and accessing cloud computing environments are public clouds, private/enterprise clouds, and hybrid clouds.

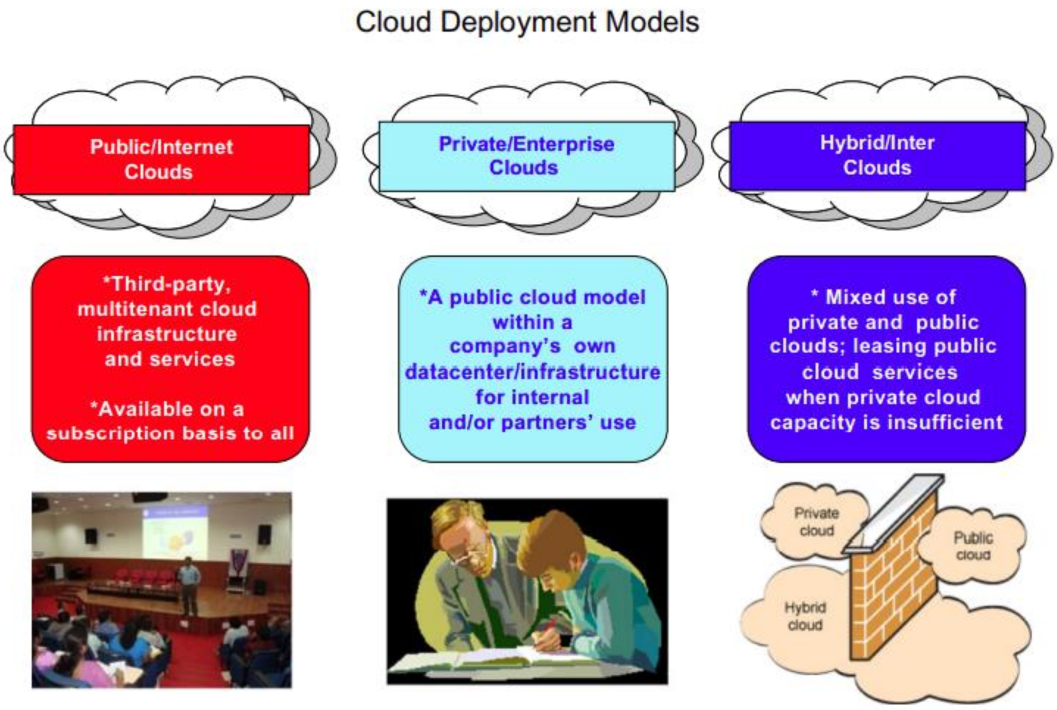


FIGURE 1.4

Major deployment models for cloud computing.

Public clouds are the most common deployment models in which necessary IT infrastructure (e.g., virtualized datacenters) is established by a third-party service provider that makes it available to any consumer on a subscription basis. Such clouds are appealing to users because they allow users to quickly leverage compute, storage, and application services. In this environment, users' data and applications are deployed on cloud datacenters on the vendor's premises.

Large organizations that own massive computing infrastructures can still benefit from cloud computing by replicating the cloud IT service delivery model in-house. This idea has given birth to the concept of **private clouds** as opposed to public clouds. The use of cloud-based in-house solutions is also driven by the need to keep confidential information within an organization's premises. Institutions such as governments and banks that have high security, privacy, and regulatory concerns prefer to build and use their own private or enterprise clouds.

Whenever private cloud resources are unable to meet users' quality-of-service requirements, hybrid computing systems, partially composed of public cloud resources and privately owned infrastructures, are created to serve the organization's needs. These are often referred as **hybrid clouds**, which are becoming a common way for many stakeholders to start exploring the possibilities offered by cloud computing

Q8) Discuss the most important model for message-based communication.

Models for message-based communication

- **Point-to-point message model** This model organizes the communication among single components. Each message is sent from one component to another, and there is a direct addressing to identify the message receiver. In a point-to-point communication model it is necessary to know the location of or how to address another component in the system. There is no central infrastructure that dispatches the messages, and the communication is initiated by the message sender. It is possible to identify two major subcategories: direct communication and queue-based communication. In the former, the message is sent directly to the receiver and processed at the time of reception. In the latter, the receiver maintains a message queue in which the messages received are placed for later processing. The point-topoint message model is useful for implementing systems that are mostly based on one-to-one or many-to-one communication.

- **Publish-and-subscribe message model** This model introduces a different strategy, one that is based on notification among components. There are two major roles: the publisher and the subscriber. The former provides facilities for the latter to register its interest in a specific topic or event. Specific conditions holding true on the publisher side can trigger the creation of messages that are attached to a specific event. A message will be available to all the subscribers that registered for the corresponding event. There are two major strategies for dispatching the event to the subscribers:
  - Push strategy. In this case it is the responsibility of the publisher to notify all the subscribers— for example, with a method invocation.
  - Pull strategy. In this case the publisher simply makes available the message for a specific event, and it is responsibility of the subscribers to check whether there are messages on the events that are registered.

  The publish-and-subscribe model is very suitable for implementing systems based on the oneto-many communication model and simplifies the implementation of indirect communication patterns. It is, in fact, not necessary for the publisher to know the identity of the subscribers to make the communication happen.
- **Request-reply message model** The request-reply message model identifies all communication models in which, for each message sent by a process, there is a reply. This model is quite popular and provides a different classification that does not focus on the number of the components involved in the communication but rather on how the dynamic of the interaction evolves. Point-to-point message models are more likely to be based on a request-reply interaction, especially in the case of direct communication. Publishand-subscribe models are less likely to be based on request-reply since they rely on notifications

Q9) Discuss the vision and era of cloud computing

The vision of cloud computing

Cloud computing allows anyone with a credit card to provision virtual hardware, runtime environments, and services. These are used for as long as needed, with no up-front commitments required.
The entire stack of a computing system is transformed into a collection of utilities, which can be provisioned and composed together to deploy systems in hours rather than days and with virtually no maintenance costs.
Previously, the lack of effective standardization efforts made it difficult to move hosted services from one vendor to another.
The long-term vision of cloud computing is that IT services are traded as utilities in an open market, without technological and legal barriers. In this cloud marketplace, cloud service providers and consumers, trading cloud services as utilities, play a central role.

FIGURE 1.1
Cloud computing vision.

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

The need for ubiquitous storage and compute power on demand is the most common reason to consider cloud computing.

A scalable runtime for applications is an attractive option for application and system developers that do not have infrastructure or cannot afford any further expansion of existing infrastructure.

The capability for Webbased access to documents and their processing using sophisticated applications is one of the appealing factors for end users.

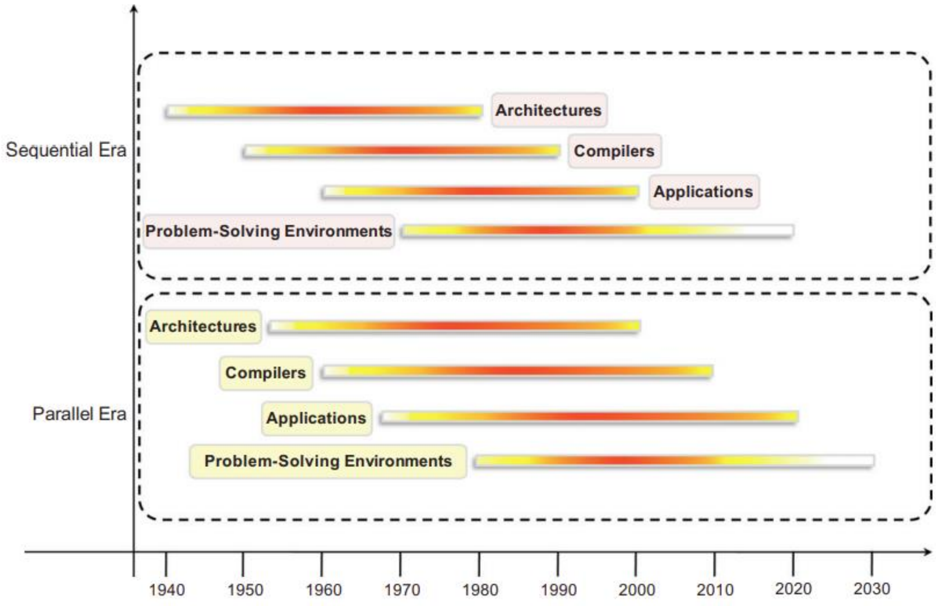
Vision of cloud computing is that in the near future it will be possible to find the solution that matches our needs by simply entering our request in a global digital market that trades cloud computing services.

The existence of such a market will enable the automation of the discovery process and its integration into existing software systems, thus allowing users to transparently leverage cloud resources in their applications and systems.

The existence of a global platform for trading cloud services will also help service providers become more visible and therefore potentially increase their revenue. A global cloud market also reduces the barriers between service consumers and providers.

Eras of computing

The sequential computing era began in the 1940s; the parallel (and distributed) computing era followed it within a decade



The four key elements of computing developed during these eras are architectures, compilers, applications, and problem-solving environments. The computing era started with a development in hardware architectures, which actually enabled the creation of system software—particularly in the area of compilers and operating systems—which support the management of such systems and the development of applications. The development of applications and systems are the major element of interest to us, and it comes to consolidation when problem-solving environments were designed and introduced to facilitate and empower engineers. This is when the paradigm characterizing the computing achieved maturity and became mainstream. Moreover, every aspect of this era underwent a three-phase process: research and development (R&D), commercialization, and commoditization.

Q10) Explain the system architectural styles

System architectural styles cover the physical organization of components and processes over a distributed infrastructure

Client/server

This architecture is very popular in distributed computing and is suitable for a wide variety of applications. As depicted in Figure 2.12, the client/server model features two major components: a server and a client. These two components interact with each other through a network connection using a given protocol. The communication is unidirectional: The client issues a request to the server, and after processing the request the server returns a response. There could be multiple client components issuing requests to a server that is passively waiting for them. Hence, the important operations in the client-server paradigm are request, accept (client side), and listen and response (server side).

. For the client design, we identify two major models:

- Thin-client model. In this model, the load of data processing and transformation is put on the server side, and the client has a light implementation that is mostly concerned with retrieving and returning the data it is being asked for, with no considerable further processing.
- Fat-client model. In this model, the client component is also responsible for processing and transforming the data before returning it to the user, whereas the server features a relatively light implementation that is mostly concerned with the management of access to the data.

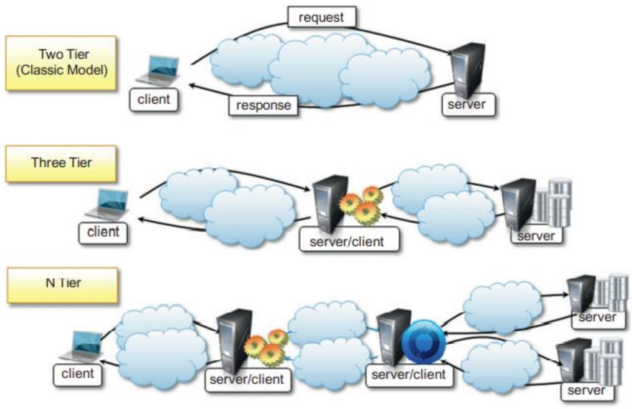


FIGURE 2.12
Client/server architectural styles.

Two-tier architecture
This architecture partitions the systems into two tiers, which are located one in the client component and the other on the server. The client is responsible for the presentation tier by providing a user interface; the server concentrates the application logic and the data store into a single tier. The server component is generally deployed on a powerful machine that is capable of processing user requests, accessing data, and executing the application logic to provide a client with a response. This architecture is suitable for systems of limited size and suffers from scalability issues
Three-tier architecture/N-tier architecture
The three-tier architecture separates the presentation of data, the application logic, and the data storage into three tiers. This architecture is generalized into an N-tier model in case it is necessary to further divide the stages composing the application logic and storage tiers. This model is generally more scalable than the two-tier one because it is possible to distribute the tiers into several computing nodes, thus isolating the performance bottlenecks. At the same time, these systems are also more complex to understand and manage. A classic example of three-tier architecture is constituted by a medium-size Web application that relies on a relational database management system for storing its data. In this scenario, the client component is represented by a Web browser that embodies the presentation tier, whereas the application server encapsulates the business logic tier, and a database server machine (possibly replicated for high availability) maintains the data storage. Application servers that rely on third-party (or external) services to satisfy client requests are examples of N-tiered architectures.

Peer-to-peer
The peer-to-peer model, depicted in Figure 2.13, introduces a symmetric architecture in which all the components, called peers, play the same role and incorporate both client and server capabilities of the client/server model.

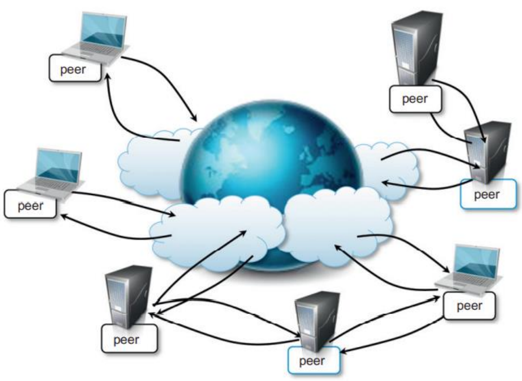


FIGURE 2.13
Peer-to-peer architectural style.

More precisely, each peer acts as a server when it processes requests from other peers and as a client when it issues requests to other peers. With respect to the client/ server model that partitions the responsibilities of the IPC between server and clients, the peer-topeer model attributes the same responsibilities to each component. Therefore, this model is quite suitable for highly decentralized architecture, which can scale better along the dimension of the number of peers.

The disadvantage of this approach is that the management of the implementation of algorithms is more complex than in the client/server model. The most relevant example of peer-to-peer systems is constituted by file-sharing applications such as Gnutella, BitTorrent, and Kazaa. Despite the differences among these networks in coordinating nodes and sharing information on the files and their locations, all of them provide a user client that is at the same time a server providing files to other peers and a client downloading files from other peers. To address an incredibly large number of peers, different architectures have been designed that divert slightly from the peer-to-peer model. For example, in Kazaa not all the peers have the same role, and some of them are used to group the accessibility information of a group of peers. Another interesting example of peer-to-peer architecture is represented by the Skype network