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A Survey on Cloud Computing Providers and Applications

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***Abstract*—** One of the most dominant technologies of today is cloud computing. This dominance is due to its potential to reduce costs while providing the services that are needed to carry out any business more efficiently and effectively. Cloud computing can be deployed universally in very little time. It offers flexibility as well as agility. This paper reviews the features and models of cloud computing. The different models of cloud are discussed in detail and comparison between them is used to understand the functionality and use of each. This paper also provides a comparison between the major cloud computing service providers. The three main cloud providers Amazon, Google, and Microsoft are compared against various features. This helps to understand the services and benefits of each provider. It also includes an overview of the challenges and limitations faced in the field of cloud computing and also the current scope of its application in various industries.

***Keywords*—** Cloud computing, Comparison, Challenges, Applications

I. INTRODUCTION

Cloud computing can be most easily understood as the model by which you access shared resources in an easy and convenient manner over the Internet. It traces back to 1960 when it was predicted that computation might be used as a utility. Today, the cloud provides its users with a plethora of resources at their disposal. The most common usage of it is in file sharing, social network, storage, and also to avail better performance [1]. It is necessary to have a broad overview of cloud computing models and services in order to understand their working in detail. The contribution of this paper is to review the cloud computing concepts and provide a comparison between its various models. It also provides a comparison between the cloud technologies offered by Microsoft, Google, and Amazon. These are the market leaders in cloud and their features and services are highlighted in this paper. In addition to this, the challenges and applications of cloud computing are also highlighted.
The structure of the paper is organized as such. Section II contains an overview of cloud computing. Section III covers the essential concepts of cloud computing. Section IV highlights the differences between the top cloud service providers based on various parameters. Section V includes the challenges faced in the field of computing. Section VI describes the applications of cloud computing in various sectors and fields. Sector VII includes the conclusion of the paper.

II. OVERVIEW OF CLOUD COMPUTING

There has been a defining shift in the past few years to move towards a world of technology that is dominated by the usage of cloud. One of the main reasons behind this is the need to improve the capabilities of systems without investing in new infrastructure [2]. This not only provides the extensibility but also has the advantage of reducing cost up to a certain extent. This shift is clearly visible as major players in the industry have invested in and rolled out their own cloud platforms [3]. The current market is dominated by AWS, IBM Cloud, Google Cloud. Cloud computing has become an integrated part of everyday lives. A few examples of the daily usage of cloud are media streaming and e-commerce.

Features of Cloud computing:

1. The major feature of cloud computing is resource pooling. This feature provides the ability to serve multiple clients with scalable services. Sharing resources also allows for the economical utilization of infrastructure [4].
2. The on-demand self-service allows the provision of cloud resources whenever they are needed.
3. Pay as you go allows users to only pay for the resources they consumed. It allows control over the cost. An economical solution is provided by cloud computing as the company has to put in a one-time investment [5]. There is a reduction in running and installation charges.
4. The data on the cloud can be accessed from anywhere if there is an active internet connection. It provides the feature of large network access.

An overview of cloud computing is shown in Figure 1. It includes its essential features, the main deployment models as well as the service models. These topics have been covered in detail in further sections. It also highlights the applications that cloud can have.

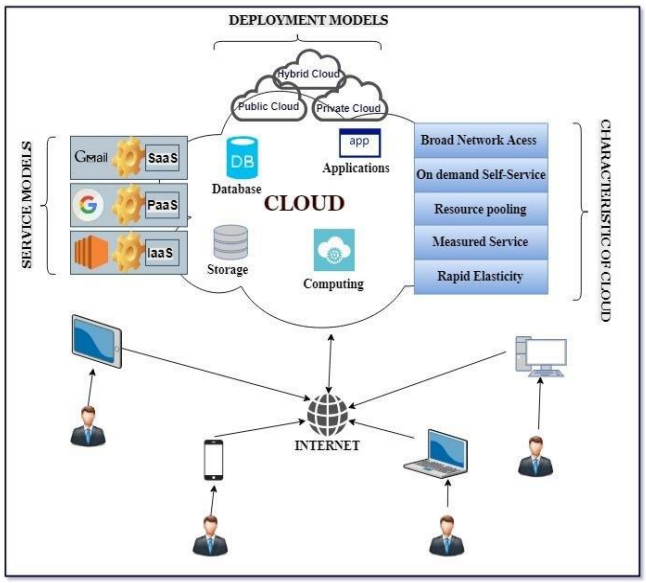

Figure 1 Overview of Cloud Computing [6]

III. CLOUD COMPUTING CONCEPTS

A. Deployment Models of Cloud Computing

The four deployment models in cloud computing are:

1. **Public Cloud**: These are the clouds available to the general population [5]. The data is used and stored on third-party servers. The organizations that wish to use resources obtain them from the service providers by paying for only the services they wish to use. Companies no longer have to buy their own hardware. However, the issue of Data Security and privacy is a concern using the public cloud.

The growth in public cloud computing market size in the last 12 years has been massive. The jump from 2008 to 2020 is almost 150 billion U.S dollars. This trend is depicted in Figure 2.

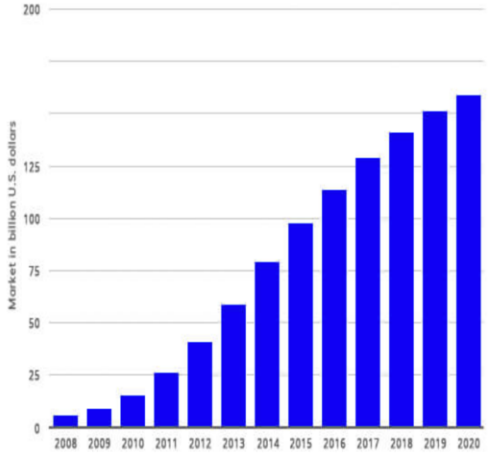

Figure 2 Size of public cloud computing market over the years

2. **Private Cloud:** These are very similar in their designs and structure. The main difference is that private clouds are owned by a single company and are protected by firewalls. These are used internally in the organization that owns them. The protection, reliability, and security of these clouds are also higher. This entails that the cost of this model is much higher to support hardware and software expenses.
3. **Community Cloud**: A model that is extremely similar to the private one but has one major difference. Instead of being used by a single company, multiple organizations that have similar usage and background share the cloud to form the community cloud model [7]. The companies share the cost of the resources among themselves. This works on solving the disadvantage of the cost of the private cloud. However, the sharing of storage can sometimes create issues.
4. **Hybrid Cloud:** This cloud allows companies to incorporate the best features of private, public, and hybrid clouds and allows them to pick the features that best suit their purpose. For example, only the highly critical details can be stored on a private cloud with firewalls and security while rest is on a cheaper public cloud. This allows a balance between cost and security.

The current trends show a greater inclination towards using public clouds. However, hybrid clouds are increasing in popularity due to the balance in security and cost. Figure 3 shows the preference of current enterprises between the different cloud models.

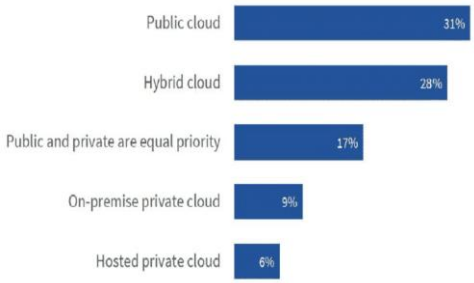

Figure 3 Cloud Priority for Enterprises

A comparison between the four deployment models based on various attributes is done in Table 1. The factors based on which these models are compared are the ones used commonly to select the best cloud model for an application. For example, a company that holds its user data would value security highly and would go ahead with a private or community cloud to ensure data leaks are limited. Looking at these factors, it is easier to choose a deployment model based on the needs of the application and the organization.

B. Service Models of Cloud Computing

The three service or delivery models in cloud computing are:

- Software as a Service (Saas)
- Platform as a Service (Paas)
- Infrastructure as a Service (Iaas)

Table 1 Comparison of different cloud deployment models [8][9][10]

	Public Cloud	*Private Cloud*	*Hybrid Cloud*	*Community Cloud*
Maintenance cost	Lowest	Highest	Medium	High
Reliable	Lowest	Highest	Medium	High
Ownership	Customer	Single Organization	Service provider and Customer	Multiple organizations
Security	Lowest	Highest	Medium	High
Setup Cost	Lowe	High	Medium	Depends on number of organizations
User Control	Limited Control	Full Control	Mixed. Full control over Private parts and limited over public	High but limited control based on community policies

1. The **SaaS Model** allows companies to access cloud-based applications without investing in new infrastructure [11]. They are run on a vendor cloud and do not require any installations or downloads. The advantage of SaaS is that they are affordable and ready to use from wherever they are needed.

   However, using SaaS limits the amount of control you have. The majority control of the program is with the vendor. Also, compared to other models, it's slower as it depends on the Internet connection.

SaaS Characteristics:

- It is managed centrally.
- The software and hardware are beyond the scope of the user's responsibilities.
- Housed on a remote server.[12]

SaaS Limitations:

- Limited interoperability makes integration with existing apps and services difficult.
- There is very little scope of customization. Users have to work with functionalities and performance offered by vendors.
- Large amounts of data are exchanged and may lead to compromised data security.

A popular example of SaaS is **Dropbox**. Dropbox helps keep all documents and files at the user's fingertip. Any file uploaded on Dropbox will be available across all the user's devices. Users can give access to others to browse through select folders and files. This is done in a password protected manner. Another example is **Lumen5** which is used to create videos from text in an easy manner. It has an automated AI that analyses the text to calculate the length of the scene.

Examples of SaaS by major cloud providers are chime by Amazon, Office 365 by Microsoft, and Gsuite by Google.

A survey done in the IT sector showed results that by 2022, 78% of the organizations will run almost all their application on SaaS. A graph depicting this trend is shown in Figure 4.

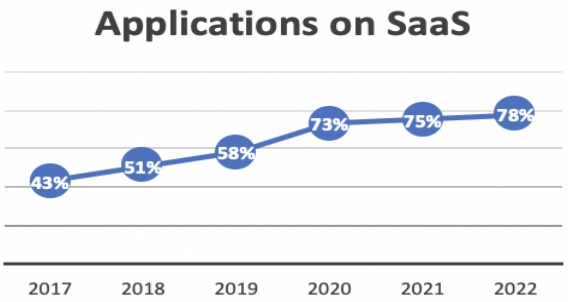

Figure 4 Percentage of applications on SaaS

2. The **PaaS Model** provides companies with a platform to develop their applications. The vendor hosts the infrastructure of the cloud and removes the need for companies to download and install hardware and software [13]. This model provides control over the application while still being affordable [11]. Security is a big issue in this model. Also, migration issues arise due to each vendor having their own infrastructure.

PaaS Characteristics:

- Integrates web services and databases.
- Can be used by multiple users through the same development application.
- Resources can be scaled up or down based on requirements [14].

PaaS Limitations:

- Data security is an issue as data resides in vendor-controlled cloud servers.
- PaaS solutions may not be suited to certain frameworks. It may not work as well for other languages. Certain frameworks will not work optimally with the PaaS service.

A popular example of PaaS is **OpenShift**. Languages like Java EE6, Ruby, PHP, Python, etc are also supported. It also provides automated workflow which is useful during peak workloads by automatically scaling as per the needs. Another popular example is **CloudFoundry** to self-host and run any service.

PaaS is commonly used to manage and run microservices. Another application is to use it in communications. It can be used as a mechanism to deliver messages. It is necessary for businesses to analyze their data and find trends. PaaS

provides the tools to do these analytics. It helps predict trends like the demand for the product, etc.

Examples of PaaS by major cloud providers are AWS elastic beanstalk by Amazon, Azure cloud services by Microsoft and App Engine by Google.

3. The **IaaS Model** is the one that provides companies with maximum flexibility. The cloud provider only hosts the company's infrastructure. The control over applications, deploying, and storage relies on the company. The cost of this model is much higher than SaaS or PaaS.

IaaS Characteristics:

- In IaaS resources are used as services [14].
- Services are highly scalable [15].
- The infrastructure remains under the control of the organization.

IaaS Limitations:

- Hosts and other virtual machines can be a major threat and can compromise data security [16].
- It will be necessary to train additional resources to manage the complex infrastructure.

A popular example of IaaS is **Digital Ocean.** It provides a simple web infrastructure for developers to use. It offers a simple and robust platform to easily launch and scale applications. The platform is being advanced to support growing teams and larger applications.

One of the major applications using IaaS is big data analytics. Finding patterns and sequences in huge data sets is a requirement in many fields today. It helps find associations between different parameters. Doing this type of analytics requires a massive amount of processing power. IaaS can provide it in an easy manner.

Examples of IaaS by major cloud providers are EC2 and S3 by Amazon, Azure VM by Microsoft, and Compute Engine Virtual Machines by Google.

IV. MAJOR SERVICE PROVIDERS OF CLOUD COMPUTING

There are many popular cloud service providers. The biggest cloud computing service providers are:

- AWS by Amazon
- GCP by Google
- Microsoft Azure

A comparison between these three in various spheres is given in Table 2, Table 3, Table 4, and Table 5. Table 2 covers the strengths and expertise of each particular provider. AWS has been around for a long time and is dominant. Azure has been developed with a focus on easy integration of MS apps. Finally, GCP is relatively young and is built on Google's global operations.

Table 2 Strengths of Azure vs GCP vs AWS [17][18][19]

	Strengths
Amazon Web Services	• Provides better support for a larger organization. • It has dominated the market for many years because of the huge array of services it provides. • It has a global reach. • Works efficiently on all varieties of workloads. • Allows for easy open-source tool integration.
Google Cloud Platform	• Designed for cloud-based business. • Offers flexible contracts and good discounts. • Committed to open source and portability. • DevOps Expertise.
Microsoft Azure	• Allows easy integration with Microsoft tools. • Has good support for open source. • Highly scalable & secure. • Strong hybrid options. • It has a broad set of features and services available.

Table 3 Comparison of compute services of Azure vs GCP vs AWS

	Compute Service
Amazon Web Services	• EC2 or Elastic Compute Cloud is the most prominent compute service offered by AWS. • It offers a collection of services including HPC. • Provides secure compute services. • EC2 supports not only Windows but also Linux. • The compute capacity is modifiable. • Container services allow support for Docker and Kubernetes. • There is also an option of a virtual private cloud
Google Cloud Platform	• Just like AWS gives Linux and Windows support. • Increases efficiency as its infrastructure consumes only 50% of other similar ones. • It allows custom and pre-defined types. • Its major highlight is Kubernetes in which it has in-depth expertise.
Microsoft Azure	• It provides an assortment of services including GPU, HPC. • It has availability of services optimized for AI and machine learning. • It offers support on Oracle, Windows, Linux, etc which gives it an edge over competitors. • It can leverage both Kubernetes and Docker. • It has a service for batch computing jobs. • Its highlight is a service that helps develop applications with microservice architecture.

Table 4 Comparison of Storage and Database services of Azure vs GCP vs AWS

	Storage Service
Amazon Web Services	• AWS offers different types of services for storage: file, object, and persistent. • Elastic File System, Simple Storage Service, and Elastic Block Storage are the ones for each type. • A highlight is Snowball, a physical hardware device that allows you to transfer data when the internet isn't accessible. • The different databases offered are SQL, NoSQL, graph database, data warehouse, etc. • It can easily backup data using Storage Gateway.
Google Cloud Platform	• It has fewer services compared to others. • It offers online transfer. • Storage on cloud is in the form of object storage that is unified. • It also gives the choice of a Persistent Disk. • In databases, it offers SQL and NoSQL options. • Unlike AWS, it doesn't offer backup services.
Microsoft Azure	• The different options of storage are Blob, File, Queue, and Disk. • Azure offers the most extensive database service among the three. • It offers SQL based like MySQL databases. • It offers in-memory service like Redis Cache. • Data Warehouse option like Cosmos DB is a part of Azure's offerings. • Azure offers site recovery and archive storage options.

Table 5 Comparison of Key services and technologies of Azure vs GCP vs AWS

	Key Services
Amazon Web Services	• Machine learning is one of the technologies that will give cloud providers an edge in the market in the future. AWS offers a service, SageMaker for training Machine learning models. • It has offered the option of a deep learning library to simplify training of neural networks. This library is called Gluon. • It also has services that help deploy algorithms for projects involving OCR, etc.
Google Cloud Platform	• Google is a dominant force in AI through TensorFlow. TensorFlow is a popular library used for various machine learning problems. • It also offers services for speech translation.
Microsoft Azure	• It offers a Bot Service as a part of its machine learning services. • It has various API as a part of cognitive services. These services are used to solve AI problems.

Table 3 included the various compute service offered by the three and also discussed the container services. It also includes the operating systems each service provider offers support for. Table 4 included different database and storage options. It also included information regarding the recovery of lost data in each of the providers' services. Services pertaining to new technologies like AI and machine learning are covered in Table 5.

V. CHALLENGES AND ISSUES

As the popularity of cloud increases, a large number of companies and organizations have begun to move towards a cloud-based development. However, there are many issues and challenges that arise as part of cloud computing.

1. **Security**: As the amount of data stored on the cloud increases, keeping this data secure becomes increasingly challenging. Some of the security threats are DDOS attack, loss of data, IP spoofing [20]. A Distributed Denial-of-Service (DDoS) attack can cause the system to experience difficulties or to go down completely. Inadequate data backups and improper data syncing may result in making an organization vulnerable to ransomware. These risks can be mitigated to a certain extent by using techniques like end-to-end encryption and Single sign-on (SSO).

2. **Load Balancing**: Load balancing is a method by which workload is distributed among different clusters and nodes [21][22]. Even in the case of a failure, resources should be provisioned and utilized in such a manner that the service is continuous. The issues that are faced while trying to implement load balancing are:

- Geographically spread out nodes: Since most load balancing algorithms and methods are designed for smaller areas, factors like communication and network delay are not taken into account [23].
- Central Failure: Most dynamic algorithms contain a central node that takes decisions regarding load balancing. The failure of this node affects the computation of all nodes.

- Complexity: Many algorithms are extremely complex and affect the performance and scalability of the cloud system.
- Heterogenous Nodes [23].

3. **Communication in Virtual Network Topologies:** The VM communicate among each other and form network topologies. If the communicating VM maybe be housed on distant physical nodes, communication between them becomes expensive [24]. If the host has dispersed VM, network switching may be used during communication and maybe cause excess power consumption. It is imperative to allocate VM on nearby nodes to avoid this.

4. **Portability**: There is a surge in the number of services and vendors. This raises the challenge of portability on cloud. Portability is the capacity to use an application in several environments. An application's behavior depends on the configuration files. These files can be platform-specific. An application must have a configuration file specific to each platform in order to run in it. This lack of portability creates issues in moving data between different public or private environments [25]. There is a lack of interoperability between different cloud systems.

VI. APPLICATIONS

Cloud computing has many features and benefits that make it an active and dominant part of various fields.

1. **Cloud Computing in Medical fields**: Cloud computing can be used in hospitals by allowing medical professionals to access patient information and history. Having a cloud-based system will ensure all the data is stored at a common point [26]. Activities like updating test results, past medical history, personal information, diagnosis, and updating the chart can be done on the cloud easily and efficiently. This data can be available in an emergency. Ambulances can access this data without having to reach the hospital. This can help provide better and faster treatment. Also, these records can be accessed if the patient has to be admitted to another hospital. In the field of medicine, these benefits can help treat patients better.

2. **Cloud Computing in Entertainment**: The customers of media and entertainment today demand flexibility and choices. Alongside this, the usage patterns are unpredictable which can be difficult to handle. A delay of a few seconds during streaming can cost millions of dollars in some situations. The on-demand feature of cloud provides the stability to meet the consumers' demands [6].

Surges and dips in viewership are handled by increasing and decreasing the servers as per real-time demand. Users of today are demanding more choice, convenience, and control over their viewing. This requires more computing power and resources. Cloud computing is effective in meeting these requirements. Cloud also allows for storing huge quantities of digital content in a cost-effective manner.

3. **Cloud Computing in Education**: The use of cloud computing in education opens avenues for allowing better interactions and collaborations between all parties concerned. The potential users of cloud computing in the education sector will be the students and staff. Activities like quizzes, attendance can be done more effectively and efficiently. Resources can be available for all users at all times and at any location. Sharing of documents or media resources will be much simpler [27].

The concept of virtual classrooms can help in a twofold manner. Firstly, it can help reduce infrastructure. Secondly, students can attend lectures and exams from anywhere [28]. This also opens up room for collaboration with experts to deliver talks to students from a different location in a cost-effective manner. Cloud computing also helps students go beyond the norm and explore other courses and materials that interest them. It helps them broaden their horizons. However, privacy and security are big risks while integrating cloud computing into the education sector. It is necessary to ensure specific steps are taken to prevent the loss of confidential data.

4. **Cloud Computing in Finance and Banking:** The finance and banking sector is gradually moving towards digital solutions in order to innovate and evolve. Cloud provides the most transformative digital solution. The banking sector has use cases like data storage and analytics which can be done more flexibly and efficiently by accessing the resources on the cloud.

Agile innovation is one of the key reasons why cloud computing has become popular in this sector. Cloud computing also mitigates risks such as capacity, redundancy, and resiliency concerns. In addition to this, the cost savings of using cloud computing are significant [29]. A major application where cloud has been deployed is payment gateways. Cloud offers security and unified customer experience. Also, continuous uptime ensures no disruptions in the processing of payments.

VII. CONCLUSION AND FUTURE WORK

In this paper, we have discussed the building blocks of cloud computing. The four deployment models of cloud were covered along with a detailed comparison. This paper also included a broad overview of the service models of cloud computing. This overview covered the characteristics and limitations of each model and also gave popular examples for each model. It also addressed the growth predictions for one of the service models. This paper includes a broad review of the services and technologies provided by the market leaders of the cloud industry. Features like compute services, database and

storage services and key technologies were the parameters for comparing the cloud service providers. In addition to this, the paper addressed the challenges and issues faced in cloud computing. This paper also includes various applications of cloud computing in different sectors.

Cloud computing is on the rise as most major companies have migrated towards a cloud platform. The scope for further research and improvements is unlimited. Some major fields of research are cloud cryptography, virtualization, quantum computing, and automation. Quantum computing is an area in which research is happening at a rapid pace. Many companies are currently engaged in research in the field of Quantum Computing. They are working towards quantum computing by leveraging the best cloud-based tools. Quantum computing offers faster processing, stores data in a quicker and simpler form of data, and also reduces the cost

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