Cloud Service Providers: A Comparative Study

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Abstract — Cloud computing is a new emerging technology that is expected to significantly change the field of IT in the next few years. Today, numerous cloud services are provided by leading enterprise companies such as Amazon, Microsoft, and Google in the form of customized, reliable and cost-effective web applications. These services attract many individuals and organizations from different disciplines such as health, business and education. In this paper we aim to introduce the most popular Cloud Service Providers (CSPs) to cloud customers. We also provide a comparison between these CSPs with respect to different criteria related to the services they provide. The study presented in this paper helps individuals and organizations make critical decisions on benefits and cost of cloud technology before they move their business to this new environment.

Key words — Cloud computing, Cloud Service Providers, SaaS, PaaS, IaaS.

1. INTRODUCTION

The basic concept of cloud computing appeared in the 1950s, when enterprises and learning institutes increased the efficiency of their large-scale mainframe computers to allow multiple user to access computers simultaneously from multiple terminals via shared central processing unit. After the dot-com bubble burst in the early 2000s, companies such as e-tail giant Amazon.com Inc. played a key role in the development of cloud computing. The present availability of high-capacity networks and low-cost computers, together with the widespread adoption of virtualization and service-oriented architecture, have led to the version of cloud computing we know today. It is a recent trend in IT that moves computing and data away from desktop and portable PCs into large data centers [1]. It simply means the delivery of computation recourses such as CPU, memory storage, and networks over the Internet.

The National Institute of Standards and Technology (NIST) defines cloud computing as: "*Cloud computing is a model for enabling 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"* [2,5]. The ultimate goal of cloud technology is to increase usability of distributed resources working together to achieve high availability and reliability with minimum cost. This technology is also associated with many useful characteristics such as virtualization, scalability, and quality of service [3,4].

Cloud Service Providers (CSPs) (e.g., Google, Microsoft, Amazon) are vendors who lease to their customers cloud services that are dynamically utilized based on customer's demand. The relationship between cloud customers and CSPs is organized according to a certain contract called Service Level Agreements (SLA). CSPs provide to their customers four main types of cloud as shown in table 1, these types are Public Cloud, Private Cloud, Community Cloud and Hybrid Cloud. They also offer three main categories of cloud services as described in table 2, these categories are: Infrastructure as a Service (IaaS): Platform as a Service (PaaS) and Software as a Service (SaaS) [13].

Table 1: Types of cloud computing offered by CSPs

Deployment model	scope of services	owned by	managed by	security level	location
public	general public and large industry groups	CSP	CSP	low	off premise

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private	single organization	single organization	single organization or CSP	high	off or on premise
community	organizations that share the same mission, policy and security requirements	several organizations	several organizations or CSP	high	off or on premise
Hybrid	organizations and public	organizations and CSP	organizations and CSP	medium	off and on premise

Table 2: A comparison between cloud service models

	Application Software	Operating System	Virtual recourses/ HW
SaaS	CSP	CSP	CSP
PaaS	customer	CSP	CSP
IaaS	customer	customer	CSP

This paper aims to introduce the most popular CSPs and their services to cloud customers. It also provides a comparison between CSPs in order to help individuals and organizations make critical decisions on benefits and cost of cloud computing services and applications before they move their business to this new emerging environment. The rest of this paper is organized as follows: in section 2, we summarize the most important characteristics of cloud computing, in section 3, we introduce the most common CSPs and illustrate the services they provide to customers, in section 4, we compare CSPs based on different criteria, and finally, in section 5, we give our conclusion remarks and future work.

2. CLOUD COMPUTING CHARACTERISTICS

Cloud computing technology introduces many interesting characteristics that make it a promising solution for many challenge that face individuals and organizations [14-25]. Among these characteristics are:

a) *Scalability:* The cloud is a large scale solution, for example Google, Yahoo, Amazon have hundred thousands of servers around the world. CSPs can add new nodes and servers to cloud with minor modifications to cloud infrastructure and software.

b) *Virtualization:* Cloud isolates physical resources from users at the virtual level, hence, users can reach any resources they need without having to worry about physical interconnection detail.

c) *Reliability:* Using multiple redundant computational nodes (replication) insure the high reliability of services and makes cloud more reliable than local computers.

d) *Versatility:* Cloud computing doesn't aim to certain special application. A lot of applications are supported by the cloud and can be run in parallel.

e) *Elastic Resource Pooling:* Users view cloud as if it is an infinite pool of resources that can be rapidly and elastically provisioned and released based on their demand.

f) *On Demand Measured Services:* You can lease services according to your need; cloud services are just like water, electricity, and gas that can be charged by the amount you used.

g) *Economic:* Cloud can be built by very inexpensive nodes and the centered management makes the enterprise avoid the management cost of data centers that increases very fast.

h) *Maintainability:* The maintenance of the infrastructure, be it hardware or software, is the responsibility of CSPs. This put less headaches on the IT team in an organization.

i) *Easy Management:* Applications that are quite storage extensive are easier to use and manage in the cloud environment compared to inside the organization. Also at the user level, what you mostly need is a simple web browser with internet connectivity.

j) *Cost Reduction:* Cloud computing drastically reduces the IT spending for SMEs. Costly systems need not be required for occasional use of intensive computing resources. Also the man power required for such systems is highly reduced. Even simple applications, such as email, can be set up and mostly free through applications such as Google Apps.

k) *Availability:* Cloud services are quite available from anywhere and at anytime via broadband network access through different types of platform (e.g., mobile phones, laptops, and PDAs). Lower outages are

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provided by CSPs, thus providing uninterrupted services to the user. However, some occurrences of outages have occurred in the past, such as the Gmail outage in 2009. Also other cloud vendors such as EC2 have failed at some point of time, however, they are much more dependable compared to the infrastructure installed on the organization.

l) *Disaster Management:* In case of disasters, an offsite backup is always helpful. Keeping crucial data backed up using cloud storage services is the need of the hour for most organizations. In addition, CSPs ensure that they have systems in place for disaster recovery.

m) *Green Computing:* Harmful emissions due to the extensive use of systems in organizations, electronic waste generated as the time passes and energy consumption are the main disadvantage of the present day computing systems. This can be reduced by using cloud computing services which preserves the environment and generates e-waste to minimum extent.

3. CLOUD SERVICE PROVIDERS (CSPs)

In this paper, we focus on the most famous cloud service providers in the IT market. We have chosen seven companies that provide extensive cloud services to compare between them from different perspectives. These companies are described below:

1. *Amazon*

Amazon.com [6] is one of the most popular CSPs, it offers a lot of cloud services including:

- Amazon EC2 (Amazon Elastic Compute Cloud): provides computing capacity on the cloud.
- Amazon S3 (Amazon Simple Storage Service): is dedicated for high reliable storage on the cloud.
- Amazon RDS (Amazon Rational Database Services): provides powerful tools for managing databases on the cloud.
- Amazon Simple DB: provides the core database functions.
- Amazon Rout 53 (Amazon scalable DNS): provides secure routing servers over the Internet.
- Amazon CloudFront: is dedicated for managing and distributing contents over the Internet with high speed.
- Amazon Elastic MapReduce: is a web service that enables customers to process vast amount of data on the Cloud.

2. *Google*

Google [7] joint the cloud market in 2007 by simple services such as email, calendars, online documentation. Now, google has various cloud services such as:

- Compute Engine: an IaaS where customers can run large-scale work load in virtual servers hosted in Google's infrastructure.
- App Engine: a PaaS where customers can develop applications using built-in high performance platforms.
- Cloud Storage: where customers can store any type of files with any size using secure, reliable, storage services from google.
- Cloud SQL: dealing with relational Databases with different DBMS.
- Cloud Datastore: a service to deal with unstructured database.
- BigQuery: with recent big data revolution google provides specific service to process large amount of data.

3. *Microsoft*

In late of 2009, Microsoft starts the cloud services by introducing Microsoft windows Azure [8]. Microsoft windows Azure is a platform on cloud that offers various types of services such as:

- Infrastructure: on-demand, scalable infrastructure with full support and high performance.
- Web development: provides very powerful platform that allows developers to build and deploy web applications.
- Mobile development platform: provides services to build and test a mobile application on the cloud.
- Media: one of the competitive advantages of Microsoft windows azure and is dedicated for creating, editing, and publishing any type of media.
- Storage: a cloud storage solution to manage and process data even if they are regular or large-scale data.

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- Big data cloud: a big data solution supported by apache Hadoop.
- Identity and access management: user can put active directory on the cloud and control access via a single sign.

4. HP

HP [10] is one of famous hardware company in the world with excellent market share in servers and data centers. In last years, HP started to offer cloud services such as:

- HP Cloud Compute: scalable processing power that customers can control and pay as you use.
- HP Cloud Storage: offers range of storage options for individuals and business sectors.
- HP Cloud CDN: refers to Content Delivery Networks and it is a web service that delivers data from HP Cloud Storage to customers around the world at high speed using global network of servers from HP and Akamai
- HP Cloud Relational Database: offers an environment for database developers to configure and process relational databases.
- HP Cloud Application platform: offers a platform that enables an enterprise to develop, deploy and scale application in the cloud.
- HP Cloud DNS: a user can manage his/her DNS zones securely and efficiently.
- HP Cloud Identity Service: provides a single method for managing HP cloud users' identities and authentication.

5. AT&T

AT&T [12] is the leader American international communication and information technologies company. It starts providing cloud computing service with four major services:

- Cloud Compute: provides computing resources for business and individual sectors.
- Cloud Storage: provides Storage as service.
- Network Enablement: provides networking services in cloud by providing VPN to customers.
- Platform as Service: provides platform for developers to develop an application on the cloud.

6. Salesforce

Salesforces [11] mainly focuses on specific cloud applications related to sales and customer relationship management. It provides some cloud products such as:

- Sales Cloud: a platform dedicated for Sales application on the cloud.
- Service Cloud: a platform dedicated for customer service management system on the cloud.
- Platform: as a majority of cloud providers they also provide platform as a service.

7. Rackspace

Unlike previous providers, Rackspace Company [9] focuses on cloud computing as main core business. They have about 11 different cloud services as follows:

- Cloud Servers: on-demand servers featuring local, powerful Intel® Xeon® processors, and 40Gbps of highly available throughput to every host.
- Block storage: fast, reliable storage for I/O-intensive apps. Use standard or SSD volumes, connected to Cloud Servers via fast network.
- Cloud Files: easy-to-use online storage for files and media. Deliver content globally to users over Akamai's content delivery network (CDN).
- Cloud backup: file-level backup for Cloud Servers. Cloud Backup lets users quickly protect and restore important files.
- Cloud Databases: high-performance MySQL databases in the cloud, with built-in redundancy and automated configuration to save time.
- Big Data Platform: production-ready, performance-tested big data clusters on OpenStack-powered cloud, supported by a broad ecosystem of partners.
- Load Balancers: easy-to-configure, reliable failover for high-traffic site or applications hosted on Cloud Servers or Cloud Databases.
- Cloud DNS: allows user to add, modify, and remove domains, subdomains, and records, as well as import and export domains and records.

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- Cloud Networks: fully isolated, single-tenant networks which provides control over network topology, IP addressing (IPv4 or IPv6), and architecture.
- Cloud Queues: a scalable cloud message queue service that allow users to easily connect distributed applications without installing complex software.
- Cloud Monitoring: allows users to stay on top of their infrastructure by receiving alerts anytime their URLs, ports, or protocols need attention.

4. COMPARING CSPs

We compare CSPs described above based on different criteria as shown in table 3. The criteria we used for comparison are listed below:

1) Types of service provided by the CSPs,
2) Key features,
3) Average price of service,
4) Payment plan offered, either monthly based, annual or pay per use,
5) Number of operating system that the cloud services support,
6) For how long this provider offered cloud computing service, this reflects the experience of the provider in the field,
7) Service usability which means how easy can the end users configure and deploy the services and how much help and training the need,
8) Security and privacy protection, based on security certification, we have classified the security levels of the providers into three levels high, medium and low,
9) Quality of service according to SLA
10) Supporting API (application programming interface) to interface with other web services
11) Number of Data centers for cloud computing providers is also an important factor since it increases availability of service, reliability and scalability.

A quick inspection to table 3 revealed that Google cloud provides services with the minimum cost while Sales force is the most expensive. All CSPs offer almost the same basic services (i.e., IaaS, PaaS, SaaS, storage). However, Sales force focuses more on CRM services. Big data analytics is an interesting service for many organization that deal with a vast amount of data and it is provided by Google, Microsoft, and Rackspace. In terms of security, HP has a security level lower that other CSPs and AT&T provides more data centers than the others. We recommend that a customer should choose the CSP that fits his/her needs. For example, if an organization have a low budget, Google cloud would be a good choice. If it works in sales & customer relations, it is better to use slaesfore.com. Also if the organization develop mobile applications, it is better to choose Microsoft azure cloud services. Organizations should choose the CSP that help achieve their business goals.

Table 3: COMPARING DIFFERENT CSPs

Criteria	Cloud Service Providers						
	Amazon	*Google*	*Microsoft*	*HP*	*AT&T*	*Salesforce*	*Rackspace*
Types of cloud services provided	Iaas, Paas, Storge, Database	Iaas,Paas, Storge, mobile, database, Big Data	Iaas, paas, mobile, Media, Database, Big Data	Iaas, Paas, Storage, Database, DNS	Iaas, Paas, Storage, Network	Saas, Paas, Storage, business application	Iaas,Paas, Storage, Database, big Data, Network
Key features	A various cloud services	Including big data and mobile development platform	Including media and mobile development.	Including storage and cloud load balancer, Openstack software	Proving a private network for enterprise	Focusing on sales and CRM application	Provide about 11 different CC products, Openstack software.
Average Monthly price	66 $	42.2 $	65.7 $	87.60$	121$	195$	116$
Payment Plan	Pay per use, monthly	Pay per use	Pay per use, yearly, Monthly	Pay per use	Pay per use	Pay per use, Monthly	Pay per use

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Criteria	Cloud Service Providers						
	Amazon	*Google*	*Microsoft*	*HP*	*AT&T*	*Salesforce*	*Rackspace*
Number of OS Supported	9	2	6	4	2	3	4
Service Age	5+ years	1-2 years	1-2 years	1-2 years	4-5 years	4-5 years	5+ years
Easy to use	Good	Good	Good	Medium	Medium	Good	Good
Security level	High	High	High	medium	High	High	High
Security Certification	yes	yes	yes	no	yes	yes	yes
Integration Standard	Proprietary	Proprietary	hyperV	openstack	VMware	VMware	openstack
Availability as SLA	99.95%	99.95%	99.95%	99.95%	99.9%	99.9%	100.00%
API support	yes	yes	yes	yes	no	yes	yes
Number of Data Centers	8	11	8	3	26	6	9

5. CONCLUSIONS AND FUTURE WORK

In this paper, we made some comparison between most famous cloud computing service providers. This comparison will help individuals and organizations make critical decisions on benefits and cost of cloud technology before they move their business to this new environment. Cloud computing has a very promising potential market. Hence, it needs more effort to explore from researchers and technical specialists. Comparative studies between cloud models, cloud methodologies, and specific cloud techniques are still needed. In addition, innovative solutions to cloud computing security challenges need more investigation.

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