Cloud Computing Fundamentals: Literature Review on Cloud Computing Service Providers

Cha Zhi Ye[1], Jonathan Ting Moi Yao[1], Lee Wan Fu[1], and Yu Kok Yong[1]

[1] N28A, School of Computing, Faculty of Engineerin, Malaysia Technology University, 81310 Johor Bahru, Johor, Malaysia
{zhiye, ting2001, leefu, k.yong-2001}@graduate.utm.my

1 Introduction

In recent times, the global use of computers and smart phones has increased significantly. This trend has heightened global competition and therefore the need for businesses to expand into different geographical areas so as to be sustainable. To address this need, there's a necessity for efficient use of resources toward operational excellence. Cloud computing, a network model that makes it possible to achieve on-demand network access and a shared pool of configurable resources, e.g. networks and servers, which may be given minimal management or interaction. Even though cloud computing isn't totally new, its commercialization started around year 2000. Cloud computing simply involves the supply of data technology (IT) solutions as a service instead of as a product through the web . Clouds are so integrated in our everyday life that most people don't even think about them being used. In this area, there is fierce competition among major cloud service providers such as Amazon Web Services, Google Cloud Platform, and Microsoft Azure. In this paper, comparisons between all the services will be done according to the considered aspects.

2 Comparative Evaluation

There are some considered aspects that be used for a detailed comparison and discussion.

2.1 Service Model

Services Model	*Amazon Web Services*	*Google Cloud Computing*	*Microsoft Azure*
IaaS	✓ Service Functionality ✓ Enterprise and Hybrid Workload Support ✓ Support for DevOps	✓ Economical ✓ Efficient ✓ Productivity ✓ Reliable ✓ Scalable	✓ Eliminates capital ✓ Improves business continuity ✓ Innovate rapidly
PaaS	✓ Easy integration ✓ Instant results, rapid prototyping ✓ No need to invest in infrastructure and its maintenance costs	✓ Fast development and deployment ✓ Scalable, on-demand computing power ✓ Less time spent on managing your infrastructure	✓ Cut coding time ✓ Add development capabilities without adding staff ✓ Develop for multiple platforms
SaaS	✓ Run applications anywhere ✓ Speeds up execution ✓ Developers do not have to focus on infrastructure	✓ Simplified support for mobile and remote working ✓ Improved business resilience ✓ Flexibility	✓ Gain access to sophisticated applications ✓ Pay only for what you use ✓ Use free client software

Figure 1. Magic Quadrant for Cloud Infrastructure and Platform Services

Summary of AWS, GCP, Azure:-

Amazon Web Services – With a vast tool set that continues to grow exponentially, Amazon's capabilities are unmatched. Yet its cost structure can be confusing, and its singular focus on public cloud rather than hybrid cloud or private cloud means that interoperating with your data center is not AWS's top priority.

Microsoft Azure – A close competitor to AWS with an exceptionally capable cloud infrastructure. If you are an enterprise customer, Azure speaks your language – few companies have the enterprise background (and Windows support) as Microsoft. Azure knows you still run a data center, and the Azure platform works hard to interoperate with data centers; hybrid cloud is a true strength.

Google Cloud – A well-funded underdog in the competition, Google entered the cloud market later and does not have the enterprise focus that helps draw corporate customers. But its technical expertise is profound, and its industry-leading tools in deep learning and artificial intelligence, machine learning, and data analytics are significant advantages.

2.2 Virtual Machine

Example of different VM instance type provided.

Services / Type	Amazon Web Services	Google Cloud Computing	Microsoft Azure
Tier 1	Storage optimized (i3,D2,D3,H1)	A2 Accelerator-Optimized	N-Series GPU enabled virtual machines
Tier 2	Accelerated computing (P4,P3,P2,P2, Inf1,G4dn,G4ad,G3,F1)	C2 Compute-Optimized	Mv2-Series Largest memory optimized virtual machines
Tier 3	Memory optimized (R6g,R5,R4,X1)	M2, M1 Memory-Optimized	M-Series Memory optimized virtual machines
Tier 4	Compute optimized (C6g,C6gn,C5,C4)	N2, N2D, N1 General purpose	Ls-Series Storage optimized virtual machines
Tier 5	General purpose (Mac,T4g,T3,T2, M6g,M5,M4,A1)	E2 General purpose	H-Series High Performance Computing virtual machines

Definition: A machine type is a set of virtualized hardware resources available to a virtual machine (VM) instance, including the system memory size, virtual CPU (vCPU) count, and persistent disk limits. In Compute Engine, machine types are grouped and curated by families for different workloads. You can choose from general-purpose, memory-optimized, and compute-optimized families.

2.3 Storage

AWS vs. Azure vs. Google

Provider	Storage	Pricing
Amazon S3	S3 Standard Storage	First 50 TB / Month $0.023 per GB Next 450 TB / Month $0.022 per GB Over 500 TB / Month $0.021 per GB
	S3 Standard-Infrequent Access (S3 Standard-IA) Storage	All storage / Month $0.0125 per GB
	S3 One Zone-Infrequent Access (S3 One Zone-IA) Storage	All storage / Month $0.01 per GB
Amazon EBS	Amazon EBS General Purpose SSD (gp2) Volumes	$0.10 per GB-month of provisioned storage
	Amazon EBS Provisioned IOPS SSD (io1) Volumes	$0.125 per GB-month of provisioned storage $0.065 per provisioned IOPS-month
	Amazon EBS Throughput Optimized HDD (st1) Volumes	$0.045 per GB-month of provisioned storage
Amazon Glacier	S3 Glacier Storage	All storage / Month $0.004 per GB
	S3 Glacier Deep Archive Storage	All storage / Month $0.00099 per GB
Google Cloud Storage	Multi-Regional	$0.026 - $0.036 per GB/month
	Regional	$0.02 - $0.035 per GB/month
	Nearline	$0.01 - $0.02 per GB/month
	Coldline	$0.004 - $0.014 per GB/month
Microsoft Azure	Block Blobs	$0.002/GB per month
	Azure Data Lake Storage	$0.001/GB per month
	Managed Disks	$1.54 per month
	Files	$0.060/GB per month

The AWS Storage Gateway is a hybrid storage service that enables your on-premises applications to seamlessly use AWS cloud storage. You can use the service for backup and archiving, disaster recovery, cloud data processing, storage tiering, and migration. The storage services can be divided into three types, that is, object storage, file storage, and block/volume storage. For object storage, AWS offers S3. Google Cloud object storage is available in four performance tiers: Standard, Nearline, Coldline and Archive. Each service offers myriad configurations, options, and price reduction options, such as prepaid or reserved capacity and lower-performance price tiers. AWS file storage available in HDD and SSD performance and single and multiple availability zone configurations. For block storage, Amazon Elastic Block Store provides SSD- and HDD-based block devices at various IOPS and latency levels. Azure's block offerings include Managed Disks and Page Blobs. Managed Disks are designed for VM attachment and available in ultra, premium and standard SSD tiers, as well as an HDD tier.

2.4 OS Environment Offered

Amazon EC2	Azure	Google
LINUX	WINDOW	WINDOW
Amazon Linux	Windows Server, version 1709	Windows Server 2008 R2 SP1 or higher
Amazon Linux 2	Windows Server 2019	Windows Server 2012/Windows Server 2012 R2
CentOS	Windows Server 2016	Windows Server 2016
Debian Server	Windows Server 2012	Windows server 1709
Oracle Linux	Windows Server 2012	Windows Server 2003, Windows Server 2003 R2
Red Hat Enterprise Linux (RHEL)	Windows Server 2008	Windows Server 2008 R1
SUSE Linux Enterprise Server (SLES)	Windows Server 2008	
Ubuntu Server	Windows 10	LINUX
		CentOS 6.4+
macOS	LINUX	CentOS 7
10.14.x (Mojave)	CentOS-based 6.9	RHEL 6.4+
10.15.x (Catalina)	CentOS-based 7.5	RHEL 7
	CentOS-based 7.3	Debian 8.5+
Raspbian	ClearLinux	Debian 9
Jessie	CoreOS Linux (Stable)	Ubuntu Server 14.04 LTS
Stretch	Debian 8 "Jessie"	Ubuntu Server 16.04 LTS
	Debian 9 "Stretch"	Ubuntu Server 18.04 LTS
Windows Server	Oracle Linux	SUSE 11 SP3+
2008	Red Hat Enterprise Linux 7.1 (and later)	SUSE 12 SP2
2008 R2	LES 11SP4	SUSE 12 SP3
2012 and 2012 R2	SLES 12SP3	SUSE 12
2016	Ubuntu 14.04-LTS	SUSE 15
2019	Ubuntu 16.04-LTS	Ubuntu 12.x
	Ubuntu 18.04-LTS	

2.5 Security

For Amazon Web Services, most core security features are available: from robust API activity monitoring to basic threat intel (Guard Duty), WAF, DLP (Macie), Vulnerability Assessment (Inspector), and security event triggers for automations, two of the best AWS security features are their excellent implementation of security groups (firewalls) and granular IAM. Besides, Azure has two other central features which are particularly appealing to enterprise users: activity logs cover console and API activity for the entire tenant (organization) by default, across regions. The Azure Security Centre also covers the entire tenant (with the right licensing) and can be scoped to allow subscription-level access so local teams can manage their own alerts. Like Azure, Google Cloud Platform is better centralized because many capabilities were planned out from the start: compared to AWS features which were only added a few years ago. Within your account Projects are isolated from each other except where you connect services.

2.6 Pricing Model

The pricing models have a few similarities and differences for three of these. One of the similarities is that three of the cloud computing service provides free trial to user so as to attract them to use their products.

For AWS, it offers 750 hours of EC2 service monthly up to 1 year.

For Azure, it offers 750 hours of the windows of Linux B1S addition of their primary compute platform, Virtual Machines per year.

While Google provide new customers to run over 90 days, test and put their workloads.

The table below shows the differences of the three cloud service providers.

AWS Pricing	Azure Pricing	Google Pricing
Low transparency, hard to calculate the price	The pricing is situational with the needs of each customer	The friendliest pricing, it gives steep discounts and many incentives
-	200-dollar free credits	300-dollar free credits

2.7 Auto-Scaling / Elasticity

Auto-scaling is a built-in feature of cloud services that helps an application to perform their best when the customers' demand changes. A good auto-scaling service will let the user to optimize between cost and performance. In general, auto-scaling helps the apps to handle increased in traffic and reduce costs when the need for resources is lower.

For Azure, it has package everything into Virtual Machine Scale Set (VMSS). The auto-scaling is built directly into this service and it is easy to use by setting up a few configurations only.

For AWS, it separated into different services. The launch configuration and launch templates has define the ways to set up a new EC2. While the auto scaling groups and AWS auto scaling is a load-balanced group of EC2. However, the scaling can be set in schedule, manually or dynamically.

While for Google Cloud Computing, compute engine offers auto-scaling to automatically add or remove VM instances based on the changes in load. After the user define the autoscaling policy, the auto-scaler performs automatic scaling based on the measured load. Before using the auto-scaler, the customer must specify at least one auto-scaling policy.

2.8 Monitoring Tools / Service Provided

There are too much services that provide to user or customer. Here we list only 4 of the tools and services provided.

AWS	Azure	Google
Artificial Intelligence		
● SageMaker ● Lex ● Transcribe ● Polly ● Translate ● …	● Machine Learning ● Azure Bot Service ● Cognitive Services	● Cloud Natural Language ● Cloud Video Intelligence ● Dialogflow Enterprise Edition ● Cloud Speech API ● Cloud Translation API ● …
Internet of Things (IoT)		
● IoT Core ● IoT Device Management ● IoT Analytics ● Greengrass ● IoT 1-Click ● …	● IoT Hub ● IoT Edge ● Stream Analytics ● Time Series Insights	● Cloud IoT Core (Beta)

Serverless		
• Lambda • Serverless Application Repository	• Functions	• Cloud Functions (Beta)
Storage		
• Snowball • Snowmobile • Simple Storage Service(S3) • …	• Blob Storage • Queue Storage • File Storage • …	• Cloud storage • Persistent disk • Transfer appliance • …

3 Opinion

Cha Zhi Ye

In my opinion, I will choose Google Cloud Computing Service among three of these. There are several advantages and points that lead me to this opinion. First of all, it is the cheapest and most user friendly for the new user who wants to use the cloud computer service. As if I am one of the new users, I will often choose the cheapest one because it is to learn and test whether it is good or not. There are many services given and it even gives 300 dollars to user to use within 90 days. The other service provider gives 200 dollars or even none is given. In term of long-term usage, it also saves me a lot of money as it gives so many discounts to the user. Besides, Google Cloud Computing Service provides premium tier and standard tier. It may let me to choose either I want high security and speed or the otherwise with the lower cost. Google even have powerful data analytics as it uses big data and it will only become better in the future. Thus, I choose Google as my cloud computing service provider as I believe in it.

Jonathan Ting Moi Yao

Cloud computing in 2021 has become the go-to model for information technology as companies prioritize as-a-service providers over traditional vendors With so many vendors out there, this report is to compare the top 3 most popular cloud computing. For me, I would choose Microsoft Azure for my cloud computing. The main reason I choose this over the two other vendors is because Azure provides scale-on-demand. How your company can expand can be difficult to foresee, or whether and where you will need increased capital for short-term 'bursts' of traffic or transaction volume. Increased growth or other demands also include high-load running applications, or additional applications that can not be managed by most conventional hosting models. Also, Microsoft Azure provides a wide array of solutions suitable for all types of industry. All your business needs will be taken into consideration. This results in a package better suited for needs.

Lee Wan Fu

As for my perspective, with a view to developing my software, i might choose Microsoft Azure as my service provider. For a developer, Microsoft Azure is right because connecting Visual Studio with Azure is extremely easy and simple . we will select either Windows or Linux to create an internet app for the software. meaning it's easy to customize and integrate, and there are less compatibility issues. they need a vibrant culture, a reputable brand that's synonymous with corporate computing, and support. to spice up accessibility and performance, Azure offers a wider range of hybrid connections, including virtual private networks (VPNs), caches, content delivery networks (CDNs), and ExpressRoute connections. The new regional standard for cloud privacy, ISO 27018, is that the first to be implemented. For pricing, it's flexible, reasonable and affordable on behalf of me . As a result, I definitely would choose Azure for my software development.

Yu Kok Yong

In my opinion, Microsoft Azure is more suitable for me as a service provider because its cloud storage service is more reliable and user-friendly. It also provides a great user interface and that is easy to use for a beginner. Besides, it also supports window 10 system since I am a user of window 10, I am more prefer to use Microsoft Azure because Window is the most popular operating system in worldwide.

4 Conclusion

In this current world, technology drives the society. The baseline of which is that the cloud computing that piles up the other new technologies like Fog Computing and IoT. this study specialize in the literature review on cloud computing service providers. The study elaborates the tiny print and comparisons of various cloud service provide according to the considered aspects. As for Amazon Web Services, the resources of Amazon are unmatched with a huge tool set that continues to expand exponentially. However, its cost structure are often frustrating, and its particular emphasis on the overall public cloud rather than hybrid cloud or private cloud means it isn't the very best priority of AWS to talk with the data center. Microsoft Azure, a near AWS rival with a cloud infrastructure that's exceptionally capable. If you're an enterprise user, Azure speaks your language, as Microsoft has the company history (and Windows support) for a few of companies . Azure understands you're already running a knowledge center, and thus the Azure software works hard to talk with data centers; a real strength is that the hybrid cloud. Google Cloud joined the cloud market later, a well-funded competitor within the competition, and doesn't have the commercial emphasis that helps attract corporate customers. However, its technical experience is in-depth, and its industry-leading deep learning and AI software, machine learning and data analytics are essential advantages.

References

1. Abbot M (2009) A New Path for Science? In The Fourth Paradigm: Data-Intensive Scientific Discovery (Tony Hey ST, Kristin Tolle, Ed), pp 111-116, Microsoft Research.
2. Armbrust M, Fox A, Griffith R, Joseph A, Katz R, Konwinski A, Lee G, Patterson D, Rabkin A, Stoica I and Zaharia M (2009) Above the Clouds: A Berkeley View of Cloud Computing UC Berkeley Reliable Adaptive Distributed Systems Laboratory Archived at http://bishop.camp.clarkson.edu/Cloud_Computing_Papers/berkely-abovetheclouds.pdf.
3. Ballmer S (2010a) Cloud Computing Remarks by Microsoft CEO Steve Ballmer Microsoft News Centre Archived at http://www.microsoft.com/en-us/news/exec/steve/2010/03-04Cloud.aspx.
4. Behrend TS, Wiebe EN, London JE and Johnson EC (2011) Cloud computing adoption and usage in community colleges. Behaviour & Information Technology 30(2), 231-240.
5. Benlian A and Hess T (2011) Opportunities and risks of software-as-a-service: Findings from a survey of IT executives. Decision Support Systems 52(1), 232-246.
6. Berman F and Hey T (2004) The scientific imperative. In The Grid 2: Blueprint for a New Computing Infrastructure (Foster I and Kesselman C, Eds), pp 13-23, Morgan Kauffman, San Francisco.
7. Brodkin J (2009) 10 Cloud Computing Companies to Watch (18 May) Archived at http://www.networkworld.com/supp/2009/ndc3/051809-cloud-companies-to-watch.html?page=1.
8. Brynjolfsson E, Hofmann P and Jordan J (2010) Economic and Business Dimensions Cloud Computing and Electricity:Beyond the Utility Model. Communications of the ACM 53(5), 32-34.
9. Clarke R (2012) How reliable is cloudsourcing? A review of articles in the technical media 2005–11. Computer Law & Security Review 28(1), 90-95.
10. Cubitt S, Hassan R and Volkmer I (2011) Does cloud computing have a silver lining? Media Culture & Society 33(1), 149-158.
11. Cusumano M (2010) Cloud Computing and SaaS as New Computing Platforms. Communications of the ACM 53(4), 27-29.
12. Dignan L (2011) Cloud Computing Market:$241 billion by 2020 (22nd April) Archived at http://www.zdnet.com/blog/btl/cloud-computing-market-241-billion-in-2020/47702.
13. Foster I and Kesselman C (2004b) The Grid 2: Blueprint for a New Computing Infrastructure. Elsevier, San Francisco, CA.
14. Greenpeace (2010) Make IT Green: Cloud Computing and its contribution to Climate Change Greenpeace International Archived at http://www.greenpeace.org/usa/Global/usa/report/2010/3/make-it-green-cloud-computing.pdf.
15. Halpert B (2011) Auditing cloud computing : a security and privacy guide. Wiley, Hoboken, NJ.
16. Hodges C (2011) Cloud Computing Rains Cost Savings, Productivity Benefits:Manufacturers are migrating to the cloud to increase cost savings and productivity. IndustryWeek, Penton Media.
17. Iyer B and Henderson J (2010) Preparing for the Future: Understanding the Seven Capabilities of Cloud Computing. MIS Quarterly Executive 9(2), 117-131.
18. Kirsker H (2012) 10 Cloud Predictions for 2012 Forrester.com Archived at http://blogs.forrester.com/holger_kisker/11-12-13-10_cloud_predictions_for_2012.
19. Krutz RL and Vines RD (2010) Cloud security : a comprehensive guide to secure cloud computing. Wiley, Indianapolis, IN.
20. Lohr S (2007) Google and IBM Join in 'Cloud Computing' Research New York Times (8 October) Archived at http://www.nytimes.com/2007/10/08/technology/08cloud.html.
21. McAfee A (2011) What Every CEO Needs to Know About the Cloud. Harvard Business Review 89(11), 124-.
22. Nikolov GI (2011) Cloud computing and government : background, benefits, risks. Nova Science Publishers, New York.
23. Owens D (2009) Securing elasticity in the cloud. Communications of the ACM 53(6), 48-51.
24. Regalado A (2011) Who Coined "Cloud Computing"? Technology Review (31 October) Archived at http://www.technologyreview.com/business/38987/.
25. Ryan M (2010) Viewpoint: Cloud Computing Privacy Concerns on Our Doorstep. Communications of the ACM 54(1), 36-38.
26. Sarkar P and Young L (2011) Sailing the cloud: a case study of perceptions and changing roles in an australian university. In 19th European Conference on Information Systems (Tuunainen V, Nandhakumar J, Rossi M and Soliman W, Eds), Helsinki, Finland.
27. Shroff G (2010) Enterprise cloud computing : technology, architecture, applications. Cambridge University Press, Cambridge.
28. Smith R (2009) Computing in the Cloud. Research-Technology Management 52(5), 65-68.
29. Stevens M (2009) What Cloud Computing Means to You: Efficiency, Flexibility, Cost Savings IT Business Edge Archived at http://www.itbusinessedge.com/offer.aspx?o=00820001search.
30. Vouk M (2008) Cloud Computing - Issues, Research and Implications. Journal of Computing and Information Technology - CIT 16(4), 235-246.
31. Willcocks LP, Venters W and Whitley EA (2011b) Cloud and the Future of Business: From Costs to Innovation Five Reports: Promise, Challenges, Impact, Innovation and Management Accenture and the Outsourcing Unit Archived at http://outsourcingunit.org/publications/.
32. Yoo CS (2011) Cloud Computing: Architectural and Policy Implications. Review of Industrial Organization 38(4), 405-421.
33. Zhang Q, Cheng L and Boutaba R (2010) Cloud computing: state-of-the-art and research challenges. Journal of Internet Service Applications 1(1), 7-18.