

Cloud computing service providers: A comparative study

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Abstract

With the advances in ICT infrastructure, a new technology has emerged, that is cloud computing. Cloud computing is one of the most significant technologies enabling companies to manage their resources, and to save and share data safely through the internet. Choosing the right cloud computing platform which meets the company's needs is not easy to handle task. In this Paper, the main three cloud computing platforms, namely, Google, Microsoft, and Amazon, were studied. Also, these platforms were compared and classified according to the possibilities they offer. This study aims at helping companies to choose the right cloud computing platform which meets their needs and requirements.

Introduction

Nowadays, and maybe without paying due notice to the fact, cloud computing is used by many people to share files with friends or colleagues. Therefore, people don't have to be in the same place every time to be able to work from anywhere and share any file. Cloud computing is an emerging field which is growing exponentially as is the case with its application. This technology can be used in making applications accessible from anywhere and pay only for the use [1]. With cloud computing, users use a range of devices, including personal computers, smart phones, notebooks, to access platforms, storage, and programs for the development of applications over the web, through services presented by cloud providers. The main advantages of using cloud computing technology are: cost reduction, mobility (access from any device and any place), pay for use, always updated technology, scalability, security, and less need for maintenance [2].

Cloud Computing: An Overview

Cloud computing uses a built-in virtualization technology that permits the rental of physical infrastructure for small pay per use compared to the old ways of designing web software. In addition, it provides cloud platform tools to accelerate the development process. Cloud computing is a model which allows easy, on demand access to a shared set of configurable computing resources (for instance, storage, servers, networks, services, and applications) that can be provisioned and released quickly with minimal interaction with the service provider or minimal management effort [3,4].

Features of Cloud Computing

Cloud computing has several features as shown in figure 1:



Fig. 1: Cloud Computing Features

- **Agility:** the ability to quickly deliver advanced technology resources to the user by the supplier.
- **Cost-effective:** cloud computing can reduce spending in software, hardware, renewal fees, and licensing. Cloud Computing avoid hiring IT personnel and saves energy consumption. Cloud computing is use based, i.e., pay to the services provider only for what is actually used, just when needed [5].
- **Scalability and Elasticity:** cloud computing provides resources in almost real time, without users needing long-term duration. Cloud computing supports businesses to grow without having to make costly changes to the already existing systems. With cloud platform, companies can scale up or scale down their businesses as needed [6].
- **Remote Access:** users can access the systems via a web browser, from any location and from any device they use (Smartphone, PC, etc.).
- **Virtualization Technology:** allows the sharing of storage devices and servers, in addition to the ability to migrate applications from one server to another easily.
- **Performance:** allows to optimize and control the use of resources automatically with a high level of transparency for both the service provider and the customer.
- **Built-in Security:** with cloud computing, security can be improved due to the centralization of the data. Security in the cloud is considered to be same as or even better than other traditional systems, this is partly due to the ability of service providers to allocate resources to solve security problems that customers cannot afford.
- **Simplified IT Management and Maintenance:** there is less demand for in-house IT staff, because the hardware is being owned by service provider and stored in off-site locations.

If there is a need for repair or upgrade hardware, it is the responsibility of the service provider and, in turn, it will not cost users any time or money [2].

Cloud Computing for End Users

Cloud computing allows users to access data and run applications from any computer, from any place, at any time, without the need to install or update any applications manually on a local computer or server. This is one of the most important features of cloud computing that has made cloud computing popular today. Cloud computing makes it easier to do work at any time and from anywhere.

Cloud Computing for System Administrators

The superiority of the cloud model comes from realizing that desktop applications are static to some extent, and cloud applications can be continuously refined. Desktop applications must be manually installed on a local computer, updated, and reinstalled when the user moves to a new computer [7]. Cloud computing preclude all of such complexity and inconveniences.

Cloud Computing for Software Developers

Cloud computing is a cloud application, so there is no need to have anything installed on the desktop. All updates take place at the back end, a process which does not require action, patience or attention of the end user. Thus, developers can continuously and easily develop their applications and make these updates available to users in real time.

Upon reaching a deeper level of the cloud platform, cloud computing offers developers a wide range of services that have been proven robust, making applications more stable and faster as well [8].

Types of Cloud Models

There are four models of cloud:

- 1. Public Cloud** is a computational cloud maintained and managed by third parties. In public cloud both the processes and the data of several clients are mixed in the storage systems, servers, and other cloud infrastructures. End client of the cloud do not know what other users may be running on the same storage systems, server, network, etc. [2]. Storage systems, applications, and other resources are available to the public through the cloud service provider who owns the whole infrastructure in its data centers. Access to services is only offered remotely, usually through the internet. An example of this model is Gmail.
- 2. Private Clouds** are the best choice for companies that require a high level of protection for their data. Private clouds are in an infrastructure on demand, managed by one client who controls what applications should work and when. In private clouds, companies own the storage disk, network, and server and can decide which users are authorized to use the this infrastructure. Internal management of services gives companies preference in maintaining the privacy of their information and allows unifying of access to corporate applications for their users. An example of this model is the data centers in which the servers and infrastructure of a particular organization are maintained and that host their applications and data.

3. Hybrid Clouds combine public and private cloud models. In hybrid clouds, the user can own some parts and share others. A user owns some parts and shares others, through a controlled manner. This model offer the promise of on demand scaling and external provision, but with additional complications in determining how applications are distributed across these different environments [9].

4. Community Cloud is one of platform that allows multi-tenants to work on the same platform, where these companies have the same concerns or function (policy, security, compliance, etc.). An example of this is testing a new security product. Community cloud is managed internally or by third parties and hosted internally or externally [2].

Cloud Computing Service Models

Cloud service models are divided into three main sections as shown in figure 2; Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS):

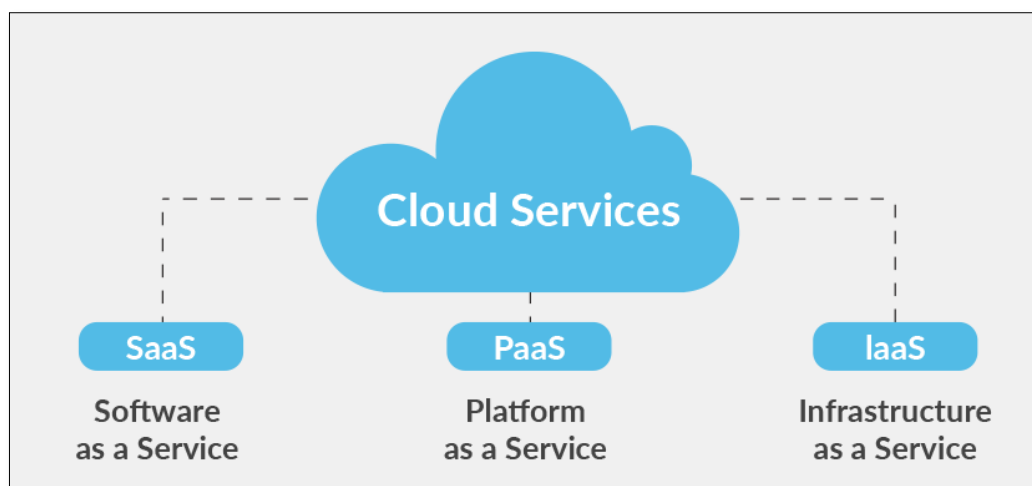


Fig. 2: Cloud computing models

1. Software as a Service (SaaS): provided by delivering virtual computing infrastructure such as servers, hardware, and networks online. Cloud computing users can install and run an application that is located in a central server from a client's computer [10].

Features:

- Access and administration through a network.
- Activities managed from central locations.
- The distribution of the application is closer to the one-to-many model.
- Centralized updates.

2. Infrastructure as a Service (IaaS): supplies organizations with equipment on an outsourced basis used to support organizations' operations. This includes storage, servers, hardware and network components [2].

Features:

- The provider is responsible for the administration of computer equipment.
- Payment for use.
- Scalability.
- Platform virtualization.

3. Platform as a Service (PaaS): comprises platforms provisioned by service provider at its data center, to create and run applications where customer can access software over the internet via a standard web browser [10].

Features:

- In addition to solving hardware infrastructure problems, the cloud provider also handles the software. The user does not need to install, update, or maintain operating systems, application of servers, and databases since all this is provided by the platform.
- PaaS solves more problems compared to IaaS, since IaaS has many limitations related to the execution environment. Among these is the type of system, the programming language, the database manager.
- Uses sophisticated tools affordably. Companies like Amazon, Google, and Microsoft are some of the companies using this model and making it possible to access new capabilities, such as analytics tools and business intelligence, that users cannot explicitly purchase.
- PaaS offers a faster model and cost-benefit for application development and delivery.
- Platform virtualization.

Trends of Cloud Computing

Companies currently use cloud computing for the following reasons:

- Financial need
- Support from leading software providers
- Small business demand for distinctive features
- Demand of business users for solutions that bring them more profits
- Need for new collaborative methods and tools
- Cloud computing technology has already passed the initial testing stage

In addition, the main software providers have many offers for the new demand of the cloud computing market. With cloud computing, small business companies have the cloud at their disposal, and, as well, the leading vendors such as Microsoft, Google, Amazon and even Apple offer a wide range of cloud-based services and applications [11].

Another feature is the decentralization of the workplace, telecommuting and solutions that require collaboration technologies to work, which is now only possible through cloud technology. The main forecasts for the near future of cloud computing are:

- Demand for cloud infrastructure will rise and prices will fall.
- The development in the cloud will become increasingly easier for users.
- The physical offices will gradually disappear, because all services will be available in the cloud.
- Companies decentralize, which will lead to a higher level of outsourcing.
- Smartphones can be used as real work machine, which is happening step by step.
- Cloud computing will progressively replace huge local implementations with a more modular approach [12].

Cloud Computing Platform Providers

Various companies provide cloud computing services; however, the main cloud computing platforms are Google Cloud, Microsoft Azure, and Amazon (EC2).

Google Cloud Platform

Google cloud platform is a set of cloud services which operates on the same infrastructure that Google uses internally for end-user products as for instance, YouTube, Google Maps, and Google Search.

One of the services offered by Google is Google App Engine or also more commonly known as GAE or App Engine. It is Google-managed cloud computing platform for developing and hosting web applications, it was launched on April 7, 2008 as a cloud service [13].

App Engine allows to build scalable web applications in any programming language on Google's infrastructure. With GAE, applications can be created, maintained and updated easily. Through the appspot.com domain, applications can be published using a free domain name. Applications can be shared with everyone or they come with a limited access to individuals of organization.

Google App Engine provides two types of environment; flexible and standard environments. User can run applications using the flexible or standard environment. Flexible environment automatically scales up and down application while balancing the load, whereas standard environment uses preconfigured container instances. Table 1 illustrates some of the differences between the two environments [14].

Table1: Differences between the two environments [14].

Feature	Flexible environment	Standard environment
Startup time	Minutes	Seconds
Background processes	Yes	No
Background threads	Yes	Yes, with restrictions
SSH debugging	Yes	No
Scaling	Manual, Automatic	Basic, Automatic, Manual
Scale to zero	No, minimum one instance	Yes
Writing to local disk	Yes, ephemeral (disk initialized every time Virtual Machine startup)	• Java, Go, Python, Java, Ruby, Node.js, and PHP (have read and write access to the/tmp directory). • Some versions of PHP, Go, and Python (don't have write access to the disk).
Modifying the runtime	Yes	No
Deployment time	Minutes	Seconds
Access to Services & App Engine APIs such as Images API, Users API, NDB, and others.	No	• Yes: for some versions of PHP, Java, Python, and Go • No: for some versions of PHP, Java, Ruby, Python, Node.js, and Go
Network access	Yes	• Yes: for some versions of Python, Node.js, Ruby, Java, Go, PHP.

		• Some versions of Go, PHP, and Python: Only through App Engine services (billing-enabled).
possibility of installing a third-party binaries	Yes	• Yes for some versions of PHP, Node.js, Python, Java, Go, and Ruby. • No for some versions of PHP, Go, and Python.
Location	Europe, Asia Pacific, North America	Europe, Asia Pacific, North America
Pricing	Based on usage of memory, vCPU, and persistent disks.	Based on instance class and instance hours

With standard environment, Google App Engine service allows to create a free account with some usage limits.

Google App Engine service offers another option, that is "free trial". This free trial gives the user the opportunity to get to free resources to use Google Cloud Platform (GCP) for a specified period of time and within a specified amount of credit. Free trial ends when user spends all of the credit, or at the end of the specified period. After that, user must upgrade to a paid account to continue using Google Cloud Platform.

Google App Engine is a high-performance Platform as a Services that works with a variety of storage options, including Cloud SQL, Blobstore, and Datastore. In addition, the engine also provides access to the search API.

App Engine permits the creation of web applications on the same scalable systems with which Google applications work, comprising of several features [14]:

1. High scalability.
2. Payment for use.
3. Hardware and system maintenance expenses will not be necessary: user will not have to worry about hardware, it will be the responsibility of Google to do the work.
4. Supports various programming languages such as: Java, Python, PHP, GO, Node.js, Ruby, and .Net.
5. User can run, and test an application locally via using the Google Cloud SDK which is containing tools that simulate the application running in App Engine [15].
6. Reliable and officially supported by Google.
7. Safe environment: The applications are hosted in highly secure servers.

Google cloud platform has many other services within IaaS, and SaaS, like Cloud Compute Engine, and Google Docs.

Microsoft AZURE

Azure platform is a combination of cloud services offered by Microsoft. Microsoft is having hundreds of data centers, with a lot of resources, which can be used by individuals or companies from anywhere in the world, paying only for what is used. In addition to storing a database in the cloud, it allows to offer advanced platform services. A feature which forms an important difference with other cloud platforms.

Azure is a cloud platform which is presented as a service, and hosted in Microsoft Data Centers. It was first announced on October 27-30, 2008 in its beta version, then it became a commercial product on January 2010 [16]. Azure provides various services for applications, such as hosting applications in Microsoft data centers and running them on its infrastructure in addition to secure communication services and the federation between applications.

StorSimple service is the Microsoft's hybrid online cloud storage which contains main storage, backup and archiving. This service can be accessed through an Azure-based portal. StorSimple offers AES-256 encryption, and disaster recovery to any data center.

One of the other services that Azure provides is its Machine Learning service. There is no benefit from collecting large amounts of data unless this data is analyzed, so Microsoft has successfully applied advanced machine learning to its business and to its advanced analyzes and made it available to a wide audience. The service includes Machine Learning Studio for the creation and evaluation of predictive analytics solutions.

Microsoft relied on a way to protect important information through automatic backups that were available within the storage service, in addition to the encryption process that occurs before the transmission process as it is stored encrypted in Windows Azure. These backups are off-site, away from user's data center, which reduces the need to secure and protect the data backup in place. Incremental backups can also be used to ensure efficient storage use and reduce bandwidth consumption, while allowing in a timely manner several data versions to be recovered.

Within the platform, Azure service is responsible for providing applications hosting and non-relational storage. It can be developed in PHP, NET, Java, C ++, Ruby, etc. In addition to the execution services, Azure has different data services; Azure Blobs, Azure Files, Azure Tables (NoSQL store for structured data), Azure Storage Queues (for reliable messaging within and between services) [17].

Azure allows easy creation and managing of highly available and scalable applications. Azure makes use of the Fabric Controller to ensure that all hosted applications receive the required computing resources, computing power, and network. Fabric Controller is a distributed program that is used internally by Azure to manage hardware and applications as it assign appropriate resources to an application depending on the number of roles, number of role instances, and the fault domains and upgrade specified by the application. Fabric Controller also ensures that all hosted applications are efficiently distributed among the resources [18].

Windows Azure uses the Content Delivery Network (CDN) for caching data that is frequently accessed near its users, geographically closest to the user, to speed up access such data and to decrease latency.

Microsoft SQL Azure service is a cloud database based on SQL Server technologies. SQL Azure services include: Azure SQL Database, Azure SQL Reporting, and Azure SQL Data Sync.

The key-features of Microsoft SQL Azure are:

1. High Availability.
2. Payment for use.
3. Supports various programming languages.
4. Security.
5. Scalability.
6. Cost-Effectiveness.

With Microsoft Azure, user can create a free account (with specific period and credit) of free using of services to explore any of the services provided by Azure, and more than 25 services which will always be free [19].

Amazon EC2

Amazon Elastic Compute Cloud (Amazon EC2) is a main part of the Amazon cloud platform that called Amazon Web Services (AWS). EC2 allows clients to rent virtual computers to run their applications.

With Amazon EC2, a user can start an Amazon Machine Image (AMI) to create a virtual machine called "Instance". User can create, start and terminate instances as necessary, with the hourly payment for servers in active. EC2 provides users with control over geographic locations of instances that allow optimization of high levels of redundancy.

Amazon EC2 depends on virtualization technology, that allows users to use multiple operating systems; such as Windows Server, Ubuntu, Amazon Linux, and Debian; through its web service interfaces, customize them, run as many systems as they want, and manage network access permissions.

Amazon EC2 has a web services interface to start and configure the service. It provides complete control of resources and reduces the startup time of servers, allowing user to quickly scale resources according to user needs. It also provides strong isolation against other processes performed on their machines and data recovery tools [20].

Amazon EC2 provides users with four data storage options, with unique combination of durability and performance of each one, to be used with instances independently or in combination, to fit user requirements. These options are Amazon EC2 Instance Store, Amazon Elastic Block Store (EBS), Amazon Simple Storage Service (Amazon S3), and Amazon Elastic File System (Amazon EFS) [21].

Amazon Elastic Block Store (EBS) is a block level storage device that can be linked to a single instance and used as any other physical hard drive. EBS can be used with data that requires frequent updates as primary storage or storage of a database application. furthermore, EBS supports a lot of storage features, including snapshot to hold a backup of the data, which is stored in Amazon S3. Simple Storage Service (S3) is a storage system in which data is accessible at the request of EC2, or anywhere on the web. The storage cost in S3 is paid for every gigabyte/month.

Amazon EC2 provides user's account with elastic IP address which is a public IP address (reachable from the Internet) designed for dynamic cloud computing. Its function is similar to the static IP address in traditional data centers, with a key difference. User can assign an IP address to any virtual machine instance without having to wait for the DNS to propagate the binding and without the help of a network administrator. In this sense, an elastic IP address belongs to the account and not to a virtual machine instance.

With Amazon EC2, users can monitor and manage their service. Amazon CloudWatch is a service that enables users to near real-time monitoring their use of resources, such as CPU, memory, and disk space. AWS management console is responsible for aggregated and providing data. This data can be accessed through the command line tools and Web API if user wants to monitor their resources through the company's monitoring software. The indicators collected by CloudWatch allow for the automatic scaling function to dynamically add or remove instances of EC2. User must pay for the number of surveillance cases [22].

The main features of Amazon EC2 are:

- Easy to use
- Scalable and high-performance
- Secure
- Reliable
- Flexible
- Cost-Effective

Amazon offers a free tier that allows users to try out most of AWS services with some limitations such as storage and usage hours [23].

Comparison of Platforms

To evaluate the possibilities of the main platforms studied, a comparative analysis method has been applied to the cloud computing giants as detailed in table 2.

Table 2: Comparison of main cloud computing platforms.

	Google Cloud [23]	Microsoft AZURE [19]	Amazon [24]
Initial release date	2008	2010	2006
Cloud Service models	PaaS SaaS IaaS	PaaS SaaS IaaS	PaaS SaaS IaaS
Billing	Pay per hour or month. Discounts proportional to consumption hours (on average a 24% discount)	Pay per hour, except virtual machine (per minute). Discounts on contracts of 1 or 3 years.	Payment per hour or per Second, with a one-minute minimum. Discounts on contracts of 1 or 3 years (Only for Reserved Instances).
Backups	Make On-demand backups or Automated backups copies around the world.	Make 3 copies in the same geographical area, Possibility of duplicating copies to other areas.	Make 3 copies in the same geographical area, Possibility of duplicating copies to other areas.

Worldwide availability	20 regions worldwide. More than 200 countries.	54 regions worldwide. 140 countries.	25 regions worldwide. 206 countries.
Support	24x7 Free support (access to knowledge center). 4 hours response time: \$100 per month 1-hour response time: \$250 per month.	24x7 Free support (access to knowledge center). 8 hours response time: \$29 / month, via email. 2 hours response time: \$100 / month, via email and phone	Free support (access to knowledge center). Contact by email during office hours: \$29 /month. 24x7 phone, email, and chat contact with 1-hour response time: \$100 /month.
Virtual Machine Types	59	195	170
Volume Type	Network-attached HDD, Locally-attached SSD, or Network-attached SSD	Standard HDD, can be customized to SSD	The default: General Purpose SSD, it can be customized to highest performance SSD or HDD
Other Cloud Services	Computing and hosting, Networking, Storage, Databases, AI and Machine learning, API management, Data Analytics, Internet of Things, Networking, Security	Computing, AI and Machine Learning, Storage, Databases, Office 365, Internet of Things, Data Analytics, Management and Governance, Networking, Security	Data Analytics, Storage, Databases, Computing, Internet of Things, Machine learning, Networking and content delivery, Security
Security	40 certifications	87 certifications	25 certifications
Stability	99.99% monthly availability. Between 99.00% and 99.99%: 10% penalty. Between 95.00% and 99.00%: 25% penalty. Below 95%: 50% penalty.	99.95% monthly availability. Between 99.00% and 99.99%: 10% penalty. Between 95.00% and 99.00%: 30% penalty. Below 95%: 100% penalty.	99.99% monthly availability. Between 99.99% and 99%: 10% penalty Between 99% and 95%: 30% penalty. Below 95%: 100% penalty.
Server Migration	Accept VMware. No cost.	Accept Hyper-V, VMware, and physical servers. In most cases, no cost	Accept VMware and Hyper-V servers. No cost.

Conclusion

Cloud computing has come to establish itself more and more formally, contributing with solutions which are increasing in a way that makes more users integrate to this way of working. There are several major providers who provide cloud computing services. The three most popular cloud computing platforms are Google, Microsoft, and Amazon. In this paper, these suppliers were studied and compared from different aspects.

In general, all platforms have very good documentation, many manuals, and free trial account to start using them from scratch. Each cloud service provider offers multiple services, tools, functionalities, and applications.

Amazon provides an effective way to calculate the cost of the service as it depends on pay per hour or per second, with a one-minute minimum, while other platforms depend only on pay per hour or month. In addition, it provides the least response time and price for technical support better than other platforms.

On the other hand, Azure provides the largest set of virtual hardware resources available to create a virtual machines to meet customer needs. In addition, Azure have the largest number of compliance certificates.

Both Amazon and Azure offer a penalty downtime better than Google in the event that the uptime falls below 95%. On the other hand, Azure outperforms other platforms in the possibility of server migration from several different types of virtual machines or physical servers. What all users have to do is just determine what their priorities are in order to choose a suitable service provider that meets their aspirations.

A comparative study is still required between cloud models and cloud methodologies, and/or between other cloud computing platforms.

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مزودو خدمة الحوسبة السحابية: دراسة مقارنة

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معلومات البحث:	الخلاصة:
تاريخ الاستلام: 2020/01/09 تاريخ القبول: 2020/02/09	ظهرت تكنولوجيا جديدة هي الحوسبة السحابية مع التقدم الكبير الحاصل في البنية التحتية لتكنولوجيا المعلومات والاتصالات. تعد الحوسبة السحابية واحدة من أهم التقنيات التي تمكّن الشركات من إدارة مواردها وحفظ البيانات ومشاركتها بأمان عبر الإنترنت. إن اختيار منصة الحوسبة السحابية المناسبة التي تلبي احتياجات الشركات ليست بالمهمة السهلة. في هذا البحث، تمت دراسة المنصات الأساسية الثلاثة للحوسبة السحابية، وهي منصة Google ومنصة Microsoft و منصة Amazon. كذلك تمت مقارنة هذه المنصات وتصنيفها وفقا للإمكانيات التي توفرها. لذلك هدفت هذه الدراسة إلى مساعدة الشركات على اختيار منصة الحوسبة السحابية المناسبة التي تلبي احتياجاتها ومتطلباتها.
الكلمات المفتاحية:	
الحوسبة السحابية، منصة كوكل السحابية، منصة امازون السحابية، منصة ازور السحابية.	