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A COMPREHENSIVE SURVEY OF INFRASTRUCTURE AS A SERVICE BY TOP PUBLIC CLOUD VENDORS

Mr. Yugansh Garg[1] Ms. Bhavana Gupta[2]
M. Tech Scholar[1] Assistant Professor[2]
yuganshgarg97@gmail.com[1], bhavanagupta@sistec.ac.in[2]
Department of Computer Science & Engineering
Sagar Institute of Science and Technology, Gandhinagar Bhopal

Abstract: *With the Industrialization 4.0 the organizations are becoming more dependent on the public clouds as they save the Infrastructure, Installation and Management cost, however it always remains a question that which service provider serves better. The paper attempts to address issues of Performance analysis and compares the various services by different Cloud vendors on multiple parameters including their services, Market Share, performance as provided by different scholars and Research organisations. The paper surveys the service providers in various domains including CPU, Memory, Storage and Network performance.*

Keywords: Cloud Computing, Public Cloud, IaaS and Virtual Machines

I. INTRODUCTION

The global cloud market is dominated by four cloud service providers: Alibaba in China and Asia Pacific, and AWS, Microsoft and Google in other countries. Overall, the cloud market leaders provide a wide range of solutions for different use cases by meeting the needs of high performance, availability, security and support

The Paper tries to address the problem of selection of cloud. It thoroughly surveys the various cloud service vendors and compares them on the multiple parameters.

1.1 Cloud Computing

Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be quickly provisioned and released with minimal management effort or service provider interaction. This cloud model consists of five basic characteristics, three service models and four deployment models[1]

Cloud computing provides various services with the growth of their offerings. They face many challenges with effective services. It is based on virtualization, which provides users with an abundance of computing resources over the Internet without managing any virtual machine (VM) infrastructure. With network virtualization, Virtual Machine Manager (VMM) provides isolation between different virtual machines. However, sometimes the levels of abstraction involved in virtualization reduce workload performance, which is also a concern when implementing virtualization into the cloud computing domain. . It also compares VMs and Linux Containers with respect to quality of service, network performance, and security ratings.[2], [3]

1.1.1 Types of Clouds

The NIST divides cloud computing on the basis of Service models in broadly three categories, i..e Private, Public and Hybrid.[1]

First, it is needed to determine the type of cloud deployment or cloud computing architecture on which the cloud services will be implemented. There are three different ways to deploy cloud services: in a public cloud, a private cloud, or a hybrid cloud.

1.1.1.1. Public Cloud

Public clouds are owned and operated by third-party cloud service providers who deliver their computing resources, such as servers and storage, over the Internet. In the case of a public cloud, all hardware, software, and other supporting infrastructure are owned and managed by the cloud provider. You access these services and manage your account using a web browser [4]

1.1.1.2. Private Cloud

A private cloud refers to cloud computing resources used exclusively by one business or organization. A private cloud can be physically located in a company's on-site data center. Some companies also hire third-party service providers to host their private cloud. A private cloud is one in which services and infrastructure are maintained on a private network.[4]

1.1.1.3. Hybrid Cloud

Hybrid clouds combine public and private clouds that are connected by technology that allows data and applications to be shared between them. By enabling the movement of data and applications between private and public clouds, the hybrid cloud gives your business greater flexibility, more deployment options, and helps optimize your existing infrastructure, security and compliance.[5]

1.2 Virtualization

Virtualization uses software to create an abstract layer over computer hardware that allows the hardware elements of a single computer—processors, memory, storage, and more—to be partitioned into multiple virtual computers, commonly called virtual machines (VMs). Each VM runs its own operating system (OS) and behaves like an independent computer, even though it runs on only a portion of the actual underlying computer hardware. The implication is that virtualization enables more efficient use of physical computer hardware and allows for a greater return on an organization's hardware investment.[2]

Virtualization technology enables the operation of a single machine multiple platforms at the same time, for example different versions of Windows running simultaneously on one machine. Sometimes referred to as a machine or processor virtualization allows a single physical machine emulate the behaviour of multiple machines with ability to host multiple/heterogeneous operating system on same hardware.[6]

1.2.1 Virtual Machines

Virtual machines (VMs) represent the virtualization of the compute layer in data centre resources; so a physical server's CPU, cache, memory, and all other computing hardware can be shared among multiple virtual machines. Each virtual machine has its own dedicated operating system (OS), platforms and applications. Isolation, configuration, and resource allocation of virtual machines is essentially done by the system hypervisor, which manages the relationship between virtual machines and physical machines. The benefits of data centre virtualization are basically higher physical resource utilization, lower energy consumption, lower total infrastructure cost of ownership (TCO), higher system availability, dynamic resource management, less vendor lock-in, and the transition to cloud computing. These fundamental benefits to the IT industry lead to more than eighty percent of global data centres using virtualization technologies.[6][7]

1.3 Public Cloud

The cloud infrastructure is intended for open use by the general public. It can be owned, managed and operated by a commercial, academic or governmental organization or some combination of them. It exists on the cloud provider's premises.[1]

A public cloud provider owns and manages the data centres where customers' workloads run. Service providers take responsibility for all hardware and infrastructure maintenance and provide broadband network connectivity to ensure fast access to applications and data. The cloud provider also manages the underlying virtualization software. At its simplest, the public cloud model is a computational version of the "utility" model we all use when using electricity or water in our homes.[4]

Public cloud architectures are multi-tenant environments – users share a pool of virtual resources that are automatically provisioned and allocated to individual tenants through a self-service interface. This means that in a multi-tenant workload, CPU instances can be running on a shared physical server at the same time. However, each cloud tenant's data is logically isolated from other tenants' data.[8]

All clouds become public clouds when environments are partitioned and redistributed to multiple tenants. The bare IT infrastructure used by public cloud providers can also be abstracted and sold as IaaS, or developed into a cloud platform sold as PaaS.[9]Some of the Major public cloud vendors are Oracle Cloud, Google Cloud, Alibaba Cloud, Amazon Web Services (AWS), IBM Cloud, and Microsoft Azure.

The rise and adoption of public cloud services is one of the most important shifts in the history of enterprise computing. A public cloud is a type of cloud computing in which a third-party service provider creates computing resources—which can include anything from ready-to-use software applications to individual virtual machines (VMs) to complete enterprise infrastructures and development. platforms – available to users over the public internet. These resources may be accessible for free, or access may be sold under subscription-based or pay-per-use pricing models.[8].

1.3.1 Infrastructure as a Service (IaaS).

Infrastructure as a Service (IaaS) is a service of cloud computing that provides virtualized computing resources the include memory, storage bandwidth, processor over the Internet. IaaS is one of the three main categories of cloud computing services, along with Software as a Service (SaaS) and Platform as a Service (PaaS).

The NIST Defines IaaS as The capability provided by the consumer is to provide the processing, storage, networking and other underlying computing resources where the consumer is able to deploy and run any software, which may include operating systems and applications. The customer need not to manage, maintain or control the underlying cloud infrastructure, but has control over operating systems, storage and deployed applications; and possibly limited control of selected network components (eg, host firewalls).[1]

Infrastructure-as-a-Service, commonly referred to simply as "IaaS," is a form of cloud computing that provides consumers with basic computing, networking, and storage resources on demand, over the Internet, and for a fee. you-go base. IaaS allows end-users to scale up and down resources as needed, reducing the need for high initial capital expenditures or unnecessary "proprietary" infrastructure, especially for "peak" workloads. Unlike PaaS and SaaS (and even newer computing models such as containers and serverless models), IaaS provides the lowest level of resource management in the cloud.[10]

II LITERATURE REVIEW

The IaaS market continues to grow unabated ascloud-native becomes the primary architecture for modern workloads," said the Gartner's Report 2021. The global Infrastructure as a Service (IaaS) market grew 41.4% in 2021 to a total of $90.9 billion, up from $64.3 billion in 2020, according to Gartner, Inc. Amazon retained the leading position in the IaaS market in 2021, followed by Microsoft, Alibaba, Google and Huawei.[11]

In the IaaS market, the largest companies by revenue are Amazon (Web Services), Microsoft (Azure) and Google (Compute Engine), as well as the Chinese multinational technology company Alibaba. Despite Amazon being the largest cloud infrastructure vendor by some margin, its market influence may be shrinking as Google and Microsoft advance, with surveys suggesting that cloud services companies are fighting for a piece of the IaaS cloud market.[11], [12]

2.1 Major Cloud Platforms

2.1.1 Amazon Web Services

Amazon Web Services offers a broad set of global cloud products including compute, storage, database, analytics, networking, mobile, developer tools, management tools, IoT, security and enterprise applications: on demand, available in seconds and for a fee. -as-you-go prices. From data warehouses to deployment tools, directories to content delivery, more than 200 AWS services are available. New services can be provided quickly, without upfront fixed costs. This gives enterprises, start-ups, SMEs and public sector customers access to the building blocks they need to quickly respond to changing business requirements. This white paper gives you an overview of the benefits of AWS Cloud and introduces you to the services that make up the platform.[13]

Amazon Elastic Compute Cloud (Amazon EC2)

Amazon Elastic Compute Cloud (Amazon EC2) is a web based service that provides secure, resizable computing capacity in the cloud. It is designed to make it easier for developers to work with web-scale computing.[14]

Amazon EC2's simple web interface allows to acquire and configure capacity with minimal friction. It gives you complete control over your computing resources and enables to run Amazon's proven computing environment. Amazon EC2 cuts the time it takes to acquire and deploy new server instances (called Amazon EC2 instances) to minutes, allowing to quickly scale capacity, both up and down, as your computing demands change. Amazon EC2 changes the economics of computing by allowing you to pay only for the capacity you actually use. Amazon EC2 provides developers and system administrators with the tools to build fault-tolerant applications and isolates itself from common failure scenarios.[13], [15]

2.1.2 Microsoft Azure

Microsoft Azure is Microsoft's public cloud platform for developers and administrators they want to run their own software applications partly or entirely in the cloud. The platform includes a number of cloud services that can be used separately or in combination and are provided on-demand in almost any capacity and billed according to usage. These services include, but are not limited to, those used to run applications in the cloud, others that serve to store and efficiently process various data in the cloud, and yet others that can be used to connect cloud elements securely and efficiently with z resources customer data center or locally running client applications.[16]

The main strength of Microsoft Azure actually lies in such hybrid solutions in which individual application components are run together with other components in the local environment execution environment.

Microsoft Azure has a wide range services. Azure offers virtual machines as part of its IaaS offering, an Active Directory service for on-premises directory synchronization, and enables single sign-on. The company also provides mobile engagement with real-time analytics and user behaviour monitoring and storage services, as well as data management tools such as Azure Data Explorer, Azure SQL Database, Severless, CDN, Azure AI, Azure Blockahung Workbench, Azure IoT and Others services.[17]

Microsoft is prominent for reusing and running on-premises software (Windows Server, Office, SQL Server, SharePoint, Dynamics Active Directory, .Net, etc.) in the cloud. Did.

Key reason for Azure's success: Millions of companies use Windows and other Microsoft software. Azure is tightly integrated with these other applications, so it often makes sense for companies that use a lot of Microsoft software to use Azure. This creates loyalty to existing Microsoft customers. Additionally, existing Microsoft Enterprise customers can expect significant discounts on service contract.[18][19]

2.1.3 Google Cloud

Google Cloud has third place on Gartner’s Magic Quadrant of cloud providers, after AWS and Microsoft Azure. In the last year, Google Cloud has substantially increased it’s hybrid and multi-cloud workload using Antos which allows users to manage workloads on on cross platform environments such as Google, AWS and Azure. Besides, Firebase, a Google-purchased cloud mobile Backend-as-a-Service (BaaS), has grown quite rapidly and became widely adopted by developers.[11]. Google Cloud consists of a set of physical assets, such as computers and hard drives, and virtual resources, such as virtual machines (VMs), contained in Google data centers around the world. It offers big data, analytics, machine learning (ML), load balancing and scaling. It also fully encrypt data transfers and communications between data centres.[20] Overall, it competes with AWS and Azure in terms of price, privacy, traffic safety, and ML. It offer several services, but GCP has one of the best features in mobile app development[[21]

2.1.4 IBM Cloud

IBM Cloud stands among the top public cloud providers. Instead of competing directly with the major cloud service providers, IBM has doubled down on Red Hat (a company acquired by IBM in 2019 that provides open-source products for enterprises) to accelerate hybrid cloud services across its offerings. The acquisition of Red Hat has equipped IBM Cloud with a technology foundation that includes security and portability across multiple clouds, allowing IBM to scale its resources and capabilities.[12]

IBM Cloud provides solutions that enable higher levels of compliance, security, and management, with proven architecture patterns and fast delivery methods for running mission-critical workloads. Available in data centers worldwide, across 19 countries.

IBM Cloud offers the most open and secure public cloud for business hybrid cloud platform, advanced data and AI capabilities and deep business knowledge across 20 industries. Solutions are available depending on your needs for working in the public

cloud, on-premises, or a combination:
It is a multi-tenant environment, and resources like hardware and infrastructure are managed by IBM.[22]
The Major strength of the IBM Cloud lies in its Hybrid Cloud Solution. Available services include compute, storage, networking, end-to-end developer solutions for application development, testing and and deployment, security management services, traditional and open source databases.
IBM's Hybrid cloud solutions area combination of public and private, with the flexibility to move workloads between the two based on business and technology needs. IBM uses Red Hat OpenShift on IBM Cloud. It's the market-leading hybrid cloud container platform for hybrid solutions: build once, deploy anywhere. Open source technologies such as Kubernetes, Red Hat OpenShift, and a wide range of computing options, including virtual machines, containers, bare metal, and serverless, give you the control and flexibility. [5]

2.1.5 Oracle

Oracle offers 65 cloud services, including industry standards such as Kubernetes, Terraform and CloudEvents. Oracle offers an autonomous database, a service that uses machine learning to self-heal and self-optimize and deliver higher performance. The company also provides dedicated regions in data centers, edge computing, cluster databases, bare metal GPUs (graphics processing units) and database engines.[12], [23]
Oracle has designed its cloud offerings for superior performance with low-latency, high-throughput networks that run HPC use cases in the cloud as well. OCI has a royalty-free, highly scalable network with approximately 1 million network ports in each availability domain, high-speed interconnects, and sub-100 microsecond latency between hosts in an availability domain.[24]
OCI is Oracle's IaaS and PaaS providing. OCI is the foundational layer of Oracle Cloud, and gives agencies with networking, compute, garage, and platform offerings that may run even the most critical and information-extensive workloads within the cloud. due to the fact OCI become built the use of insights from first-technology clouds, it's capable of offer a number of advantages from stellar performance to comprehensive protection.[23]

2.1.6 Alibaba Cloud

As per Gartner's report, Alibaba Cloud have fourth place amongst cloud service providers market share, after AWS, Microsoft Azure and Google Cloud.[11]. Founded in 2009 with an objective to deliver platform support to the Alibaba.
Alibaba Cloud offers a full range of cloud products and services for database, networking, security, analytics and big data, domain and website management, application services, media services, middleware and more. In this section, we provide an overview of Alibaba's cloud services, including their key computing, storage and management offerings.[25]
Alibaba Cloud's ECS core service runs on both Windows and Linux operating systems and includes automatic scaling and server load balancing that are billed only at runtime, such as ECS instance creation, real-time public or private load balancer rental, and networking Operations.[26], [27]

2.2 Comparison Based on Cloud Services Offered

The provider's cloud service specifications on his website are often the first point of comparison for end-users, followed by price comparisons.

However, as mentioned above, the specs of any given VM only give you a very high level view of its potential performance when running your workload.

The number of vCPUs (virtual CPUs), physical server chip technology, amount of random access memory (RAM), and comparison of storage type and volume size are factors that can be easily examined. In practice, however, the performance does not correlate well with the website specifications advertised by the provider. For a more complete comparison, we need to dig deeper into pricing.

Table 1 : Public Clouds IaaS Services Comparison

Features and Solutions	**AWS**	**GCP**	**IBMCloud**	**Azure**
Maximum Processors in VM	128	160	56	128
Maximum memory in VM (GiB)	3904	1433	242	3800
Maximum memory in VM (GiB)	3904	1433	242	3800
Operating Systems supported	Windows, SLES, CentOS, CoreOS, OpenSUSE, RHEL, CloudLinux, Debian, FreeBSD, Ubuntu, Oracle Linux	Windows, SLES, CentOS, CoreOS, OpenSUSE, RHEL, Debian, FreeBSD, Ubuntu,	Windows, CentOS, CoreOS, RHEL, CloudLinux, Debian, FreeBSD, Ubuntu,	Windows, SLES, CentOS, CoreOS, OpenSUSE, RHEL, Debian, FreeBSD, Ubuntu, Oracle Linux
SLA Availability	Amazon S3:Monthly	99.95% Monthly	100% Uptime for Private	99.9% Uptime

	uptime of at least 99.9% for any billing cycle. Amazon EC2:99.95% annual uptime in service year.	Uptime	& Public Network, Customer Portal and redundant infrastructure	
Marketplace	AWS Marketplace	G Suite Marketplace	IBM Marketplace	Azure Marketplace
COMPUTE				
Scalability	AWS Auto Scaling	Autoscaling	Auto Scaling	Azure Autoscaling, Virtual Machine Scale Sets, Azure App Service Scale Capability (PaaS)
Virtual Servers	Elastic Compute Cloud (EC2) Instances,Amazon LightSail	Custom Machine Types, Compute Engine	IBM Virtual Servers	Azure Virtual Machines, Azure Virtual Machines & Images
Backend process logic	–	–	–	Web Jobs
Container Instances	EC2 Container Service (ECS), EC2 Container Registry	Kubernetes Engine	IBM Cloud Container Service	Azure Container Service (AKS), Azure Container Registry
Container Orchestrators/ Micro services	Elastic Container Service for Kubernetes (EKS)	Google Container Engine	IBM Cloud Container Service	Azure Container Service (AKS), Service Fabric, Azure Container Service (ACS)
Batch Computing	AWS Batch	Preemptible VMs	–	Azure Batch
Serverless	Lambda, Lambda @ Edge	Google Cloud Functions (Beta)	IBM Cloud Functions	Azure Functions, Azure Event Grid
STORAGE				
Object storage	Simple Storage Services (S3)	Google Cloud Storage	IBM Cloud Object Storage	Azure Storage
Shared file storage	Elastic File System	Google Cloud Storage FUSE	File Storage	Azure Files
Virtual Server disk infrastructure	Elastic Block Store (EBS)	Google Persistent Disk	Block Storage	Azure Storage Disk
Archiving– cool storage	S3 Infrequent Access (IA)	Cloud Storage	Object Storage	Azure Storage – Standard Cool
Archiving– cold storage	S3 Glacier	Google Cloud Storage Nearline & Coldline	Backup Storage	Azure Storage – Standard Archive
Hybrid Storage	Storage Gateway	–	–	StorSimple
Backup	–	–	–	Azure Backup
Data transfer	AWS Import/Export Disk, AWS Import/Export Snowball, AWS Snowball Edge, AWS Snowmobile	Cloud Data Transfer	Data Transfer Service	Import/ Export, Azure Data Box

Disaster Recovery	AWS Disaster Recovery	–	–	Site Recovery
DATABASE				
Relational Database	RDS for MariaDB, RDS for SQL Server, RDS for MySQL, RDS for Oracle DB, RDS for Postgre SQL	SQL Server, Google Cloud SQL, Cloud SQL support for Postgre SQL (Beta)	Compose for MySQL, Compose for Postgre SQL	SQL Database, Azure Database for MySQL, Azure Database for PostgreSQL (Preview)
NoSQL– key/value storage, document storage	Dynamo DB and SimpleDB	Cloud Spanner	Db2 on Cloud	Table Storage Azure Cosmos DB
Non-relational database	Amazon Neptune (Preview), Amazon EMR, Amazon Dynamo DB, Amazon SimpleDB	Google Cloud Dataproc, Google Cloud Dataflow, Google Cloud Bigtable, Google Cloud Datastore	Compose for JunusGraph, IBM Open Platform, Cloudant	Azure HDInsight, Azure Batch, Cosmos DB
Database Migration	Database Migration Service	–	Lift	Azure Database Migration Service
Caching	ElastiCache	None – App Engine only	Compose for Redis	Azure Redis Cache

[29], [30][12], [19], [31]

2.3 Performance Analysis of the Public Clouds

Performance analysis is the method to compare the process Public cloud on the basis of the performance rather than the number of services provided by them, the objective is to compare the ability of the machine to handle multiple processes simultaneously. Comparing cloud providers and the cloud computing services they offer can often be difficult. Procurement professionals have the expertise to perform the vendor due diligence necessary to determine the health, reliability, and overall capabilities and pricing of a vendor's business, but cloud services have There are a number of underlying aspects that require to be paid heed.[28], [32]

2.3.1 Servers Performance Benchmark

All performance is limited by the weakest link where the bottleneck occurs. Currently, technology has advanced significantly in the field of virtualization with respect to CPU and RAMS usage. For example, one physical machine can be virtualized and have multiple cloud servers with minimal loss of overall aggregate performance. Sadly, there is still a lot of progress to be made in the case of storage. The end result is that, in most cases, the performance of virtual servers in the cloud is determined by the performance of that cloud's storage solution.
In short, storage is currently the performance limiting factor for most cloud computing workloads. Whatever results pov-ray and other benchmarking for pure compute workloads may yield, the reality is that the speed at which a virtual server can acquire and write data to physical storage disks will determine the cloud server's actual real-world performance.[33]

2.4 Recent Performance Comparisons

According to the Gartner's, AWS Remains at the leading position in the field of Cloud Market share, and Various other parameters including Cloud Performance, different strengths and weaknesses.[11]
The cockroach Labs presents a much detailed scenario of the recent trends on the cloud performance and compares them on the various parameters such as computational Capabilities, Network Latency, Storage , read write operations memory and process management and many more.[**34]**

III. OBSERVATION

3.1 Challenges In Performance Analysis

1. Majority of the Independent / Stand alone tools such as Geekbench,[35] Cinebench[36] are not able to perform in virtual machines of low configuration of 1 GB Ram, 8 GB Storage and Frequency range of 1-1.5GHz
2. Majority of the work done on benchmarking belongs to high end servers, Thus low end virtual Machines remains untouched.[34]
3. Majority of the reports deals with the AWS, Azure and GCP, however performance and other features of Cloud Service Providers such as Alibaba[27], Oracle Cloud[37] and IBM Public Cloud remains untouched. More over emerging players such as digital-ocean[38] , linode[39], kamatera[40], Cloudways[41], Vultr Cloud and many more can also be explored.
4. Majority of the modern start ups , use basic machines to deploy stand alone application, Thus there is need to tap the potential the low end machines too as they can save cost of the company.

5. The performance of the Virtual Machine is highly dependent on the underlying hardware, and Hypervisor,[42] Thus there is need to analyse the performance of these too.

IV. CONCLUSION

The Public Cloud infrastructure is the back bone of the modern IT industry, majority of the emerging Start ups depends highly on the them. Thus there is a need to explore multiple dimensions in this domain. There is a need to analyse the performance of the low end machines which are most widely used. Secondly there is a need to analyse the load handling ability, I/O operations of the different vendors.

V. FUTURE WORK

There is a need to compare the cloud platforms not only on the basis of number of services offered but also on the parameters such as pricing Vs Performance, performance of the different types of machines etc.

Light Machines in the categories of Micro and small having minimum configurations such as 1 GB RAM, sigle processing core and 8-10 GB storage can benchmarked and compared of multiple parameters.

Apart from the traditional Cloud Platforms, the performance of emerging players can also be test, benchmarked and presented.

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