Cloud Computing and Comparison based on Service and Performance between Amazon AWS, Microsoft Azure, and Google Cloud

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***Abstract*— Cloud computing is the on-request supply of computing resources through the Web with pay-as-you-use billing. Instead of purchasing, operating, and maintaining physical computers, hardware, and servers, cloud solutions providers such as Microsoft Azure of Microsoft, Amazon Web Services (AWS) of Amazon, and Google Cloud Platform (GCP) by Google offer cloud solutions such as processing power, memory, and databases on an as-needed basis. This research paper discusses the architecture and types of cloud computing services, as well as comparison of the performance and service among three main Cloud Computing platforms: Microsoft Azure, Amazon AWS, and Google Cloud Platform. All three systems have been evaluated in identical virtual environments, specifically micro instance of Ubuntu 16.04. The benchmark application Phoronix Test Suite 10.4 is used to assess performance, and the results for the Apache, Dbench, and RAM speed benchmarks are evaluated in this paper.**

Keywords*— Cloud, Cloud Computing, Amazon AWS, Microsoft Azure, Google Cloud, Virtual Environment, Virtualization

I. INTRODUCTION

Cloud computing in simple terms is providing computer services such as servers, storage, databases, networking, software, analytics, and intelligence over the Web in order to provide innovation at pace, more flexible resources, and economies of scale. A user pays for the cloud solution that they use, allowing them to reduce operational expenses, run infrastructure more productively, and scale as their enterprise needs to expand.

Cloud computing represents a significant departure from the typical way that enterprises think about computing resources. It removes the investment cost of purchasing hardware and software, as well as establishing and operating on-site datacenters—server racks, the 24 hours electricity for power and cooling, and IT specialists to manage the system. The capacity to scale elastically is one of the advantages of cloud computing services. In cloud parlance, this means delivering the appropriate quantity of computing resources as most cloud computing solutions are self-service and on-demand, even massive volume of computing power may be delivered in moments, generally with only a few keystrokes and taps on mouse, allowing enterprises a lot of flexibility and relieving capacity planning strain. In addition to these, most cloud providers provide such a comprehensive set of terms, technologies, and restrictions that increases the user's overall security posture, assisting in the protection of data, apps, and architecture from cyber threats.

Cloud computing is the ultimate successor of virtualization, a technology based on service-based infrastructure that provides the user with the abstraction and encapsulation of software and hardware parts in order to use them productively for specific needs. Virtualization provides for more suitable use of the system by allowing it to be used by multiple operating systems at the same time. When used in conjunction with cloud computing, it provides a more safe and stable environment, owing mostly to VM isolation. A User of cloud solutions do not need to be knowledgeable of system details, since they can access documents and resources through a basic web browser account to the operator's cloud interface. The most significant advantage of this technique is the ease of having a group of data centers in one location, while the cost of using these resources is several times less than the cost of operating one's personal computing infrastructure.

A data center is suitable for businesses which require a tailored, specialized solution that offers them complete control over their resources and hardware. A data center, on the other hand, has finite capacity; if a corporation constructs a data center, it will be unable to adjust the storage capacity

and load it can withstand without spending on and maintaining additional tools. A cloud system, on the other hand, maybe scaled to meet the needs of a company's operations. Based on the seller's products and service options, it has theoretically infinite capacity. One downside of the cloud solution is that the user does not have as much power as they would in a data center because the system is managed by a third party.

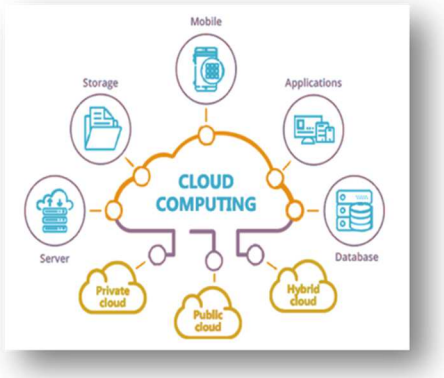

Figure 1

II. SIMILAR RESEARCH IN THE FIELD OF CLOUD

Over the last decade, there's been a great deal of study and work in the developing field of cloud computing. One of the most pertinent problems is the provision of methodology and quantitative evaluation of service quality and performance parameters among various cloud computing service providers. Some researchers raised the issue of potential interference among Cloud users when pooling resources, and as a result, they presented various figures of measurement to assess the performance isolation of cloud-based systems. Apart from that they define novel methods for attaining performance isolation in cloud computing. Data centers consume a significant amount of energy, which is predicted to increase significantly in line with current technological advancements. As a result, a number of studies have been carried to address the developing issue of delivering an energy-efficient cloud solution. To address the dispute of cloud resource scheduling optimization, few researchers suggested a specific cost-effective solution for service request scheduling in cloud computing, with the purpose of processing dynamic user service requests more effectively in terms of price and without violating any Service Level Agreement (SLA). Some studies additionally look into design enhancement, policy related to data security, and method enforcement. This paper compares the fulfillment and service quality of three cloud platforms: Amazon AWS, Microsoft Azure, and Google Cloud.

III. THE ARCHITECTURE AND CATEGORIES OF CLOUD SERVICES

The Computing infrastructure, which relies on a variety of applied technologies to enforce the abstraction of physical resources through virtualization and their subsequent dissemination to diverse users, is the foundation of cloud computing. Two elements serve as the foundation of the Cloud computing architectural paradigm.

A. ***Frontend*** – The client-side (client infrastructure) of cloud computing is referred to as the frontend of the cloud architecture. That is, it contains all of the UI and applications that the client uses to access cloud resources. For example, to access the cloud platform, you may need the help of a web browser.

B. ***Backend*** - The cloud itself, as used by the service provider, is referred to as the backend. It holds the resources, maintains them, and incorporates security procedures. It also contains massive storage, virtual applications, virtual computers, traffic management techniques, deployment models, etc.

1. *Application* – It is the platform that provides the cloud service to the user as per their requirements.

2. Storage - Provides scalable storage service and management of data in cloud as per user requirements.

3. Service - There are mainly three major types of cloud services IaaS, PaaS, and SaaS.

   a. *IaaS* – IaaS - Infrastructure as a service (IaaS) is a solution delivery model that entails the leasing of a company's hardware to support the business of other customers, which includes storage space, hardware, servers, and network components. Users of IaaS often spend money for services on a per-use basis. Virtual computers, storage space, firewalls, and load balancers are all available from operators. These things can be leased on demand, and the user has no control over or maintenance of the cloud architecture, only managing the on-site OS, software upgrades, and apps used by user.

   b. *PaaS* - PaaS - Platform as a service (PaaS) is a solution delivery paradigm that allows users to lease virtualized machines along with related facilities for the use of current software as well as for the production, quality test, and use of new softwares. Unlike traditional systems, however, PaaS provides a environment to produce scalable applications at cheap price.

   c. *SaaS* - Software as a service (SaaS) is a software model used for distribution of software which is based on the availability and global accessibility of programs hosted by service providers to users over a specialized network or web. This technique enables

for the most efficient working of software applications, smooth administration, lower pricing, and the elimination of the need for obtaining software license, physical installation, maintenance, and buying the hardware resources required for the programs to function properly. The flexibility obtained by splitting the workload across a group of servers is one of the most significant advantages of SaaS over traditional applications.

4. *Cloud Runtime* – It refers to the provision of executing and running environments to virtual machines.

5. *Infrastructure* - This includes hardware like network devices, servers, storage systems etc.

6. *Security* - It implements security mechanisms to protect data stored in cloud, system, and architecture to cloud users.

7. *Management* - It ensures integration and smooth working of all backend components.

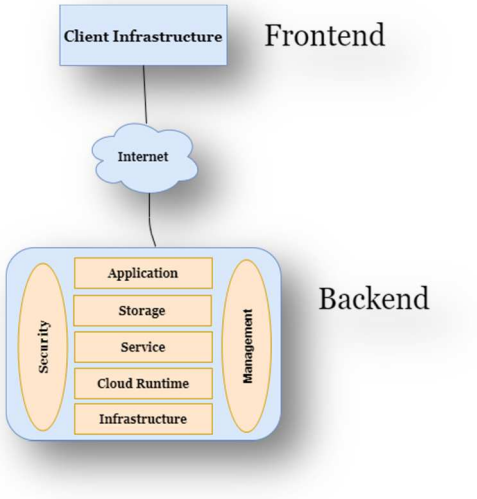

Figure 2

IV. About Cloud Service Used And Their Service Comparison

In this paper, to compare the service and performance we carried out a study on three of the cloud giants ruling the cloud computing market. Those three are

- Microsoft Azure (Azure)
- Amazon Web Services (AWS)
- Google Cloud Platform (GCP)

A. *Microsoft Azure (Azure)*

Microsoft Azure is a service for cloud computing and a web platform that allows users to access and administer Microsoft's cloud services and resources. These services and resources include storing and altering data based on user needs. All a user needs to gain access to these resources and services is an established internet connection and the ability to log on to the Azure portal. It was launched in 2010, and now is among the top cloud service providers and competitor to AWS and GCP. Azure offers over 100+ cloud computing services.

For their cloud computing requirements, 80 percent of Fortune 500 organizations use Azure. eBay, Samsung, HP, and other well-known corporations are on this list. It is compatible with a variety of programming languages, including Java, Node.js, and C#. There are over 42 Azure data centers located throughout the world, which is the most of any cloud platform. In addition, Azure plans to add 12 more data centers, bringing the total number of data centers to 54 soon.

B. *Amazon Web Services (AWS)*

Amazon Web Services is a platform that offers flexible and cost-effective cloud services. AWS is a widely used cloud platform that provides numerous on-demand activities such as computational power, database and management, information and data delivery, and so on to help businesses develop and flourish. Businesses can use AWS to create a variety of sophisticated apps. On AWS, organizations of all sizes and industries may run every potential use case. It was launched in 2002 and now is among the top cloud service providers and competitor to Azure and GCP. Azure offers over 170+ cloud computing services.

Amazon claims that the number of active AWS users tops one million. Many firms around the world use AWS to create, deploy, and host applications, whether they are IT behemoths, startups, governments, or retail groups. Netflix, Adobe, Coinbase, and others are among them.

C. *Google Cloud (GCP)*

Google Cloud Platform is a collection of services equipped with cloud techniques provided by Google that operate on the same architecture as Google's other major applications such as YouTube, Gmail, and others. Google Cloud Platform provides over 100 services. It was launched in 2008.

For their cloud computing needs, companies such as PayPal, Twitter, Airbus etc. use the services offered by Google Cloud Platform.

V. On-Demand Pricing Comparison Among The Three

Instance Type	AWS	Azure	GCP	AWS pricing (per hour)	Azure pricing (per hour)	GCP pricing (per hour)
General Purpose	m6g.xlarge	B4MS	e2-standard-4	$0.154	$0.166	$0.156
Compute Optimized	c6g.xlarge	F4s v2	c2-standard-4	$0.136	$0.169	$0.235
Memory Optimized	r6g.xlarge	E4a v4	m1-ulramem-40	$0.202	$0.252	$6.303
Accelerated Computing	p2.xlarge	NC4as T4 v3	a2-highcpu-1g	$0.90	$0.526	$3.839

Table 1

The table illustrates the on-demand pricing for certain instances by AWS, Azure and GCP. For general purpose instance, AWS has the cheapest service at $0.154 per hour followed by GCP at $0.156 per hour. Azure is the most expensive for General purpose instance among the three at $0.166 per hour. For Compute optimized instance, AWS is again the cheapest at $0.136 per hour followed by Azure at $0.169 per hour. GCP is most expensive among the three for compute optimized instance at $0.235 per hour. For Memory Optimized instance, GCP is the most expensive at $6.303 per hour, followed by Azure at $0.252 per hour and again AWS being the cheapest at $0.202 per hour. For Accelerated Computing instance, Azure offers the cheapest service at $0.526 per hour and GCP the most expensive at $3.839 per hour.

The overall analysis and comparison of on-demand pricing of these cloud service providers show that AWS is the cheapest among most of the instance type and will be pocket friendly for anyone who wishes to use it.

VI. PERFORMANCE COMPARISON

For testing performance VM instances of Ubuntu Linux Server 16.04 64 bit were created on AWS, Azure and GCP.

Phoronix Test Suite3 was adopted for benchmarking since it facilitates the evaluation of Linux systems and system performance under specific situations. Installing this package from the Ubuntu Repository is simple. On both platforms, the Apache, Dbench, and RAM speed benchmark test processes (included in the Phoronix Test Suite3) were completed.

TEST	AZURE	AWS	GCP
TEST1	1269.89	1022.43	1240.8
TEST2	1235.11	1026.06	1239.37
TEST3	1240.18	1027.38	1235.45
AVERAGE	1248.13	1025.29	1238.54

Table 2: APACHE BENCHMARK

Apache measures the total system's performance and relates to the count of requests that the server can reply to when there are 1 million requests and 100 of them being competitive. Through the table and graph, we can see that Azure can handle more HTTP requests than the other two. GCP comes at second place in this Apache benchmark test for handling number of requests that the server can reply to. GCP is giving a tough competition to Azure in this test case. This is an important factor to consider for customers who plan to use VM as a host with a high per second request volume. For such users Azure is the better option among the three.

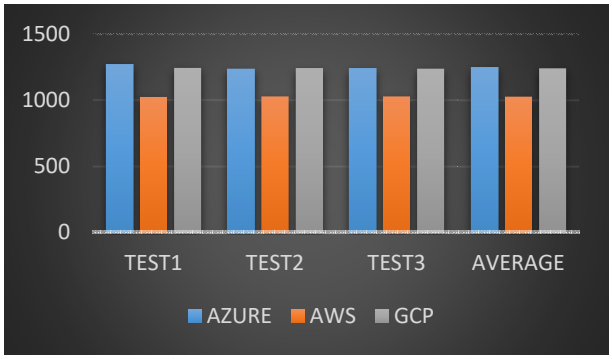

Figure 3: APACHE BAR CHART

Dbench test is a free alternative to the netbench utility produced by the Samba project. This freeware tests disc performance by sending requests to the file system. The table and chart show the comparison between the three cloud services providers obtained from dbench test. From the table we can see that the average of Google Cloud is less than Azure and AWS. Also, the difference between average of Azure and AWS is negligible. So, it won't matter much if the user selects either of the two considering the disc performance.

TEST	AZURE	AWS	GCP
TEST1	69.826	69.822	63.887
TEST2	70.426	70.418	63.5841
TEST3	71.865	71.89	63.6282
AVERAGE	70.7	70.71	63.7

Table 3: DBENCH BENCHMARK

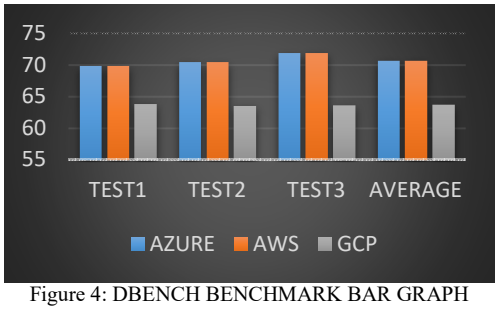

Figure 4: DBENCH BENCHMARK BAR GRAPH

RAM speed is a benchmark test for determining RAM efficiency. Copy, Scale, Add, Triad, and Average were the five test configuration for this. All these five test configurations are tested for integer as well as floating point.

TEST	AZURE	AWS	GCP
ADD	9073.35	9088.03	8756.46
COPY	8837.64	8848.58	6572.52
SCALE	8956.66	8980.09	7790.98
TRIAD	9488.59	9482.88	9400.73
AVERAGE	9368.71	9099.89	8095.64

Table 4.1: RAMSPEED BENCHMARK (INTEGER)

Figure 5.1: RAMSPEED INTEGER BENCHMARK

As seen through the chart and table for RAM speed Integer benchmark, AWS and Azure are in neck-to-neck competition, but with AWS having a better average. However, GCP is still behind in this benchmark test.

For RAM speed Floating-point benchmarks, AWS remains to hold the first position as well.

So, a user looking for better RAM speed and performance can choose to avail services provided by AWS.

TEST	AZURE	AWS	GCP
ADD	8888.73	8950.33	8449.1
COPY	9114.04	9119.1	6548.46
SCALE	8316.65	8322.93	6646.07
TRIAD	8694.09	8732.45	8520.02
AVERAGE	8635.46	8781.2	7581.94

Table 4.2: RAMSPEED BENCHMARK (FLOATING)

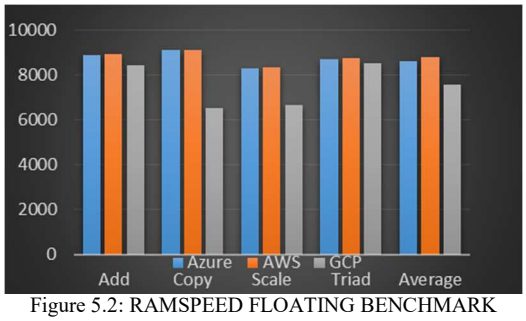

Figure 5.2: RAMSPEED FLOATING BENCHMARK

VII. CONCLUSION

Even though Google cloud is ahead in the race of cloud computing than many cloud providers, it still has a long way to go before it captures the whole market like it did with its search engine. The difference between average of Azure and GCP was not much in Apache benchmark test, GCP failed to give them tough competition in Dbench and RAM speed benchmark.

Azure has a simple and intuitive UI for controlling virtual resources, but there is no option for VM tweaks. AWS, on the other hand, provides additional facilities for system tuning and more alternatives for administering Linux VM's.

When it comes to performance of these cloud services, the performed tests and their results from testing micro instance VM's are very similar for both AWS and Azure, but AWS manages to excel in both Dbench and RAM speech benchmarks. Nonetheless, testing benchmark performance of more sophisticated VM instances should be conducted in conformity with the virtual hardware representation made available to the cloud users. The AWS infrastructure is better suited for Linux VM's since it provides more possibilities for end users to customize, as evidenced by memory and RAM speed test results.

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