UNIT-2

CLOUD COMPUTING

2.1 Cloud-Computing:

Cloud computing is the delivery of different services through the Internet, including data storage, servers, databases, networking, and software. Cloud-based storage makes it possible to save files to a remote database and retrieve them on demand.

The word "cloud" often refers to the Internet, which more precisely means a datacentre full of servers connected to the Internet performing a service.

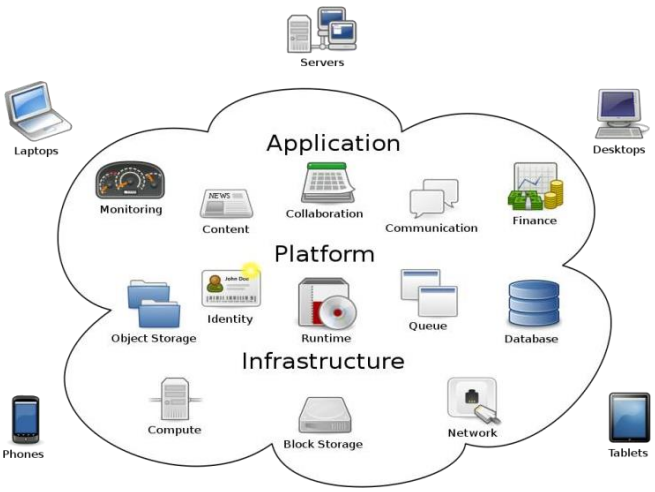

Fig 2.1 Cloud Computing Application

Cloud computing offers platform independency, as the software is not required to be installed locally on the PC. Hence, the Cloud Computing is making our business Applications mobile and collaborative.

2.1.1 Deployment Models of Cloud-Computing

Deployment models define the type of access to the cloud, i.e., how the cloud is located? Cloud can have any of the four types of access: Public, Private, Hybrid, and Community.

Public Cloud

The **public cloud** allows systems and services to be easily accessible to the general public. Public cloud may be less secure because of its openness.

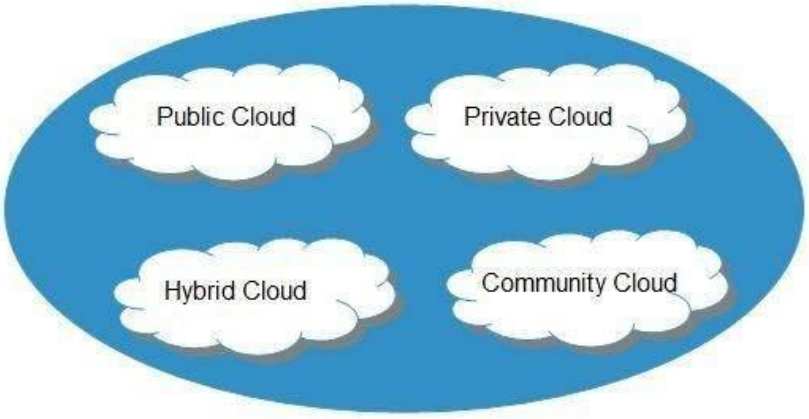

Fig 2.2 Deployment Models of Cloud Computing

Private Cloud

The **private cloud** allows systems and services to be accessible within an organization. It is more secured because of its private nature.

Community Cloud

The **community cloud** allows systems and services to be accessible by a group of organizations.

Hybrid Cloud

The **hybrid cloud** is a mixture of public and private cloud, in which the critical activities are performed using private cloud while the non-critical activities are performed using public cloud.

2.1.2 Service Models of Cloud-Computing

i. SaaS (Software as a Service)

SaaS or Software as a Service is a model that gives quick access to cloud-based web applications. The vendor controls the entire computing stack, which you can access using a web browser. These applications run on the cloud and you can use them by a paid licensed subscription or for free with limited access.

SaaS does not require any installations or downloads in your existing computing infrastructure. This eliminates the need for installing applications on each of your computers with the maintenance and support taken over by the vendor. Some known examples of SaaS include Google G Suite, Microsoft Office 365, Dropbox, etc.

Some of the core benefits of using SAAS model are:

- Easier administration.
- automatic updates and patch management.
- compatibility: all users will have the same version of software.
- easier collaboration, for the same reason.
- global accessibility.

ii. PaaS (Platform as a Service)

Platform as a Service or PaaS is essentially a cloud base where you can develop, test, and organize the different applications for your business. Implementing PaaS simplifies the process of enterprise software development. The virtual runtime environment provided by PaaS gives a favourable 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. Google App Engine and AWS Elastic Beanstalk are two typical

examples of PaaS. PaaS is also subscription-based and gives you flexible pricing options depending on your business requirements.

Some of the main characteristics of PAAS are:

- Scalability and auto-provisioning of the underlying infrastructure.
- Security and redundancy.
- Build and deployment tools for rapid application management and deployment.
- Integration with other infrastructure components such as web services, databases, and LDAP.
- Multi-tenancy, platform service that can be used by many concurrent users.
- Logging, reporting, and code instrumentation.
- Management interfaces and/or API.

iii. IaaS (Infrastructure as a Service)

IaaS or Infrastructure as a Service is basically a virtual provision of computing resources over the cloud. An IaaS cloud provider can give you the entire range of computing infrastructures such as storage, servers, networking hardware alongside maintenance and support.

Businesses can opt for computing resources of their requirement without the need to install hardware on their premises. Amazon Web Services, Microsoft Azure, and Google Compute Engine are some of the leading IaaS cloud service providers.

iv. 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.

v. 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.

vi. 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.

vii. 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.

Vendors providing Cloud Services:

1. Amazon Web Services.
2. Microsoft Azure.
3. Google Cloud Platform.
4. Alibaba Cloud.
5. IBM. Etc.

2.2 AWS (Amazon Web Services (AWS):

In 2006, **Amazon Web Services (AWS)** started to offer IT services to the market in the form of web services, which is nowadays known as **cloud computing**. With this cloud, we need not plan for servers and other IT infrastructure which takes up much of time in advance. Instead, these services can instantly spin up hundreds or thousands of servers in minutes and deliver results faster. We pay only for what we use with no up-front expenses and no long-term commitments, which makes AWS cost efficient.

How AWS works: AWS is separated into different services; each can be configured in different ways based on the user's needs. Users should be able to see configuration options and individual server maps for an AWS service.

More than 100 services comprise the Amazon Web Services portfolio, including those for compute, databases, infrastructure management, application development and security. These services, by category, include:

- Compute
- Storage databases
- Data management
- Migration
- Hybrid cloud
- Networking
- Development tools
- Management
- Monitoring
- Security
- Governance
- Big data management
- Analytics
- Artificial intelligence (AI)
- Mobile development
- Messages and notification

2.2.1 Services provided by AWS

Availability

Amazon Web Services provides services from dozens of data centers spread across availability zones (AZs) in regions across the world. An AZ is a location that contains multiple physical data centers. A region is a collection of AZs in geographic proximity connected by low-latency network links.

A business will choose one or multiple availability zones for a variety of reasons, such as compliance and proximity to end customers. For example, an AWS customer can spin up virtual machines (VMs) and replicate data in different AZs to achieve a highly reliable infrastructure that is resistant to failures of individual servers or an entire data center.

Amazon Elastic Compute Cloud (EC2) is a service that provides virtual servers -- called EC2 instances -- for compute capacity. The EC2 service offers dozens of instance types with varying capacities and sizes, tailored to specific workload types and applications, such as memory-intensive and accelerated-computing jobs. AWS also provides an Auto Scaling tool to dynamically scale capacity to maintain instance health and performance.

Storage

Amazon Simple Storage Service (S3) provides scalable object storage for data backup, collection and analytics. An IT professional stores data and files as S3 objects -- which can range up to 5 gigabytes (GB) -- inside S3 buckets to keep them organized. A business can save money with S3 through its Infrequent Access storage tier or by using Amazon Glacier for long-term cold storage.

Amazon Elastic Block Store provides block-level storage volumes for persistent data storage when using EC2 instances. Amazon Elastic File System offers managed cloud-based file storage.

A business can also migrate data to the cloud via storage transport devices, such as AWS Snowball and Snowmobile, or use AWS Storage Gateway to enable on-premises apps to access cloud data.

Databases, data management

The Amazon Relational Database Service -- which includes options for Oracle, SQL Server, PostgreSQL, MySQL, MariaDB and a proprietary high-performance database called Amazon Aurora -- provides a relational database management system for AWS users. AWS also offers managed NoSQL databases through Amazon DynamoDB.

An AWS customer can use Amazon ElastiCache and DynamoDB Accelerator as in-memory and real-time data caches for applications. Amazon Redshift offers a data warehouse, which makes it easier for data analysts to perform business intelligence (BI) tasks.

Migration, hybrid cloud

AWS includes various tools and services designed to help users migrate applications, databases, servers and data onto its public cloud. The AWS Migration Hub provides a location to monitor and

manage migrations from on premises to the cloud. Once in the cloud, EC2 Systems Manager helps an IT team configure on-premises servers and AWS instances.

Amazon also has partnerships with several technology vendors that ease hybrid cloud deployments. VMware Cloud on AWS brings software-defined data center technology from VMware to the AWS cloud. Red Hat Enterprise Linux for Amazon EC2 is the product of another partnership, extending Red Hat's operating system to the AWS cloud.

Networking

An Amazon Virtual Private Cloud (Amazon VPC) gives an administrator control over a virtual network to use an isolated section of the AWS cloud. AWS automatically provisions new resources within a VPC for extra protection.

Admins can balance network traffic with the Elastic Load Balancing (ELB) service, which includes the Application Load Balancer and Network Load Balancer. AWS also provides a domain name system called Amazon Route 53 that routes end users to applications.

An IT professional can establish a dedicated connection from an on-premises data center to the AWS cloud via AWS Direct Connect.

Developer tools

A developer can take advantage of AWS command-line tools and software development kits (SDKs) to deploy and manage applications and services. This includes:

- The AWS Command Line Interface, which is Amazon's proprietary code interface.
- A developer can use AWS Tools for Powershell to manage cloud services from Windows environments.
- Developers can use AWS Serverless Application Model to simulate an AWS environment to test Lambda functions.

AWS SDKs are available for a variety of platforms and programming languages, including Java, PHP, Python, Node.js, Ruby, C++, Android and iOS.

Amazon API Gateway enables a development team to create, manage and monitor custom application program interfaces (APIs) that let applications access data or functionality from back-end services. API Gateway manages thousands of concurrent API calls at once.

AWS also provides a packaged media transcoding service -- Amazon Elastic Transcoder -- and a service that visualizes workflows for microservices-based applications -- AWS Step Functions.

A development team can also create continuous integration and continuous delivery pipelines with services like:

- AWS CodePipeline
- AWS CodeBuild
- AWS CodeDeploy
- AWS CodeStar

A developer can also store code in Git repositories with AWS CodeCommit and evaluate the performance of microservices-based applications with AWS X-Ray.

Management and monitoring

An admin can manage and track cloud resource configuration via AWS Config and AWS Config Rules. Those tools, along with AWS Trusted Advisor, can help an IT team avoid improperly configured and needlessly expensive cloud resource deployments.

AWS provides several automation tools in its portfolio. An admin can automate infrastructure provisioning via AWS CloudFormation templates, and also use AWS OpsWorks and Chef to automate infrastructure and system configurations.

An AWS customer can monitor resource and application health with Amazon CloudWatch and the AWS Personal Health Dashboard, as well as use AWS CloudTrail to retain user activity and API calls for auditing.

Security and governance

AWS provides a range of services for cloud security, including AWS Identity and Access Management, which allows admins to define and manage user access to resources. An admin can also create a user directory with Amazon Cloud Directory, or connect cloud resources to an existing Microsoft Active Directory with the AWS Directory Service. Additionally, the AWS Organizations service enables a business to establish and manage policies for multiple AWS accounts.

Amazon Web Services has also introduced tools that automatically assess potential security risks. Amazon Inspector analyzes an AWS environment for vulnerabilities that might impact security and compliance. Amazon Macie uses machine learning (ML) technology to protect sensitive cloud data.

AWS also includes tools and services that provide software- and hardware-based encryption, protect against DDoS attacks, provision Secure Sockets Layer (SSL) and Transport Layer Security (TLS) certificates and filter potentially harmful traffic to web applications.

The AWS Management Console is a browser-based graphical user interface (GUI) for AWS. The Management Console can be used to manage resources in cloud computing, cloud storage and security credentials. The AWS Console interfaces with all AWS resources.

Big data management and analytics

AWS includes a variety of big data analytics and application services. This includes:

- Amazon Elastic MapReduce, which offers a Hadoop framework to process large amounts of data.
- Amazon Kinesis, which provides several tools to process and analyze streaming data.
- AWS Glue, which is a service that handles extract, transform and load jobs.
- Amazon Elasticsearch Serviceenables a team to perform application monitoring, log analysis and other tasks with the open source Elasticsearch tool.
- Amazon Athena for S3, which allows analysts to query data.
- Amazon QuickSight, which help analysts visualize data.

Artificial intelligence

AWS offers a range of AI model development and delivery platforms, as well as packaged AI-based applications. The Amazon AI suite of tools includes:

- Amazon Lex for voice and text chatbot technology;
- Amazon Polly for text-to-speech translation; and
- Amazon Rekognition for image and facial analysis.

AWS also provides technology for developers to build smart apps that rely on machine learning technology and complex algorithms.

With AWS Deep Learning Amazon Machine Images (AMIs), developers can create and train custom AI models with clusters of graphics processing units (GPUs) or compute-optimized instances. AWS also includes deep learning development frameworks for MXNet and TensorFlow.

On the consumer side, AWS technologies power the Alexa Voice Services, and a developer can use the Alexa Skills Kit to build voice-based apps for Echo devices.

Mobile development

The AWS Mobile Hub offers a collection of tools and services for mobile app developers, including the AWS Mobile SDK, which provides code samples and libraries.

A mobile app developer can also use Amazon Cognito to manage user access to mobile apps, as well as Amazon Pinpoint to send push notifications to application end users and then analyze the effectiveness of those communications.

Messages and notifications

AWS messaging services provide core communication for users and applications. Amazon Simple Queue Service (SQS) is a managed message queue that sends, stores and receives messages between components of distributed applications to ensure that the parts of an application work as intended.

Amazon Simple Notification Service (SNS) enables a business to send publish/subscribe messages to endpoints, such as end users or services. SNS includes a mobile messaging feature that enables push messaging to mobile devices. Amazon Simple Email Service (SES) provides a platform for IT professionals and marketers to send and receive emails.

AR & VR (Augmented reality and virtual reality)

AWS offers augmented reality (AR) and virtual reality (VR) development tools through the Amazon Sumerian service. Amazon Sumerian allows users to create AR and VR applications without needing to know programming or create 3D graphics. The service also enables users to test and publish applications in-browser. Amazon Sumerian can be used in:

- 3D web applications
- E-commerce & sales applications
- Marketing

- Online education
- Manufacturing
- Training simulations
- Gaming

Game development

AWS can also be used for game development. Large game developing companies, such as Ubisoft, will use AWS services for their games, like For Honor. AWS can provide services for each part of a game's lifecycle.

For example, AWS will provide a developer back-end services, analytics and developer tools. Developer tools should help aid developers in making their game, while back-end services might be able to help with building, deploying or scaling a developer's platform. Analytics might help developers better know their customers and how they play the game. Developers can also store data, or host game data on AWS servers.

Internet of Things

AWS also has a variety of services that enable the internet of things (IoT) deployments. The AWS IoT service provides a back-end platform to manage IoT devices and data ingestion to other AWS storage and database services. The AWS IoT Button provides hardware for limited IoT functionality and AWS Greengrass brings AWS compute capabilities to IoT devices.

Other services

Amazon Web Services has a range of business productivity SaaS options, including:

- The Amazon Chime service enables online video meetings, calls and text-based chats across devices.
- Amazon WorkDocs, which is a file storage and sharing service
- Amazon WorkMail, which is a business email service with calendaring features.

Desktop and streaming application services include Amazon WorkSpaces, a remote desktop-as-a-service platform (DaaS), and Amazon AppStream, a service that lets a developer stream a desktop application from AWS to an end user's web browser.

2.3 Google Cloud:

Google Cloud consists of a set of physical assets, such as computers and hard disk drives, and virtual resources, such as virtual machines (VMs), that are contained in Google's data centers around the globe. Each data center location is in a region. Regions are available in Asia, Australia, Europe, North America, and South America. Each region is a collection of zones, which are isolated from each other within the region. Each zone is identified by a name that combines a letter identifier with the name of the region. For example, zone a in the East Asia region is named asia-east1-a.

This distribution of resources provides several benefits, including redundancy in case of failure and reduced latency by locating resources closer to clients. This distribution also introduces some rules about how resources can be used together.

2.3.1 Google Cloud Functions

Google Cloud Functions is a serverless, event-driven computing service within Google Cloud Platform. Developers can use it to create and implement programmatic functions within Google's public cloud, without having to provision the underlying cloud infrastructure -- such as servers, storage and other resources.

Google Cloud Functions allows small code segments to perform specific, limited tasks, which are typically related to triggering responses to real-world and software-driven events. When an event triggers an associated function, the function is loaded into a provisioned cloud environment and executed. All infrastructure resources are provisioned and recovered automatically by Google Cloud Platform (GCP).

Google Cloud vs AWS

Google Cloud is a suite of Google's public cloud computing resources & services whereas AWS is a secure cloud service developed and managed by Amazon. Google Cloud offers Google Cloud Storage, while AWS offers Amazon Simple Storage Services.

2.3.2 Advantages of Google Cloud

- **Higher Productivity owing to Quick Access to Innovation:** Google's systems can deliver updates efficiently and on a weekly basis.
- **Less Disruption When Users Adopt New Functionality:** Rather than large disruptive batches of change, Google delivers manageable improvements in a continuous stream.

- **Employees Can Work from Anywhere:** They can gain full access to information across devices from anywhere in the world through web-based apps powered by Google cloud.
- **Google Cloud Allows Quick Collaboration:** Many users can contribute to and access projects at the same time as data is stored in the cloud instead of their computers.
- **Google's Investments in Security Protect Customers:** Customers benefit from process-based and physical security investments made by Google. Google hires leading security experts.
- **Fewer Data stored on Vulnerable Devices:** Minimal data is stored on computers that may get compromised after a user stops using web-based apps on the cloud.
- **Customers get Higher Uptime and Reliability:** If a data center is not available for some reason, the system immediately falls back on the secondary center without any service interruption being visible to users.
- **Control and Flexibility Available to Users:** They have control over technology and have ownership over their data in Google apps. If they decide to not use the service anymore, they can get their data out of Google cloud.
- **Google's Economies of Scale Let Customers Spend Less:** Google minimizes overheads and consolidates a small number of server configurations. It manages these through an efficient ratio of people to computers.

2.3.3 Google Cloud Categories

Products offered by Google Cloud are categorized into four categories: Compute, Storage, Big Data, and Services.

Compute: It further consists of two sub-categories:

i. Compute Engine

It is Google's infrastructure-as-a-service (IaaS). Through this, Google's infrastructure can be used to run workloads on a large scale on virtual machines. You can select a virtual computer to fit your needs and enjoy the consistency and performance of Google's network worldwide. You have to pay only for what you use since the billing is per minute.

Features

- Security and Compliance
- Easy and Fast Provisioning
- Balancing of Loads
- High-Performance Virtual Computers

ii. App Engine

It is a platform-as-a-service (PaaS). You can ensure productivity by using in-built services to develop your apps. You must download the software development kit (SDK) and can start development work immediately and for free.

Features

- Google Scale Deployment
- Known Development Tools
- Strong In-Built Services
- Many Options for Storage
- Code Focus
- Popular Frameworks and Languages

Storage

It further consists of three sub-categories:

i. Cloud SQL

Cloud SQL is a relational MySQL database that helps manage and store data. To ensure performance and availability, Google takes care of database management, patch management, and replication.

Features

- Completely Managed
- Easy to Control

- Simpler Migration Without Lock-In
- Robustness, Accessibility, Security
- Pay Per Use and Package Charging
- Standard Infrastructure

ii. Cloud Storage

It is an object storage service that is highly available and durable. Users can quickly access data from their app from anywhere, on account of edge-caching on a global scale. Google presents a simple application programming interface (API), provides a robust service-level agreement, and runs versioning to let you handle data programmatically.

Features

- Variable Access
- Storage of Objects with Feature-Rich API
- Adjustable and Viable Pricing
- Safe and Secure

iii. Cloud Datastore

It provides a database, which is schemaless, NoSQL, and managed, for storage of non-relational data. SQL-like queries are supported well, in addition to transactions, and the data store also scales as required.

Features

- Access to Data Anywhere
- Local Tools for Development
- In-built Redundancy
- ACID Transactions
- Scaling Automatically with Users
- Database Management
- SQL-Like Querying and Schemaless Access

Big Data

BigQuery analyzes big data in the cloud. It can process datasets containing several terabytes in a few seconds and run quick SQL-like queries. It even provides insights in real-time and is scalable and straightforward to use.

Features

- Suitable Interface
- Economical Big Data
- Easy Import of Data

- Queries Executed in Background

Google also provides developer tools such as Google Plugin for Eclipse, Google Cloud SDK, Android Studio, Cloud Playground, and Push-to-Deploy, along with the cloud platform.

Services

Javascript, Android, and iOS clients can access your code through RESTful services from your system with Cloud Endpoints. The front-end wiring can become smooth, and the generation of client libraries can generate automatically. Client key management, OAuth 2.0 support, and protection against denial of service are part of the significant in-built infrastructure.

Features

- Integration of client-side becomes flexible
- Client-server maintenance is low
- App engine infrastructure can be extended
- Multiple clients handling with a single tool

2.4 Microsoft Azure

Azure is Microsoft's cloud platform, just like Google has it's Google Cloud and Amazon has it's Amazon Web Service or AWS.000. Generally, it is a platform through which we can use Microsoft's resource. For example, to set up a huge server, we will require huge investment, effort, physical space and so on. In such situations, Microsoft Azure comes to our rescue. It will provide us with virtual machines, fast processing of data, analytical and monitoring tools and so on to make our work simpler. The pricing of Azure is also simpler and cost-effective. Popularly termed as "Pay As You Go", which means how much you use, pay only for that.

Azure History

Microsoft unveiled Windows Azure in early October 2008 but it went to live after February 2010. Later in 2014, Microsoft changed its name from Windows Azure to Microsoft Azure. Azure provided a service platform for .NET services, SQL Services, and many Live Services. Many people were still very skeptical about "the cloud". As an industry, we were entering a brave new world with many possibilities. Microsoft Azure is getting bigger and better in coming days. More tools and more functionalities are getting added. It has two releases as of now. It's famous version **Micorosft Azure v1** and later **Microsoft Azure v2**. Microsoft Azure v1 was more like JSON script driven then the new version v2, which has interactive UI for simplification and easy learning. Microsoft Azure v2 is still in the preview version.

Azure can help in our business in the following ways-

- **Capitaless:** We don't have to worry about the capital as Azure cuts out the high cost of hardware. You simply pay as you go and enjoy a subscription-based model that's kind to your cash flow. Also, to set up an Azure account is very easy. You simply register in Azure Portal and select your required subscription and get going.
- **Less Operational Cost:** Azure has low operational cost because it runs on its own servers whose only job is to make the cloud functional and bug-free, it's usually a whole lot more reliable than your own, on-location server.
- **Cost Effective:** If we set up a server on our own, we need to hire a tech support team to monitor them and make sure things are working fine. Also, there might be a situation where the tech support team is taking too much time to solve the issue incurred in the server. So, in this regard is way too pocket-friendly.
- **Easy Back Up and Recovery options:** Azure keep backups of all your valuable data. In disaster situations, you can recover all your data in a single click without your business getting affected. Cloud-based backup and recovery solutions save time, avoid large up-front investment androll up third-party expertise as part of the deal.
- **Easy to implement:** It is very easy to implement your business models in Azure. With a couple of on-click activities, you are good to go. Even there are several tutorials to make you learn and deploy faster.
- **Better Security:** Azure provides more security than local servers. Be carefree about your critical data and business applications. As it stays safe in the Azure Cloud. Even, in natural disasters, where the resources can be harmed, Azure is a rescue. The cloud is always on.
- **Work from anywhere:** Azure gives you the freedom to work from anywhere and everywhere. It just requires a network connection and credentials. And with most serious Azure cloud services offering mobile apps, you're not restricted to which device you've got to hand.
- **Increased collaboration:** With Azure, teams can access, edit and share documents anytime, from anywhere. They can work and achieve future goals hand in hand. Another advantage of the Azure is that it preserves records of activity and data. Timestamps are one example of the Azure's record keeping. Timestamps improve team collaboration by establishing transparency and increasing accountability.

2.4.1 Microsoft Azure Services

Some following are the services of Microsoft Azure offers:

1. **Compute:** Includes Virtual Machines, Virtual Machine Scale Sets, Functions for serverless computing, Batch for containerized batch workloads, Service Fabric for microservices and container orchestration, and Cloud Services for building cloud-based apps and APIs.
2. **Networking:** With Azure you can use variety of networking tools, like the Virtual Network, which can connect to on-premise data centers; Load Balancer; Application Gateway; VPN Gateway; Azure DNS for domain hosting, Content Delivery Network, Traffic Manager, ExpressRoute dedicated private network fiber connections; and Network Watcher monitoring and diagnostics
3. **Storage:** Includes Blob, Queue, File and Disk Storage, as well as a Data Lake Store, Backup and Site Recovery, among others.
4. **Web + Mobile:** Creating Web + Mobile applications is very easy as it includes several services for building and deploying applications.
5. **Containers:** Azure has a property which includes Container Service, which supports Kubernetes, DC/OS or Docker Swarm, and Container Registry, as well as tools for microservices.
6. **Databases:** Azure has also includes several SQL-based databases and related tools.
7. **Data + Analytics:** Azure has some big data tools like HDInsight for Hadoop Spark, R Server, HBase and Storm clusters
8. **AI + Cognitive Services:** With Azure developing applications with artificial intelligence capabilities, like the Computer Vision API, Face API, Bing Web Search, Video Indexer, Language Understanding Intelligent.
9. **Internet of Things:** Includes IoT Hub and IoT Edge services that can be combined with a variety of machine learning, analytics, and communications services.
10. **Security + Identity:** Includes Security Center, Azure Active Directory, Key Vault and Multi-Factor Authentication Services.

2.4.2 Difference between AWS (Amazon Web Services), Google Cloud and Azure

Table 2.1 AWS vs Google Cloud vs Azure

	AWS	Google Cloud	Azure
Technology	EC2 (Elastic Compute Cloud)	Google Compute Engine (GCE)	VHD (Virtual Hard Disk)
Databases Supported	AWS fully supports relational and NoSQL databases and Big Data.	Technologies pioneered by Google, like Big Query, Big Table, and Hadoop, are naturally fully supported.	Azure supports both relational and NoSQL databases, and Big Data, through Windows Azure Table and HDInsight.
Pricing	Per hour – rounded up	Per minute – rounded up (minimum 10 minutes)	Per minute – rounded up commitments (pre-paid or monthly)
Models	On demand, reserved, spot	On demand – sustained use .	On demand – short term commitments (pre-paid or monthly)
Difficulties	Many enterprises find it difficult to understand the company's cost structure	Fewer features and services.	Less "enterprise-ready"
Storage Services	• Simple Storage Service (S3) • Elastic Block Storage (EBS) • Elastic Block Storage (EBS)	• Blob Storage • Queue Storage • File Storage • Disk Storage • Data Lake Store	• Cloud Storage • Persistent Disk • Transfer Appliance
Machine Learning	• Sage Maker • Lex • Polly • And many more	• Machine Learning • Azure Bot Service • Cognitive Service	• Cloud Speech API • Cloud Video Intelligence • Cloud Machine Learning Engine • And many more.

2.5 Vendor **Offering – IBM**

IBM Cloud is a suite of cloud computing services from IBM that offers both platform as a service (PaaS) and infrastructure as a service (IaaS). With IBM Cloud IaaS, organizations can deploy and access virtualized IT resources -- such as compute power, storage and networking -- over the internet. For compute, organizations can choose between bare-metal or virtual servers.

With IBM Cloud PaaS -- which is based on the open source cloud platform Cloud Foundry -- developers can use IBM services to create, manage, run and deploy various types of applications for the public cloud, as well as for local or on-premises environments. IBM Cloud supports various programming languages, such as Java, Node.js, PHP and Python and extends to support other languages. IBM Cloud products and services IBM Cloud platform supports access to other IBM tools and services -- including IBM Watson and IBM Cloud Functions for serverless computing -- as well as those from third-party vendors.

The IBM Cloud Catalog lists over 170 services across categories, including:

- Compute -- Offers various compute resources, including bare-metal servers, virtual servers, serverless computing and containers, on which enterprises can host their workloads;

- Network -- Provides cloud networking services, such as a load balancer, a content delivery network (CDN), virtual private network (VPN) tunnels and firewalls;
- Storage -- Offers object, block and file storage for cloud data;
- Management -- Provides tools to manage and monitor cloud deployments, such as those for log analysis, automation and Infrastructure as Code (IaC);
- Security -- Includes services for activity tracking, identity and access management and authentication;
- Data management -- Provides SQL and NoSQL databases, as well as data querying and migration tools;
- Analytics -- Offers data science tools such as Apache Spark, Apache Hadoop and IBM Watson Machine Learning, as well as analytics services for streaming data;
- Artificial Intelligence (AI) -- Uses IBM Watson to deliver services such as machine learning, natural language processing and visual recognition;
- Internet of things (IoT) -- Includes the IBM IoT Platform, which provides services that connect and manage IoT devices, and analyzes the data they produce;
- Mobile -- Enables a development team to build and monitor mobile applications and their back-end components;
- Developer tools -- Includes a command-line interface (CLI), as well as a set of tools for continuous delivery, continuous release and application pipelines;
- Blockchain -- Provides IBM's Blockchain Platform, a software-as-a-service offering to develop apps, enforce governance and monitor a Blockchain network;
- Integration -- Offers services to integrate cloud and on-premises systems, or various applications, such as API Connect, App Connect and IBM Secure Gateway;
- Migration -- Provides tools to migrate apps to the cloud, such as IBM Lift CLI and Cloud Mass Data Migration;
- VMware -- Enables the migration of VMware workloads into the cloud.

2.5.1 IBM Cloud deployment models:

Public: A public cloud that provides access to virtual servers in a Multi-tenant environment. An enterprise can choose to deploy its applications in one or multiple geographical regions.

Dedicated: A single tenant private cloud that IBM hosts in one of its data centers. An enterprise can connect to the environment using a direct network connection or virtual private network (VPN), and IBM manages the platform.

IBM Cloud Private: A version of the IBM platform that an organization deploys as a private cloud in its own data center behind a firewall.

Questions:

1. What is cloud computing?
2. What are the benefits of cloud computing?
3. What are the different layers in cloud computing? Explain working of them.
4. What do you mean by software as a service (SaaS)?
5. What is the platform as a service (PaaS)?
6. Explain Infrastructure as s Service (IaaS)?
7. Write short notes on following
   a) AWS
   b) Google
   c) Microsoft
8. List the name of vendors offering Cloud Services.
9. Enlist the real-life scenarios where Cloud- Computing services are being used.