UNIT -3: CLOUD COMPUTING ARCHITECTURE AND MANAGEMENT

1Q: What are the different layers of cloud architecture ? explain briefly?(or)Explain the Architecture of the cloud?

1A:

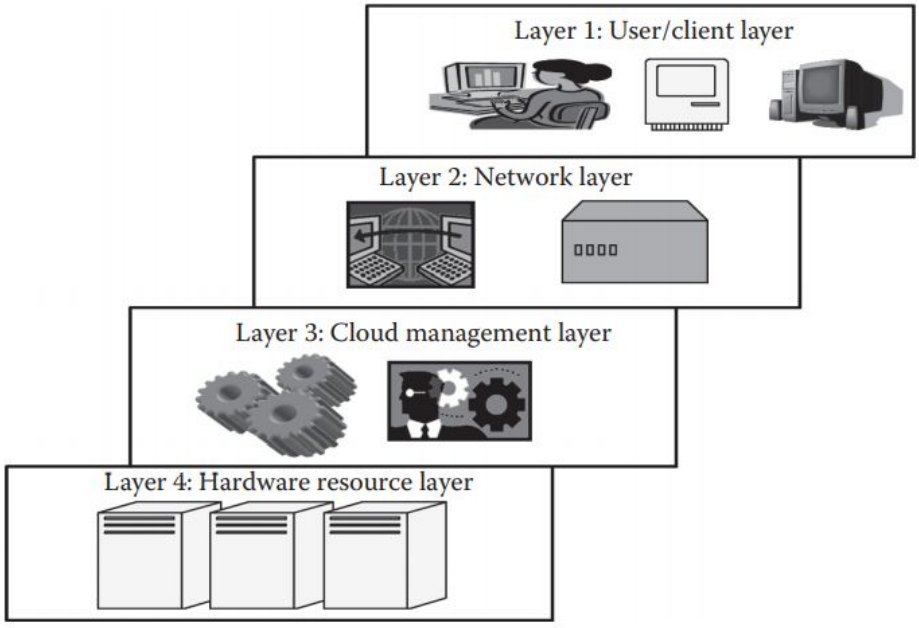

FIGURE 3.1
Cloud architecture.

Layer 1 (User/Client Layer):

- This layer is the lowest layer in the cloud architecture.
- All the users or clients belong to this layer.
- This is the place where the client/user initiates the connection to the cloud.
- The client can be any device such as a thin client, thick client, or mobile or any handheld device that would support basic functionalities to access a web application.
- The thin client here refers to a device that is completely dependent on some other system for its complete functionality.
- In simple terms, they have very low processing capability.
- Similarly, thick clients are general computers that have adequate processing capability.
- They have sufficient capability for independent work.
- Usually, a cloud application can be accessed in the same way as a web application.
- But internally, the properties of cloud applications are significantly different.

- Thus, this layer consists of client devices.

Layer 2 (Network Layer):

- This layer allows the users to connect to the cloud.
- The whole cloud infrastructure is dependent on this connection where the services are offered to the customers.
- This is primarily the Internet in the case of a public cloud.
- The public cloud usually exists in a specific location and the user would not know the location as it is abstract.
- And, the public cloud can be accessed all over the world.
- In the case of a private cloud, the connectivity may be provided by a local area network (LAN).
- Even in this case, the cloud completely depends on the network that is used.
- Usually, when accessing the public or private cloud, the users require minimum bandwidth, which is sometimes defined by the cloud providers.
- This layer does not come under the purview of service-level agreements (SLAs), that is, SLAs do not take into account the Internet connection between the user and cloud for quality of service (QoS).

Layer 3 (Cloud Management Layer):

- This layer consists of softwares that are used in managing the cloud.
- The softwares can be a cloud operating system (OS), a software that acts as an interface between the data center (actual resources) and the user, or a management software that allows managing resources.
- These softwares usually allow resource management (scheduling, provisioning, etc.), optimization (server consolidation, storage workload consolidation), and internal cloud governance.
- This layer comes under the purview of SLAs, that is, the operations taking place in this layer would affect the SLAs that are being decided upon between the users and the service providers.
- Any delay in processing or any discrepancy in service provisioning may lead to an SLA violation.
- As per rules, any SLA violation would result in a penalty to be given by the service provider.
- These SLAs are for both private and public clouds Popular service providers are Amazon Web Services (AWS) and Microsoft Azure for public cloud.
- Similarly, OpenStack and Eucalyptus allow private cloud creation, deployment, and management.

Layer 4 (Hardware Resource Layer):

- Layer 4 consists of provisions for actual hardware resources.
- Usually, in the case of a public cloud, a data center is used in the back end.
- Similarly, in a private cloud, it can be a data center, which is a huge collection of hardware resources interconnected to each other that is present in a specific location or a high configuration system.
- This layer comes under the purview of SLAs.
- This is the most important layer that governs the SLAs.

- This layer affects the SLAs most in the case of data centers.
- Whenever a user accesses the cloud, it should be available to the users as quickly as possible and should be within the time that is defined by the SLAs.
- As mentioned, if there is any discrepancy in provisioning the resources or application, the service provider has to pay the penalty.
- Hence, the data center consists of a high-speed network connection and a highly efficient algorithm to transfer the data from the data center to the manager.
- There can be a number of data centers for a cloud, and similarly, a number of clouds can share a data center

2Q:Discuss in detail about Anatomy of the cloud?(OR) How is cloud anatomy different from cloud architecture?
2A:

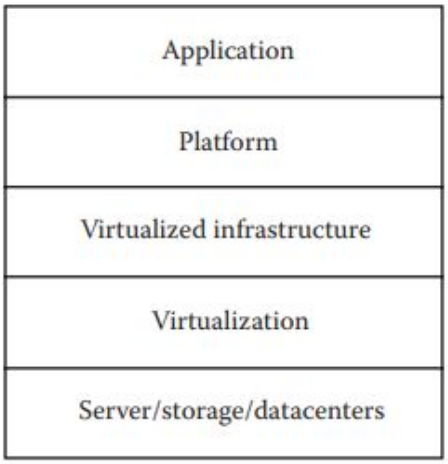

FIGURE 3.2
Cloud structure.

- Cloud anatomy can be simply defined as the structure of the cloud.
- Cloud anatomy cannot be considered the same as cloud architecture.
- It may not include any dependency on which or over which the technology works,whereas architecture wholly defines and describes the technology over which it is working.
- Architecture is a hierarchical structural view that defines the technology as well as the technology over which it is dependent or/and the technology that are dependent on it.
- Thus, anatomy can be considered as a part of architecture.
- The basic structure of the cloud is described in Figure 3.2, which can be elaborated, and minute structural details can be given.
- Figure 3.2 depicts the most standard anatomy that is the base for the cloud. It depends on the person to choose the depth of description of the cloud.

There are basically five components of the cloud:

1. Application:

The upper layer is the application layer. In this layer, any applications are executed.

2. Platform: This component consists of platforms that are responsible for the execution of the application. This platform is between the infrastructure and the application.

3. Infrastructure: The infrastructure consists of resources over which the other components work. This provides computational capability to the user.

4. Virtualization: Virtualization is the process of making logical components of resources over the existing physical resources. The logical components are isolated and independent, which form the infrastructure.

5. Physical hardware: The physical hardware is provided by server and storage units.

3Q:Write short notes on Network Connectivity in Cloud computing?

3A:

- Cloud computing is a technique of resource sharing where servers, storage, and other computing infrastructure in multiple locations are connected by networks.
- In the cloud, when an application is submitted for its execution, needy and suitable resources are allocated from this collection of resources;
- as these resources are connected via the Internet, the users get their required results.
- For many cloud computing applications, network performance will be the key issue to cloud computing performance.
- Since cloud computing has various deployment options, we now consider the important aspects related to the cloud deployment models and their accessibility from the viewpoint of network connectivity.

1 Public Cloud Access Networking:

- **I**n this option, the connectivity is often through the Internet, though some cloud providers may be able to support virtual private networks (VPNs) for customers.
- Accessing public cloud services will always create issues related to security, which in turn is related to performance.
- One of the possible approaches toward the support of security is to promote connectivity through encrypted tunnels, so that the information may be sent via secure pipes on the Internet.
- This procedure will be an overhead in the connectivity, and using it will certainly increase delay and may impact performance.
- If we want to reduce the delay without compromising security, then we have to select a suitable routing method such as the one reducing the delay by minimizing transit hops in the end-to-end connectivity between the cloud provider and cloud consumer.
- Since the end-to-end connectivity support is via the Internet, which is a complex federation of interconnected providers (known as Internet service providers [ISPs]), one has to look at the options of selecting the path.

2 Private Cloud Access Networking:

- In the private cloud deployment model, since the cloud is part of an organizational network, the technology and approaches are local to the in-house network structure.

- This may include an Internet VPN or VPN service from a network operator.
- If the application access was properly done with an organizational network—connectivity in a precloud configuration—transition to private cloud computing will not affect the access performance.

3 Intracloud Networking for Public Cloud Services:

- Another network connectivity consideration in cloud computing is intracloud networking for public cloud services.
- Here, the resources of the cloud provider and thus the cloud service to the customer are based on the resources that are geographically apart from each other but still connected via the Internet.
- Public cloud computing networks are internal to the service provider and thus not visible to the user/customer;
- However, the security aspects of connectivity and the access mechanisms of the resources are important.
- Another issue to look for is the QoS in the connected resources worldwide.
- Most of the performance issues and violations from these are addressed in the SLAs commercially

4 Private Intracloud Networking:

- The most complicated issue for networking and connectivity in cloud computing is private intracloud networking.
- What makes this particular issue so complex is that it depends on how much intracloud connectivity is associated with the applications being executed in this environment.
- Private intracloud networking is usually supported over connectivity between the major data center sites owned by the company.
- At a minimum, all cloud computing implementations will rely on intracloud networking to link users with the resource to which their application was assigned.
- Once the resource linkage is made, the extent to which intracloud networking is used depends on whether the application is componentized based on service-oriented architecture (SOA) or not, among multiple systems.
- If the principle of SOA is followed, then traffic may move between components of the application, as well as between the application and the user.
- The performance of those connections will then impact cloud computing performance overall.
- Here too, the impact of cloud computing performance is the differences that exist between the current application and the network relationships with the application.

5 New Facets in Private Networks:

- Conventional private networks have been architected for on-premise applications and maximum Internet security.
- Typically, applications such as e-mail, file sharing, and enterprise resource planning (ERP) systems are delivered to on-premise-based servers at each corporate data center.
- Increasingly today, software vendors are offering Software as a Service (SaaS) as an alternative for their software support to the corporate offices, which brings more

challenges in the access and usage mechanisms of software from data center servers and in the connectivity of network architectures.

- The traditional network architecture for these global enterprises was not designed to optimize performance for cloud applications, now that many applications including mission-critical applications are transitioning (moving) from on-premise based to cloud based, wherein the network availability becomes as mission critical as electricity.
- the business cannot function if it cannot access applications such as ERP and e-mail.

6 Path for Internet Traffic:

- The traditional Internet traffic through a limited set of Internet gateways poses performance and availability issues for end users who are using cloud-based applications.
- It can be improved if a more widely distributed Internet gateway infrastructure and connectivity are being supported for accessing applications, as they will provide lower-latency access to their cloud applications.
- As the volume of traffic to cloud applications grows, the percentage of the legacy network's capacity in terms of traffic to regional gateways increases.
- Applications such as video conferencing would hog more bandwidth while mission-critical applications such as ERP will consume less bandwidth, and hence, one has to plan a correct connectivity and path between providers and consumers.
-

4Q:List out the Applications On the Cloud?

4A:

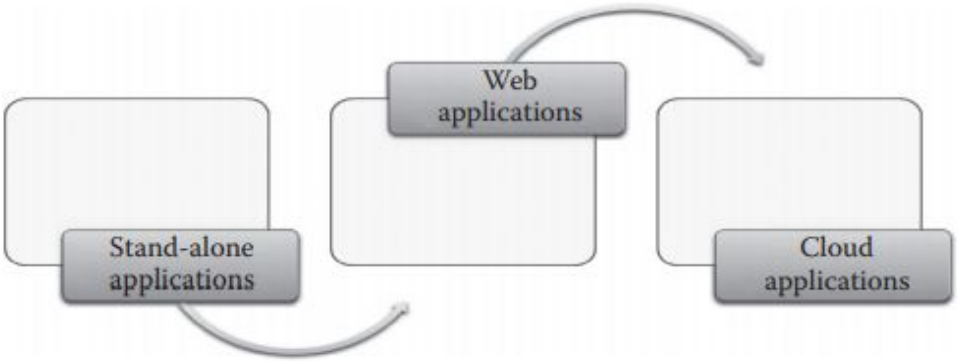

FIGURE 3.3
Computer application evolution.

• The web application is not elastic and cannot handle very heavy loads, that is, it cannot serve highly varying loads.
• The web application is not multitenant.
• The web application does not provide a quantitative measurement of the services that are given to the users, though they can monitor the user.
• The web applications are usually in one particular platform.

• The web applications are not provided on a pay-as-you-go basis; thus, a particular service is given to the user for permanent or trial use and usually the timings of user access cannot be monitored.
• Due to its nonelastic nature, peak load transactions cannot be handled.

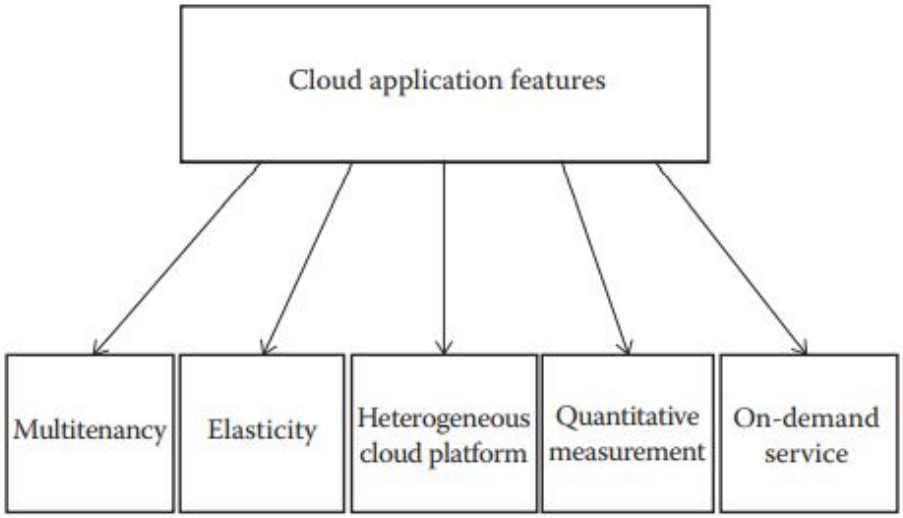

FIGURE 3.4
Features of cloud.

1. **Multitenancy**:
   - Multitenancy is one of the important properties of cloud that make it different from other types of application in which the software can be shared by different users with full independence.
   - Here, independence refers to logical independence
   - Each user will have a separate application instance and the changes in one application would not affect the other.
   - Physically, the software is shared and is not independent.
   - The degree of physical isolation is very less.
   - Logical independence is what is guaranteed.
   - There are no restrictions in the number of applications being shared.
   - The difficulty in providing logical isolation depends on the physical isolation to a certain extent.
   - If an application is physically too close, then it becomes difficult to provide multi tenancy.
   - Web application and cloud application are similar as the users use the same way to access both.
   - Figure 3.5 depicts a multi tenant application where several users share the same application.

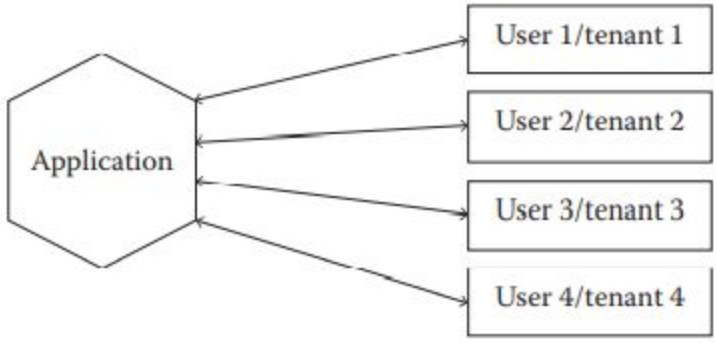

FIGURE 3.5
Multitenancy.

2. Elasticity:

- Elasticity is also a unique property that enables the cloud to serve better.
- According to Herbst et al. [4], elasticity can be defined as the degree to which a system is able to adapt to workload changes by provisioning and deprovisioning resources in an autonomic manner such that at each point in time, the available resources match the current demand as closely as possible.
- Elasticity allows the cloud providers to efficiently handle the number of users, from one to several hundreds of users at a time.
- In addition to this, it supports the rapid fluctuation of loads, that is, the increase or decrease in the number of users and their usage can rapidly change

3. Heterogeneous cloud platform:

- The cloud platform supports heterogeneity, wherein any type of application can be deployed in the cloud.
- Because of this property, the cloud is flexible for the developers, which facilitates deployment.
- The applications that are usually deployed can be accessed by the users using a web browser.

4. Quantitative measurement:

- The services provided can be quantitatively measured.
- The user is usually offered services based on certain charges.
- Here, the application or resources are given as a utility on a pay-per-use basis.
- Thus, the use can be monitored and measured.
- Not only the services are measurable, but also the link usage and several other parameters that support cloud applications can be measured.
- This property of measuring the usage is usually not available in a web application and is a unique feature for cloud-based applications.

5. On-demand service:

- The cloud applications offer service to the user, on demand, that is, whenever the user requires it.
- The cloud service would allow the users to access web applications usually without any restrictions on time, duration, and type of device used.

5Q:How Can you manage the cloud infrastructure ?
5A:

Managing the Cloud Infrastructure:

- The infrastructure of the cloud is considered to be the backbone of the cloud.
- This component is mainly responsible for the QoS factor.
- If the infrastructure is not properly managed, then the whole cloud can fail and QoS would be adversely affected.
- The core of cloud management is resource management.
- Resource management involves several internal tasks such as resource scheduling, provisioning, and load balancing.
- These tasks are mainly managed by the cloud service provider's core software capabilities such as the cloud OS that is responsible for providing services to the cloud and that internally controls the cloud.
- A cloud infrastructure is a very complex system that consists of a lot of resources.
- These resources are usually shared by several users.
- Poor resource management may lead to several inefficiencies in terms of performance, functionality, and cost.
- If a resource is not efficiently managed, the performance of the whole system is affected.
- Performance is the most important aspect of the cloud, because everything in the cloud is dependent on the SLAs and the SLAs can be satisfied only if performance is good.
- Similarly, the basic functionality of the cloud should always be provided and considered at any cost.
- Even if there is a small discrepancy in providing the functionality, the whole purpose of maintaining the cloud is futile.
- A partially functional cloud would not satisfy the SLAs.
- Lastly, the reason for which the cloud was developed was cost.
- The cost is a very important criterion as far as the business prospects of the cloud are concerned.
- On the part of the service providers, if they incur less cost for managing the cloud, then they would try to reduce the cost so as to get a strong user base.
- Hence, a lot of users would use the services, improving their profit margin.
- Similarly, if the cost of resource management is high, then definitely the cost of accessing the resources would be high and there is never a lossy business from any organization and so the service provider would not bear the cost and hence the users have to pay more.
- Similarly, this would prove costly for service providers as they have a high chance of losing a wide user base, leading to only a marginal growth in the industry.
- And, competing with its industry rivals would become a big issue. Hence, efficient management with less cost is required.
- At a higher level, other than these three issues, there are few more issues that depend on resource management.
- These are power consumption and optimization of multiple objectives to further reduce the cost.

- To accomplish these tasks, there are several approaches followed, namely, consolidation of server and storage workloads.
- Consolidation would reduce the energy consumption and in some cases would increase the performance of the cloud.
- According to Margaret Rouse , server consolidation by definition is an approach to the efficient usage of computer server resources in order to reduce the total number of servers or server locations that an organization requires .
- The previously discussed prospects are mostly suitable for IaaS.
- Similarly, there are different management methods that are followed for different types of service delivery models.
- Each of the type has its own way of management. All the management methodologies are based on load fluctuation.
- Load fluctuation is the point where the workload of the system changes continuously.
- This is one of the important criteria and issues that should be considered for cloud applications.
- Load fluctuation can be divided into two types: predictable and unpredictable.
- Predictable load fluctuations are easy to handle.
- The cloud can be pre configured for handling such kinds of fluctuations.
- Whereas unpredictable load fluctuations are difficult to handle, ironically this is one of the reasons why cloud is preferred by several users
- This is as far as cloud management is concerned.
- Cloud governance is another topic that is closely related to cloud management.
- Cloud governance is different from cloud management.
- Governance in general is a term in the corporate world that generally involves the process of creating value to an organization by creating strategic objectives that will lead to the growth of the company and would maintain a certain level of control over the company.
- Similar to that, here cloud organization is involved.
- There are several aspects of cloud governance out of which SLAs are one of the important aspects.
- SLAs are the set of rules that are defined between the user and cloud service provider that decide upon the QoS factor.
- If SLAs are not followed, then the defaulter has to pay the penalty. The whole cloud is governed by keeping these SLAs in mind.

6Q:List out the steps in managing the cloud Application?
6A:

Managing the Cloud Application:

- Business companies are increasingly looking to move or build their corporate applications on cloud platforms to improve agility or to meet dynamic requirements that exist in the globalization of businesses and responsiveness to market demands.
- But, this shift or moving the applications to the cloud environment brings new complexities.

- Applications become more composite and complex, which requires leveraging not only capabilities like storage and database offered by the cloud providers but also third-party SaaS capabilities like e-mail and messaging.
- So, understanding the availability of an application requires inspecting the infrastructure, the services it consumes, and the upkeep of the application.
- The composite nature of cloud applications requires visibility into all the services to determine the overall availability and uptime.
- Cloud application management is to address these issues and propose solutions to make it possible to have insight into the application that runs in the cloud, as well as implement or enforce enterprise policies like governance and auditing and environment management while the application is deployed in the cloud.
- These cloud-based monitoring and management services can collect a multitude of events, analyze them, and identify critical information that requires additional remedial actions like adjusting capacity or provisioning new services.
- Additionally,application management has to be supported with tools and processes required for managing other environments that might coexist, enabling efficient operations.

7Q:What is cloud migration? And explain phases of cloud migration in detail?
7A:

Migrating Application to Cloud:

- Cloud migration encompasses moving one or more enterprise applications and their IT environments from the traditional hosting type to the cloud environment, either public, private, or hybrid.
- Cloud migration presents an opportunity to significantly reduce costs incurred on applications.
- This activity comprises, of different phases like evaluation, migration strategy, prototyping, provisioning, and testing

Phases of Cloud Migration:

1. Evaluation:

- Evaluation is carried out for all the components like current infrastructure and application architecture, environment in terms of compute, storage, monitoring, and management, SLAs, operational processes, financial considerations, risk, security, compliance, and licensing needs are identified to build a business case for moving to the cloud

2. Migration strategy:

- Based on the evaluation, a migration strategy is drawn—a hotplug strategy is used where the applications and their data and interface dependencies are isolated and these applications can be operationalized all at once.
- A fusion strategy is used where the applications can be partially migrated;
- but for a portion of it, there are dependencies based on existing licenses, specialized server requirements like mainframes, or extensive interconnections with other applications.

3. Prototyping:

- Migration activity is preceded by a prototyping activity to validate and ensure that a small portion of the applications are tested on the cloud environment with test data setup.

4. Provisioning:

- Premigration optimizations identified are implemented.
- Cloud servers are provisioned for all the identified environments, necessary platform softwares and applications are deployed, configurations are tuned to match the new environment sizing, and databases and files are replicated.
- All internal and external integration points are properly configured.
- Web services, batch jobs, and operation and management software are set up in the new environments.

5. Testing:

- Postmigration tests are conducted to ensure that migration has been successful.
- Performance and load testing, failure and recovery testing, and scale-out testing are conducted against the expected traffic load and resource utilization levels.

8Q:What are The Different Approaches for Cloud Migration?Explain?
8A:

Approaches for Cloud Migration:

The following are the four broad approaches for cloud migration that have been adopted effectively by vendors:

1. Migrate existing applications:

- Rebuild or re architect some or all the applications, taking advantage of some of the virtualization technologies around to accelerate the work.
- But, it requires top engineers to develop new functionality.
- This can be achieved over the course of several releases with the timing determined by customer demand.

2. Start from scratch:

- Rather than cannibalize sales, confuse customers with choice, and tie up engineers trying to rebuild existing applications. it may be easier to start again.
- Many of the R&D decisions will be different now, and with some of the more sophisticated development environments, one can achieve more even with a small focused working team.

3. Separate company:

- One may want to create a whole new company with separate brand, management, R&D, and sales.
- The investment and internet protocol (IP) may come from the existing company, but many of the conflicts disappear once a newborn in the cloud company is established.
- The separate company may even be a subsidiary of the existing company.
- What is important is that the new company can act, operate, and behave like a cloud-based start-up.

4. Buy an existing cloud vendor:

- For a large established vendor, buying a cloud-based competitor achieves two things.

- Firstly, it removes a competitor
- secondly, it enables the vendor to hit the ground running in the cloud space.
- The risk of course is that the innovation, drive, and operational approach of the cloud-based company are destroyed as it is merged into the larger acquirer

UNIT -4: CLOUD SERVICE MODELS

1Q: Define iaas,paas,saas briefly?

1A:

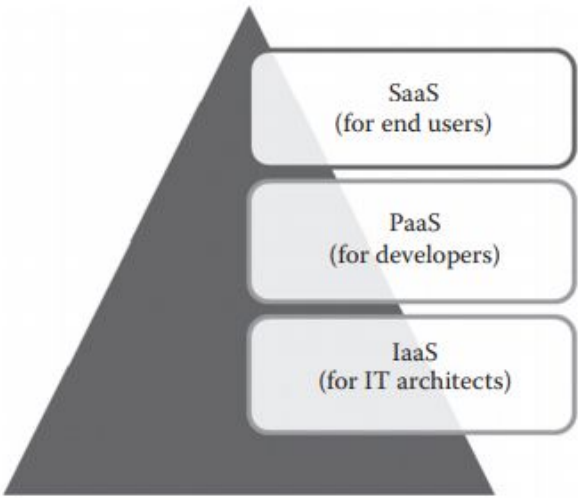

FIGURE 5.1
Basic cloud service models.

1. IaaS:

- The ability given to the infrastructure architects to deploy or run any software on the computing resources provided by the service provider.
- Here, the underlying infrastructures such as compute, network, and storage are managed by the service provider.
- Thus, the infrastructure architects are exempted from maintaining the data center or underlying infrastructure.
- The end users are responsible for managing applications that are running on top of the service provider cloud infrastructure.
- Generally, the IaaS services are provided from the service provider cloud data center.

- The end users can access the services from their devices through web command line interface (CLI) or application programming interfaces (APIs) provided by the service providers.
- Some of the popular IaaS providers include Amazon Web Services (AWS), Google Compute Engine, OpenStack, and Eucalyptus.

2. PaaS:

- The ability given to developers to develop and deploy an application on the development platform provided by the service provider.
- Thus, the developers are exempted from managing the development platform and underlying infrastructure.
- Here, the developers are responsible for managing the deployed application and configuring the development environment.
- Generally, PaaS services are provided by the service provider on an on-premise or dedicated or hosted cloud infrastructure.
- The developers can access the development platform over the Internet through web CLI, web user interface (UI), and integrated development environments (IDEs).
- Some of the popular PaaS providers include Google App Engine, Force.com, Red Hat OpenShift, Heroku, and Engine Yard.

3. SaaS:

- The ability given to the end users to access an application over the Internet that is hosted and managed by the service provider.
- Thus, the end users are exempted from managing or controlling an application, the development platform, and the underlying infrastructure.
- Generally, SaaS services are hosted in service provider– managed or service provider–hosted cloud infrastructure.
- The end users can access the services from any thin clients or web browsers.
- Some of the popular SaaS providers include Saleforce.com, Google Apps, and Microsoft office 365.

2Q:Write short notes on end user and service provider responsibilities of cloud service models with a suitable diagram?

2A:

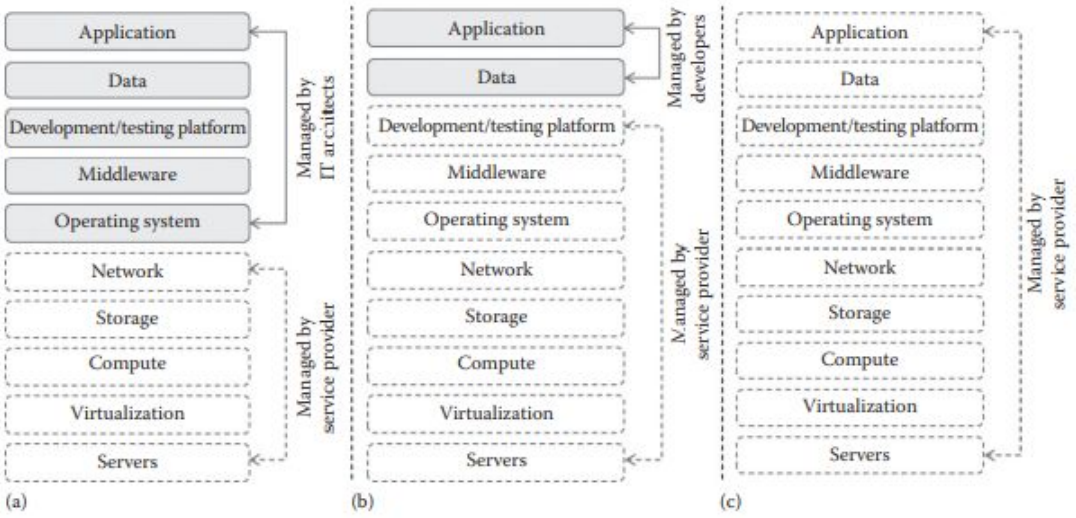

FIGURE 5.2
User and service provider responsibilities of cloud service models: (a) IaaS, (b) PaaS, and (c) SaaS.

- The different cloud service models target different audiences
- . For example, the IaaS model targets the information technology (IT) architects, PaaS targets the developers, and SaaS targets the end users.
- Based on the services subscribed, the responsibility of the targeted audience may vary as shown in Figure 5.2.
- In IaaS, the end users are responsible for maintaining the development platform and the application running on top of the underlying infrastructure.
- The IaaS providers are responsible for maintaining the underlying hardware as shown in Figure 5.2a.
- In PaaS, the end users are responsible for managing the application that they have developed.
- The underlying infrastructure will be maintained by the infrastructure provider as shown in Figure 5.2b.
- In SaaS, the end user is free from maintaining the infrastructure, development platform, and application that they are using.
- All the maintenance will be carried out by the SaaS providers as shown Figure 5.2c

3Q:Write short notes on the deployment and delivery of cloud service models with a neat diagram?

3A:

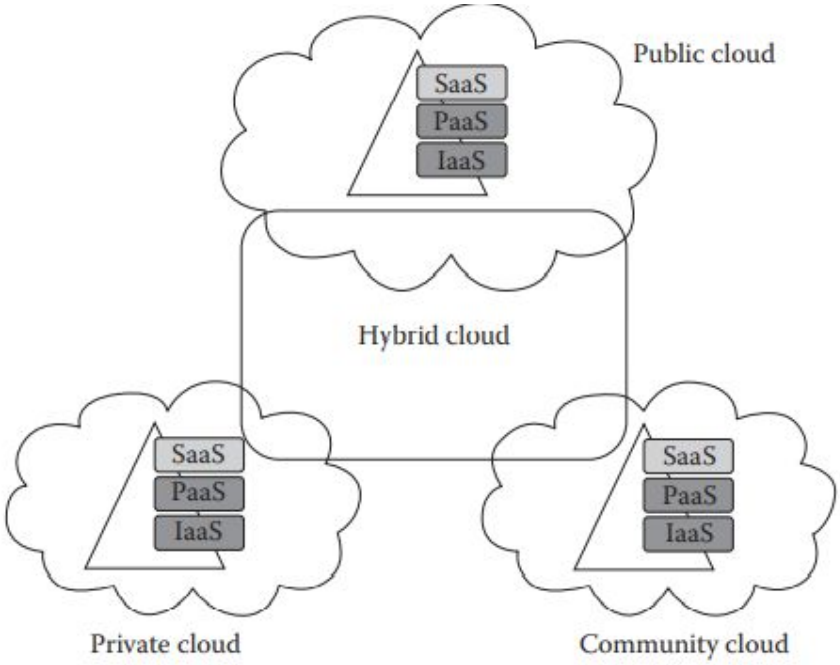

FIGURE 5.3
Deployment and delivery of different cloud service delivery models.

- The different service models of cloud computing can be deployed and delivered through any one of the cloud deployment models.
- The NIST defines four different types of cloud deployment models, namely, public cloud, private cloud, community cloud, and hybrid cloud.
- The public cloud is provided for the general public.
- The private cloud is used by an organization for its multiple business units.
- The community cloud is for some group of organizations with the same goals.
- The hybrid cloud is any combination of the public, private, and community clouds.
- The service delivery of cloud services through different deployment models is shown in Figure 5.3

4Q:Explain in detail about the overview of IaaS, PaaS, and SaaS with suitable diagrams?
4A:

Iaas:

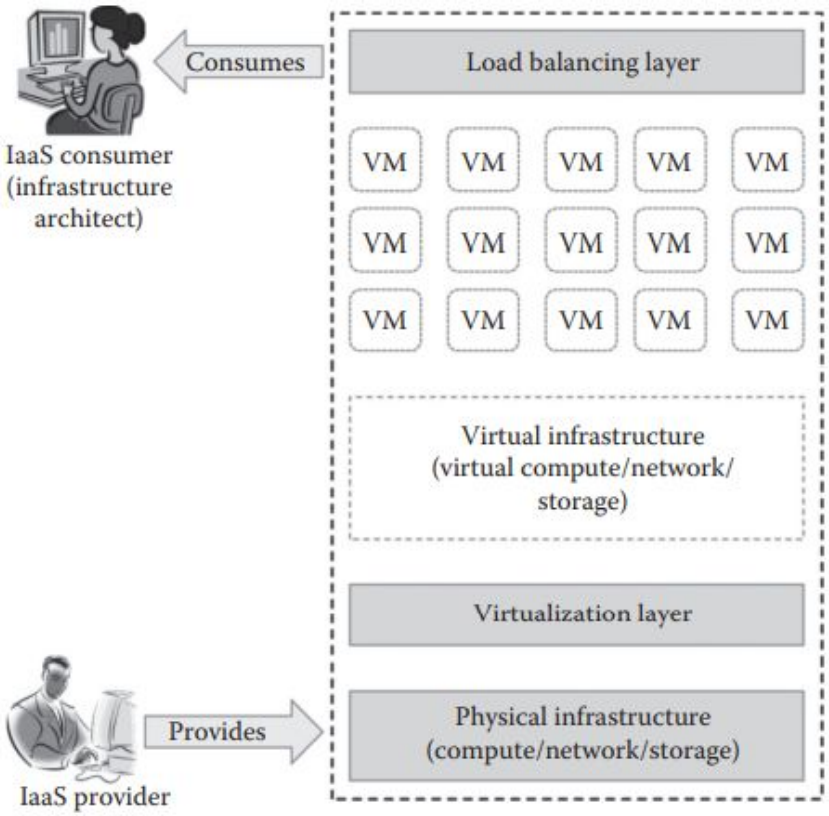

FIGURE 5.4
Overview of IaaS.

- IaaS changes the way that the compute, storage, and networking resources are consumed.
- In traditional data centers, the computing power is consumed by having physical access to the infrastructure.
- IaaS changes the computing from a physical infrastructure to a virtual infrastructure.
- IaaS provides virtual computing, storage, and network resources by abstracting the physical resources.
- Technology virtualization is used to provide the virtual resources.
- All the virtual resources are given to the virtual machines (VMs) that are configured by the service provider.
- The end users or IT architects will use the infrastructure resources in the form of VMs as shown in Figure 5.4.
- The targeted audience of IaaS is the IT architect.
- The IT architect can design virtual infrastructure, network, load balancers, etc., based on their needs.
- The IT architects need not maintain the physical servers as it is maintained by the service providers.

- The physical infrastructure can be maintained by the service providers themselves.
- Thus, it eliminates or hides the complexity of maintaining the physical infrastructure from the IT architects.
- A typical IaaS provider may provide the flowing services as shown in Figure 5.5:

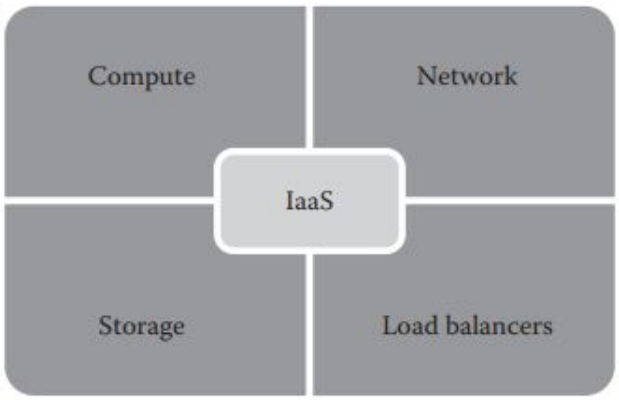

FIGURE 5.5
Services provided by IaaS providers.

1. Compute:
Computing as a Service includes virtual central processing units (CPUs) and virtual main memory for the VMs that are provisioned to the end users.

2. Storage:
STaaS provides back-end storage for the VM images. Some of the IaaS providers also provide the back end for storing files.

3. Network:
Network as a Service (NaaS) provides virtual networking components such as virtual router, switch, and bridge for the VMs.

4. Load balancers:
Load Balancing as a Service may provide load balancing capability at the infrastructure layer.

Paas:

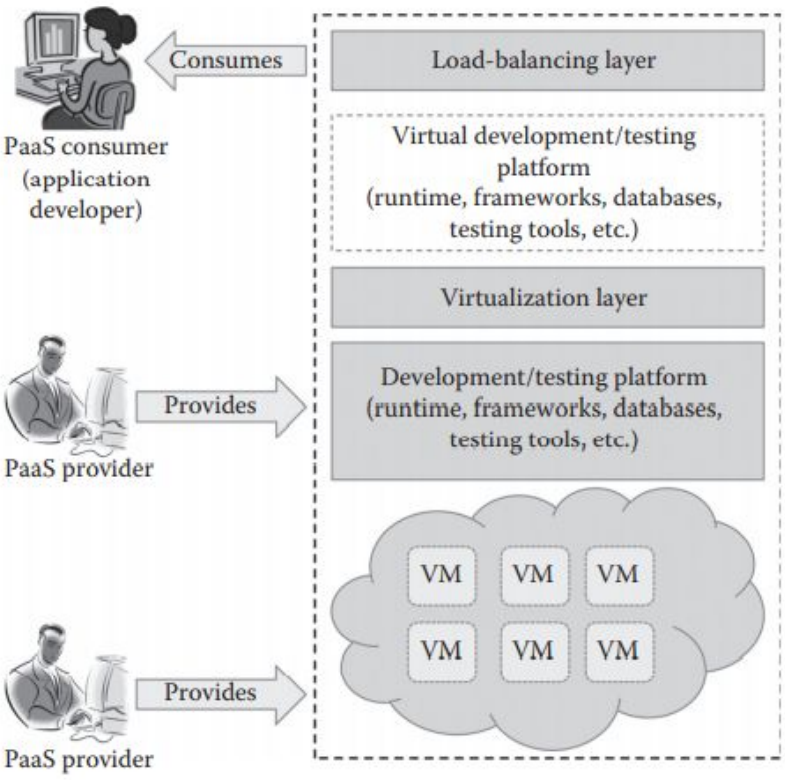

FIGURE 5.6
Overview of PaaS.

- PaaS changes the way that the software is developed and deployed.
- In traditional application development, the application will be developed locally and will be hosted in the central location.
- In stand-alone application development, the applications will be developed and delivered as executables.
- Most of the applications developed by traditional development platforms result in a licensing-based software, whereas PaaS changes the application development from local machine to online.
- PaaS providers provide the development PaaS from the data center. The developers can consume the services over the Internet as shown in Figure 5.6.
- PaaS allows the developers to develop their application online and also allows them to deploy immediately on the same platform.
- PaaS consumers or developers can consume language runtimes, application frameworks, databases, message queues, testing tools, and deployment tools as a service over the Internet.
- Thus, it reduces the complexity of buying and maintaining different tools for developing an application.

- Typical PaaS providers may provide programming languages, application frameworks, databases, and testing tools as shown in Figure 5.7

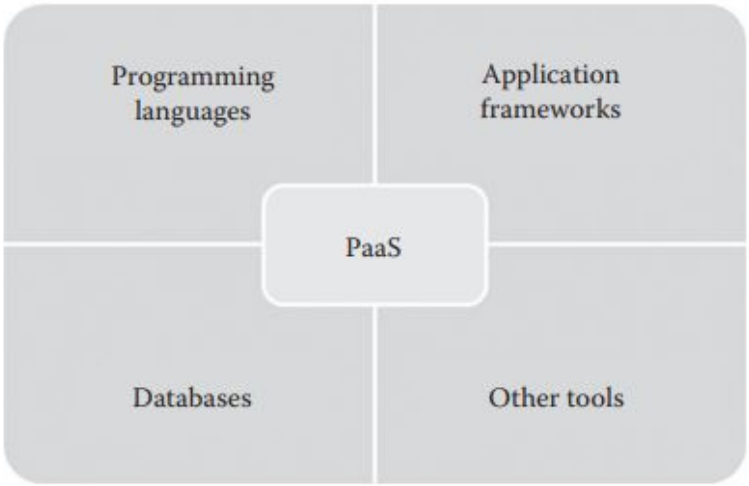

FIGURE 5.7
Services provided by PaaS providers.

Some of the PaaS providers also provide build tools, deployment tools, and software load balancers as a service:

1. Programming languages:

PaaS providers provide a wide variety of programming languages for the developers to develop applications.

Some of the popular programming languages provided by PaaS vendors are Java, Perl, PHP, Python, Ruby, Scala, Clojure, and Go.

2. Application frameworks:

PaaS vendors provide application frameworks that simplify the application development.

Some of the popular application development frameworks provided by a PaaS provider include Node.js, Rails, Drupal, Joomla, WordPress, Django, EE6, Spring, Play, Sinatra, Rack, and Zend.

3. Database:

Since every application needs to communicate with the databases, it becomes a must-have tool for every application.

PaaS providers are providing databases also with their PaaS platforms.

The popular databases provided by the popular PaaS vendors are ClearDB, PostgreSQL, Cloudant, Membase, MongoDB, and Redis.

4. Other tools:

PaaS providers provide all the tools that are required to develop, test, and deploy an application

Saas:

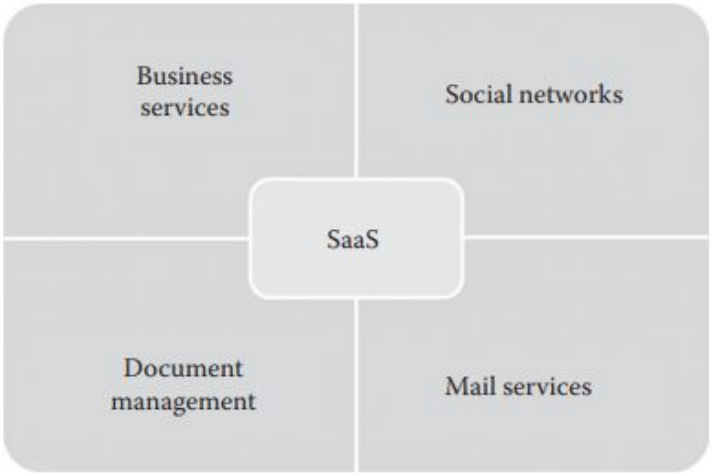

FIGURE 5.8
Services provided by SaaS Providers.

- SaaS changes the way the software is delivered to the customers.
- In the traditional software model, the software is delivered as a license-based product that needs to be installed in the end user device.
- Since SaaS is delivered as an on-demand service over the Internet, there is no need to install the software to the end user's devices.
- SaaS services can be accessed or disconnected at any time based on the end user's needs.
- SaaS services can be accessed from any lightweight web browsers on any devices such as laptops, tablets, and smartphones.
- Some of the SaaS services can be accessed from a thin client that does not contain much storage space and cannot run much software like the traditional desktop PCs.
- The important benefits of using thin clients for accessing the SaaS application are as follows:
- it is less vulnerable to attack, has a longer life cycle, consumes less power, and is less expensive.
- A typical SaaS provider may provide business services, social networks, document management, and mail services as shown in Figure 5.8:

1. Business services:

Most of the SaaS providers started providing a variety of business services that attract start-up companies.

The business SaaS services include ERP, CRM, billing, sales, and human resources.

2. Social networks:

Since social networking sites are extensively used by the general public, many social networking service providers adopted SaaS for their sustainability.

Since the number of users of the social networking sites is increasing exponentially, cloud computing is the perfect match for handling the variable load.

3. Document management:

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

4. Mail services:

E-mail services are currently used by many people.

The future growth in e-mail usage is unpredictable.

To handle the unpredictable number of users and the load on e-mail services, most of the e-mail providers started offering their services as SaaS services.

5Q:. Write short notes on the characteristics of IaaS, PaaS, and SaaS. ?

5A:

Characteristics of IaaS:

- IaaS providers offer virtual computing resources to the consumers on a payas-you-go basis.
- IaaS contains the characteristics of cloud computing such as on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service.
- Apart from all these, IaaS has its own unique characteristics as follows:

1. Web access to the resources:

- The IaaS model enables the IT users to access infrastructure resources over the Internet. When accessing a huge computing power, the IT user need not get physical access to the servers.
- Through any web browsers or management console, the users can access the required infrastructure.

2. Centralized management:

- Even though the physical resources are distributed, the management will be from a single place.
- The resources distributed across different parts can be controlled from any management console.
- This ensures effective resource management and effective resource utilization.

3. Elasticity and dynamic scaling:

- IaaS provides elastic services where the usage of resources can be increased or decreased according to the requirements.
- The infrastructure need depends on the load on the application.
- According to the load, IaaS services can provide the resources.
- The load on any application is dynamic and IaaS services are capable of proving the required services dynamically.

4. Shared infrastructure:

- IaaS follows a one-to-many delivery model and allows multiple IT users to share the same physical infrastructure.
- The different IT users will be given different VMs.
- IaaS ensures high resource utilization.

5. Preconfigured VMs:

- IaaS providers offer preconfigured VMs with operating systems (OSs), network configuration, etc.
- The IT users can select any kind of VMs of their choice. The IT users are free to configure VMs from scratch.
- The users can directly start using the VMs as soon as they subscribed to the services

6. Metered services:

- IaaS allows the IT users to rent the computing resources instead of buying it.
- The services consumed by the IT user will be measured, and the users will be charged by the IaaS providers based on the amount of usage.

Characteristics of PaaS:

- PaaS development platforms are different from the traditional application development platforms.
- The following are the essential characteristics that make PaaS unique from traditional development platforms:

1. All in one:

- Most of the PaaS providers offer services to develop, test, deploy, host, and maintain applications in the same IDE.
- Additionally, many service providers provide all the programming languages, frameworks, databases, and other development-related services that make developers choose from a wide variety of development platforms.

2. Web access to the development platform:

- A typical development platform uses any IDEs for developing applications.
- Typically, the IDE will be installed in the developer's machines.
- But, PaaS provides web access to the development platform.
- Using web UI, any developer can get access to the development platform.
- The web-based UI helps the developers create, modify, test, and deploy different applications on the same platform.

3. Offline access:

- A developer may not be able to connect to the Internet for a whole day to access the PaaS services.
- When there is no Internet connectivity, the developers should be allowed to work offline.
- To enable offline development, some of the PaaS providers allow the developer to synchronize their local IDE with the PaaS services.
- The developers can develop an application locally and deploy it online whenever they are connected to the Internet.

4. Built-in scalability:

- Scalability is an important requirement for the new generation web or SaaS applications.
- It is very difficult to enable the dynamic scalability for any application developed using traditional development platforms.
- But, PaaS services provide built-in scalability to an application that is developed using any particular PaaS.
- This ensures that the application is capable of handling varying loads efficiently.

5. Collaborative platform:

- Nowadays, the development team consists of developers who are working from different places.
- There is a need for a common platform where the developers can collaboratively work together on the same project.
- Most of the PaaS services provide support for collaborative development.
- To enable collaboration among developers, most of the PaaS providers provide tools for project planning and communication.

6. Diverse client tools:

- To make the development easier, PaaS providers provide a wide variety of client tools to help the developer.
- The client tools include CLI, web CLI, web UI, REST API, and IDE.
- The developers can choose any tools of their choice.
- These client tools are also capable of handling billing and subscription management.

Characteristics of SaaS :

- SaaS services are different and give more benefits to end users than the traditional software.
- The following are the essential characteristics of SaaS services that make it unique from traditional software:

1. One to many:

SaaS services are delivered as a one-to-many model where a single instance of the application can be shared by multiple tenants or customers.

2. Web access:

SaaS services provide web access to the software. It allows the end user to access the application from any location if the device is connected to the Internet.

3. Centralized management:

Since SaaS services are hosted and managed from the central location, management of the SaaS application becomes easier. Normally, the SaaS providers will perform the automatic updates that ensure that each tenant is accessing the most recent version of the application without any user-side updates.

4. Multi Device support:

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

5. Better scalability:

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

6. High availability:

SaaS services ensure the 99.99% availability of user data as proper backup and recovery mechanisms are implemented at the back end.

7. API integration:

SaaS services have the capability of integrating with other software or service through standard APIs.

6Q:Explain the suitability of different cloud service models. ?
6A:

Suitability of IaaS:

IaaS reduces the total cost of ownership (TCO) and increases the return on investment (ROI) for start-up companies that cannot invest more in buying infrastructure. IaaS can be used in the following situations:

1. Unpredictable spikes in usage:

- When there is a significant spike in usage of computing resources, IaaS is the best option for IT industries.
- When demand is very volatile, we cannot predict the spikes and troughs in terms of demand of the infrastructure.
- In this situation, we cannot add or remove infrastructure immediately according to the demand in a traditional infrastructure.
- If there is an unpredictable demand for infrastructure, then it is recommended to use IaaS services.

2. Limited capital investment:

- New start-up companies cannot invest more on buying infrastructure for their business needs.
- And so by using IaaS, start-up companies can reduce the capital investment on hardware.
- IaaS is the suitable option for start-up companies with less capital investment on hardware.

3. Infrastructure on demand:

- Some organizations may require large infrastructure for a short period of time.
- For this purpose, an organization cannot afford to buy more on-premise resources.
- Instead, they can rent the required infrastructure for a specific period of time.
- IaaS best suits the organizations that look for infrastructure on demand or for a short time period.

IaaS helps start-up companies limit its capital expenditure.

While it is widely used by start-up companies, there are some situations where IaaS may not be the best option.

In following situations, IT users should avoid using the IaaS:

1. When regulatory compliance does not allow off-premise hosting:

For some companies, its regulation may not allow the application and data to be hosted on third-party off-premise infrastructure.

2. When usage is minimal:

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

3. When better performance is required:

Since the IaaS services are accessed through the Internet, sometimes the performance might be not as expected due to network latency.

4. When there is a need for more control on physical infrastructure:

Some organizations might require physical control over the underlying infrastructure. As the IaaS services are abstracted as virtual resources, it is not possible to have more control on underlying physical infrastructure

Suitability of PaaS :

- Most of the start-up SaaS development companies and independent software vendors (ISVs) widely use PaaS in developing an application.
- PaaS technology is getting attention from other traditional software development companies also.

PaaS is a suitable option for the following situations:

1. Collaborative development:

- To increase the time to market and development efficiency, there is a need for a common place where the development team and other stakeholders of the application can collaborate with each other.
- Since PaaS services provide a collaborative development environment, it is a suitable option for applications that need collaboration among developers and other third parties to carry out the development process.

2. Automated testing and deployment:

- Automated testing and building of an application are very useful while developing applications at a very short time frame.
- The automated testing tools reduce the time spent in manual testing tools.
- Most of the PaaS services offer automated testing and deployment capabilities.
- The development team needs to concentrate more on development rather than testing and deployment.
- Thus, PaaS services are the best option where there is a need for automated testing and deployment of the applications.

3. Time to market:

- The PaaS services follow the iterative and incremental development methodologies that ensure that the application is in the market as per the time frame given.
- For example, the PaaS services are the best option for application development that uses agile development methodologies.
- If the software vendor wants their application to be in the market as soon as possible, then the PaaS services are the best option for the development.

PaaS is used widely to accelerate the application development process to ensure the time to market.

Most of the start-up companies and ISVs started migrating to the PaaS services.

Even though it is used widely, there are some situations where PaaS may not be the best option:

1. Frequent application migration:

The major problem with PaaS services are vendor lock-in. Since there are no common standards followed among PaaS providers, it is very difficult to migrate the application from one PaaS provider to the other.

2. Customization at the infrastructure level:

PaaS is an abstracted service, and the PaaS users do not have full control over the underlying infrastructure.

There are some application development platforms that need some configuration or customization of underlying infrastructure.

In these situations, it is not possible to customize the underlying infrastructure with PaaS.

If the application development platform needs any configuration at the hardware level, it is not recommended to go for PaaS.

3. Flexibility at the platform level:

PaaS provides template-based applications where all the different programming languages, databases, and message queues are predefined.

It is an advantage if the application is a generic application.

4. Integration with on-premise application:

A company might have used PaaS services for some set of applications.

For some set of applications, they might have used on-premise platforms.

Since many PaaS services use their own proprietary technologies to define the application stack, it may not match with the on-premise application stack.

This makes the integration of application hosted in on-premise platform and PaaS platform a difficult job.

Suitability of SaaS :

- SaaS is popular among individuals and start-up companies because of the benefits it provides.
- Most of the traditional software users are looking for SaaS versions of the software as SaaS has several advantages over traditional applications
- **. SaaS applications are the best option for the following:**

1. On-demand software:

- The licensing-based software model requires buying full packaged software and increases the spending on buying software.
- Some of the occasionally used software does not give any ROI.
- Because of this, many end users are looking for a software that they can use as and when they needed.
- If the end users are looking for on-demand software rather than the licensing-based full-term software, then the SaaS model is the best option.

2. Software for start-up companies:

- When using any traditional software, the end user should buy devices with minimum requirements specified by the software vendor.
- This increases the investment on buying hardware for start-up companies.
- Since SaaS services do not require high-end infrastructure for accessing, it is a suitable option for start-up companies that can reduce the initial expenditure on buying high-end hardware.

3. Software compatible with multiple devices:

- Some of the applications like word processors or mail services need better accessibility from different devices.

- The SaaS applications are adaptable with almost all the devices.

4. Software with varying loads:

- We cannot predict the load on popular applications such as social networking sites.
- The user may connect or disconnect from applications anytime.
- It is very difficult to handle varying loads with the traditional infrastructure.
- With the dynamic scaling capabilities, SaaS applications can handle varying loads efficiently without disrupting the normal behavior of the application.

Most of the traditional software vendors moved to SaaS business as it is an emerging software delivery model that attracts end users.
But still many traditional applications do not have its SaaS versions.
This implies that SaaS applications may not be the best option for all types of software.
The SaaS delivery model is not the best option for the applications mentioned in the following:

1. Real-time applications:

- Since SaaS applications depend on Internet connectivity, it may not work better with low Internet speed.
- If data is stored far away from the end user, the latency issues may delay the data retrieval timings.
- Real-time applications require fast processing of data that may not be possible with the SaaS applications because of the dependency on high-speed Internet connectivity and latency issues.

2. Applications with confidential data:

- Data security, data governance, and data compliance are always issues with SaaS applications.
- Since data is stored with third-party service providers, there is no surety that our data will be safe.
- If the stored confidential data get lost, it will make a serious loss to the organization.
- It is not recommended to go for SaaS for applications that handle confidential data.

3. Better on-premise application:

- Some of the on-premise applications might fulfill all the requirements of the organization.
- In such situations, migrating to the SaaS model may not be the best option.

7Q:Write short notes on pros and cons of IaaS, PaaS, and SaaS?
7A:

Pros and Cons of IaaS:

The following are the benefits provided by IaaS:

1. Pay-as-you-use model:

- The IaaS services are provided to the customers on a pay-per-use basis.
- This ensures that the customers are required to pay for what they have used.
- This model eliminates the unnecessary spending on buying hardware.

2. Reduced TCO:

- Since IaaS providers allow the IT users to rent the computing resources, they need not buy physical hardware for running their business.
- The IT users can rent the IT infrastructure rather than buy it by spending large amounts.
- IaaS reduces the need for buying hardware resources and thus reduces the TCO.

3. Elastic resources:

- IaaS provides resources based on the current needs.
- IT users can scale up or scale down the resources whenever they want.
- This dynamic scaling is done automatically using some load balancers.
- This load balancer transfers the additional resource request to the new server and improves application efficiency.

4. Better resource utilization:

- Resource utilization is the most important criteria to succeed in the IT business.
- The purchased infrastructure should be utilized properly to increase the ROI.
- IaaS ensures better resource utilization and provides high ROI for IaaS providers.

5. Supports Green IT:

- In traditional IT infrastructure, dedicated servers are used for different business needs.
- Since many servers are used, the power consumption will be high.
- This does not result in Green IT.
- In IaaS, the need of buying dedicated servers is eliminated as single infrastructure is shared between multiple customers, thus reducing the number of servers to be purchased and hence the power consumption that results in Green IT.

The following are the drawbacks of IaaS:

1. Security issues:

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

2. Interoperability issues:

- There are no common standards followed among the different IaaS providers.
- It is very difficult to migrate any VM from one IaaS provider to the other.
- Sometimes, the customers might face the vendor lock-in problem.

3. Performance issues:

- IaaS is nothing but the consolidation of available resources from the distributed cloud servers.
- Here, all the distributed servers are connected over the network.
- Latency of the network plays an important role in deciding the performance. Because of latency issues, sometimes the VM contains issues with its performance.

Pros and Cons of PaaS:

PaaS has the following benefits:

1. Quick development and deployment:

- PaaS provides all the required development and testing tools to develop, test, and deploy the software in one place.
- Most of the PaaS services automate the testing and deployment process as soon as the developer completes the development.
- This speeds up application development and deployment than traditional development platforms.

2. Reduces TCO:

- The developers need not buy licensed development and testing tools if PaaS services are selected.
- Most of the traditional development platforms require high-end infrastructure for its working, which increases the TCO of the application development company.
- But, PaaS allows the developers to rent the software, development platforms, and testing tools to develop, build, and deploy the application.
- PaaS does not require high-end infrastructure to develop the application, thus reducing the TCO of the development company.

3. Supports agile software development:

- Nowadays, most of the new-generation applications are developed using agile methodologies.
- Many ISVs and SaaS development companies started adopting agile methodologies for application development.
- PaaS services support agile methodologies that the ISVs and other development companies are looking for.

4. Different teams can work together:

- The traditional development platform does not have extensive support for collaborative development.
- PaaS services support developers from different places to work together on the same project.
- This is possible because of the online common development platform provided by PaaS providers.

5. Ease of use:

- The traditional development platform uses any one of CLI- or IDE-based interfaces for development.
- Some developers may not be familiar with the interfaces provided by the application development platform.
- This makes the development job a little bit difficult.
- But, PaaS provides a wide variety of client tools such as CLI, web CLI, web UI, APIs, and IDEs.
- The developers are free to choose any client tools of their choice.
- Especially, the web UI–based PaaS services increase the usability of the development platform for all types of developers.

6. Less maintenance overhead:

- In on-premise applications, the development company or software vendor is responsible for maintaining the underlying hardware.
- They need to recruit skilled administrators to maintain the servers.
- This overhead is eliminated by the PaaS services as the underlying infrastructure is maintained by the infrastructure providers.
- This gives freedom to developers to work on the application development.

7. Produces scalable applications:

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

PAAS contains following drawbacks:

1. Vendor lock-in:

- The major drawback with PaaS providers is vendor lock-in.
- The main reason for vendor lock-in is lack of standards.
- There are no common standards followed among the different PaaS providers.
- The other reason for vendor lock-in is proprietary technologies used by PaaS providers. Most of the PaaS vendors use the proprietary technologies that are not compatible with the other PaaS providers.
- The vendor lock-in problem of PaaS services does not allow the applications to be migrated from one PaaS provider to the other.

2. Security issues:

- Like in the other cloud services, security is one of the major issues in PaaS services.
- Since data is stored in off-premise third-party servers, many developers are afraid to go for PaaS services.
- Of course, many PaaS providers provide mechanisms to protect the user data, and it is not sufficient to feel the safety of on premise deployment.
- When selecting the PaaS provider, the developer should review the regulatory, compliance, and security policies of the PaaS provider with their own security requirements.
- If not properly reviewed, the developers or users are at the risk of data security breach.

3. Less flexibility:

- PaaS providers do not give much freedom for the developers to define their own application stack.
- Most of the PaaS providers provide many programming languages, databases, and other development tools.
- But, it is not extensive and does not satisfy all developer needs.
- Only some of the PaaS providers allow developers to extend the PaaS tools with the custom or new programming languages.
- Still most of the PaaS providers do not provide flexibility to the developers.

4. Depends on Internet connection:

- Since the PaaS services are delivered over the Internet, the developers should depend on Internet connectivity for developing the application.
- Even though some of the providers allow offline access, most of the PaaS providers do not allow offline access.
- With slow Internet connection, the usability and efficiency of the PaaS platform do not satisfy the developer requirements.

Pros and Cons of SaaS:

SaaS services provide the following benefits:

1. No client-side installation:

- SaaS services do not require client-side installation of the software.
- The end users can access the services directly from the service provider data center without any installation.
- There is no need for high-end hardware to consume SaaSservices.
- It can be accessed from thin clients or any handheld devices, thus reducing the initial expenditure on buying high-end hardware.

2. Cost savings:

- Since SaaS services follow the utility-based billing or pay-as-you-go billing, it demands the end users to pay for what they have used.
- Most of the SaaS providers offer different subscription plans to benefit different customers.
- Sometimes, the generic SaaS services such as word processors are given for free to the end users.

3. Less maintenance:

- SaaS services eliminate the additional overhead of maintaining the software from the client side.
- For example, in the traditional software, the end user is responsible for performing bulk updates.
- But in SaaS, the service provider itself maintains the automatic updates, monitoring, and other maintenance activities of the applications.

4. Ease of access:

- SaaS services can be accessed from any devices if it is connected to the Internet.
- Accessibility of SaaS services is not restricted to any particular devices.
- It is adaptable to all the devices as it uses the responsive web UI.

5. Dynamic scaling:

- SaaS services are popularly known for elastic dynamic scaling.
- It is very difficult for on-premise software to provide dynamic scaling capability as it requires additional hardware.
- Since the SaaS services leverage elastic resources provided by cloud computing, it can handle any type of varying loads without disrupting the normal behavior of the application.

6. Disaster recovery:

- With proper backup and recovery mechanisms, replicas are maintained for every SaaS services.
- The replicas are distributed across many servers.
- If any server fails, the end user can access the SaaS from other servers.
- It eliminates the problem of single point of failure. It also ensures the high availability of the application.

7. Multitenancy:

- Multitenancy is the ability given to the end users to share a single instance of the application.
- Multitenancy increases resource utilization from the service provider side.

The following are the major problems with SaaS services:

1. Security:

- Security is the major concern in migrating to SaaS applications
- Since the SaaS application is shared between many end users, there is a possibility of data leakage.
- Here, the data is stored in the service provider data center.
- We cannot simply trust some third-party service provider to store our company-sensitive and confidential data.
- The end user should be careful while selecting the SaaS provider to avoid unnecessary data loss.

2. Connectivity requirements:

- SaaS applications require Internet connectivity for accessing it.
- Sometimes, the end user's Internet connectivity might be very slow.
- In such situations, the user cannot access the services with ease.
- The dependency on high-speed Internet connection is a major problem in SaaS applications.

3. Loss of control:

- Since the data are stored in a third-party and off premise location, the end user does not have any control over the data.
- The degree of control over the SaaS application and data is lesser than the on-premise application.

8Q:Write short notes on other cloud service models that emerged after the introduction of cloud computing?

8A:

Other Cloud Service Models:

- The basic cloud services such as IaaS, PaaS, and SaaS are widely used by many individual and start-up companies.
- Now, cloud computing becomes the dominant technology that drives the IT world.
- Because of the extensive use of basic cloud services, the end users realize the importance and benefits of specific services such as network, storage, and database.
- The basic cloud service models are the unified models that contain multiple services in it.

- Now, the end users' expectations have changed, and they are expecting the individual services to be offered by service providers.
- This makes most of the service providers think about the separate services that meet end user requirements.
- Many service providers already started offering separate services such as network, desktop, database, and storage on demand as given in the following:

1. NaaS :

- is an ability given to the end users to access virtual network services that are provided by the service provider.
- Like other cloud service models, NaaS is also a business model for delivering virtual network services over the Internet on a pay-per-use basis.
- In on-premise data centers, the IT industries spent a lot of money to buy network hardware to manage in-house networks.
- But, cloud computing changes networking services into a utility-based service.
- NaaS allows network architects to create virtual networks, virtual network interface cards (NICs), virtual routers, virtual switches, and other networking components.
- Additionally, it allows the network architect to deploy custom routing protocols and enables the design of efficient in-network services, such as data aggregation, stream processing, and caching.
- Some of the popular services provided by NaaS include virtual private network (VPN), bandwidth on demand (BoD), and mobile network virtualization.

2. Desktop as a Service (DEaaS):

- is an ability given to the end users to use desktop virtualization without buying and managing their own infrastructure.
- DEaaS is a pay-per-use cloud service delivery model in which the service provider manages the back-end responsibilities of data storage, backup, security, and upgrades.
- The end users are responsible for managing their own desktop images, applications, and security.
- Accessing the virtual desktop provided by the DEaaS provider is device, location, and network independent.
- DEaaS services are simple to deploy, are highly secure, and produce better experience on almost all devices.

3. STaaS:

- is an ability given to the end users to store the data on the storage services provided by the service provider.
- STaaS allows the end users to access the files at any time from any place.
- The STaaS provider provides the virtual storage that is abstracted from the physical storage of any cloud data center.
- STaaS is also a cloud business model that is delivered as a utility.
- Here, the customers can rent the storage from the STaaS provider.
- STaaS is commonly used as a backup storage for efficient disaster recovery.

4. DBaaS:

- is an ability given to the end users to access the database service without the need to install and maintain it.

- The service provider is responsible for installing and maintaining the databases.
- The end users can directly access the services and can pay according to their usage.
- DBaaS automates the database administration process.
- The end users can access the database services through any API or web UIs provided by the service provider.
- The DBaaS eases the database administration process.
- Popular examples of DBaaS include SimpleDB, DynamoDB, MongoDB as a Service, GAE datastore, and ScaleDB.

5. Data as a Service (DaaS) :

- is an ability given to the end users to access the data that are provided by the service provider over the Internet.
- DaaS provides data on demand. The data may include text, images, sounds, and videos.
- DaaS is closely related to other cloud service models such as SaaS and STaaS.
- DaaS can be easily integrated with SaaS or STaaS for providing the composite service.
- DaaS is highly used in geography data services and financial data services.
- The advantages of DaaS include agility, cost effectiveness, and data quality.

6. SECaaS:

- is an ability given to the end user to access the security service provided by the service provider on a pay-per-use basis.
- In SECaaS, the service provider integrates their security services to benefit the end users.
- Generally, the SECaaS includes authentication, antivirus, antimalware/spyware, intrusion detection, and security event management.
- The security services provided by the SECaaS providers are typically used for securing the on-premise or in-house infrastructure and applications.
- Some of the SECaaS providers include Cisco, McAfee, Panda Software, Symantec, Trend Micro, and VeriSign.

7. IDaaS :

- is an ability given to the end users to access the authentication infrastructure that is managed and provided by the third-party service provider.
- The end user of IDaaS is typically an organization or enterprise.
- Using IDaaS services, any organization can easily manage their employees' identity without any additional overhead.
- Generally, IDaaS includes directory services, federated services, registration, authentication services, risk and event monitoring, single sign-on services, and identity and profile management.