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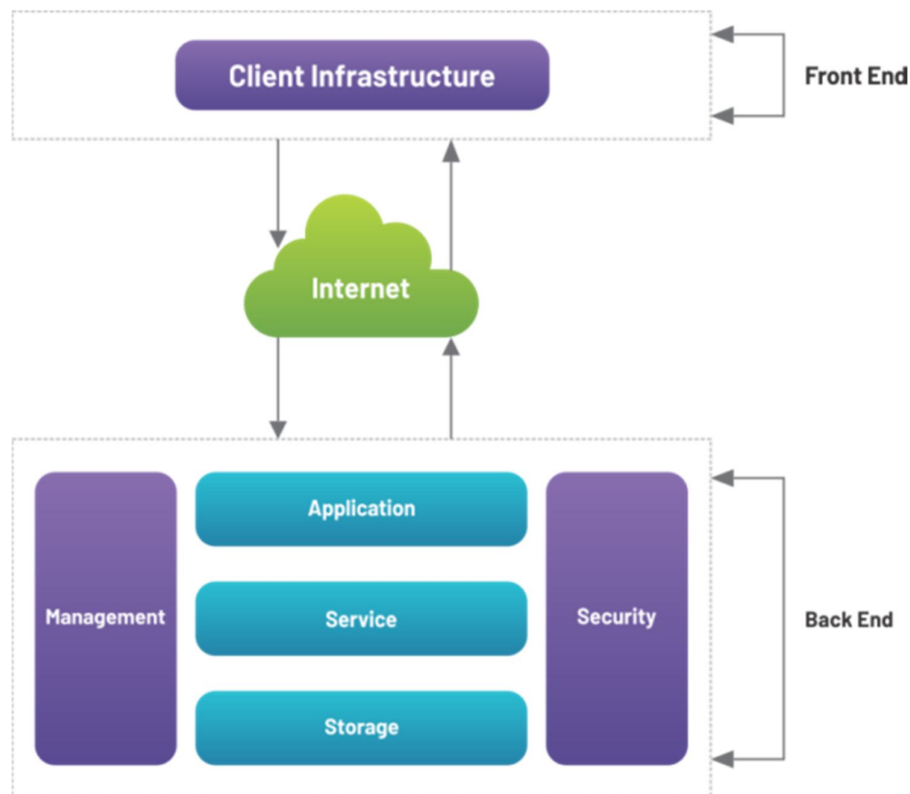
CLOUD COMPUTING ARCHITECTURE

As we know, cloud computing technology is used by both small and large organizations to **store the information** in cloud and **access** it from anywhere at anytime using the internet connection.

Cloud computing architecture is a combination of **service-oriented architecture** and **event-driven architecture**.

Cloud computing architecture is divided into the following two parts:

- o   Front End
- o   Back End

Figure: Cloud Computing Architecture

Front End
The front end is used by the client. It contains client-side interfaces and applications that are required to access the cloud computing platforms. The front end includes web servers (including Chrome, Firefox, internet explorer, etc.), thin & fat clients, tablets, and mobile devices.

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Back End
The back end is used by the service provider. It manages all the resources that are required to provide cloud computing services. It includes a huge amount of data storage, security mechanism, virtual machines, deploying models, servers, traffic control mechanisms, etc.

- It is the responsibility of the back end to provide built-in security mechanism, traffic control and protocols.

- The server employs certain protocols known as middleware, which help the connected devices to communicate with each other.

Components of Cloud Computing Architecture

There are the following components of cloud computing architecture:

1. Client Infrastructure
Client Infrastructure is a Front end component. It provides GUI (Graphical User Interface) to interact with the cloud.

2. Application
The application may be any software or platform that a client wants to access.

3. Service
A Cloud Services manages that which type of service you access according to the client's requirement.

Cloud computing offers the following three type of services:

i. Software as a Service (SaaS) – It is also known as **cloud application services**. Mostly, SaaS applications run directly through the web browser means we do not require to download and install these applications.
Example: Google Apps, Salesforce Dropbox, Slack, Hubspot, Cisco WebEx.

ii. Platform as a Service (PaaS) – It is also known as **cloud platform services**. It is quite similar to SaaS, but the difference is that PaaS provides a platform for software creation, but using SaaS, we can access software over the internet without the need of any platform.
Example: Windows Azure, Force.com, Magento Commerce Cloud, OpenShift.

iii. Infrastructure as a Service (IaaS) – It is also known as **cloud infrastructure services**. It is responsible for managing applications data, middleware, and runtime environments.
Example: Amazon Web Services (AWS) EC2, Google Compute Engine (GCE), Cisco Metapod.

4. Runtime Cloud
Runtime Cloud provides the **execution and runtime environment** to the virtual machines.

5. Storage
Storage is one of the most important components of cloud computing. It provides a huge amount of storage capacity in the cloud to store and manage data.

6. Infrastructure
It provides services on the **host level**, **application level**, and **network level**. Cloud infrastructure includes hardware and software components such as servers, storage, network devices, virtualization software, and other storage resources that are needed to support the cloud computing model.

7. Management
Management is used to manage components such as application, service, runtime cloud, storage, infrastructure, and other security issues in the backend and establish coordination between them.

8. Security
Security is an in-built back end component of cloud computing. It implements a security mechanism in the back end.

9. Internet
The Internet is medium through which front end and back end can interact and communicate with each other.

Infrastructural Constraints
Followings are the basic constraints:
- Transparency
- Scalability
- Intelligent Monitoring
- Security

Transparency
- In a Cloud environment, virtualization is the key to share the resources.
- It is impossible to satisfy the demand with single resource or server. Hence, there should be transparency in resources, load balancing and application, so that we can scale the resources on demand.

Scalability
- Scaling up an application is easy but scaling up an application delivery solution is not easy, because it includes configuration overhead or even re-architecting the network.
- Hence, application delivery is required to be scalable that need the virtual infrastructure so that, resources are provisioned and de-provisioned easily.

Intelligent Monitoring
- Application solution delivery is required to be capable of intelligent monitoring to achieve transparency and scalability.

Security
- In security, the mega data center in the cloud must be securely architected.
- The control node, an entry point in mega data center also requires to be secure.

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CLOUD COMPUTING STACK

Cloud computing has commonly been referred to as a "stack" because it typically encompasses many different types of services which have been built on top of each other under a "cloud". Cloud computing has been defined by the NIST (National Institute of Standards and Technology) as a model that enables on-demand access to a shared resource pool consisting of servers, networks, applications, services and storage which can be rapidly deployed with minimal management efforts. There are three different types of cloud computing services namely Platform as a Service or PaaS, Software as a Service or SaaS and Infrastructure as a Service or IaaS.
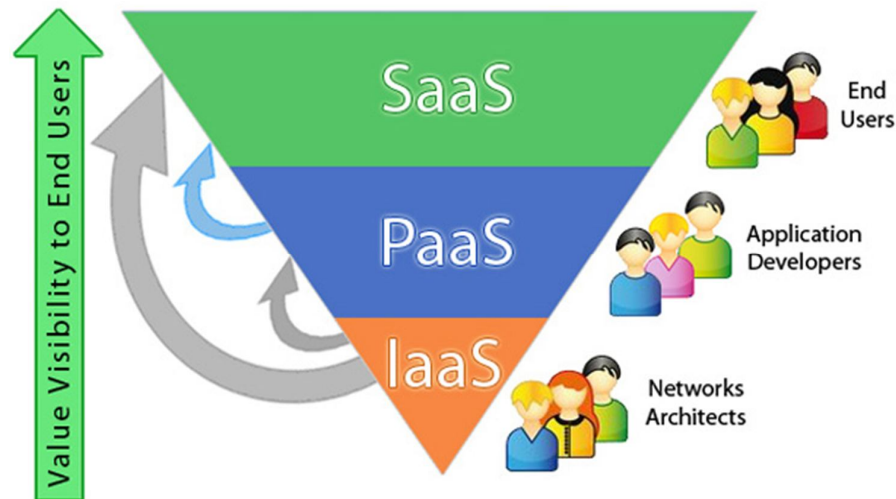
Figure: Cloud Computing Stack

Users can make use of bulk resources which can be obtained quickly whenever there are demands. NIST has also stated some features as being essential for services to be regarded as cloud hosting services.
• **On-demand services** that end users can sign up for and obtain without delays.
• **Wide network access** because users can access such services through multiple platforms like laptops, desktops and mobiles.
• **Measured services** because users will pay according to what they use; so, billing is offered as a utility service.
• **Elasticity and scalability** to cope with increases in demand.

The SaaS applications have been designed for end users and they are offered across the Internet. The PaaS refers to sets of tools or services designed for coding and implementing the applications efficiently. IaaS refers to the software and hardware which powers it, such as, servers, networks, storage, and operating system.

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COMPARISON OF CLOUD COMPUTING ARCHITECTURE WITH TRADITIONAL COMPUTING ARCHITECTURE (CLIENT/SERVER)

In a traditional client-server model, which is definitely still in common use today, a client connects to a server that performs a particular job. This server may host a database, or a series of file shares, or a webpage. When the client connects to that server, there is an implicit understanding of the type of communication and data transmission that will ensue between the two computers. There may also be an understanding by the client, or the end user, of the capabilities of the server's hardware, and its limitations. This relatively "tight coupling" between the client machine and its server can pose problems for a system admin who needs to take down a server for maintenance; all the applications dependent upon resources provided by this server have to be pointed at another server, and not all applications and infrastructures are designed with this type of redundancy and failover-tolerance in mind.

In a cloud model, the hardware, topology, division of labor, and even number of actual machines involved is all abstracted behind a single endpoint. The analogy could be drawn to a modern "web application", as opposed to older generations of "website" which were more static. We might guess that there is an application server and a DB server behind the scenes, but we really don't have to care; the web server, as part of its job to serve the full application to users beyond the "edge", provides a unified endpoint allowing controlled access to all the data and services provided by other machines behind this front door.

Client server is a process where data processing is distributed between a client and a server. The best example of client/server is – emails and RDBMS based web applications. In simpler words, client server is a kind of application architecture whereas cloud computing is the way that defines how applications are hosted. Cloud is the latest technology that allows businesses to abstract software from the hardware, and scale up/down the applications as per the business demands.
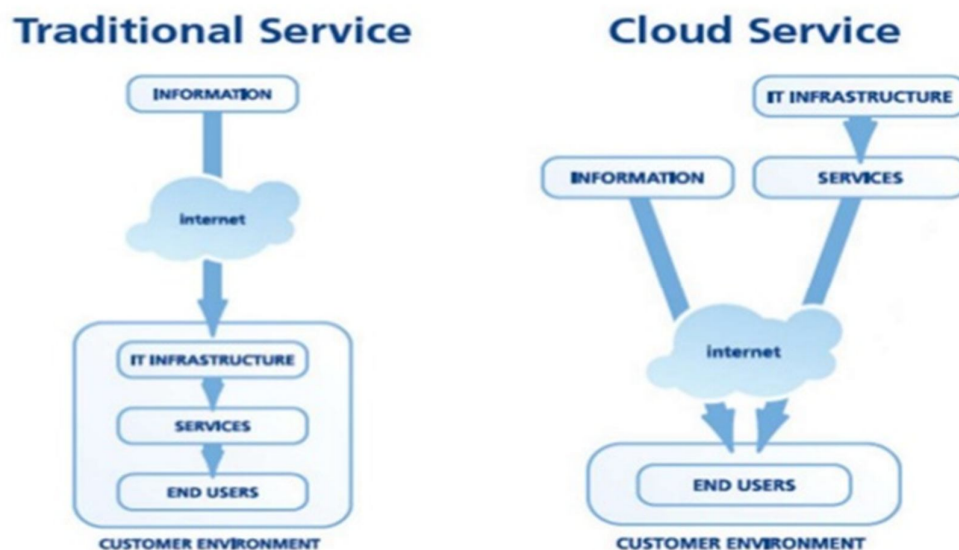

Figure: Comparison of Cloud computing and Client-Server Architecture

The primary difference in cloud computing and traditional networking or hosting is the implementation, and in one word that is "virtualization." Virtualization allows for extensive scalability, giving clients virtually limitless resources. **Client-Server** is a kind of application architecture whereas **Cloud Computing** is the way that defines how applications are hosted.

SERVICES PROVIDED AT VARIOUS LEVELS IN CLOUD COMPUTING

Cloud computing allows your business to work wherever you like, whenever you like. However, cloud computing is not quite as simple as it may seem. Inside of the world of cloud computing, there are three major service models. By comparing the three different models, you will be better able to determine which cloud computing service model is right for your business.

Each offers a different level of flexibility and control over the product that your business is 'buying'. Each also varies in its relationship to your existing IT infrastructure. Because of the wide variances between the three, it is important to determine which model will suit your business's needs the best.
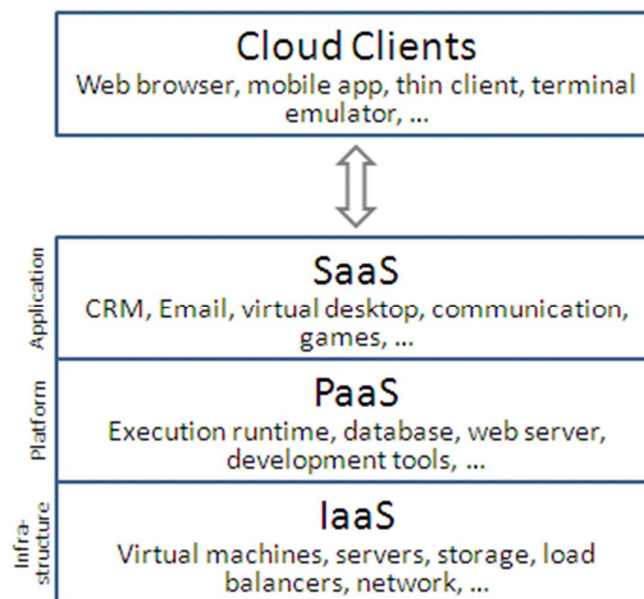
IaaS (Infrastructure As A Service)

IaaS is the lowest-level cloud service paradigm and possibly the most important. With IaaS, pre-configured hardware resources are provided to users through a virtual interface. Unlike PaaS and SaaS, IaaS doesn't include applications or even an operating system (implementing all of that is left up to the customer), it offers the fundamental infrastructure of virtual servers, network, operating systems and data storage drives. It allows for the flexibility, reliability and scalability that many businesses seek with the cloud, and removes the need for hardware in the office. This makes it ideal for small and medium sized organizations looking for a cost-effective IT solution to support business growth. IaaS is a fully outsourced pay-for-use service and is available as a public, private or hybrid infrastructure.

Popular IaaS offerings like Amazon EC2, IBM Soft Layer, and Google's Compute Engine (GCE) are silently powering a huge portion of the backbone of the internet, whether users realize it or not.

PaaS (Platform As A Service)

PaaS is a cloud service model where the cloud is used to deliver a platform to users from which they can develop, initialize and manage applications. PaaS offerings typically include a base operating system and a suite of applications and development tools. PaaS eliminates the need for organizations to build and maintain the infrastructure traditionally used to develop applications. PaaS is sometimes called 'middleware', referring to how it conceptually sits somewhere between SaaS and IaaS.

Platform's like Google's App Engine, IBM BlueMix, and Apache's Stratos are popular PaaS products which are helping to streamline and democratize software development.

SaaS (Software As A Service)

Sometimes referred to as 'on-demand software', SaaS is a software licensing and delivery model where a fully functional and complete software product is delivered to users over the web on a subscription basis. SaaS offerings are typically accessed by end users through a web browser (making the user's operating system largely irrelevant) and can be billed based on consumption or, more simply, with a flat monthly charge. SaaS offerings are the most widely visible of all the cloud computing service models. In fact, many users might be using SaaS products without even realizing it.

Popular products like Office365 and Salesforce have thrust SaaS offerings to the forefront of the workplace and are used by thousands of businesses every day.

Some of the other service categories which are more commonly classified as anything as a Service (XAAS) are:

Storage as a Service (SAAS)

Storage as a Service is a business model in which a large company rents space in their storage infrastructure to a smaller company or individual. The economy of scale in the service provider's infrastructure theoretically allows them to provide storage much more cost-effectively than most individuals or corporations can provide their own storage when the total cost of ownership is considered.

Communications as a Service (CAAS)

Communications as a Service (CAAS) can include voice over IP (VoIP or Internet telephony), instant messaging (IM), collaboration and video conference applications using fixed and mobile devices. The CAAS vendor is responsible for all hardware and software management and offers guaranteed Quality of Service (QoS). CAAS allows businesses to selectively deploy communications devices and modes on a pay-as-you-go, as-needed basis.

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Network as a Service (NAAS)

NAAS is a new cloud computing model in which the clients have access to additional computing resources collocated with switches and routers. NAAS can include flexible and extended Virtual Private Network (VPN), bandwidth on demand, custom routing, multicast protocols, security firewall, intrusion detection and prevention, Wide Area Network (WAN), content monitoring and filtering, and antivirus.

Monitoring as a Service (MAAS)

Monitoring-as-a-service (MAAS) is a framework that facilitates the deployment of monitoring functionalities for various other services and applications within the cloud. The most common application for MAAS is online state monitoring, which continuously tracks certain states of applications, networks, systems, instances or any element that may be deployable within the cloud. MAAS makes it easier for users to deploy state monitoring at different levels of Cloud services.

HOW CLOUD COMPUTING WORKS

Assume that you are an executive at a very big corporation. Your particular responsibilities include making sure that all of your employees have the right hardware and software they need to do their jobs. Buying computers for everyone isn't enough. You also have to purchase software or software licenses to give employees the tools they require. Whenever you have a new hire, you have to buy more software or make sure your current software license allows another user. It's so stressful that you find it difficult to go to sleep on your huge pile of money every night.

There may be an alternative for this problem. Rather than owning their own computing infrastructure or data centers, companies can rent access to anything from applications to storage from a cloud service provider. One benefit of using cloud computing services is that firms can avoid the upfront cost and complexity of owning and maintaining their own IT infrastructure, and instead simply pay for what they use, when they use it.

How it works:
In a cloud computing system, there's a significant workload shift. Local computers no longer have to do all the heavy lifting when it comes to running applications. The network of computers that make up the cloud handles them instead. Cloud technology can handle those heavy loaded tasks automatically easily and efficiently. This brings down the hardware & software demands. The only thing that the users have to think is the cloud computing interface software of the system, which works merely as a web-browser in the front end of the user. The cloud's network takes care of the rest along with the back-end.

One central server is used to manage the entire cloud system architecture. The server is solely responsible for handling the smoothness of traffic without disruption. Middleware is a particular type of software that is used to perform processes & also connects networked computers. Depending on the demand of client/user, the storage is provided by the cloud technology's service provider.

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The back-end is connected through a virtual network or internet. The backend is used by service providers that include various servers, computers, virtual machines & data storage facilities that are combined to form the cloud technology. Its dedicated server handles each application in the system.

The back-end has two principal responsibilities:

- To provide traffic control mechanisms, security postures & governing the protocols.
- To employ those internet protocols that are connected to the networked computer for communication.

The front end includes the cloud computing system or network that is used for accessing the cloud computing system. The cloud computing systems' interface varies from cloud to cloud.
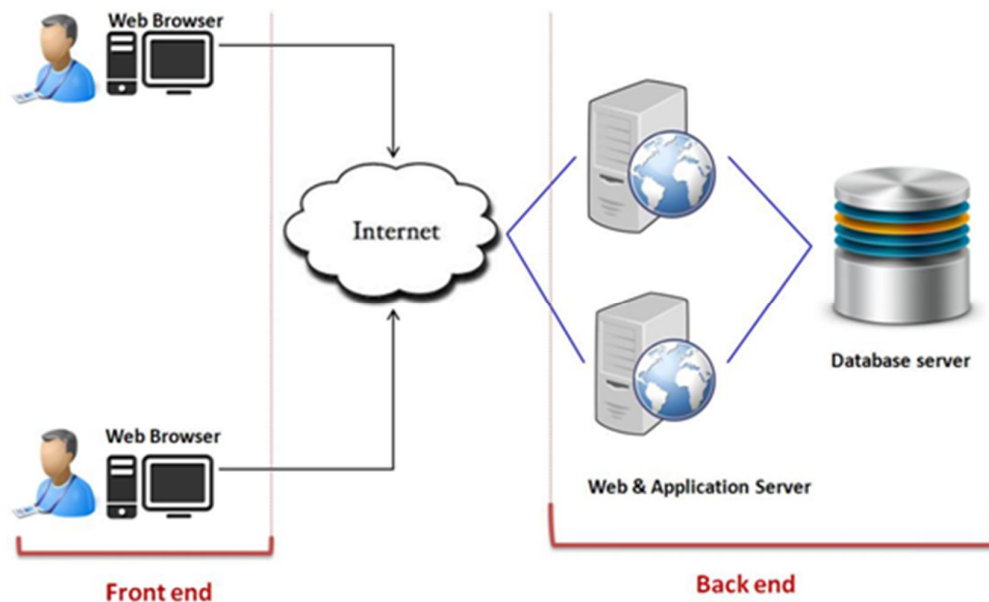
Figure: How cloud computing works?

Cloud technology users can use the data center through the company's network or internet facilities. This technology provides various advantages; as users can access the cloud from anywhere at any time, but the network bandwidth should have to be more. This technology not only facilitates desktop and laptop users but the mobile users can also access their business systems based on their demand.

As we already know that cloud computing is fast and efficient, applications running on the cloud take advantages of flexibility and computing power, i.e., the speed of processing a task. Many computers of a single organization work together along with their application on the cloud as if all the applications were running on a single machine. This flexibility of accessing the cloud resources allows users to use much or little of the resource based on the demand.

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ROLE OF NETWORKS IN CLOUD COMPUTING

The confluence of technology advancements and business developments in web services, computing systems, broadband, Internet and application software over the past decade has created a perfect storm for cloud computing. The "cloud model" of delivering and consuming IT functions as services is poised to fundamentally transform the IT industry and rebalance the inter-relationships among end users, enterprise IT, software companies, and the service providers.

Emerging capabilities of network have enabled cloud to successfully provide on-demand services which can unilaterally provision computing capabilities such as servers, network, OS and storage. Further, it allows resource pooling where multiple users through multiple tenant model (multiple customer utilizing the same facility) can access different physical and virtual resources. Additionally, virtualization permits applications, compute and network resources to reside anywhere, which are then accessed through the network, thus allowing these resources to be flexible and scalable. Cloud computing also has the capability to measure the services being offered through the usage of charge back or metering where it can control and optimize resource usage.

The network plays a key role in the delivery of cloud-based services as it provides a means to connect every IT system and has the ability to provision and scale these resources to meet application and end-user requirements. It also is one of strategic element used for management of security objectives in the cloud as it:
- Enables infrastructure enhancements by supporting server consolidation, virtualized environment, automated infrastructure and support application mobility.
- Addresses access requirements emerging from thin clients or organization mobility requirements which may extend to any device at any time from any place.
- Offers application analytics by clustering requirements and enabling remote usage or community services
- Supports varied traffic patterns through location independent endpoints while ensuring automated provisioning and orchestration.

With network as a service (NaaS), customers access third-party network transport services over the Internet and pay for them in a subscription-based model. This allows providers to allocate resources based on users' changing needs.

Providers offer a range of NaaS technologies, but three services are especially common:
- Virtual Private Networks
- Bandwidth on-demand
- Transport optimization

VPNs allow organizations to extend the function of their secure, on-premises networks to insecure networks such as the Internet. To protect the integrity and confidentiality of the data traversing those insecure networks, VPNs implement additional security measures. While similar to wide area networks, VPNs do not depend on dedicated communication links between networks.

Bandwidth on-demand is a service that allocates network resources based on the needs of particular devices on that network. More bandwidth is allocated to nodes experiencing peak demands, and, as demand subsides, bandwidth is scaled down. Major network and

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telecommunication providers such as Verizon, Century-Link and XO Communications provision bandwidth on-demand services, which complement compute and storage on-demand.

One way to minimize the amount of data transmitted over a network is to use a content distribution network (CDN). CDNs cache content across geographically distributed nodes. When users access static content from a service, they are routed to the closest available CDN node. If the requested content is cached on the node, it is delivered to the user immediately. Otherwise, the content is retrieved from the source system, delivered to the user and then cached for future reference. There are many CDN providers, including Amazon, Comcast, Level 3, Microsoft Azure and Verizon.

PROTOCOLS USED IN CLOUD COMPUTING

Cloud computing protocols is a set of rules that allow 2 electronics item to connect and exchange information to one another. Used for storage, communication, for encryption, decryption, networking, security, user-login management etc.

Examples of cloud computing protocols:
1. Gossip Protocol (GP)
2. Connection-less n/w protocol (CLNP)
3. State Routing Protocol (SRP)
4. Internet Group Management Protocol (IGMP)
5. Secure Shell Protocol (SSHP)
6. Coverage Enhanced Ethernet Protocol (CEE)
7. Media Transfer Protocol (MTP)
8. Extensible Messaging and Presence Protocol (XMPP)
9. Advanced Message Queuing Protocol (AMQP)
10. Enhanced Interior Gateway Routing Protocol (EIGRP)

Gossip protocol (GP) is a procedure or process of computer peer-to-peer communication that is based on the way epidemics spread. Some distributed systems use peer-to-peer gossip to ensure that data is dispersed to all members of a group. Some ad-hoc networks have no central registry and the only way to spread common data is to rely on each member to pass it along to their neighbors.

The term **epidemic protocol** is sometimes used as a synonym for a gossip protocol, as gossip spreads information in a manner similar to the spread of a virus in a biological community. (An **epidemic** is the rapid spread of infectious disease to a large number of people in a given population within a short period of time, usually two weeks or less.)

Connectionless Network Protocol (CLNP) is a datagram network protocol. It provides fundamentally the same underlying service to a transport layer as IP. CLNP provides essentially the same maximum datagram size, and for those circumstances where datagrams may need to traverse a network whose maximum packet size is smaller than the size of the datagram, CLNP provides mechanisms for fragmentation (data unit identification, fragment/total length and offset).

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Like IP, a checksum computed on the CLNP header provides a verification that the information used in processing the CLNP datagram has been transmitted correctly, and a lifetime control mechanism ("Time to Live") imposes a limit on the amount of time a datagram is allowed to remain in the internet system. As is the case in IP, a set of options provides control functions needed or useful in some situations but unnecessary for the most common communications.

State Routing Protocol (SRP) uses software and routing algorithms to determine optimal network data transfer and communication paths between network nodes. Routing protocols facilitate router communication and overall network topology understanding. A routed protocol is used to deliver application traffic. It provides appropriate addressing information in its internet layer or network layer to allow a packet to be forwarded from one network to another. Examples of routed protocols are the Internet Protocol (IP) and Internetwork Packet Exchange (IPX).

Internet Group Management Protocol (IGMP) is a communication protocol of the multicast transfer data in the IP networks. IGMP is used by routers and IP hosts for organizing the network devices in groups. IGMP is a part of IP multicast. IGMP is located at the network level. It is used only on IPv4 networks. IGMP can be used for one-to-many networking applications such as online streaming video and online gaming. IGMP is used by the client computer and the neighboring switches to connect a client and a local router that implements a multicast. Then between the local and remote routers is used the Protocol Independent Multicast (PIM). With its help the group traffic is routed from the video server to numerous clients of the group transfer.

Secure Shell Protocol (SSH) is a method for secure remote login from one computer to another. It provides several alternative options for strong authentication, and it protects the communications security and integrity with strong encryption. It is a secure alternative to the non-protected login protocols (such as **telnet**) and insecure file transfer methods (such as **FTP**). The protocol is used in corporate networks for:
- providing secure access for users and automated processes
- interactive and automated file transfers
- issuing remote commands
- managing network infrastructure and other mission-critical system components.

Converged enhanced Ethernet Protocol (CEE) eliminates the dropping of frames due to congestion and thereby ensures lossless transmission of FCoE (Fibre Channel over Ethernet) traffic over an Ethernet network. The lossless Ethernet is required for the reliable transmission of FC data over an Ethernet network. Unlike TCP/IP, the loss of a single FC frame typically requires the entire FC exchange to be aborted and re-transmitted, instead of just re-sending a particular missing frame. CEE makes a high-speed (such as 10 Gbps or higher) Ethernet network a viable storage networking option, similar to an FC SAN.

Media Transfer Protocol (MTP) is an extension to the Picture Transfer Protocol (PTP) communications protocol that allows media files to be transferred atomically to and from portable devices. MTP, the new transmission rules set by Microsoft. MTP applies not only to USB, but also to IP. But mostly on USB devices. Many mobile phones are now supported.

MTP is part of the "Windows Media" framework and thus closely related to Windows Media Player. Whereas PTP was designed for downloading photographs from digital cameras, Media Transfer Protocol allows the transfer of music files on digital audio players and media files on portable media players, as well as personal information on personal digital assistants. MTP is a key part of digital rights management (DRM) service for the Windows Media platform. In 2011, it became the standard method to transfer files from/to Android.

Extensible Messaging and Presence Protocol (XMPP) is a set of open technologies for instant messaging, presence, multi-party chat, voice and video calls, collaboration, lightweight middleware, content syndication, and generalized routing of XML data. The XMPP protocol is based on the typical client server architecture, in which the XMPP client uses the XMPP server with the TCP socket.

XMPP provides a general framework for messaging across a network, offering a multitude of applications beyond traditional instant messaging (IM) and the distribution of presence data. It enables the discovery of services residing locally or across a network, as well as finding out about the availability of these services.

XMPP is well-matched for cloud computing where virtual machines, networks and firewalls would otherwise present obstacles to alternative service discovery and presence-based solutions. Cloud computing and storage systems rely on diverse forms of communication over multiple levels, including not only messaging between systems to relay state but also the migration of the distribution of larger objects, like storage or virtual machines.

Advanced Message Queuing Protocol (AMQP) is an open standard application layer protocol for message-oriented middleware. The protocol has been adopted for a broad variety of messaging applications, from classic enterprise messaging to application telemetry handling to attaching IoT devices to the cloud.

One of the protocol's core strengths is that it provides a very flexible foundation for creating multiplexed and reliable message transfer capabilities between peers, while leaving the interactions pattern choice wide open. AMQP can be used for unidirectional message transfers as well as for request/response interactions, and two connected parties can easily initiate new conversations from either end.

Enhanced Interior Gateway Routing Protocol (EIGRP) is an evolved version of IGRP that addresses the demands of large-scale internetworks and the changes in network technology that have been developed since the implementation of IGRP. EIGRP protocol is very flexible and it supports both IPv4 and IPv6. It is an advanced distance-vector routing protocol that is used on a computer network for automating routing decisions and configuration. It is also considered as a Hybrid Routing Protocol because it has characteristics of both Distance Vector and Link State Routing Protocols.

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ROLE OF WEB SERVICES IN CLOUD COMPUTING

Cloud computing is a style of computing in which virtualized and standard resources, software and data are provided as a service over the Internet. Consumers and businesses can use the cloud to store data and applications and can interact with the Cloud using mobiles, desktop computers, laptops etc. via the Internet from anywhere and at any time.

Modern day business applications use variety of programming platforms to develop web-based applications. Since they are built using different development languages, it becomes really difficult to ensure accurate communication between applications. Web services provide a common platform that allows multiple applications built on various programming languages to have the ability to communicate with each other.

A web service is a collection of open protocols and standards used for exchanging data between applications or systems. This interoperability (e.g., between Java and Python, or Windows and Linux applications) is due to the use of open standards. Web service is a standardized medium to propagate communication between the client and server applications on the World Wide Web.

The main component of a web service is the data which is transferred between the client and the server, and that is XML. XML (Extensible markup language) is a counterpart to HTML and easy to understand the intermediate language that is understood by many programming languages. So when applications talk to each other, they actually talk in XML. This provides a common platform for application developed in various programming languages to talk to each other.

A web service enables communication among various applications by using open standards such as HTML, XML, WSDL, and SOAP. A web service takes the help of:

- XML to tag the data
- SOAP to transfer a message
- WSDL to describe the availability of service.

Architecture of Web Services

The architecture of web service interacts among three roles: **service provider, service requester,** and **service registry**. The interaction involves the three operations: **publish, find,** and **bind**. These operations and roles act upon the **web services artifacts**.
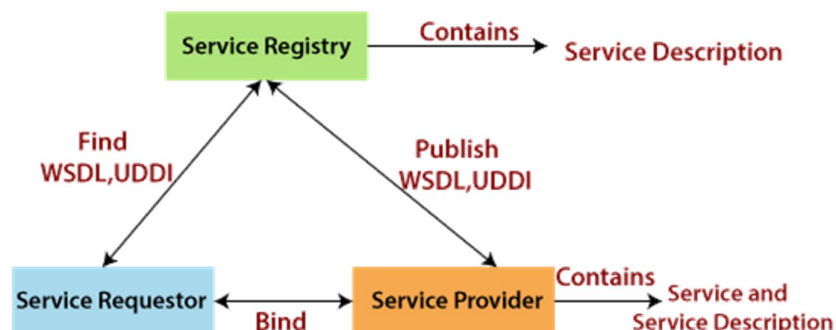

Figure: Web Services Roles, Operations and Artifacts

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Web Service Roles

Service Provider: The service provider implements the service and makes it available on the Internet.

Service Requestor: Service requestor is the application that is looking for and invoking or initiating an interaction with a service. The browser plays the requester role, driven by a consumer or a program without a user interface.

Service Registry: The registry provides a central place where developers can publish new services or find existing ones.

Operations in Web Service Architecture

Three behaviors that take place in the micro-services:
- Publication of service descriptions **(Publish)**
- Finding of services descriptions **(Find)**
- Invoking of service based on service descriptions **(Bind)**

Components of Web Services

The basic web services platform is XML + HTTP. Web Services using SOAP, REST, and JSON.
All the standard web services work using the following components:

- SOAP (Simple Object Access Protocol)
- UDDI (Universal Description, Discovery and Integration)
- WSDL (Web Services Description Language)

SOAP (Simple Object Access Protocol) was originally part of the specification that included the Web Services Description Language (WSDL) and Universal Description, Discovery, and Integration (UDDI). It is used now without WSDL and UDDI. SOAP essentially provides the envelope for sending the Web Services messages. SOAP generally uses HTTP, but other means of connection may be used.

REST (Representation State Transfer) appeals to developers because it has a simpler style that makes it easier to use than SOAP. It also less verbose so that less volume is sent when communicating.

While both SOAP and REST use XML for interchange, JavaScript Object Notation (JSON) uses a subset of JavaScript.

WSDL (Web Services Description Language) forms the basis for the original Web Services specification. It consists a service provider and a service consumer. A service provider describes its service using WSDL. A service consumer issues one or more queries to the repository to locate a service and determine how to communicate with that service. The service consumer uses the WSDL to send a request to the service provider.

UDDI (Universal Description, Discovery and Integration) registry was intended to eventually serve as a means of "discovering" Web Services described using WSDL. The idea is that the UDDI registry can be searched in various ways to obtain contact

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information and the Web Services available for various organizations. Nevertheless, even without the discovery portion, the UDDI registry is a way to keep up-to-date on the Web Services your organization currently uses.

SERVICE MODELS IN CLOUD COMPUTING

The future of computing is in the cloud. What it implies is that you adapt your business to fit in the cloud model. Once you sign up for cloud service models Saas, IaaS, Paas, you can influence its wider possibilities to bring the flexibility and efficiency that pushes your business growth.

Over the years cloud services have witnessed an exponential growth worldwide. Although cloud computing has evolved over the time it has been majorly divided into three broad service categories:

- Software as a Service (SAAS)
- Platform as a Service (PAAS)
- Infrastructure as a Service (IAAS)
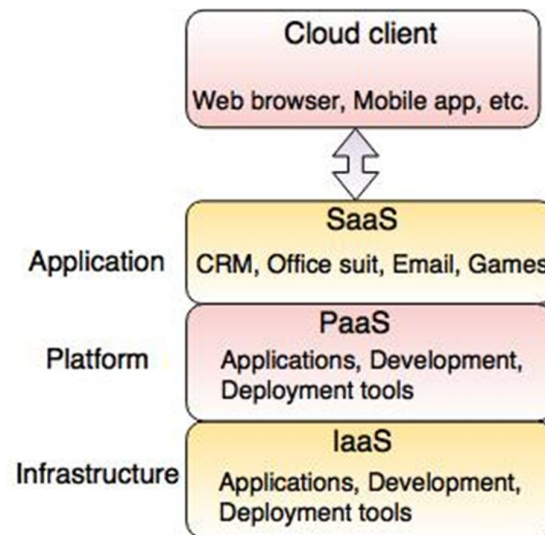
Figure: Cloud Service Models

Their basic functions can be summarized in the phrases 'Host', 'Build', and 'Consume'. Each offers a different level of flexibility and control over the product that could serve the needs of various businesses. Each also varies in its relationship to your existing IT infrastructure. Because of the wide variances between the three, it is important to determine which model will suit your business's needs the best.

Software as a Service (SaaS)

SaaS is also known as "**on-demand software**". It is a software distribution model in which services are hosted by a cloud service provider. These services are available to end-users over the internet so, the end-users do not need to install any software on their devices to access these services. The applications run on the vendor's cloud, which they, of course, control and maintain. The applications are available for use with a paid licensed subscription, or for free with limited access.

SaaS does not require any installations or downloads in your existing infrastructure, which in turn eliminates the need to install, maintain, and update applications on each of your computers.

SAAS has become an increasingly prevalent delivery model as underlying technologies that support Web services and service-oriented architecture (SOA) mature and new development approaches, such as Ajax, become popular. SAAS is closely related to the ASP (Application service provider) and on-demand computing software delivery models.

Many important tasks like accounting, sales, invoicing and planning all can be performed using SaaS. SaaS is the ideal choice for small-scale businesses who do not have the necessary budget and resources to deploy on-premise hardware. Besides, companies that require frequent collaboration on their projects will find SaaS platforms useful.

There are the following services provided by SaaS providers -

Business Services - SaaS Provider provides various business services to start-up the business. The SaaS business services include **ERP** (Enterprise Resource Planning), **CRM** (Customer Relationship Management), **billing**, and **sales**.

Document Management - SaaS document management is a software application offered by a third party (SaaS providers) to create, manage, and track electronic documents. For example**:** Slack, Samepage, Box, and Zoho Forms.

Social Networks - As we all know, social networking sites are used by the general public, so social networking service providers use SaaS for their convenience and handle the general public's information.

Mail Services - To handle the unpredictable number of users and load on e-mail services, many e-mail providers offering their services using SaaS.

CRM, Office Suite, Email, games, etc. are the software applications which are provided as a service through Internet. The companies like Google, Microsoft provide their applications as a service to the end users.

Advantages of SaaS

1. **Affordable**: On-premise hardware is not required for this model, which keeps the costs associated low. Small-scale businesses might find this cloud platform particularly appealing.

2. **Accessible Everywhere:** Cloud-based applications are accessible everywhere that there is internet access. As such, companies that require frequent collaboration find SaaS platforms useful as their employees can easily access the programs that they need.

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3. **Ready-to-Use:** With SaaS, the programs you need are already fully developed and ready to use. The set-up time for SaaS programs is greatly decreased from the other two types of cloud-based platforms.

4. **Low maintenance required:** Software as a service removes the need for installation, set-up, and daily maintenance for the organizations. The initial set-up cost for SaaS is typically less than the enterprise software. SaaS vendors are pricing their applications based on some usage parameters, such as a number of users using the application. So SaaS does easy to monitor and automatic updates.

5. **No special software or hardware versions required:** All users will have the same version of the software and typically access it through the web browser. SaaS reduces IT support costs by outsourcing hardware and software maintenance.

Disadvantages of SaaS

1. **Lack of Control:** With SaaS, the vendor has control over the programs that your company is using. If you do not feel comfortable releasing the control of your critical business applications to another party, perhaps SaaS is not the best option for your business.

2. **Slower Speeds:** Relying upon internet access to function, SaaS applications tend to be slower than client/server applications. However, these programs are still typically quick, though not instantaneous.

3. **Variable Functions & Features:** In many cases, SaaS cloud-based applications have less functionality and features than their client/server counterparts. This disadvantage, however, may be void if your business only needs the features offered in the SaaS version to function.

4. **Switching between SaaS vendors is difficult:** Switching SaaS vendors involves the difficult and slow task of transferring the very large data files over the internet and then converting and importing them into another SaaS also.

Platform-as-a-Service (PaaS)

PaaS is a programming platform for developers. This platform is generated for the programmers to create, test, run and manage the applications. A developer can easily write the application and deploy it directly into PaaS layer. Implementing PaaS simplifies the process of enterprise software development. The virtual runtime environment and deployment tools provided by PaaS give a favorable space for developing and testing applications. The entire resources offered in the form of servers, storage and networking are manageable either by the company or a platform provider.

With this model, a third-party vendor provides your business with a platform upon which your business can develop and run applications. Because the vendor is hosting the cloud infrastructure which supports the platform, PaaS eliminates your need to install in-house hardware or software. Your business would not manage or control the underlying cloud infrastructure, but you would maintain control over the deployed applications (unlike

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with SaaS). PaaS providers provide the Programming languages, Application frameworks, Databases, and Other tools.

AWS Elastic Beanstalk, Heroku, Force.com, Apache Stratos, Magento Commerce Cloud, OpenShift Google Apps Engine(GAE), Windows Azure and SalesForce.com are the examples of PaaS.

To understand in a simple terms, let compare this with painting a picture, where you are provided with paint colors, different paint brushes and paper by your school teacher and you just have to draw a beautiful picture using those tools.

Advantages of PaaS

1. **Rapid Time-to-Market:** PaaS simplifies application management by eliminating the need to maintain and control the underlying infrastructure. As a result, applications can be developed and deployed faster.

2. **Cost Effective Development:** A cloud-based platform provides your business with a base upon which to build your applications, as opposed to building from nothing, thus dramatically reducing the costs associated.

3. **Scalability:** Cloud-based platforms offer reusable code which, of course, makes it easier to develop and deploy applications, but also offers increased scalability.

4. **Prebuilt business functionality:** Some PaaS vendors also provide already defined business functionality so that users can avoid building everything from very scratch and hence can directly start the projects only.

Disadvantages of PaaS

1. **Vendor Lock-In:** It is difficult to migrate many of the services provided by one PaaS product to a competing product, thus making it hard to switch PaaS vendors. Downtime and additional expenses are likely to occur when switching from one PaaS provider to another.

2. **Security & Compliance:** In the PaaS model, the vendor will store most, or even all, of the application's data. As such, it is imperative to assess the security measures of the provider. This, though, often proves difficult as the vendor may be storing their databases via a third party, thus leaving you uninformed of the safety of your data.

3. **Lack of Compatibility:** It is possible that your current infrastructure may not be compatible with a cloud platform. If some elements cannot be cloud-enabled, you may have to switch from your current apps and programs to cloud-compatible counterparts in order to fully integrate. Alternately, you may need to leave these elements out of the cloud, and within your current infrastructure.

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Infrastructure as a Service (IaaS)

IaaS is also known as **Hardware as a Service (HaaS)**. It is a computing infrastructure managed over the internet. The main advantage of using IaaS is that it helps users to avoid the cost and complexity of purchasing and managing the physical servers. It is one of the layers of the cloud computing platform. It allows customers to outsource their IT infrastructures such as servers, networking, processing, storage, virtual machines, and other resources. Customers access these resources on the Internet using a pay-as-per use model.

IaaS is a complete package for computing. It provides computing infrastructure like virtual server space, network connections, bandwidth, load balancers and IP addresses. The pool of hardware resource is extracted from multiple servers and networks usually distributed across numerous data centers. This provides redundancy and reliability to IaaS.

In traditional hosting services, IT infrastructure was rented out for a specific period of time, with pre-determined hardware configuration. The client paid for the configuration and time, regardless of the actual use. With the help of the IaaS cloud computing platform layer, clients can dynamically scale the configuration to meet changing requirements and are billed only for the services actually used. IaaS cloud computing platform layer eliminates the need for every organization to maintain the IT infrastructure.

IaaS provider provides the following services:
1. **Compute:** Computing as a Service includes virtual central processing units and virtual main memory for the Vms that is provisioned to the end- users.
2. **Storage:** IaaS provider provides back-end storage for storing files.
3. **Network:** Network as a Service (NaaS) provides networking components such as routers, switches, and bridges for the Vms.
4. **Load balancers:** It provides load balancing capability at the infrastructure layer.

Advantages of IaaS

1. **Eliminates Capital Expenses:** Employing a cloud-based infrastructure eliminates the capital expense of deploying in-house hardware and software. Additionally, IaaS typically is offered as a pay-as-you-go model, with charges based either in time, or in the amount of virtual machine space that was used.

2. **Shared infrastructure:** IaaS allows multiple users to share the same physical infrastructure.

3. **Web access to the resources:** Iaas allows IT users to access resources over the internet.

4. **Pay-as-per-use model:** IaaS providers provide services based on the pay-as-per-use basis. The users are required to pay for what they have used.

5. **Focus on the core business:** IaaS providers focus on the organization's core business rather than on IT infrastructure.

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6. **On-demand Scalability:** On-demand scalability is one of the biggest advantages of IaaS. Using IaaS, users do not worry about to upgrade software and troubleshoot the issues related to hardware components.

7. **Supports Flexibility:** IaaS is useful in supporting workloads that are temporary, may change unexpectedly, or are experimental. Like all workloads, these loads need infrastructure to support them, however it is expensive to commit to additional permanent in-house infrastructure for a temporary need. Cloud-based infrastructure answers the need for flexibility.

8. **Simple Deployment:** It is much easier for your cloud provider to deploy your servers, processing, storage, and networking in the IaaS model than it is for you to deploy these elements in-house, with no previous no base to build off of. As a result, your uptime will increase as your systems will be available for use more rapidly.

Disadvantages of IaaS

1. **Security:** Security is one of the biggest issues in IaaS. Most of the IaaS providers are not able to provide 100% security.

2. **Maintenance & Upgrade:** Although IaaS service providers maintain the software, but they do not upgrade the software for some organizations.

3. **Interoperability issues:** It is difficult to migrate VM from one IaaS provider to the other, so the customers might face problem related to vendor lock-in.

4. **Inconsistency of Flexibility:** The availability and performance of the workload is highly dependent upon the provider. If the IaaS providers experiences internal or external downtime, your workloads will also be affected.

5. **Costly:** IaaS models are typically much more costly than PaaS and SaaS models because they offer much more support to your business than the other two cloud models. However, they can still be cost-effective based on their utility to your business.

DigitalOcean, Linode, Amazon Web Services (AWS), Microsoft Azure, Google Compute Engine (GCE), Rackspace, Sify Technologies and Cisco Metacloud.

Some of the other service categories which are more commonly classified as **Anything as a Service** (**XAAS**) are:

Storage as a Service (SAAS)

Storage as a Service is a business model in which a large company rents space in their storage infrastructure to a smaller company or individual. The economy of scale in the service provider's infrastructure theoretically allows them to provide storage much more cost-effectively than most individuals or corporations can provide their own storage when the total cost of ownership is considered. Storage as a Service is generally seen as a good

alternative for a small or mid-sized business that lacks the capital budget and/or technical personnel to implement and maintain their own storage infrastructure.

Communications As A Service (CAAS)

Communications as a Service (CAAS) is an outsourced enterprise communications solution that can be leased from a single vendor. Such communications can include voice over IP (VoIP or Internet telephony), instant messaging (IM), collaboration and video conference applications using fixed and mobile devices. The CAAS vendor is responsible for all hardware and software management and offers guaranteed Quality of Service (QoS). CAAS allows businesses to selectively deploy communications devices and modes on a pay-as-you-go, as-needed basis.

Network As A Service (NAAS)

Network as a Service (NAAS), a framework that integrates current cloud computing offerings with direct, yet secure, client access to the network infrastructure. NAAS is a new cloud computing model in which the clients have access to additional computing resources collocated with switches and routers. NAAS can include flexible and extended Virtual Private Network (VPN), bandwidth on demand, custom routing, multicast protocols, security firewall, intrusion detection and prevention, Wide Area Network (WAN), content monitoring and filtering, and antivirus.

### Monitoring As A Service (MAAS)

Monitoring-as-a-service (MAAS) is a framework that facilitates the deployment of monitoring functionalities for various other services and applications within the cloud. The most common application for MAAS is online state monitoring, which continuously tracks certain states of applications, networks, systems, instances or any element that may be deployable within the cloud. MAAS makes it easier for users to deploy state monitoring at different levels of Cloud services.

Difference between IaaS, PaaS, and SaaS

IaaS	Paas	SaaS
It provides a virtual data center to store information and create platforms for app development, testing, and deployment.	It provides virtual platforms and tools to create, test, and deploy apps.	It provides web software and apps to complete business tasks.
It provides access to resources such as virtual machines, virtual storage, etc.	It provides runtime environments and deployment tools for applications.	It provides software as a service to the end-users.

IaaS is there to provide you with maximum flexibility when it comes to hosting custom-built apps, as well as a providing a general data center for data storage.	PaaS is most often built on top of an IaaS platform to reduce the need for system administration. It allows you to focus on app development instead of infrastructure management.	SaaS offers ready-to-use, out-of-the-box solutions that meet a particular business need (such as website or email).
It is used by network architects.	It is used by developers.	It is used by end users.
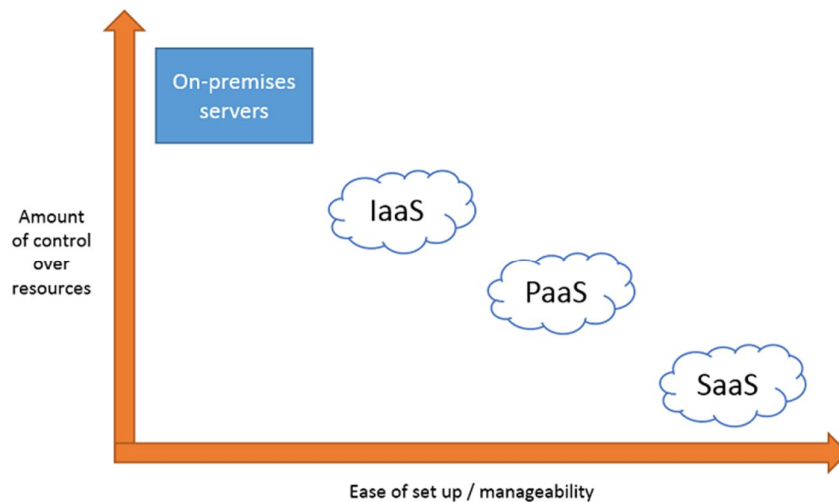
Figure: Relationship between SaaS, PaaS and IaaS

Knowing which cloud service model is appropriate for you is much like the decision between public, private, and hybrid cloud: it all depends on your situation. You might choose to start with one cloud computing service model or find a need for all three: that depends on the size and complexity of your business.

Common Examples of SaaS, PaaS, & IaaS

Platform Type	Common Examples
SaaS	Google Apps, Dropbox, Salesforce, Cisco WebEx, Concur, GoToMeeting
PaaS	AWS Elastic Beanstalk, Windows Azure, Heroku, Force.com, Google App Engine, Apache Stratos, OpenShift
IaaS	DigitalOcean, Linode, Rackspace, Amazon Web Services (AWS), Cisco Metapod, Microsoft Azure, Google Compute Engine (GCE)

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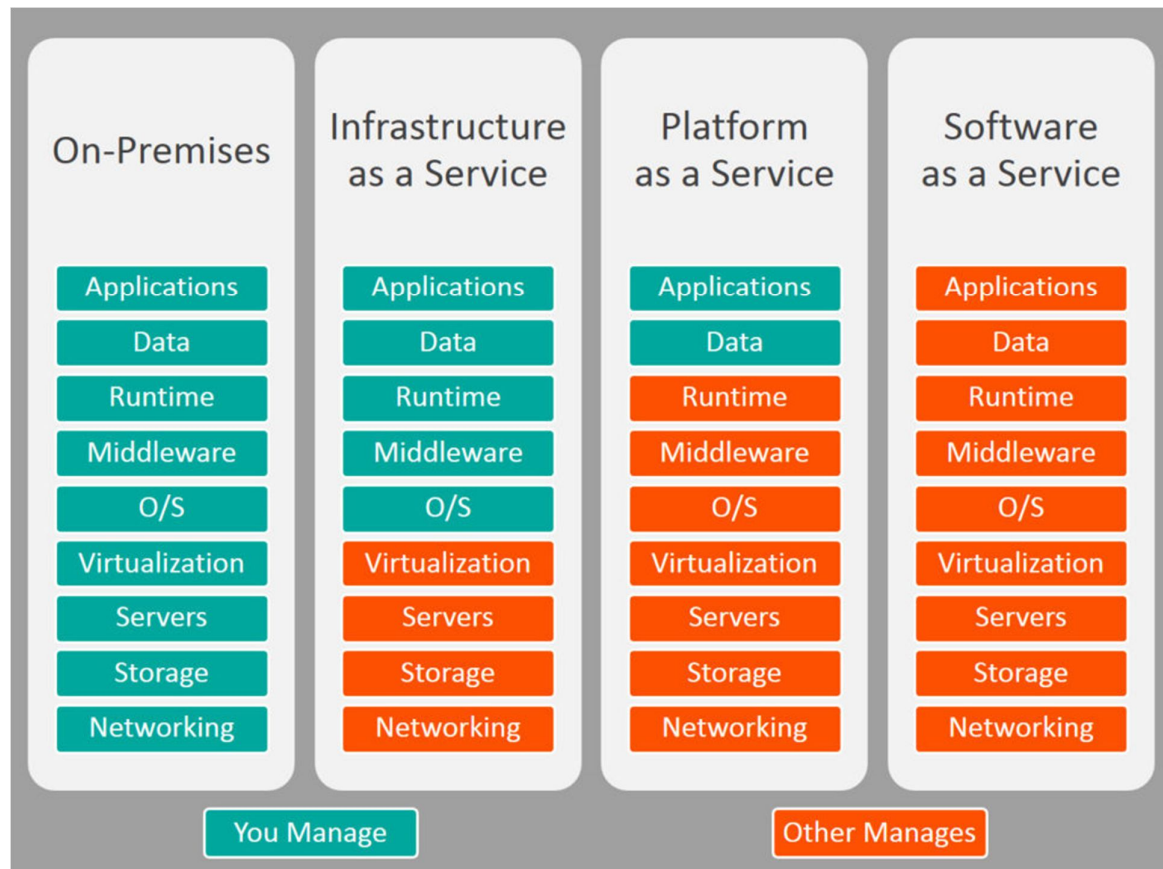## Summary of Key Differences between SaaS, PaaS and IaaS

Figure: Key Differences

Deployment Models in Cloud Computing

A cloud deployment model is a 'configuration' of certain cloud environment parameters such as the storage size, accessibility and proprietorship. Cloud deployment refers to the enablement of SaaS (software as a service), PaaS (platform as a service) or IaaS (infrastructure as a service) solutions that may be accessed on demand by end users or consumers. A cloud deployment model refers to the type of cloud computing architecture a cloud solution will be implemented on. Cloud deployment includes all of the required installation and configuration steps that must be implemented before user provisioning can occur. To select the one that suits you the most, it is recommended based on computing, networking, storage requirements, available resources, TCO expectations and business goals. There are the following 4 types of cloud that you can deploy according to the organization's needs-

- o Public Cloud
- o Private Cloud
- o Hybrid Cloud
- o Community Cloud

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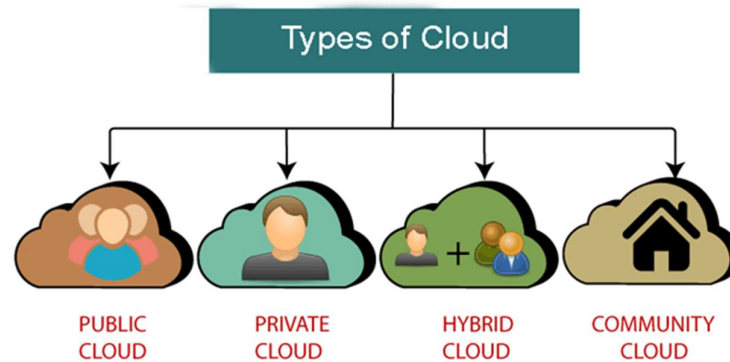
Figure: Types of CLOUD

PUBLIC CLOUD

A cloud is called public when services are rendered by third-party providers over a network open for public use, meaning that you share the same hardware, software, and network devices with other clients of the same provider (other companies, for example).

In a public cloud, because you are only "renting" a space on the cloud from a third-party provider, he will be the one assuming the costs and the maintenance of the whole infrastructure. As a client you are paying for this service, you have no responsibilities over the management of the cloud – you only use it to store your data, and pay as you go.

It is also popular among businesses of all sizes for their web applications, webmail, and storage of non-sensitive data.

Example: Amazon elastic compute cloud (EC2), IBM SmartCloud Enterprise, Google App Engine, IBM's Blue, Salesforce Heroku, Windows Azure Services Platform.

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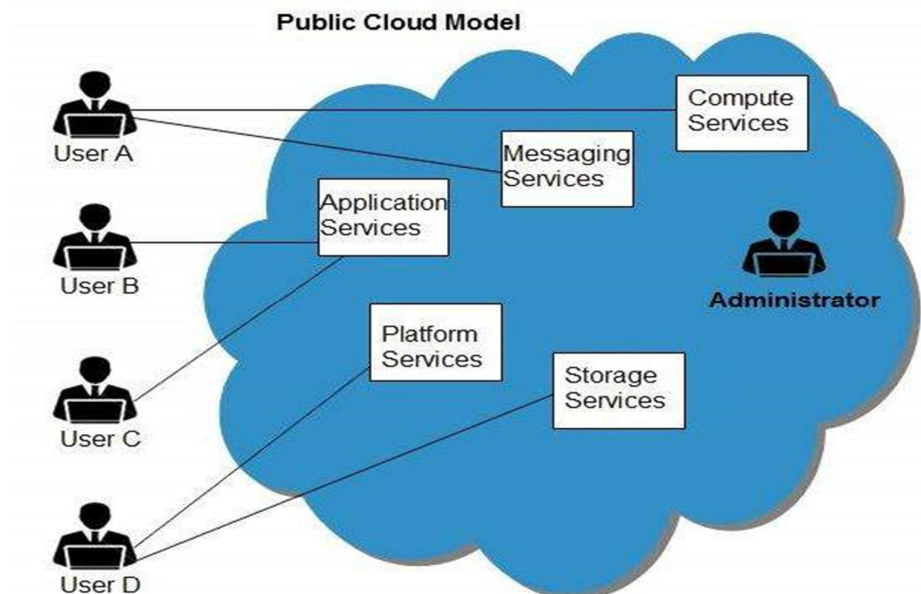
Benefits of Public Cloud

- **Cost Effective: -** Since **public cloud** shares same resources with large number of customers it turns out inexpensive.
- **Reliability: -** The **public cloud** employs large number of resources from different locations. If any of the resources fails, public cloud can employ another one.
- **Flexibility: -** The public cloud can smoothly integrate with private cloud, which gives customers a flexible approach.
- **Location Independence: - Public cloud** services are delivered through Internet, ensuring location independence.
- **Utility Style Costing: -** Public cloud is also based on **pay-per-use** model and resources are accessible whenever customer needs them.
- **High Scalability: -** Cloud resources are made available on demand from a pool of resources, i.e., they can be scaled up or down according the requirement.

Disadvantages of Public Cloud

- **Low Security: -** Public Cloud is less secure because resources are shared publicly.
- **Performance: -** In the public cloud, performance depends upon the speed of internet connectivity.
- **Less customizable: -** Public cloud is less customizable than the private cloud.

PRIVATE CLOUD

Private Cloud also termed as an **internal cloud** or **corporate cloud**; which allows the accessibility of systems and services within a specific boundary or organization. The cloud platform is implemented in a cloud-based secure environment that is guarded by advanced firewalls under the surveillance of the IT department that belongs to a particular organization. Private clouds permit only authorized users, providing the organizations greater control over data and its security. Business organizations that have dynamic, critical, secured, management demand based requirement should adopt Private Cloud.

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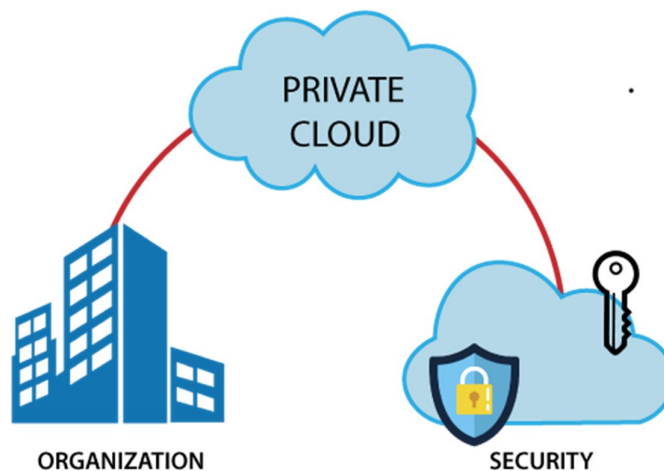
In a private cloud, resources are not shared with other organizations, but this also means that the company using it is entirely responsible for its management, maintenance, and regular updates – which can also get significantly more expensive than public ones.

Example: HP Data Centers, Microsoft, Elastra-private cloud, and Ubuntu, Apache, and OpenStack.
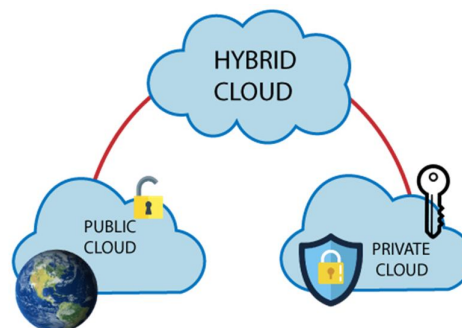
Benefits of Private Cloud

- **High Security and Privacy: -** Private cloud operations are not available to general public and resources are shared from distinct pool of resources. Therefore, it ensures high security and privacy.
- **More Control: -** The private cloud has more control on its resources and hardware than public cloud because it is accessed only within an organization.
- **Efficiency: -** The private cloud resources are not as cost effective as resources in public clouds but they offer more efficiency than public cloud resources.

Disadvantages of Private Cloud

- **High cost: -** The cost is higher than a public cloud because set up and maintain hardware resources are costly.
- **Restricted area of operations: -** As we know, private cloud is accessible within the organization, so the area of operations is limited.
- **Limited scalability: -** Private clouds are scaled only within the capacity of internal hosted resources.
- **Skilled people: -** Skilled people are required to manage and operate cloud services.

HYBRID CLOUD

Hybrid cloud is a combination of public and private clouds. The main aim to combine these clouds (Public and Private) is to create a unified, automated, and well-managed computing environment. In the Hybrid cloud, non-critical activities are performed by the public cloud and critical activities are performed by the private cloud. It allows companies to mix and match the facets of all three types that best suit their requirements. Mainly, a hybrid cloud is used in finance, healthcare, and Universities.

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This model also offers the so-called "**cloud-bursting**" option – simply put, if an application or a resource on the private cloud reaches a spike in demand, the company can move it to the public cloud to reap the benefits of additional computing resources and higher capacity.

The best hybrid cloud provider companies are Amazon, Microsoft, Google, Cisco, NetApp, VMware and RackSpace.

Benefits of Hybrid Cloud

- **Scalability: -** It offers features of both, the public cloud scalability and the private cloud scalability.
- **Flexibility: -** It offers secure resources and scalable public resources.
- **Cost Efficiency: -** Public clouds are more cost effective than private ones. Therefore, hybrid clouds can be cost saving.
- **Security: -** The private cloud in hybrid cloud ensures higher degree of security.

Disadvantages of Hybrid Cloud

- **Networking Issues: -** Networking becomes complex due to presence of private and public cloud.
- **Security Compliance: -** It is necessary to ensure that cloud services are compliant with security policies of the organization.
- **Infrastructure Dependency: -** The **hybrid cloud model** is dependent on internal IT infrastructure; therefore it is necessary to ensure redundancy across data centres.

COMMUNITY CLOUD

The community cloud is a kind of private cloud for organizations that share common interests. This cloud can exist on-premises or off-premises. Community Cloud allows system and services to be accessible by group of organizations. It shares the infrastructure between several organizations from a specific community. It is owned, managed, and operated by one or more organizations in the community, a third party, or a combination of them.
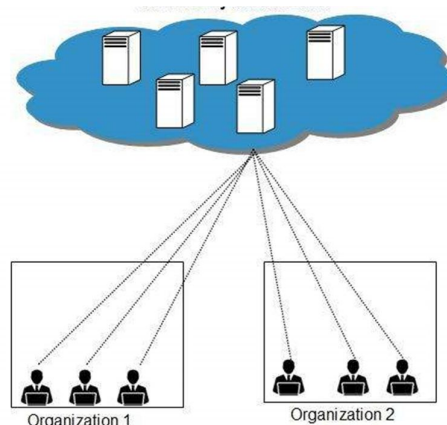
A community cloud deployment model resembles a private one to a large extent; the only difference is the set of users. While a private type implies that only one company owns the server, in the case of a community one, several organizations with similar backgrounds share the infrastructure and related resources.

Example: Example of such a community is where organizations/firms are there along with the financial institutions/banks. Our government organization within India may share computing infrastructure in the cloud to manage data.

Benefits of Community Cloud

- **Cost effective:-** Community cloud is cost effective because the whole cloud is shared between several organizations or a community.
- **Flexible and Scalable:-** The community cloud is flexible and scalable because it is compatible with every user. It allows the users to modify the documents as per their needs and requirement.
- **Security:-** Community cloud is more secure than the public cloud but less secure than the private cloud.
- **Sharing infrastructure:-** Community cloud allows us to share cloud resources, infrastructure, and other capabilities among various organizations.

Disadvantages of Community Cloud

- Community cloud is not a good choice for every organization.
- Slow adoption to data
- The fixed amount of data storage and bandwidth is shared among all community members.
- Community Cloud is costly than the public cloud.
- Sharing responsibilities among organizations is difficult.

The comparative analysis of the best cloud deployment models;

	Public	**Private**	**Community**	**Hybrid**
Ease of setup and use	Easy	Requires IT proficiency	Requires IT proficiency	Requires IT proficiency
Data security and privacy	Low	High	Comparatively high	High
Data control	Little to none	High	Comparatively high	Comparatively high
Reliability	Vulnerable	High	Comparatively high	High
Scalability and flexibility	High	High	Fixed capacity	High

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Cost-effectiveness	The cheapest one	Cost-intensive, the most expensive one	Cost is shared among community members	Cheaper than a private model but more costly than a public one
Demand for in-house hardware	No	Depends	Depends	Depends

Careful consideration of all business and technical requirements, as well as of each model's peculiarity, is a prerequisite for a successful shift to the cloud. However, it is quite a challenging task, which is why we recommend opting for professional cloud deployment services.