A Comparison of Vendor-Specific Cloud Services

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***Abstract*— Over the course of the last 20 years, cloud computing has successfully established itself as the backbone of modern digital infrastructure and services. Cloud computing has become a staple in modern businesses and operates on a model of shared resources, where data is stored in data centers and available to users over the internet[1]. The number of cloud service providers has steadily increased, though some providers may offer a broader range of features than others. Our report attempts to provide an in-depth analysis of ten cloud services from leading cloud service providers to the lesser-known ones. It attempts to differentiate the best services for various business situations through performance, business metrics and pricing structure of each service.**

***Index Terms*— Cloud Computing, Cloud Service Providers, Cloud Vendors**

I. INTRODUCTION

Cloud computing is changing the way we interact every day by offering a range of services like databases, storage, networking, software, servers, analytics, and more, all over the internet. Many people wonder, "What is the cloud?" and "Where is it?" Essentially, the cloud is just a collection of computing services provided by companies over the internet, which lets users access their data quickly and easily from anywhere. The increasing use of cloud computing comes from its many advantages, such as lowering costs, speeding up processes, allowing for growth, and boosting productivity. This paper will look into these advantages further and explain why cloud computing is making such a big impact.

Cloud computing encompasses 4 number one service fashions: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), Software as a Service (SaaS), and serverless computing. IaaS presents customers with on-call for access to critical computing resources including compute strength, networking, and garage. PaaS offers a improvement platform that allows developers to build and customize packages to satisfy their unique wishes. SaaS grants programs over the internet, commonly accessed via an internet browser, simplifying utility transport and use. Serverless computing eliminates the need to manage infrastructure, allowing builders to pay attention completely on writing and deploying code with out the burden of server protection. These services can be explored in more element later to deepen our know-how in their significance and effect.

For this paper, we will look at the services provided by ten different cloud service providers as follows:

1) Amazon Web Services(AWS)
2) Google Cloud Platform
3) Microsoft Azure
4) IBM Cloud Services
5) ServerSpace
6) DigitalOcean
7) HPE Cloud Services
8) Alibaba Cloud
9) Oracle Cloud
10) Openstack

We will analyze and compare the vendors to gain a clearer insight into what each cloud provider delivers. Furthermore, we will attempt to identify which service vendor offers the most features.

II. Cloud Computing

In this section of the paper, we will briefly go into the basic concepts of cloud computing so that we can better understand cloud computing.

A. Cloud Deployment Models

Companies adopt different cloud deployment models, often multiple, depending on their needs and preferences. Each model has its features and trade-offs. Cloud deployment models are generally categorized into the following four types[2][3].

- **Public Cloud:** In this cloud service model, providers offer services over the internet and manage the physical infrastructure, including servers housed in multiple locations for better resilience. They may also handle the operating system and other software layers. Providers benefit from economies of scale, allowing them to offer reduced costs and significant investments in advanced cybersecurity, while users can quickly access needed computational resources, including redundant options.
- **Private Cloud:** In the private cloud model, computing resources are run by a single entity, either hosted on-premises or by a third-party provider. This model enables enterprises to control and manage their dedicated resources, delivering benefits such as optimization and improved security through data extraction but with increased costs and potential complications with performance comes up compared to public clouds. To reduce costs but maintain security, some companies use virtual private clouds (VPCs), which combine hardware sharing and data isolation, although this can limit certain features compared to multi-tenant public clouds VPCs still offer scalability advantages.
- **Hybrid Cloud:** Hybrid cloud combines private and public cloud resources in a unified manner, giving enterprises the freedom to manage operations and data. Companies can use hybrid clouds to meet increased demand or move critical data from private clouds, while using public clouds to access less critical data. This approach can also provide flexibility from on-premises systems up to the public cloud have been simplified. However, managing a multi-cloud environment can increase complexity and inefficiency, which can lead to system inefficiencies.
- **Community Cloud:** The community cloud model provides shared systems and services among organizations within a specific region, industry, or industry, managed by third parties or collectively managed by member organizations. This model is cost-effective and enhances security by sharing resources and services, and enables business and data sharing across organizations, however, faces limitations in scalability and adaptability, as changes by one member can impact others, prevent individual organizational flexibility and the ability to tailor services to specific needs.

B. Cloud Service Models

In this part of the paper, we aim to analyze the various applications of cloud computing. Previously, we identified four types of applications: IaaS, PaaS, SaaS, and Serverless. Understanding this "as-a-service" model is essential to understanding the unique features each cloud service offers. The following section provides detailed information for each cloud service model[4][5].

- **IaaS:** IaaS (Infrastructure as a Service) provides access to cloud-based computing resources such as servers, storage, networking, which customers can use like on-premises hardware. Unlike on-prem systems, infrastructure is managed by a cloud service provider in their data centers is, where they use the internet to allow customers to pay at subscription or on the go and can choose between virtual machines on shared hardware or bare metal server on dedicated hardware. These features can be managed through graphical dashboards or programmatically through APIs.

- **PaaS:** PaaS (Platform as a Service) provides a comprehensive cloud-based platform that supports the entire application lifecycle from development to deployment. It is hosted by a service provider and includes all necessary hardware and software components such as servers, OS software, storage, and development tools. In addition, it offers security, update, and backup services. Users access and collaborate on this platform using images, enabling easy integration, testing and deployment.
- **SaaS:** SaaS (Software as a Service) provides cloud-hosted, ready-to-use application software that users access and pay for via subscriptions, using web browsers, desktop clients, or mobile apps. The SaaS vendor manages all infrastructure and maintenance, including upgrades and patches, ensuring service levels through agreements. It allows scalability by adding users or storage for an extra fee. Common examples of SaaS include email, social media, and cloud storage solutions like Dropbox, which are widely used in daily life.
- **Serverless:** Like PaaS, serverless computing enables developers to build applications that are just large enough without managing servers, although, servers are still deployed and managed by providers. The major features of PaaS include less control over the deployment environment, real-time scalability, and executing code only on- call. Serverless applications are cost-effective due to flat, usage-based billing and are supported by the tools of cloud providers. Often synonymous with Function as a Service (FaaS), this model offers high availability and fast startup times. However, this comes with challenges such as the possibility of vendor lock-in, although the latter is often mitigated by the wide variety of services and products offered by providers.

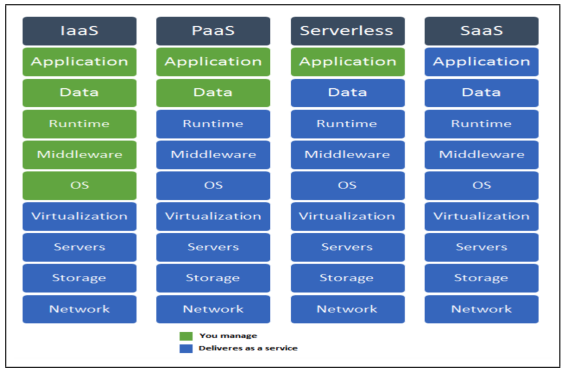

Fig. 1. Cloud Service Models[6]

C. Pros and Cons of Cloud Computing

We now discuss the pros of cloud computing[7][8].

- **Lower cost:** Cloud-based services are often hailed as cost-effective. Especially for businesses investing in Software as a Service (SaaS), a pay-as-you-go model reduces costs by paying only for what you use, resulting in significant savings and better returns they. Whereas platform as a service (PaaS) or infrastructure as a service (IaaS) can be more cost-effective for larger organizations with broader needs while avoiding expensive software costs, licensing and installation costs. Small and medium-sized enterprise can find out these options are expensive compared to simple local server setups. However, they can benefit from the flexibility of SaaS solutions, which can be easily scaled up and down to suit business needs.
- **Flexibility and scalability:** Using cloud services offers greater flexibility compared to local servers, easily adapting to changes in workload and activity. This shift extends to purchasing cloud-based applications and services, ensuring that companies don't get stuck in excessive waste that may not be necessary in the long run. Cloud computing

is especially valuable because of its scalability, which adapts to changes in demand throughout the year. Costs are directly proportional to actual usage, such as paying for only essential data storage at any given time.

- **Data control:** Data loss is a major business concern, with a data breach potentially costing £3.12 million. Storing sensitive information locally carries the risk of data loss due to hardware failure, human error, or cyberattack. Cloud servers provide a central location for data, accessible from any Internet-connected device. This makes cloud computing an ideal solution for data storage, especially for backup purposes. Keeping the backup offsite and independent of the local network protects against malware that would access backup data during events such as ransomware attacks.
- **Greater accessibility:** Cloud computing greatly increases data availability, allowing employees to access vital company information from any location at any time, if they have access to the internet this eliminates the need to be on a physical server. Additionally, cloud services are readily available on mobile devices, supporting productivity and flexibility, and enabling employees to be more productive on the move. This flexibility is especially useful for today's workforce, which is highly distributed and often works remotely, especially in the aftermath of a pandemic.
- **Effective collaboration:** Cloud computing greatly supports collaborative efforts. By storing all files and documents in a central location, team members can access, view, and modify the same information simultaneously. Cloud services also maintain records of all changes and updates, which helps eliminate confusion and keeps everyone up to date with the latest documents. Additionally, cloud platforms enable secure collaboration not only within teams but also with external parties such as customers, partners and suppliers, using strong encryption to ensure data security.

We now discuss the cons of cloud computing[7][8].

- **Limited control and visibility:** Cloud services infrastructure is managed by the provider, reducing the need for internal management but can sometimes result in businesses being disconnected and not in control of their data The nature of cloud storage a its lack of physical presence creates challenges to ensure secure data erasure and prevent attackers from leaving usable memories. In many cases, cloud service providers adopt a 'shared responsibility' model, which means you must take proactive steps to manage your data and activity in the cloud. There are effective tools that can provide visibility and control increased, such as managed solutions that indicate uniqueness or potentially compromising activity.
- **Security:** Check Point reports that 94% of organizations are very concerned about cloud security, primarily due to potential misconfigurations and data breaches. The ease of access that makes cloud computing so appealing also carries risks, as improper policies or poor security practices can allow unauthorized access to sensitive data affecting 99% of the wrong systems. This often goes unnoticed, exacerbating the weakness. Internal threats are also a major concern, as 61% of organizations are experiencing insider attacks due to perceived management in a remote office. In order to mitigate this risk, it is important that smaller organizations and sizes maintain and control access. Compared to on-premises servers that may lack comprehensive security measures, cloud services typically offer tighter security through biometric access controls, however, organizations still need to take proactive steps though protect their portion of the cloud-based infrastructure that helps prevent any security gaps.
- **Reliability:** One limitation of cloud computing is its complete reliance on internet

connectivity. When the Internet goes down, applications and services are cut off. While this may not seem like much of a problem given our frequent daily use of the internet, relying on cloud services can pose major operational risks. A recent example involves the content delivery network (CDN) service, Fastly. Although Fastly is designed to increase website speed and reliability, its system failure left major websites such as gov.uk and Reddit down for around an hour. Incidents like this highlight how impactful a single flaw can be a broad emphasis. While CDN service failures are rare, when they occur, they are highly visible and potentially costly for businesses that rely on these networks, affecting accessibility and revenue potential.

- **Vendor lock-in:** Vendor lock-in in cloud computing occurs when a customer heavily relies on one cloud provider to meet their computing needs, making it difficult and expensive to switch to another This situation often arises time a customer has deployed critical features to a particular cloud platform, such as if applications Data being developed or migrated, in addition to finding that moving to another platform is costly, vendor lock-in can occur when a customer uses specialized technology or services from only one provider. This dependency limits the buyer's ability to switch providers and can give the provider a substantial advantage in terms of pricing and negotiation.

III. SERVICE PROVIDERS

So far we have developed a good understanding of cloud computing. Now, we can start looking at the cloud service providers. In the remaining section of the paper we are going to compare ten cloud computing service providers and the different services that they provide. The services we are going to discuss are compute services, virtual machines, serverless computing, storage services, object storage and more. This will give us an understanding of the services and make an analysis as to which service we think is the best.

A. Compute Services

Compute offerings encompass a variety of services and features that each cloud provider offers. We identified five key services during our research: virtual machines, auto-scaling, container image registry, container services, and serverless computing. These components are crucial in transitioning from large physical data centers to a more virtualized infrastructure. Our study examined 10 different cloud service providers to see which types of compute services they offer. According to TABLE 1, most of these providers offer the five services we focused on. However, we noted that HPE Cloud Services and ServerSpace Cloud did not have any documentation on serverless computing. Originally, cloud computing started with virtual machines, then progressed to containers due to their lighter weight and greater portability. Now, the trend is shifting towards serverless computing, which operates on a pay-as-you-go basis for functions and events, known as Function-as-a-Service (FaaS). This model enhances productivity and reduces maintenance needs. Given that serverless computing is relatively new, it's not surprising that some providers have yet to adopt it. AWS has been a leading cloud vendor for many years, largely because it was one of the first to enter the market[9].

B. Virtual Machine Services

Next, we aimed to gather details on virtual machines, including aspects like hypervisors, auto-scaling, vCPUs, memory, and storage. Our goal was to understand the capabilities each cloud provider offered in terms of virtual machines. From reviewing TABLES II and III, it was immediately clear that AWS is the leading provider in this area, which was unsurprising given its longstanding position as a top cloud vendor. AWS provides a service called EC2, which is engineered to deliver scalable and reliable computing capacity in the cloud through the internet. Notably, they offer 43 different virtual machine sizes.

TABLE I
COMPUTE SERVICES

Cloud Service Providers	Virtual Machines	Auto-Scaling	Container Image Registry	Container Service	Serverless Computing
Amazon Web Services (AWS)	Amazon EC2	Amazon EC2 Auto-Scaling	Amazon ECS Registry	Amazon ECS Service	AWS Lambda
Google Cloud Platform	Google Compute Engine	Google Auto-Scaling MIGs	Google Container Registry	Google Kubernetes Engine	Google Cloud Functions
Microsoft Azure	Azure Virtual Machine	Azure Auto-scale	Azure Container Registry	Azure Container Instances	Azure Functions
IBM Cloud Services	IBM Cloud Virtual Servers	IBM Auto-Scaling	IBM Container Registry	IBM Kubernetes Service	IBM Cloud Functions
ServerSpace	ServerSpace Cloud Servers	Agile Scaling	ServerSpace Container Registry	ServerSpace Container Orchestration	-
DigitalOcean	Droplets	DigitalOcean Container Cluster Autoscaler	DigitalOcean Container Registry	DigitalOcean Kubernetes (DOKS)	OpenFaas (Open Function as a Service)
HPE Cloud Services	HPE GreenLake	BlueData	HPE Container Registry	HPE Ezmeral Container Service	-
Alibaba Cloud	Elastic Compute Services (ECS)	Elastic Bare Metal (EBM)	Alibaba Cloud Container Registry	Alibaba Cloud Container Service for Kubernetes (ACK)	Function Compute 2.0
Oracle Cloud	Oracle VMs	Oracle Cloud Infrastructure Auto Scaling	Oracle Container Registry	Oracle Container Engine for Kubernetes	Oracle Functions
OpenStack	Nova	Heat	Docker	Zun	Qinling

In our evaluation of these virtual machines, we found they support up to 256 vCPUs, 2400GB of memory, 16384GB of attached storage per vCPU, and 320000GB of instance storage. AWS uses a Nitro hypervisor, features auto-scaling, allows for custom VM configurations, has dedicated hosts, and supports bare metal infrastructure. In comparison, AWS proved to be the most robust. Another provider, ServerSpace, was notable but for different reasons. Despite searching their website and other online sources, we couldn't find detailed information on CPUs, memory, or storage capabilities. This lack of data was unusual, leading us to believe that they might not be as advanced as other major players or that they might disclose such details only during the purchase process.[9]

C. Serverless Computing Services

Additionally, we want to delve deeper into serverless computing. Previously mentioned, serverless computing is beginning to take precedence over traditional virtual machines and containers. With this shift in focus, we sought to gather detailed information on the features each cloud provider has integrated into their platform. Serverless computing enables users to execute code without the need to manage or provision servers. This means that the cloud providers

TABLE II

VIRTUAL MACHINES

Cloud Provider	Service	Hypervisor	Auto Scale	Max vCPUs	Max Memory (GB)
Amazon Web Services	AWS EC2	Nitro	Yes	256 (EC2)	2400
Google Cloud Platform	Compute Engine	KVM	Yes	224 (N2D)	1792 (8/vCPU)
Microsoft Azure	Azure Virtual Machines	Azure Hypervisor	Yes	32 (G5)	448 (G5)
IBM Cloud Services	Virtual Servers VPC	Hyper-V	Yes	105 (Enterprise)	840
ServerSpace	Cloud Servers	Bhyve Hypervisor	Yes	Not specified	Not specified
DigitalOcean	Droplets	KVM	Yes	32	256
HPE Cloud Services	Greenlake	VMware or Red Hat	Yes	241	829
Alibaba Cloud	ECS & EBM	Alibaba Cloud Hypervisor	Yes	256	1024
Oracle Cloud	Oracle VMs	KVM	Yes	64	1024
OpenStack	Nova	HyperV Xen KVM etc.	Yes	288	4000

TABLE III

VIRTUAL MACHINES

Cloud Provider	Max Attached Storage (GB)	Max Instance Storage (GB)	Custom VMs	Dedicated Hosts	Bare Metal
Amazon Web Services	16384 (256/vCPU)	320000	Yes	Yes	Yes
Google Cloud Platform	14336 (224/vCPU)	257000	Yes	Yes	Yes
Microsoft Azure	6598 (G5)	32000	Yes	Yes	Yes
IBM Cloud Services	12288	Not specified	Yes	Yes	Yes
ServerSpace	Not specified	Not specified	No	Yes	No
DigitalOcean	16384	Not specified	Yes	No	No
HPE Cloud Services	23998	Not specified	Yes	Yes	Yes
Alibaba Cloud	16384	100000	Yes	Yes	Yes
Oracle Cloud	15488	32000	Yes	Yes	Yes
OpenStack	18432	Not specified	No	Yes	Yes

handle the server space, infrastructure, and containers where the code is deployed. Looking at TABLE IV, we can see data related to serverless computing. Our research involved comparing the offerings from various providers, revealing that all support multiple programming languages and feature automatic scaling. There is variation in how they handle HTTP invocation, with some using HTTP triggers and others utilizing API gateways. The maximum allowed execution time per request also differs among providers, with Google Cloud and Digital Ocean offering unlimited execution time, while others range from 5 to 15 minutes. The limit for concurrent executions reaches up to a thousand instances, with AWS and IBM leading in this capacity. Overall, no single cloud provider distinctly outshone the others, as their offerings were relatively similar[10] [11].

TABLE IV

SERVERLESS COMPUTING SERVICES

Cloud Provider	Service	Supported Languages	Max Execution Time / Request	Scalability	HTTP Invocation	Log Management	Concurrent Executions
Amazon Web Services	AWS Lambda	Java, Go, PowerShell, Node.js, Python, Ruby, C	15 min	Automatic Scaling	API Gateway	AWS Log	1000 Instances
Google Cloud Platform	Cloud Functions	Java, .Net, Go, Python, Node.js	Unlimited	Automatic Scaling	HTTP Trigger	Cloud Logging	250 Instances
Microsoft Azure	Azure Functions	C, Java, F, JavaScript, PowerShell, Python, TypeScript	10 min	Automatic Scaling	HTTP Triggered	Azure Monitor Logs	250 Instances
IBM Cloud Services	IBM Functions	Node.js, Swift, Java, Ruby, Python	10 min	Automatic Scaling	API Gateway	IBM Log Analysis	1000 Instances
ServerSpace	Not specified	JavaScript, PHP, SQL, HTML	Not specified	Agile Scaling	API Gateway	Not specified	Not specified
DigitalOcean	OpenFaaS	Node.js, Python, Go, PHP, Ruby, etc.	Unlimited	Automatic Scaling	API Gateway	Logging	100 Instances
HPE Cloud Services	Not specified	Java, Ruby, Node.js, Python, Go, etc.	Not specified	Auto Scaling	HTTP Triggered	HPE OneView	Not specified
Alibaba Cloud	Function Compute 2.0	Node.js, Python, Java, C, C++, Ruby, Go, etc.	10 min	Automatic Scaling	HTTP Triggered	Log Service	100 Instances
OpenStack	OpenStack Zun	Bash, Java, Python	5 min	Automatic Scaling	API Gateway	Logging	10 Instances
Oracle Cloud	Oracle Functions	Java, Node.js, Python, Go, SQL	5 min	Automatic Scaling	API Gateway	Log Analytics	128 Instances

D. Storage Services

After delving into serverless computing, we shifted our focus to assess the storage services provided by each cloud vendor, specifically looking at object storage, virtual machine disk (block) storage, long-term cold storage, and file storage. According to TABLE V, almost all providers support these storage types. Notably, ServerSpace does not offer long-term cold storage or file storage, as our investigation of their website confirmed. We began by evaluating the object storage capabilities of each provider. Object storage organizes data as individual objects that include the data itself and associated metadata, each tagged with a unique identifier for easy retrieval. This system does not rely on a hierarchical file structure. Object storage is typically scalable and operates on a pay-as-you-go pricing model. Our anal-

ysis of pricing, regional availability, and service levels showed a variety of rates across providers, some of which offer minimal free storage options that were not included in the table. Typically, cold or archive storage is more affordable than standard or hot storage. Overall, the pricing was fairly consistent among vendors, with widespread availability averaging about 99.0%. Following this, we explored block storage among the ten cloud vendors. Block storage breaks data into blocks that are stored either on Storage Area Networks or cloud platforms, with each block assigned a unique identifier. While block storage can be scaled, it is somewhat more restricted than object storage. We refrained from extensively detailing each vendor's block storage services, but it was evident that major players such as AWS, Google Cloud, Azure, IBM, and Oracle lead in this area due to their robust offerings
[12].

Finally, we examined file storage, in which data is stored in files located on network-attached storage (NAS) devices or hard drives, neatly organized into directories. This storage method can become problematic as the number of stored files increases, potentially making data retrieval more complex. As shown in TABLE V, all but one vendor provide file storage capabilities. Once again, ServerSpace appears to be less advanced than its competitors in this area. However, most vendors are well-equipped to offer effective file storage solutions[12].

E. Database Services

Cloud databases run on cloud computing platforms like Amazon EC2, GoGrid, and Rackspace, offering users two primary deployment models. They can either manage databases independently using virtual machine images or access databases through services maintained by cloud providers. These databases may support SQL-based or NoSQL data models and are often distributed across multiple physical locations, yet appear as a single location to the user[13].

The advantages of using cloud database services include improved availability, where faults in one part of the system only affect a small fraction of the data. Performance is enhanced by storing data closer to where demand is highest and distributing loads across several servers. This setup is generally more cost-effective than using large, centralized servers, and it offers greater flexibility, allowing system adjustments without impacting the entire database.However, these services also come with disadvantages. The complexity of managing distributed databases increases the workload for database administrators and can lead to higher labor costs. Security becomes more challenging as data must be secured across multiple locations, and maintaining data integrity can be difficult if the system is overly complex or changes rapidly. Additionally, there are no established standards for converting centralized databases into cloud solutions, which can be a barrier to migration[13].

In terms of deployment, users can choose to run databases on cloud platforms via virtual machine images—either by uploading their own or using pre-configured ones offered by vendors, such as Oracle's database image on Amazon EC2. Alternatively, database as a service (DBaaS) models allow users to forego physical management of the database. This model is less burdensome as the service provider handles installation and maintenance, and users pay according to their usage. For instance, Amazon Web Services offers both SimpleDB, a NoSQL key-value store, and Amazon Relational Database Service, an SQL-based service with a MySQL interface. The architecture of cloud database services typically includes web-based consoles for provisioning and managing database instances, and APIs for performing maintenance and scaling operations. These services handle the underlying software stack, ensuring that operating systems and databases are up-to-date and secure. Scalability features and high availability commitments vary between providers, but generally, all aim to offer reliable access to database resources [13].

Finally, regarding data models, SQL databases such as Oracle, SQL Server, and MySQL are available on the cloud but can be challenging to scale.

TABLE V

STORAGE SERVICES

Cloud Provider	Object Storage	Virtual Machine Disk (Block) Storage	Long Term Cold Storage	File Storage
Amazon Web Services	Amazon S3	Amazon Elastic Block Store (EBS)	Amazon Glacier	Amazon Elastic File System (EFS)
Google Cloud Platform	Google Cloud Storage	Persistent Disk	Archive Storage	Filestore
Microsoft Azure	Azure Blob Storage	Azure Disk Storage	Azure Archive Storage	Azure Files
IBM Cloud Services	IBM Cloud Object Storage	IBM Cloud Block Storage	IBM Cloud Cold Vault	IBM File Storage
ServerSpace	S3 and Swift	Block Storage	Not specified	Not specified
DigitalOcean	DigitalOcean Spaces	DigitalOcean Block Storage	Not specified	Not specified
HPE Cloud Services	HPE Cloud Object Storage	HPE Data Storage	HPE Data Protection Solutions	HPE File Storage
Alibaba Cloud	Alibaba Cloud OSS	Alibaba Cloud Block Storage	Alibaba Cloud Archive Storage	Alibaba Cloud NAS
Oracle Cloud	Oracle Cloud Object Storage	Oracle Cloud Block Volume	Oracle Archive Storage	Oracle File Storage
OpenStack	Swift	Cinder	Swift	Manila

In contrast, NoSQL databases like Apache Cassandra, CouchDB, and MongoDB are designed for high scalability and are more naturally suited to the cloud environment. However, transitioning to NoSQL may require significant changes in application code due to its different approach to data management[13].

F. Big Data, Analytics, and Data Pipelining Services

The landscape of big data analytics and data pipeline services offered by various cloud providers showcases a diverse range of solutions tailored to meet the needs of large-scale data processing and analysis. We compared different services from the Table VIII. Amazon Web Services (AWS) provides a comprehensive suite, including AWS EMR for Hadoop processing, AWS Redshift for data warehousing, AWS Kinesis for data streaming, and AWS SQS for message queuing. Google Cloud Platform offers Dataproc for Hadoop, BigQuery for data warehousing, Cloud Dataflow for stream processing, and Cloud Pub/Sub for messaging. Microsoft Azure's lineup includes Azure HDInsight for Hadoop, Azure Synapse Analytics for data warehousing, Azure Stream Analytics for data streaming, and Azure Queue Storage for queuing.

Further enriching the field, IBM Cloud integrates services like IBM Analytics Engine for Hadoop, IBM Db2 Warehouse for data warehousing, IBM Streams for streaming, and IBM MQ for message queuing. Oracle Cloud, Alibaba Cloud, and HPE Cloud Services also contribute with their respective offerings, each bringing unique capabilities such as Oracle Big Data Service and Oracle Streaming Service, Alibaba E-MapReduce and Alibaba MQ for Apache RocketMQ, and HPE GreenLake Hadoop and HPE Ezmeral Data Fabric Stream.

OpenStack and DigitalOcean provide more flexible or DIY-oriented solutions, where services like Sahara for Hadoop and Apache Hive for data warehousing are available, and RabbitMQ can be set up manually on DigitalOcean Droplets. These varied services underscore the rich selection of tools available for constructing robust data pipelines and performing intricate analytics at scale, catering to diverse business needs and technical specifications in the evolving cloud ecosystem.

TABLE VI
OBJECT STORAGE SERVICES

Cloud Provider	Service	Store Cost (cents/GB/mo)	Availability (%)	Regions
Amazon Web Services	S3 Standard	$0.024	99.9%	23 regions across global
	S3 Intelligent	$0.0025 - $0.023	99.9%	Same as S3 Standard
	S3 One Zone	$0.01	99.9%	Same as S3 Standard
	S3 Glacier	$0.004	99.9%	Same as S3 Standard
	S3 Glacier Deep Archive	$0.00099	99.9%	Same as S3 Standard
Google Cloud Platform	Standard Storage	$0.020	99.0%	31 regions across global
	Nearline Storage	$0.010	99.0%	Same as Standard Storage
	Coldline Storage	$0.004	99.0%	Same as Standard Storage
	Archive Storage	$0.0012	99.0%	Same as Standard Storage
Microsoft Azure	Block Blobs	$0.0182	99.9%	23 regions including USA and Brazil
	Azure Data Lake Storage	$0.0182	99.9%	Same as Block Blobs
	Managed Disks	$1.54	99.9%	Same as Block Blobs
	Files	$0.058	99.9%	Same as Block Blobs
IBM Cloud Services	Smart Tier - Hot	$0.0227	Not specified	21 regions across global
	Smart Tier - Cool	$0.0144	Not specified	Same as Smart Tier - Hot
	Smart Tier - Cold	$0.0090	Not specified	Same as Smart Tier - Hot
	Standard	$0.0238	Not specified	Same as Smart Tier - Hot
	Vault	$0.0144	Not specified	Same as Smart Tier - Hot
	Cold Vault	$0.0072	Not specified	Same as Smart Tier - Hot

G. Machine Learning and Artificial Intelligence Services

Machine learning and artificial intelligence are advancing rapidly. Today, we utilize services such as language processing, speech recognition, and image recognition to improve our daily interactions. During our research, we noted that many providers are staying current with these technological advances and have integrated such services into their platforms.

H. Network Services

Virtual networking is a concept that promotes effective interaction between computers, virtual machines (VMs), and virtual servers in various office and data center locations. Virtual networks are unlike physical networks which use direct cabling and hardware for the purposes of connecting devices; these are managed by software over the internet. It thus uses virtualized versions of conventional network equipment, such as switches and network adapters, facilitating better routes while simplifying changes to the configuration of networks. It allows devices in different places to work like they are on one real network thereby broadening data center possibilities across differing geographical regions. This enhances network administrators' capabilities and efficiency. Moreover, there is an ease in adapting to changing requirements without replacing or

TABLE VII

DATABASE SERVICES

Cloud Provider	Relational Database Management	Non-Relational Database Management	In-Memory Data Store	Cloud Extract Transform Load (ETL)
Amazon Web Services	RDS & Aurora	DocumentDB	ElastiCache	AWS Data Pipeline
Google Cloud Platform	Cloud SQL & Cloud Spanner	Cloud Bigtable & Firestore	Memorystore	Cloud Data Fusion
Microsoft Azure	Azure SQL Database	Azure Cosmos DB	Azure Cache for Redis	Azure Data Factory
IBM Cloud Services	IBM Db2 PostgreSQL	MongoDB	IBM solidDB	IBM DataStage
ServerSpace	Not specified	Not specified	Not specified	Not specified
DigitalOcean	MySQL & PostgreSQL	MongoDB	Redis	Not specified
HPE Cloud Services	Not specified (earlier HPE Storage)	Not specified (earlier HPE NoSQL)	Not specified (earlier In-Memory Computing)	Not specified (earlier StreamSets)
Alibaba Cloud	ApsaraDB RDS & Distributed Relational Database Service (DRDS)	ApsaraDB for MongoDB	ApsaraDB for Redis & ApsaraDB for Memcache	Data Integration
Oracle Cloud	Oracle RDBMS	Oracle NoSQL Database	Oracle Database In-Memory	Oracle Data Integrator
OpenStack	Trove	Trove for NoSQL databases	Zaqar (Messaging) & Redis	Not specified (uses APIs for ETL)

TABLE VIII

BIG DATA, ANALYTICS, AND DATA PIPELINING SERVICES

Cloud Provider	Hadoop	Data Warehousing	Data Streaming	Data Queuing
Amazon Web Services	AWS EMR	AWS Redshift	AWS Kinesis	AWS SQS (Simple Queue Service)
Google Cloud Platform	Dataproc	BigQuery	Cloud Dataflow	Cloud Pub/Sub
Microsoft Azure	Azure HDInsight	Azure Synapse Analytics (formerly Azure SQL Data Warehouse)	Azure Stream Analytics	Azure Queue Storage
IBM Cloud Services	IBM Analytics Engine (uses Apache Hadoop)	IBM Db2 Warehouse	IBM Streams	IBM MQ (previously IBM Data Queues)
ServerSpace	Not specified	Not specified	Not specified	Not specified
DigitalOcean	Not directly provided but Hadoop can be manually installed on Droplets	Not provided	Not provided	RabbitMQ can be manually set up on Droplets
HPE Cloud Services	GreenLake Hadoop	HPE Ezmeral Data Fabric (formerly HPE Cloud Volumes)	HPE Ezmeral Data Fabric Stream	HPE NonStop Message Queue (NSMQ)
Alibaba Cloud	E-MapReduce	MaxCompute	Realtime Compute for Apache Flink	Alibaba MQ for Apache RocketMQ
Oracle Cloud	Oracle Big Data Service	Oracle Autonomous Data Warehouse	Oracle Streaming Service	Oracle Advanced Queuing
OpenStack	Sahara	Apache Hive	Sahara based on Apache Storm	RabbitMQ ZeroMQ Qpid

TABLE IX

AI AND MACHINE LEARNING SERVICES

Cloud Provider	Machine Learning	Language Processing & Speech Recognition	Image Recognition
Amazon Web Services	AWS Machine Learning	AWS Comprehend, AWS Transcribe, AWS Polly	AWS Rekognition
Google Cloud Platform	AI Platform	Cloud Natural Language, Speech-to-Text	Cloud Vision
Microsoft Azure	Azure Machine Learning	Text Analytics, Cognitive Speech Services	Azure Computer Vision
IBM Cloud Services	Watson Machine Learning	Natural Language Understanding, Watson Speech to Text	Watson Visual Recognition
ServerSpace	Not specified	Not specified	Not specified
DigitalOcean	DigitalOcean Machine Learning	Natural Language Toolkit	-
HPE Cloud Services	HPE Machine Learning	HPE NLP (Natural Language Processing), HPE Speech Recognition	HPE Image Classification
Alibaba Cloud	Machine Learning Platform for AI (PAI)	Machine Translation, Intelligent Speech Interaction	Image Search
Oracle Cloud	Oracle Machine Learning	Oracle Natural Language Processing, Oracle Digital Assistant (includes speech)	Oracle Analytics Cloud (features image recognition)
OpenStack	Gyan (Machine Learning tools)	-	OpenStack Glance (Image Service)

buying more hardware. It also affords greater ability to customize the network for specific applications or needs as well as seamless transfer of workloads across the infrastructure ensuring consistent service, security and availability for example[15].

Cloud computing networking faces sizeable challenges, along with scalability, in which networks need to dynamically adapt to increasing needs without compromising performance. Security is some other primary difficulty, requiring sturdy measures to prevent facts breaches and unauthorized get right of entry to in environments where assets are shared. The complexity of handling configurations throughout multi-cloud and hybrid setups provides to the issue, as does ensuring regular overall performance amidst capability latency issues. Moreover, keeping community visibility and monitoring in temporary cloud services is crucial for operational integrity and compliance. These demanding situations necessitate advanced techniques and solutions to ensure efficient and secure network operations in cloud environments[16].

IV. CONCLUSION

After reviewing ten different cloud providers, we found that AWS, Google Cloud Platform, Microsoft Azure, and IBM are clearly the leaders in the market. The research focuses exclusively on these four providers, likely because they are consistently recognized as top cloud service providers. The range of services, comprehensive documentation, and detailed specifications available from these companies make it challenging for smaller providers to compete. Other providers like Oracle, Alibaba, and DigitalOcean are considered mid-tier but are expected to continue growing and potentially compete at higher levels in the future. ServerSpace was the most underdeveloped vendor we encountered, showing significant deficiencies in several areas, and we anticipate improvements from them moving forward. Each of these providers offers distinct advantages depending on the business case. The choice of a service and vendor should be aligned

TABLE X
NETWORKING SERVICES

Cloud Provider	Virtual Networking	DNS Services	Private Connectivity	Content Delivery Network	Load Balancing
Amazon Web Services	AWS Virtual Private Cloud (VPC)	Route 53	AWS PrivateLink	AWS CloudFront	AWS Elastic Load Balancer
Google Cloud Platform	Google Cloud VPC	Google Cloud DNS	Google Cloud Interconnect	Google Cloud CDN	Google Cloud Load Balancing
Microsoft Azure	Azure Virtual Network	Azure DNS	Azure Private Link	Azure CDN	Azure Load Balancer
IBM Cloud Services	IBM Cloud VPC	IBM Cloud DNS	IBM Direct Link	IBM Cloud CDN	IBM Cloud Load Balancer
ServerSpace	ServerSpace VPC	ServerSpace DNS	ServerSpace Virtual Private Cloud	ServerSpace CDN	Not specified
DigitalOcean	DigitalOcean VPC	DigitalOcean DNS	DigitalOcean VPC	DigitalOcean Spaces CDN	DigitalOcean Load Balancer
HPE Cloud Services	HPE Distributed Cloud Networking	HPE DNS	HPE Private Cloud Solutions	HPE CDN	HPE Load Balancer
Alibaba Cloud	Alibaba Cloud VPC	Alibaba Cloud DNS	Alibaba Express Connect	Alibaba Cloud CDN	Alibaba Cloud Server Load Balancer (SLB)
Oracle Cloud	Oracle Cloud Infrastructure Virtual Cloud Network (VCN)	Oracle Cloud Infrastructure DNS	Oracle FastConnect	Oracle Cloud Infrastructure CDN	Oracle Cloud Infrastructure Load Balancer
OpenStack	OpenStack Neutron	OpenStack Designate	OpenStack VPN-as-a-Service (VPNaaS)	OpenStack Poppy	OpenStack Load Balancer-as-a-Service (LBaaS)

with the specific technological needs, business scale, and strategic goals of the enterprise. A thorough understanding of these factors will enable businesses to leverage the best cloud solutions to drive innovation, improve efficiency, and enhance customer satisfaction.

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