A Comparative Review of Cloud Computing Service Providers

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1 Introduction

Day by day, cloud computing had been one of the most vital component in one's life. It enables organizations and individual users to access a range of multimedia content, from infrastructure to social media, via the internet. Thus, it helps the society to cope with future problems such as managing big data, cyber-security and quality control. Presently, cloud computing applications have been widely used all over the world such as Twitter, Facebook, Gmail, Amazon, Netflix, Dropbox, Microsoft Teams, Microsoft Office 365 and many more to list. Due to the rapid growth of cloud computing, it has been adopted as an important utility across all aspects of society from academia, governmental institutions and industries [2].

The main objective of this paper is to evaluate the most prominent cloud computing service provider. This paper contains 7 sections. The first one is the introduction of cloud computing. Section 2 outlines the background of cloud computing; history and definition. Section 3 and 4 describes the type of cloud models and cloud services respectively. In the most important section, which is section 5 is a comparison of top-leading cloud computing service providers. Section 6 explains our opinions on the most preferred choice of cloud computing service provider based on section 5. Lastly, section 7 describes the conclusion and our future directions.

2 Background of Cloud Computing

2.1 History and Emergence of Cloud Computing

In the 1955, John McCarthy, an American mathematician and computer scientist who was a pioneer in the field of artificial intelligence (AI), created the "Time-Sharing" theory. It is a theory of sharing computer time among users. The theory made a big impact on small companies as it helped to make computing time available to them who could not afford to buy their own mainframes.

As technology increased gradually, the idea of cloud computing had been emerged until the late 1960s. In the mid of 1960s, an idea for an interconnected system of computers was introduced by an American computer scientist named J.C.R. Licklider which lead to the development of ARPANET (Advanced Research Projects Agency Network) by Bob Taylor and Larry Roberts. ARPANET was the first network that allows digital sources to be shared among computers that were not in the same physical location. In the following years, there were a lot of advancements in cloud computing such as Computer giant IBM which released an operating system in 1972 called the VM (Virtual Machine) operating system.

2.2 Definition

Generally, cloud computing is a way of using computers in which data and software are stored or managed on a network of servers, to which users have access over the internet [5]. An author of Storage Area Networks for Dummies, Chris Poelker, define cloud computing as a way to describe how organizations can take some or all of their existing IT infrastructure and operations and hand it over to someone else. According to the National Institute of Standards and Technology (NIST), cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. Reuven Cohen, a founder of Enomaly Inc. in Toronto, Canada, describe cloud computing as 'internet centric software'.

3 Types of Cloud Models

3.1 Public Cloud

Public clouds are the most common type of cloud computing. Public clouds are made available to the larger organizations or general public and are owned and operated by a third party cloud service provider [10]. Public cloud providers also manage and own all hardware, software, the other supporting infrastructure and pool resources into the capacity required by its users [8]. The drawbacks of public clouds are their data security and privacy. The examples of public clouds include Amazon Elastic Cloud Compute (EC2), Google App Engine, Blue Cloud by IBM and Azure services Platform by Windows.
The advantages of public clouds include [7]:

- Data availability and continuous uptime
- On demand scalability
- Easy and inexpensive setup (Pay for What You Use)
- No wasted resources
- Higher reliability

3.2 Private Cloud

Private clouds comprise cloud computing resources used solely for an organization or business. It may be managed by the organization or a third party and may exist on premise or off premise [11]. The cloud infrastructure is dedicated and accessed only by the members within the private organization or by granted third parties. The only big advantage that private cloud has over public cloud is that of data security and privacy and the major drawback of private cloud is its higher cost [7]. HP Data Centers, Microsoft, Elastra-private cloud, and Ubuntu are the examples of private clouds.

3.3 Hybrid Cloud

Hybrid Clouds are more complex models that combines the infrastructures of public clouds with private clouds such as Amazon Web Services (AWS) or Microsoft Azure. Hybrid clouds allow data and applications portability to move between the two environments [14]. Ideally, the hybrid approach allows a business to take advantage of the scalability and cost-effectiveness that a public cloud computing environment offers without exposing mission-critical applications and data to third-party vulnerabilities [7].
The advantages of hybrid cloud include:

- Control
- Flexibility
- Cost-effectiveness
- Ease

4 Cloud Services

4.1 Infrastructure as a service (IaaS)

IaaS covers a wide range of features, from individual servers, to private networks, disk drives, various long term storage devices as well as email servers, domain name servers as well as messaging systems [12]. IaaS provides a collection of physical and virtualized resources and additional resources such as images in a virtual-machine image-library, raw (block) and file-based storage, firewalls, load balancers, IP addresses, virtual local area networks (VLANs), and software bundles to users to run applications and workloads in the cloud [13]. Examples of IaaS providers include Amazon CloudFormation, Amazon EC2 and Azure IaaS.

4.2 Platform as a service (PaaS)

PaaS delivers a platform to clients, enabling them to build their own applications on top of the platform. In comparison to SaaS where the application already exists, and is usually owned by the cloud provider, PaaS offers the possibility to create and modify

applications. It is an outgrowth of the SaaS application delivery model [15]. In the PaaS model, cloud providers deliver a computing platform typically including operating system, programming language execution environment, database, and web server [13]. The developers can develop and run their software solutions on a cloud platform without the cost and complexity of buying and managing the underlying hardware and software layers[13]. Examples of PaaS include: AWS Elastic Beanstalk, Cloud Foundry, Heroku.

4.3 Software as a service (SaaS)

In the SaaS model, cloud providers install and operate application software in the cloud and cloud users access the software from cloud clients. The applications can be accessed by web browser with network connectivity. With SaaS, the consumer pays for the software on a subscription level and does not need to install any software on their computers [7]. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user-specific application configuration settings [10]. Examples of SaaS include: google apps, Microsoft Office 365

5 Operating System Used in Cloud Computing

A cloud operating system is a type of operating system that plays a vital role to operate within cloud computing and virtualization environments, internet browsing and storing data. Cloud and many core systems share several challenges with respect to the operating system. The following is the list of cloud operating system that can manage the operation, execution and processes of virtual machines, virtual servers and virtual infrastructure, as well as the back-end hardware and software resources [9].

LIST OF OPRETING SYSTEM

1	GLIDE OS	**13**	CORNELI	**25**	GETEASYPEASY
2	AMOEBA	**14**	LUCIDE	**26**	OSW3
3	KOHIVE	**15**	EYEOS	**27**	TRANS OS
4	ZIMDESK	**16**	START FORCE	**28**	GIZMAG
5	GHOST	**17**	ZEROPC	**29**	HPCLOUD
6	MY GOYA	**18**	SOLAR OS	**30**	MIRAGE OS
7	JOLI OS	**19**	ICLOUD	**31**	SLAP OS
8	CLOUDOS	**20**	DEKOHDESKTOP	**32**	OSPREY
9	MEGAHA OS	**21**	VSTARE CLOUD	**33**	JEOS OS
10	MACINE CLOUD	**22**	GUEST OS	**34**	NEBULA OS
11	OSV	**23**	THE PALCE A	**35**	I SPACES
12	XOS	**24**	MIDORY	**36**	MOBILE CLOUD

6 Top Cloud Computing Providers

Category \ CC	**Amazon EC2** [20]	**Google Cloud Platform** [17]	**Microsoft Azure** [21]
Service Model	IaaS	PaaS	IaaS
Virtual Machine	KVM(Kernel-based Virtual Machine) virtualization	KVM(Kernel-based Virtual Machine) virtualization	Container virtualization
Storage	SSD and HDD	HDD and SDD	Blob storage
OS	Linux	Linux	Linux
Security	Third-party auditors regularly test and verify the effectiveness of the security as part of the AWS Compliance Program	-The Cloud Monitoring service from GCP collects metrics, events, and metadata from both GCP and AWS - Cloud Key Management Service from GCP is integrated with Cloud IAM and Cloud Audit Logs for easier management	-Data on the **Azure** platform is always encrypted in transit, except for data that moves within customer controlled networks (such as **Azure** Virtual Networks and ExpressRoute)
Performance and Scalability	High	High	Low
Pricing Model	-On-Demand Instances -Reserved Instances -Spot Instances -Dedicated Hosts	-Free -Subscription-based pricing -Usage-based pricing -Combined pricing	-offer per-minute pricing

Auto Scaling/ Elasticity	Scheduled Scaling: Scaling based on a schedule allows you to scale your application ahead of known load changes Dynamic Scaling: Amazon EC2 auto scaling allows you to follow the demand curves of your application closely,reducing the need for a manual	-Compute Engine offers autoscaling to automatically add or remove VM instances from a managed instance group based on increases or decreases in load	-An **Azure** virtual machine **scale** set can automatically increase or decrease the number of VM instances that run your application. This **automated** and elastic behavior reduces the management overhead to monitor and optimize the performance of your application

7 CHOICE OF CLOUD SERVICE PROVIDER

To compare the 3, we would go in depth with their specifications. We will compare the crucial aspect in the table to give us an insight of the strengths and weaknesses of the Cloud Computing Providers. For service model [16], both Microsoft Azure and Amazon EC2 using IaaS (Infrastructure as a Service) service model while Google Cloud Platform uses PaaS (Platform as a Service). The differences are IaaS unsure their clients retain complete control of their infrastructure while PaaS offers no purchases hardware or pay expenses during downtime. For security aspects [16], Google Cloud Platform's security options may be limited as customers may not be able to deploy services with specific hosting policies but for both Amazon EC2 and Microsoft Azure since the customer is in control of the apps, data, middleware, and the OS platform, security threats can still be sourced from the host or other virtual machines (VMs). Insider threat or system vulnerabilities may expose data communication between the host infrastructure and VMs to unauthorized entities.
Lastly, the main attraction when it comes for considering using a cloud which is pricing. Amazon EC2 and Microsoft Azure are offering their cloud services with pay-per-minute billing options, whereas Google Cloud Platform is ahead of them by providing a pay-per-second billing option. Moreover, Google Cloud Platform is offering various discounts and flexible contracts to gain maximum demand influx [19].As for the virtual machines, Amazon EC2 and Google CP uses Kernel Virtual Machine(KVM) which uses kernel instances. They also use multiple servers with tonnes of instances, hence eliminating the possibility of a total wipe out of instances. It also makes it easier to reboot since the instances would not have to be migrated

from server to server. Microsoft Azure on the other hand uses LCX or Linux Container which champions at speed. It has a fast start up pace and stop speed, hence making it really efficient. It is also lightweight hence it is easier to maintain.
As for Elasticity, Amazon EC2 has 2 types of Scaling where Schedule scaling is a manual one and dynamic scaling is an automated one where they would scale the number of instances to fit the dynamic of the Virtual Machines. The dynamic scheduling is very helpful as it is automated and doesn't require manual work. It is similar to the Azure Virtual Machine Scale.

After I have given my points, I would clearly use Amazon EC2 as my choice as it uses the KVM virtual machine which is renowned for its credibility in comparison to the LCX, it has an efficient scaling system that is the Dynamic Scaling, it has a plethora of tools that is useful such as the Elastic Cloud Computing(EC2) itself, Amazon Simple Storage System(Amazon S3) and Amazon Virtual Private Cloud(VPC). Although Amazon EC2 is a bit costly, I would think that it is worth it

8 Conclusion

Cloud computing is an emerging and prolonged on-demand system that will drive future technological innovation. Despite the advantages and advancements in cloud computing, there are also networking concerns that will hinder its fast adoption. Networking-related issues arise due to privacy matters, resource outsourcing, vulnerability to be attacked and security measures. Therefore, building a secure network infrastructure should be the foundation of cloud computing environment.

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