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GROUP NAME / NUMBER : 3

1.		Name: Huda Najihah binti Ahmad Asri Matric Number: A20EC0045 Phone Number: 010-218 2840 E-mail: hudanajihah@graduate.utm.my
2.		Name: Keshiniy A/P Mogan Matric Number: A20EC0057 Phone Number: 013-470 9452 E-mail: keshiniy@graduate.utm.my
3.		Name: Marnisha binti Mustafa Kamal Matric Number: A20EC0075 Phone Number: 018-220 8667 E-mail: marnisha@graduate.utm.my
4.		Name: Woon Zi Jian Matric Number: A20EC0171 Phone Number: 018-2226331 E-mail: woonjian@graduate.utm.my

# **A Comparative Analysis of Cloud Computing Service Providers**

Huda Najihah binti Ahmad Asri<sup>1</sup> Keshiniy D/O Mogan<sup>2</sup> Marnisha binti Mustafa Kamal<sup>3</sup> and Woon Zi Jian<sup>4</sup>  
School of Computing, Faculty of Engineering, Universiti Teknologi Malaysia, Johor Bahru, Johor, Malaysia  
<sup>1</sup>hudanajihah@graduate.utm.my <sup>2</sup>keshiniy@graduate.utm.my  
<sup>3</sup>marnisha@graduate.utm.my <sup>4</sup>woonjian@graduate.utm.my

## **1 Introduction**

The provision of different services through the internet is called cloud computing. This includes data storage, servers, software, databases, and networking. The cloud-based storage allows them to be saved to a remote database rather than maintaining files on a proprietary hard disc or a local storage device if an electronic device is able to access the web. Many cloud applications are available for users today, such as Google Docs, Gmail, Facebook, iTunes, and many more. Cloud Computing's future can be seen as a combination of on-site computing and cloud-based software products that will help create hybrid IT solutions. We will discuss three major cloud computing systems in the world: Amazon EC2, Google Cloud Platform, and Microsoft Azure.

This paper has 7 sections, with the introduction as the starter, followed by background of cloud computing. Section 3 and 4 describes about cloud models and services, respectively. In section 5, there is comparison of the top 3 cloud computing provider, followed by an opinion in section 6. Finally, section 7 is the conclusion.

## **2 Background of Cloud Computing**

Cloud computing is the delivery of computing services including servers, storage, databases, networking, software, analytics, and intelligence over the Internet <sup>[21]</sup>. Cloud computing is crucial because it has the fastest adoption compared to other technology in the domain. It enables users to run software programs without installing them on their computers, to store and access the multimedia content through the internet, and to develop and test programs without necessarily having servers. The expectations of cloud computing are the rise of the hybrid multi-cloud. Data security and privacy are among the main concerns for anyone considering moving to the cloud too. Lastly, cloud-related shifts in businesses as businesses adopt hybrid multi-clouds, they are required to adapt to the multiple challenges.

## **3 Cloud Models**

Public clouds are the most common type, it is delivered via the Internet and can be shared with other organizations, as example is Microsoft Azure. For private clouds, its resources are dedicated for only one organization. One of its providers is HPE. The last one is hybrid clouds, just like its name, it combines a private infrastructure with a public cloud. One of the prominent providers is Amazon AWS.

## **4 Cloud Services**

Infrastructure-as-a-Service (IaaS) is a cloud-based service which provides you with services that requires a payment. With IaaS, a user can purchase what they need and more as the business grows. Platform-as-a-Service (PaaS) on the other hand is available on the internet as hardware and software tools. It is the most effective by cost and time for a developer to create an application. Lastly, Software-as-a-Service (SaaS) is a software available on the internet through a third-party. With SaaS, users are not required to install software applications, as everything is accessible on the internet.<sup>[10]</sup>

## 5 Leading Cloud Computing Service

There are many leading cloud computing services in the world, such as Kamatera and Vultr. The top three are Microsoft Azure, Amazon Elastic Compute Cloud (Amazon EC2) and Google Cloud Platform (GCP).

The advantage of Microsoft Azure is it offers high availability in data centres on a global scale where it offers a service level agreement, or SLA of 99.95% (approximately 4.38 hours of downtime per year), something that most businesses cannot achieve <sup>[11]</sup>. However, Microsoft Azure requires management. IaaS (Azure) moves the user's business' compute power from the user's data centre or office to the cloud. Therefore, Azure needs to be expertly managed and maintained which includes patching and server monitoring.

For Amazon EC2, the advantages are users have complete control over their instances. EC2 provides access to its users just like a physical server in the office would. It can be managed through the webpage of Amazon EC2, or automatically on an application program interface (API) that can be set up from a software development kit (SDK) provided by AWS. On the downside, although there are many choices of the instances and AMI, the configuration can be confusing and overwhelming for potential users who are developer illiterate, as most of the terms used are not in layman's language. Thus, it can be challenging to be understood.

Lastly, GCP has a huge private global network using fibre optic cables, which helps provide fast networking speed. It also enables users to relocate the virtual machines, where there will be no changes in the performance regardless of the VMs being moved. With the vast usage of GCP, on 29<sup>th</sup> of September 2016, Google announced several locations that will help decrease latency for Google Hosting customers by quickly building out their infrastructure. However, GCP falls in third place in market share compared to other public cloud providers, with only 8%. This occurs because it does not offer many distinctive services and features that other cloud providers do.

	Microsoft Azure	Amazon EC2	Google Cloud Platform
Service model	SaaS, PaaS, IaaS	IaaS	IaaS
VM instance type	<ul style="list-style-type: none"> <li>- General purpose</li> <li>- Compute Optimized</li> <li>- Memory Optimized</li> <li>- Storage Optimized</li> <li>- GPU</li> <li>- High-performance Comput</li> </ul>	<ul style="list-style-type: none"> <li>- General Purpose</li> <li>- Compute Optimized</li> <li>- Memory Optimized</li> <li>- Accelerated Computing</li> <li>- Storage Optimized</li> </ul>	GCE <ul style="list-style-type: none"> <li>- micro</li> <li>- small</li> <li>- medium</li> </ul>
Storage	<ul style="list-style-type: none"> <li>- Storage Service</li> <li>- Blob Service</li> <li>- Queue Service</li> <li>- File Service</li> <li>- Table Service</li> </ul>	<ul style="list-style-type: none"> <li>- EBS</li> <li>- EFS</li> <li>- NVMe SSD</li> </ul>	<ul style="list-style-type: none"> <li>- block</li> <li>- network file</li> <li>- object storage</li> </ul>
OS environment	<ul style="list-style-type: none"> <li>- Linux</li> <li>- Microsoft Windows</li> </ul>	<ul style="list-style-type: none"> <li>- Linux</li> <li>- macOS</li> <li>- Raspbian</li> <li>- Microsoft Windows</li> </ul>	<ul style="list-style-type: none"> <li>- Linux</li> <li>- Microsoft Windows</li> </ul>
Security	10 types of securities	Shared Responsibility Model	GCP security fundamentals
Performance and scalability	Up to 416 vCPUs and 12TB memory	AMI	GCS
Pricing model	Charged by minute, pay-as-you-go model	<ul style="list-style-type: none"> <li>- On-Demand</li> <li>- Spot Instances</li> <li>- Savings Plans</li> <li>- Reserved Instances</li> <li>- Dedicated Hosts</li> </ul>	<ul style="list-style-type: none"> <li>- 15GB free</li> <li>- 100GB RM8.49*</li> <li>- 200GB RM11.99*</li> <li>- 2TB RM42.99*</li> </ul> *next size, per month
Auto-Scaling/	Auto-Scaling	Auto-Scaling	- Elasticity

Elasticity			- Auto Scaling
Monitoring tools/ Service provided	- Microsoft Monitoring Agent - System Center Operations Manager	CloudWatch Amazon	- SLI - SLO - Error budget

Table 1. Comparison between Microsoft Azure, Amazon EC2 and Google Cloud Platform.

Azure provides all three services which are SaaS, PaaS, and IaaS. Amazon EC2 is an IaaS where the customer is responsible to execute the configuration and management tasks, meanwhile Amazon is responsible for networking, storage, server, and virtualisation. GCP is also an IaaS where clients are responsible for maintaining operating systems and run virtual machines on the infrastructure.

An Azure VM gives the flexibility of virtualization without having to buy and maintain the physical hardware that runs it. However, the user still needs to maintain the VM by performing tasks, such as configuring, patching, and installing the software. Azure VM can be used in various ways such as develop and test applications in the cloud, extend data centre, and utilize virtual machines featuring up to 416 vCPUs and 12TB of memory<sup>[9]</sup>. EC2 provides five options of instance types which differs according to types of applications and the usage so that the performance is optimized. Under general purpose, one of the instances they offer is the Amazon EC2 A1 instance with six different types. Google Compute Engine (GCE) is a component of GCP that runs Google's search engines, and others. In GCE, machine types are grouped by families which include different machine types with specific workload types.

Machine Type	vCPU	Baseline performance per vCPU	Memory
E2-micro	2	0.125	1GB
E2-small	2	0.25	2GB
E2-medium	2	0.5	4GB

Table 2. GCP Machine Type

Azure has 6 types of storage services which are Storage service, Blob service, Queue Service, File Service and Table Service. Most of the storage for EC2 instances are Elastic Block Storage (EBS), but there are also instance models that use Elastic File System (EFS), and NVMe SSD, as example the c5ad.large. GCP provides three services for distinctive types of storage: block, network file, and object storage. These act as the building blocks for most Google Cloud services.

Instance	vCPU	Mem (GiB)	Storage	Network Performance (Gbps)
a1.medium	1	2	EBS-Only	Up to 10
a1.large	2	4	EBS-Only	Up to 10
a1.xlarge	4	8	EBS-Only	Up to 10
a1.2xlarge	8	16	EBS-Only	Up to 10
a1.4xlarge	16	32	EBS-Only	Up to 10
a1.metal	16*	32	EBS-Only	Up to 10

Table 3. EC2 instance types and its storages [5]

The OS environment offered by Azure is Linux and Microsoft Windows. Meanwhile for EC2, they support a variety of OS environments. From Linux, macOS, Raspbian, and Windows. For GCP, the operating system environments offered are Linux, FreeBSD, NetBSD, and Windows.

Azure provides over 10 types of securities to protect user's sensitive information, modules, hybrid cloud workloads and others. Under the Shared Responsibility Model, AWS ensures the best security for their customers where the model is separated into two which are "Security of the Cloud" and "Security in the Cloud"<sup>[4]</sup>. GCP security fundamentals include having recovery plans for disasters, cloud activity log monitoring, high visibility of the environment, and plenty others.

Performance-wise, AWS eliminates contention between the Amazon EBS I/O and other network traffic so that users will have consistently high performance of instances. The network performance can be up to

100 Gbps. They also implement the Amazon Machine Image (AMI) that can launch multiple instances from a single AMI. The EC2 scale increased gradually when the demand size increased, thus not affecting the performance<sup>[1]</sup>.

Azure's services are charged by minute where you only pay for the service or resources used. It uses a pay-as-you-go model, where there is no upfront payment<sup>[6]</sup>. EC2 uses per-second billing which users pay for only what they use. The pricing model offered are On-Demand, Spot Instances, Savings Plans, Reserved Instances, and Dedicated Hosts. GCP comes in several plans that range in different sizes, where the first 15GB are free, and the next 100GB, 200GB, and more are charged monthly, inclusive of their own specialities.

Azure's best service is its ability to auto scale according to the demands of the application usage. EC2 uses auto-scaling which enables users to add or remove the instances used according to their conditions. GCP provides elasticity where you can scale up or down whenever you need to. GCP also has autoscaling that helps to add or discard VM instances based on the rise and fall in load from a managed instance group.

	Maximum Instance	Auto-Scaling Supported
Free	1	No
Shared	1	No
Basic	3	No
Standard	10	Yes
Premium	50	Yes

*Table 4. Azure Auto-Scaling services*

Active monitoring tools for Azure include Microsoft Monitoring Agent (MMA) and System Centre Operations Manager. These tools are configured to provide time alerts to Azure security personnel in situations that require immediate action. For EC2, users can monitor their instances by using the CloudWatch, as for every 5 minutes, EC2 will send their metric data to the server. The monitoring services offered in GCP include service-level indicators (SLIs), service-level objectives (SLOs), and error budget to reduce the risks in the service.

## 6 Opinion on The Best Cloud Computing Provider

After analysing the three cloud computing systems, we concluded that we chose Amazon EC2 as our cloud service provider for software development. This is because EC2 has the most experience compared to the other two providers. EC2 provides better services that are more suitable for software development. Moreover, it also provides different storage kinds to the users, regardless how big the company is. Furthermore, EC2 ensures the best security for the customer, allowing users to use this cloud system with no worries. Although the usage of EC2 is increasing gradually, we are still able to use the provider with great performance. Lastly, EC2 is the best at comparing the depth and breadth of tools and technology compared to GCP and Azure. They are at the forefront of tech learning issues and addressing the limits of facial, voice, and object recognition.

## 7 Conclusion

In conclusion, cloud computing system has played an essential role in our working areas. It provides high flexibility, business continuity, cost efficiency, scalability and performance, environment-friendly, automatic software updates, and plenty more. Companies can keep on growing in the future with the help of cloud computing. Cloud computing is substantial and expansive and will resume to grow and provide many advantages in the future. It is highly cost-effective and can be used by businesses for their growth. Therefore, we hope that cloud computing can maintain its advantages and fix their disadvantages to make our life more comfortable and easier in the future.

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