A Comparative Review of Cloud Computing Service Providers

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1 Introduction

In this era, cloud computing has increased their popularity in the market. Cloud computing is digital form that allows various of activities can be run and conduct via internet such as transactions, collecting or analysis data and so on. Cloud computing allow the user to access by using laptop, smart phone and also smart TV from anytime and anywhere via Internet. Office 365, Outlook, Google Docs, Facebook and Gmail are the common applications that used by user are supported by cloud computing. Amazon Web Service (AWS), Microsoft Azure and Goggle Cloud Platform (GCP) are the common and widely used by many companies. Many of the companies transform their business and data to cloud computing to instead of purchasing some important resources. The main objective of this paper is to compare three cloud computing service providers which are Amazon EC2, Microsoft Azure and Google Cloud Platform. This paper is categorized into 7 sections. The first section introduces aim of this paper. Section 2 describes the background of cloud computing. In section 3 presents about three type of cloud models which are public cloud, private cloud and hybrid cloud. Section 4 describe three types of cloud service which are Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). Section 5 portray Top Cloud Computing Providers which are Amazon EC2, Google Cloud Platform (GCP) and Microsoft Azure. In section 6 choose and describe the most suitable Cloud Computing. Lastly is make a conclusion and expectation in future.

2 Background of Cloud Computing

Cloud Computing is a computer services that enable on-demand network access to the partook resources pool that can quickly provide and released with minimal services provider interaction. It can replace hardware and software desktop.[1] Before the present of cloud computing, companies would store all their data and software in the company's servers or hard drives. In the big company, they need more storage to store their data. When there is a lot of orders, the company's server would be crashed. The present of cloud technology had helped company to solve many problems.

The important of cloud computing is cost efficiency. Cloud computing is model that based on subscription, there do not have any maintenance, labour or purchasing cost. It is a technology that provide on-demand services. Company can just pay for what to use and needs only. This can help company to reduce budget and use the services that needed only to develop their business.[2]

Many companies are undergoing their business in digital transformation. This is the reliable ways that company can stay competitive in the market. This is because digital transformation is going to paperless. This means that companies have to migrate all the business operations to the cloud.[2]

Cloud computing has offered a great service which is cloud storage. Cloud storage can store and access the data in the cloud easily from any device, anytime or anywhere. The cloud can save information automatically when uploaded via the internet. This can protect the data from losing from any situations. Cloud computing has a completed data backup and recovery process. This process can keep the data safe and secured form cyberattacks or physical thefts.[2]

Seamless scalability for company has provided by cloud computing. Cloud computing has provided cloud services which is Infrastructure as a Service (IaaS), Platform as a service (PaaS) and Software as a Service (SaaS). The cloud services allow company to purchase or remove and subscribe based on the needs. It provides many benefits for company to improve productivity and performance.[2]

The expectation of cloud computing is the rise of multi-cloud, highly concerned on data privacy and security and edge computing. Multi-cloud allows two or more storage services and cloud computing work in a single network composition. It is a combination of multi-cloud environment such as public, private or both. Many companies use multi-cloud to separate the companies' computer resources to reduce the risk of downtime

or data loss. Besides that. Multi-cloud increases the available storage and computing power in the companies' business. Multi-cloud provides additional choice for multi-cloud environment. This can provide user flexibility and avoid vendor lock-in when using it.[4]

The migration of data to the cloud has concerned by users especially on data security and privacy. The present of the General Data Protection Regulation (GDPR) may change the rules of cloud computing. With the implementation of privacy through design concepts, the developers need to protect the sensitive data from losing and attacking.[4]

Edge computing can achieve data flow acceleration consisting real-time data processing without delay. It enables smart applications or devices to feedback the data quickly when created and minimizing the lag time. It enables large data can be processed efficiency near the source to minimizing the internet bandwidth. It ensures applications can be processed smoothly in remote areas and reduce the budget. Edge computing will not put the data into public cloud. This can provide a protection to secure the sensitive data.[3]

3 Cloud Models

A public cloud computing is a service that available several trades on the net on a pay-as-you-go model. It allows users pay on the usage that consumed. This model provides business services and infrastructure. It also offers all maintenance and management of the system for companies. This helps the companies save the cost to purchase hardware, software application, system maintenance and so on. It also allows the companies use same system from anytime and anywhere via internet. Public cloud can scalability fulfil the volume of works and user's needs. [11]

Private Cloud Computing provides services that can access via internet and selected by users only. It could be business-owned tailors-infrastructure. It provides a number of regulated environments that focus heavily on companies' access to business gaps. Here prototype is presented externally or operated in-house Although private cloud presenting is expensive, for bigger trades this provides better security and plenty of sovereignty to customize computing and storage for computing for IT needs in part. [12]

Hybrid Cloud Computing is a combination of two cloud which are private cloud and public cloud. The movement of data and application is allowed between two cloud computing. Many data options and flexibility are provided. Hybrid Cloud allows to use private cloud to store the sensitive workloads which are low latency. The management of hybrid cloud computing depends on single management. All the cloud managements are managed together. Single management can reduce the data redundancy. This is because the separate management of environment rises the security loophole when the solution is not fully accepted by others environment. Hybrid cloud practices a best way to minimize the security risk with limited the private data exposure to the public cloud.[13]

4 Cloud Services

Infrastructure as a Service (IaaS) provides pay-as-you-go services and cloud-based services with on-premise infrastructure. It is the most usual assistance prototype about cloud computing because this provides the basic framework for virtual servers, webs, operating system plus data repository drives. This allows in place of the fluency, reliability and quantity which most trades ask over and above the cloud also eliminates need in lieu of ironware in workplace. It builds perfect in place of small and moderate-proportioned companies to look for an economical IT resolution on hold up trade extension. It allows the companies to save cost on investing or purchasing in high costly resources. It also provides the servers through Application Programming Interface (API) and allows companies control the whole infrastructure. IaaS is an outsourced payment service and available while general, private or hybrid framework. Examples of IaaS are Google Compute Engine (GCE), Digital Ocean and Amazon EC2. IaaS can de delivery via Internet. [14]

Platform as a Service (PaaS) be where cloud computing providers establish framework and shareware systems and also trades, builds and manages shareware. Internet shareware are built fast and easily through PaaS, so the facility be versatile and strong sufficient on bracing the one. The PaaS answer region units are ideal for climbing and trade atmosphere where multiple developing region units perform on a project. This is effective for additional information where an associate degree of existing data supply such as CRM equipment must get gained. Example of PaaS are Google App Engine, Windows Azure and AWS Elastic Beanstalk.[14]

Software as a Service (SaaS) provide service that allow the delivering of applications via the internet. SaaS also can define as Web-based software. It allows the applications to run on the web browser and provide management for the applications such as updating software. User no need to download, install or manage the software applications themselves. Example for SaaS are Dropbox, GoToMeeting and Salesforce. [14]

5 Top Cloud Computing Providers

Amazon Elastic Compute Cloud (Amazon EC2) is under Amazon Web Service (AWS) which allow user access infrastructure via the Internet. Amazon EC2 is an on-demand self-service which pay as what the user use. Amazon EC2 is desirable for big companies because it has long record service, flexible and has wide range od service. Cons of Amazon EC2 are it has limited to particular regions and charge fee for technical support for enterprise, developer and business.

Microsoft Azure created by Microsoft that provide cloud services. Pros of Microsoft Azure are the only cloud computing that provide hybrid cloud model, desirable to developers and also beginner and have strong security. Disadvantage of Microsoft Azure are user have managed the themselves and need an expertise to make sure work move smoothy.

Google Cloud Platform (GCP) is one of the cloud computing services allow infrastructure to run on Google. It has hyperscale networking environment, desirable for creators or developers to crate apps and software. GCP is also a complete container-based model. GCP has less featured compared to Microsoft Azure and Amazon EC2.

Cloud Computing Providers	**Amazon EC2**		**Microsoft Azure**		**Google Cloud Platform**	
Service Model	IaaS		IaaS -Azure virtual machines -Azure Storage account PaaS -Azure App Service -Azure SQL databases -Azure Cosmos DB -Azure Synapse Analytics SaaS -Outlook email -Microsoft Office 365		IaaS -Google Cloud Compute Engine PaaS -Google App Engine SaaS -Google Docs	
Virtual Machine	Amazon EC2		Azure virtual machine		Google Cloud Compute Engine	
Storage **-Block Storage** **-Object Storage** **-File Storage** **-Archive**	 Amazon Elastic Block Storage (EBS) Amazon S3 Amazon Elastics File System (EFS) Amazon Glacier		 Azure Blob Storage Azure Storage Azure File Storage Azure Backup		 Google Compute Engine Persistent Data Google Cloud Storage Avere Google Cloud Storage Nearline	
OS environments offered	-Windows -SLES -CentOS -RHEL -macOS	-Debian -FreeBSD -Ubuntu -Oracle Linux -Raspbian	-Windows -SLES -CentOS -CoreOS -RHEL	-Debian -Ubuntu -Oracle Linux	-Windows -CentOS -RHEL	-Debian -FreeBSD -Ubuntu - AWS Linux -SUSE
Security	Amazon GuardDuty, AWF WAF, Amazon Macie, AWS Shield		Microsoft Azure Security Center		Google Cloud DLP, Googgle Cloud Security Scanner	
Performance and scalability	Greatest availability zone, highest market share		Medium annual growth rate, Good performance in network		Highest annual growth rate, Good performance in network	
Pricing model	Based on service		Based on service		Based on service	
Auto-scaling	AWS Auto Scaling		Azure Autoscale		Managed Instance groups (MIGs)	
Monitoring tools/service provided	Amazon CloudWatch		Azure Monitor		Google Cloud Monitoring	

Table 1 Comparison among cloud computing

Three cloud computing providers has provided IaaS through their services. Amazon Elastic Compute Cloud (Amazon EC2) is IaaS for Amazon Web Service (AWS). Azure virtual machines and Azure Storage account are IaaS for Microsoft Azure. For Google Cloud Platform, Compute Engine is IaaS. Amazon EC2 does not provide PaaS while Microsoft Azure and Google Cloud Platform have. Microsoft Azure provide PaaS through Azure App Service, Azure SQL databases, Azure Cosmos DB and Azure Synapse Analytics. Azure App Service is the management of the web service or apps. Azure SQL databases is a database engine which manage the function of database. [7] Azure Cosmos DB is the management for NoSQL database service which focus on app development. [8] Azure Synapse Analytics provide unlimited analytics service such as Big Data analytics. [9] App Engine is PaaS of Google Cloud Platform which allow user to develop code or platform with automation. [10] Microsoft Azure and Google Cloud Platform both provide SaaS. The example of SaaS for Microsoft Azure are Outlook email and Microsoft Office 365 while Google Cloud Platform are Google Docs.

Virtual machine (VM) is typically under IaaS. Amazon EC2 is a VM of Amazon Web Services. Azure virtual machine and Google Cloud Compute Engine are VM of Azure virtual machine and Google Cloud Compute Engine. Three of this cloud computing has offered VM instance type. Amazon EC2 and Azure Virtual Machine are belonged to instance types while Google Cloud Compute Engine refer as machine type. Those cloud computing have the similar features which allow users to create and manage own instance based on demand. VM had been categorized into various types. First is general purpose that provide balanced CPU-to-memory ratio, ideal applications small to medium traffic web serves and databases. Second is compute optimized that have well batching processing volume of work, high performance for applications servers, web servers, computing and etc. Third are memory optimized has high performance in processing large data in memory analytics. [15] [16]

All cloud computing has own block storage, object storage, file storage and archive based on the table above. Amazon's storage has high data reliability, structural input and output performance and point-in-time snapshots. Microsoft Azure's storage has all-in-one storage solution, save cost, pay on the data usage and size. Google cloud platform's storage is more scalable, cheap, easy to practical and use and reliable. Three cloud computing has their own backup which are Amazon Glacier, Azure Backup and Google Cloud Storage Nearline. Amazon and Microsoft Azure has back-up solutions and disaster recovery. Microsoft Azure is the best option to store cold data for backup because it has archival storage.

Common operating system (OS) like Windows and Linus are supported by Amazon EC2, Microsoft Azure and Google Platform. Amazon EC2 offered 4 OS types which are Windows Server, macOS, Linux and Raspbian. OS that supported by Amazon EC2 are Amazon Linux, CentOS, Debian Server, Oracle Linux, Red Hat Enterprise (RHEL), SUSE Linux Enterprise Server (SLES) and Ubuntu Server. Any services supported by Amazon EC2 must using one of the OS so that the server can operate with AWS Systems Manager.[17] Microsoft Azure only offer two OS types which are Windows and Linux only. The OS of Microsoft Azure is supported by Azure Stack Hub such as Windows Server, Windows 10, CentOS, ClearLinux, CoreOS Linux, Debian, RHEL, SLES and Ubuntu. Windows 10 has allowed 64-bit which can operate more RAM and can support the processor run quickly. [18] Google Cloud Platform's OS is supported by Google Cloud Migrate. OS types for Google Cloud Platform are Windows and Linux same as Microsoft Azure. [19]

Amazon uses a "Shared Responsibility Model" for its security. Basically, Both Amazon and its customer share equal responsibility in order to secure and maintain their system. This model helps with the optimization and smooth operation of the EC2 from OS and virtualization to its smallest physical component. The customer takes control and management of the guest operating system such as updates, security patches and other associated applications etc. Here the customer has to choose carefully which services they will use as their responsibility varies according to their service subscription. It also allows flexibility and small control over user's services. Amazon provide security through Amazon GuardDuty used to threats malicious activity, AWS WAF as a firewall to protect API, Amazon Macie responsible to manage privacy and security for data and AWS Shield as a safeguard on Amazon EC2. [20] Security of Microsoft azure is supported by Microsoft Azure Security Center. Azure provides its users with a wide arrange of security. There are capable people available to assist its user with security with built in features. They have crated embedded best practice security requirements in everything. Azure Active Directory has crated built-in security features such as configurable Security options and the ability to customise its own authentication tools, access control and identity management in addition to their own highly capable network and security system. [21] GCP's security is supported by Google Cloud DLP and Google Cloud Security Scanner. Google has some of the biggest infrastructure in the internet landscape. They have a globe spanning infrastructure to support and provide

security throughout the entire information life cycle. Google call it Infrastructure security layers. They have about 6 layers of security such as operation security, internet communication, storage services, user identity, service deployment, hardware infrastructure. Each layer has its own security measures. Encryption, authentication, security of physical premises etc. This give google cloud an unmatched security compared to other cloud services. [22]

Amazon has the greatest availability zone which is 66, followed by Azure which is 54 and GCP is 20. Amazon also has the highest market share which are 30%, while Azure and GCP are 16% and 10% in cloud computing. This is because Amazon is first cloud service and more time compared to others in expanding their market. GPS has more capability than others based on the annual growth rate which is 83. Meanwhile, the growth rate of Azure and Amazon are 75% and 41%. Azure and GCP are more concentrated on networking, while Amazon is focus on the cloud market. This can be showed by Amazon has less 35% and 56% performance of network than GCP and Azure in Asia region. Thus, Azure and GCP show a rapid growth and has the better performance. [23]

Every service that offered by cloud computing does not have the same price. Amazon EC2 has a complicated model for pricing compare to other service providers. Amazon EC2 provide one of the best Return on Investment compare to other services. EC2 charge on an hourly basis about 0.0058$/hour (4.176$/month) for their smallest instance or nano instance. Storage optimization cost well around $4.199/hour and their "Reserved" version can go as much as $2.50/hour for a three-year prepaid plan. Microsoft Azure has a different model form Amazon. It charges "Per minutes". Though they also provide a huge discount compare to Amazon as well. Discounts are provided for 5% discount on the purchase bill or from Microsoft Enterprise Agreement (EAs). This is a high discount that can expect in return for an upfront monetary commitment from the user. GCP is the only service where up-front commitment is not required for discount. But they charge "Per minutes" like Microsoft. They use some call sustained Price Model is which the users discounted prices apply automatically to the services used at the end of the month or in other words through billing cycle. Although it is not very popular, it is still very effective. In December 2010, EC2 announced free resources for their new account holder.[30]

Auto scaling of Amazon EC2 is supported by AWS Auto Scaling. AWS Auto Scanning provide services to spy on applications and adjust or manage the capacity of the multiple resources in minutes at low costs.[24] Azure Autoscale is auto scaling for Microsoft Azure. It can optimize the performance of app by scaling process. Scaling of Azure Autoscale is counted by metric that user have. It allows user to know rapidly when problem occurs. [25] MIGs is auto scaling for GCP that can automatically to optimize the performance of instances by adding or removing. In MIGs, user have to choose the particular group and open the feature of auto scaling. [26]

Cloud monitoring defined as way for managing, surveying or revieing the operation in the cloud infrastructure. Monitoring services of Amazon EC2 is supported by Amazon CloudWatch. Amazon CloudWatch provides monitoring service that allow user to access the operational data and see the performance. It also provides some free significant resources to user so the user can concentrate on building stack. [27] Azure Monitor is monitoring service for Microsoft Azure that can optimize the performance of stack. It will provide solutions via telemetry so that user will know how is the performance and problem occur. [28] Google Cloud Monitoring is monitoring tools for GCP which provide service to identify the issues and avoid the problems occur. It provides SLO monitoring feature for service. When issues occur, SLO will alerted to user.[29]

6 Microsoft Azure is the best

After much compression, software development is more rely on Microsoft Azure. As it has by far the most services available for software development from macro level application development to big data analysis, it has almost all types of services to meet the demands. Its OS environment is far better than other Services and pricing models is easy to understand and it has a great auto-scaling feature compare to others. Its security is also top notch among the cloud computing. This is because Security Development Lifecycle (SDL) is created by Microsoft Azure and have more experience on security site on protecting data. Microsoft Azure is only one of the cloud computing that provide hybrid environment. We use various Microsoft Cloud services form OneDrive to Office 365 every day. The use of Microsoft Azure can get the same services like Windows and Linux. Thus, Microsoft Azure has more services which will be benefit for user than other service providers such as Amazon EC2 and Google Cloud.

7 Conclusion

Cloud computing have brought a lot of advantages to society and contribute the new technology to the world. Cloud computing has mobility and allow user to access it at anytime and anywhere in the world. It reduces the lag time for user on transportation and so on. Due to pandemic Covid-19, the use of cloud computing shows an important role in various field. It provides a virtual and remote environment for the user, companies and even school. User can stay at home to access the cloud computing to manage their works without caring social distancing. Cloud computing is concentrated on Customer Relationship Management (CRM) which can engage with their customer and improve their services in the same moment. This can boost the value of cloud computing and contribute on the rapid growth market share. Cloud technology will develop and improve their service in the future and increase the availability service zone. Thus, it can benefit to all the people from various level in the world.

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