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LECTURER : DR. SARINA BINTI SULAIMAN

PRESENTED BY :

1. LEE QING REN (A20EC0065)
2. ARVIND (A20EC0016)
3. QHAIRUL HEEDAYAH BINTI TAMSOR(A20EC0134)
4. RAGHID MUHAMMAD THAREQ (A20EC0328)

A Comparative Review of Cloud Computing Service Providers

Lee Qing Ren[1], Arvind[2], Heedayah[3], and Raghid[4],

[1,2,3,4] Universiti Teknologi Malaysia, 81310 Skudai,
Johor Bahru, Johor, Malaysia.
Email: leeren@graduate.utm.my[1],arvindarvind@graduate.utm.my [2],
qhairulheedayah@graduate.utm.my [3], raghid@graduate.utm.my [4]

1   Introduction

Cloud computing is the internet that provides access to delivery of different services such as servers, networking, software and databases especially for computing power, data storage. It offers a wide range of services with limitless potential, epic proportions of creativity , faster time-to-solution and to-market. Basically, it is resources being rented by other companies such as storage space and CPU cycles. Microsoft, Amazon and Google are types of cloud computing companies. The purpose of this paper is to compare the evaluations of the services the top three cloud computing service providers offered in the market.

2   Cloud Models

There are three types of cloud models : Public Cloud, Private Cloud and Hybrid Cloud.

- **Public Cloud**

    This model is widely used in software development as the scalability is smooth and easy due to its large amount of available space. Applications can be designed with portable attributes and often tested and analyzed in the public cloud before the production in the private cloud. It is versatile as it is "pay as you go" structured and this provides convenience to the consumers to plan the capacity on demand. Unfortunately, the service provider has the full control over the operating system and consumers are forced to encounter any significant infrastructure changes if the platform undergoes any changes. Moreover, consumers have to risk themselves for the unpatched security vulnerability.[1]

- **Private Cloud**

  Private cloud is more to business like and widely used in organizations. This is because it has firewall protection and offers security control to the organization although it is costly. Its functionality is quite similar with public cloud, but only authorized users can access the data. Moreover, the organization is able to make access restrictions to each asset and relocate the data. It is the responsibility of the organization to update the software and the infrastructure in the private cloud, which means any changes from the provider will not affect the organization.[1]

- **Hybrid Cloud**

  It is a combination of the two types of cloud, public and private cloud, providing interaction between them. Hybrid cloud has the capability such as the scalable computing power in the public cloud, and provides the security control in the private cloud at the same time. Data is able to be stored and transferred securely to a public cloud environment with the support of the features in private cloud such as the firewalls and the encryption protocols. [1]

3   Cloud Services

There are 3 types of cloud services which are popular in the market. They are Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS).

- **Infrastructure as a Service (IaaS)**

  IaaS is a virtualized computing infrastructure that allows carrying out provision and management over the Internet. In other words, customization and configuration over the resources can be done by consumers to satisfy their specific needs. Meanwhile, consumers only pay for what they used and it benefits small companies that need the support of the hardware and the software to create their own private network. In addition, update patches are updated by the provider and latest security protections are provided as well. Examples of IaaS are Microsoft Azure, Google Compute Engine (GCE) and Amazon Web Services (AWS). [23]

- **Platform as a Service (PaaS)**

  PaaS is more specialized than IaaS by little as it offers the framework needed to offer help in software development. This reduces the cost in software development for various platforms as users can access the software development tools provided through the Internet for free. Examples of PaaS are Microsoft Azure, Google App Engine and AWS Elastic Beanstalk. [23]

- **Software as a Service (SaaS)**

  SaaS deploys fully-developed software over the Internet and receives payment via subscription. It is unnecessary to install the software as users can directly use the SaaS software by browsing any web browsers. Examples of SaaS are Microsoft Office 365, Google Apps and Cisco WebEx. [23]

4 Leading Cloud Computing Providers

Many Cloud Computing Providers compete to be the top that offers cloud computing services such as storage, databases, servers, and software. Cloud Computing Providers are led by Amazon Webs Service, followed by Microsoft Azure and Google Cloud.

- **Amazon Web Services (AWS)**

  Amazon launched Amazon Web Services (AWS) in 2010 and the top cloud service provider. AWS is available in more than 190 countries and over a million active customers use AWS. AWS offers a wide range of IaaS, Paas, and many services from infrastructure technologies to emerging technologies such as Virtual Private Cloud, Elastic Cloud Compute (EC2), AWS Key Management Service, and many other offers[21]. AWS cost-effectively makes moving an application to the cloud and develops a new product faster and easier. AWS key infrastructure is made to be the most flexible and secure that can even satisfy the security requirements. AWS continuously increases the speed of innovation with leveraged new technologies.

- **Microsoft Azure**

  Microsoft Azure was launched in the year 2010 by Microsoft company that is available in 140 countries and consists of 60 regions worldwide. Azure is less expensive and only offers pricing advantages such as free extended security updates. Without leaving the network, users can transfer data with fewer costs, less latency, and high security. Azure offers advanced featured, most intelligent products and services such as AI + Machine learning, Developer Tools, Microsoft Azure Stack, and others featured[21].

- **Google Cloud**

  Google Cloud was launched in 2008 by Google. Google cloud available in 67 zones across 16 countries. Google Cloud provides a Google Security Model that focuses on keeping all data safe. Google Cloud has better

performance in network infrastructure that access to Google's private fiber networking. Google Cloud offers services such as AI and Machine learning, API Management, Databases, and other services. Also, Google Cloud provides a complete product such as Google Hardware, Firebase, Chrome Enterprise, and various products[21].

5 Comparative Evaluation

This section will compare the top 3 cloud computing service providers : Amazon EC2, Google Cloud Platform (GCP), and Microsoft Azure. Table 1 shows the comparison among the three service providers.

Table 1. Comparison Among the Top Three Cloud Computing Service Providers

Comparative Points	Cloud Computing Service Providers		
	Amazon EC2	Google Cloud Platform	Microsoft Azure
Service Model	IaaS	Mixture of IaaS,PaaS,SaaS	Mixture of IaaS,PaaS,SaaS
Virtual Machine (VM)	• t3.nano to t3.2xlarge • mg6d. medium to mg6d.metal	Micro, small and shared core	A-series, Bs-series, D-series, DC-series, E-series, F-series, G-series, H-series
Storage	Up to 16TB	Up to 5TB with 15 GB free.	500TB
OS Environment Offered	LINUX	Debian-cloud	LINUX, Microsoft Windows
Security	High security. Shared responsibility between the provider and the consumer. All configuration settings are under users' control.[1]	High security. Provides all types of security services such as encryption of inter-service communication, Google front end service, denial of service (DoS)	High security. Provides a lot of configurable security tools for the users. It enables managing data location and data access on the user's terms. It also

		protection and intrusion detection.[2]	supports penetration testing, web application firewall, web server diagnostics and layered security architecture.[3]
Performance and scalability	High quality networking provided to the users experience as the networking performance consistency is guaranteed. Users can troubleshoot the problems of the networking performance and run benchmark testing. [4]	Has two tiers: standard tier (low-cost) and premium tier (high-cost). Standard tier connects users to a lower performance network and no protection from a Global SLA. Premium tier connects users to high performance and low latency network and users get protected by a Global SLA. [5]	Overall performance is optimised by cost. Performance is down when coming across antipatterns. This will increase the scalability problems such as stalling and rejecting users' requests.[6]
Pricing Model	Amazon EC2 (t2 or t3 micro) $0.013 per hour. [7]	Google Cloud VM E2 predefined vCPUs : $0.021/vCPUs per hour E2 predefined Memory : $0.003/GB per hour. [8]	Linux Virtual Machines $0.004 per hour. [9]
Auto Scaling/ Elasticity	AWS Auto Scaling alters capacity automatically to meet the workload with the support of scheduled scaling, dynamic scaling and predictive scaling. [10] Have	Auto scaling only works with regional managed virtual machine instances.[11] Do not support scheduled scaling and have less scaling policy	Auto scaling enables scale up or down automatically according to users' term. [13] Have vertical scaling, which alters the resource capacity,

	more scaling policies.	compared to Amazon EC2.[12]	and horizontal scaling, which controls the resource instances. [14]
Monitoring Tools/Service Provided	- System and instance status check - Amazon Elastic Compute Cloud - CloudWatch agent - Amazon CloudWatch alarms [15]	- Cloud SQL - Compute Engine - Cloud Translation - Cloud Data Fusion	- Azure Cognitive Services - Azure SQL Database - Azure Lab Services - Azure IoT Hub

- **Amazon EC2**

  Amazon EC2 provides more IaaS in the market. It offers a Linux OS environment to users and the range for the instances is in between nano to metal depending on the types . For example, instances t3.nano to t3.2xlarge and mg6d. medium to mg6d.metal. Amazon EC2 can store up to 16 TB per user account. It is a shared responsibility model between the provider and the consumer. In other words, the provider only provides services and protects the service infrastructures and the users has the responsibility for the rest. It is high security and safe to use as all configuration settings are under users' control.[1] High quality networking is ensured for the users experience as the networking performance consistency is guaranteed. Users can troubleshoot the problems of the networking performance and run benchmark testing. [4] AWS Auto Scaling alters capacity automatically to meet the workload with the support of scheduled scaling, dynamic scaling and predictive scaling. [10] It has more scaling policies compared to Google Cloud Platform (GCP). The price of Amazon EC2 depends on the types of instances used by users. For example, Amazon EC2 (t2 or t3 micro) will cost $0.013 per hour. The services provided are system and instance status check, Amazon Elastic Compute Cloud, CloudWatch agent and Amazon Cloud Watch alarms.

- **Google Cloud Platform (GCP)**

  GCP provides IaaS, PaaS and SaaS as well. Its virtual machine (VM) instances can be micro, small or shared core. Firstly, a Google account can store 15 GB for free. Yet, it can store up to 5TB per account by upgrading the Google storage plan. The OS environment offered by GCP is

Debian-Cloud. It provides a high security environment for the users by providing all types of security services such as encryption of inter-service communication, Google front end service, denial of service (DoS) protection and intrusion detection.[2] The service has two tiers, which are standard tier (low-cost) and premium tier (high-cost). Standard tier connects users to a lower performance network and no protection from a Global SLA. Premium tier connects users to high performance and low latency network and users get protected by a Global SLA. [5] GCP also supports auto scaling but it only works with regional managed virtual machine instances.[11] It does not support scheduled scaling and have less scaling policy compared to Amazon EC2.[12] The examples of GCP pricing models are Google Cloud VM E2 predefined vCPUs with $0.021/vCPUs per hour E2 predefined Memory with $0.003/GB per hour. [8] The services provided are Cloud SQL, Compute Engine, Cloud Translation and Cloud Data Fusion.

- **Microsoft Azure**

  Microsoft Azure provides IaaS, PaaS and SaaS too. Its virtual machine (VM) instances have several series such as A-series, Bs-series, D-series, DC-series, E-series, F-series, G-series and H-series. Azure can store 500 TB per user account with purchasing and it offers Linux and Microsoft Windows as the OS environment. It also provides high security by offering a lot of configurable security tools for the users. It enables managing data location and data access on the user's terms. It also supports penetration testing, web application firewall, web server diagnostics and layered security architecture.[3] Overall performance is optimised by cost. The performance is down when coming across antipatterns. This will increase the scalability problems such as stalling and rejecting users' requests.[6] Azure also supports auto scaling that enables scale up or down automatically according to users' term. [13] It offers vertical scaling, which alters the resource capacity, and horizontal scaling, which controls the resource instances. [14] For example, the pricing model for Linux Virtual Machines is $0.004 per hour. [9] It provides Azure Cognitive Services, Azure SQL Database, Azure Lab Services and Azure IoT Hub.

6 Advantages and Disadvantages

Table 2. The Advantages and the Disadvantages of the Top Three Cloud Computing Service Providers

Cloud		

Computing Service Providers	Advantages	Disadvantages
Amazon EC2	- Easy to use even for a new applicant because AWS Management Console is a very user-friendly interface[17]. - Provides an unlimited capacity at low-cost. Freely to expand the capacity and more secure[16]. - Offers flexibility and agility that can instantly set up a new server. AWS provides tools to reduce time. - Provide security that keeps all data safe	- AWS provides limited resources by region to prevent malicious intent and provide safety to all clients[17]. - A limited amount of support is included in the monthly fee. Optional one of three three support packages, Developer, Business, or Enterprise for immediate assistance and will increase the monthly fee. - General Cloud Computing issues when moving to the cloud such as downtime, security, privacy, limited control, and backup protection.
Google Cloud Platform	- More favorable pricing compared to others. - Faster in processing data with excellent networking speed by using fiber optic cables[18]. - Increase performances with immediate response with no spikes, and fewer errors. - Live migration to ensure virtual machines keep running even when the host system occurs.	- Lacks innovation compared to others with a better future. - GCP is less most reliable when handling customer issues and support fees are quite expensive

	• Improve the security of all data that is encrypted when transit[18].	
Azure Microsoft	• Provided high availability and got an uptime guarantee of 99.95% with approximately 4.5 hours of downtime over a year[19]. • High-security profiles that minimize the risk of data loss and multi-factor authentication offer another layer to increase protection[20]. • Flexibility to pay with no compulsory to buy high data packets when maximizing and minimizing the amount of data. • No compulsory to buy a data packet to gain access. This structure's scalability makes it flexible to pay.	• Required management tools include patching and server monitoring also need to physically monitor the cloud-based data center[20]. • Required platform expertise to operate it so that all moving parts are functional. • A slowdown in speed if the country is far from the data center region.

7   Choosing Suitable Cloud Computing Service Provider

A suitable cloud computing service provider is essential in software development to ease the software development life cycle (SDLC), especially in the design phase, coding phase, testing phase and maintenance phase. In this case, we need to seek for the best performance, reliability, security and other requirements needed from a cloud service to suit the software development.

Among the top three cloud computing service providers, we choose Google Cloud Platform (GCP) to be our cloud computing service provider. The decision is made after a discussion in our team. The first reason is that GCP provides SaaS and acquires management tools such as patching and server monitoring, which Azure lacks, to monitor the cloud-based data center. The management tools will reduce our burden in maintenance and patched updates. Debugging and testing take a shorter time to be done. Meanwhile, Amazon EC2 has a limited amount of support included in the monthly fee.

The second reason is that data processing is fast as the networking speed is supported by fibre optics cables. Unlike Azure, GCP doesn't encounter any slowdown in speed if the location is far away from the data center region. The performance in GCP is good overall with no spikes and fewer errors.

The third reason is that the security is still high although GCP doesn't have the security policies as many as that of Amazon EC2. Moreover, the resources in GCP can be used all over the world as long as the users stay connected to the Internet. Meanwhile, Amazon EC2 provides limited resources by region in order to prevent malicious intent and provide safety to all clients[17]. All the data is encrypted over the transmission so data loss is rarely to occur. In contrast, Amazon EC2 has the General Cloud Computing issues when moving to the cloud such as downtime, security, privacy, limited control, and backup protection.

The fourth reason is that GCP supports live migration to ensure virtual machines keep running even when the host system is down. This will ensure that our software keeps running while the host system is down. Last but not least, GCP is economical as the payment is affordable compared to the other two.

8 Conclusion

In my prediction, the future is dominated by cloud computing services and every IoTs will have a strong bond with the cloud. For example, automobiles are able to self-drive with the assist of GPS and the connection to the cloud. Manual driving will be a rare scenario in the future. Artificial Intelligence (AI) will be introduced in the new era and is widely used in the market to substitute human resources and uprise the productivity in manufacturing industries. In addition, data and network transmission speed will skyrocket and Virtual Reality (VR) and Augmented Reality (AR) will be popular not only in game but also in the real world. In order to make the dreams come true, we have to study and keep researching new technologies and inventions without destroying nature.

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