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CLOUD COMPUTING: A REVIEW OF PAAS, IAAS, SAAS SERVICES AND PROVIDERS

CLOUD COMPUTING: UNA REVISIÓN DE LOS SERVICIOS Y PROVEEDORES PAAS, IAAS, SAAS

Mg. María Salas-Zárate
Instituto Tecnológico de Orizaba, México
pilarsalas@acm.org

Mg. Luis Colombo-Mendoza
Instituto Tecnológico de Orizaba, México
lcolombo@acm.org

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Abstract. Cloud computing has become an important factor for businesses, developers, workers, because it provides tools and Web applications that allows storing information on external servers. Also, Cloud computing offers advantages such as: cost reduction, information access from anywhere, to mention but a few. Nowadays, there are several Cloud computing providers such as: Google Apps, Zoho, AppEngine, Amazon E2C, among others. These providers offer Software, Infrastructure or Platform as a Service. Taking this into account, this paper presents a general review of Cloud computing providers in order to allow users, enterprises, and developers select the one that meets their needs.

Keywords: Cloud computing, IaaS, PaaS, SaaS.

Resumen. La computación en la nube se ha convertido en uno de los factores relevantes para las empresas, desarrolladores y trabajadores, porque proporciona herramientas y aplicaciones web que permite almacenar información en servidores externos. Además, la computación en la nube ofrece ventajas tales como: reducción de costos, acceso a la información desde cualquier lugar, por mencionar sólo algunos. Hoy en día hay varios proveedores de computación en la nube como: Google Apps, Zoho, AppEngine, E2C Amazon, entre otros. Estos proveedores ofrecen software, infraestructura o plataforma como un servicio. En este trabajo se presenta una revisión general de los proveedores de computación en la nube, con el fin de permitir a los usuarios, empresas y desarrolladores seleccionar el que se ajuste a sus necesidades..

Palabras clave: Computación en la nube; IaaS, PaaS, SaaS.

1. INTRODUCTION

Cloud computing is a new style of computing in which dynamically scalable and often virtualized resources are provided as a services over the Internet [1]. According to who owns and manages the Cloud services, these can be classified in: Public, Private and Hybrid Clouds. Public Cloud offers services to general public, unlike Private Cloud that are used by a single organization. Also, there are Hybrid Clouds which offer a combination of private and public Clouds. Furthermore, there are three Cloud services models: 1) SaaS (Software as a Service), 2) PaaS (Platform as a Service) and 3) IaaS (Infrastructure as a Service). IaaS offers an infrastructure of resources (storage, databases, among others), usually in terms of Virtual machine as a service. PaaS offers an environment oriented to the development, testing, deployment and hosting of applications. SaaS offers a set of applications installed and running over Internet. This paper presents a review of PaaS, SaaS and IaaS providers, with the aim of helping users to select the provider that best suits their needs and budget.

This work is structured as follows. In section 2 related works of Cloud computing are discussed. Section 3 presents the architecture and features of Cloud computing. Section 4 presents the public, private and hybrid Cloud services. In section 5 a comparison of IaaS, SaaS and PaaS providers is presented. Finally, we present our conclusions and emphasize our contribution.

2. RELATED WORK

In [2] discuss both features and benefits of Cloud computing, and the Infrastructure as a Service (IaaS). Also, they provide a means of understanding and investigating IaaS. They outline the responsibilities of IaaS providers and the facilities to IaaS consumers. In [3] present the design of a trusted Cloud computing platform (TCCP) that enables IaaS services such as Amazon EC2 to provide a closed box execution environment. TCCP guarantees confidential execution of guest Virtual Machines, and allows users attesting the IaaS provider and determining if the service is secure before they launch their Virtual Machines In [4] describe a PaaS architecture for provisioning of real-time service-oriented application in Clouds. Also, they show how the combination of methods, tools and services can be used to improve the usability, maintainability and efficiency of services targeting Clouds with strict QoS constraints. In [5] propose a taxonomy which identifies and classifies eight important elements that characterize Cloud computing infrastructures: 1) service type, 2) resource deployment, 3) hardware, 4) runtime tuning, 5) security, 6) business model, 7) middleware, and 8) performance. The taxonomy is based on a survey conducted on an important set of seven IaaS providers, six Web hosting companies, and two mixed PaaS and Web hosting providers. In [6] present a Cloud services comparison based on aspects such as architecture, features, and application. In [7] present a survey of Cloud computing, highlighting its key concepts, architectural principles, state-of-the-art, implementation as well as research challenges. Also, they provide a better understanding of the design challenges of Cloud computing and they identify important research directions in this area. In [8] examine the available Cloud computing services and propose a tree-structured taxonomy which offers a common terminology and baseline information for easy communication. In [9] analyze public quality information of Cloud services in terms of service types, also they show that IaaS quality information is more detailed and balanced than those of PaaS and SaaS. In [10] present a detailed comparison of Cloud services according to the Cloud types, interfaces, compatibility, implementation, deployment requirement and development support.

3. CLOUD COMPUTING

According to NIST(National Institute of standards and Technology) Cloud computing is defined as *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* [11].
The aforementioned definition has been adopted by a great number of authors. Next, a Cloud computing general architecture is presented.

3.1 Cloud Computing Architecture

A Cloud computing architecture consists of four layers: Hardware, Infrastructure, Platforms and Application. This general architecture is shown in Fig. 1.

The layers of this Cloud computing architecture are described below.

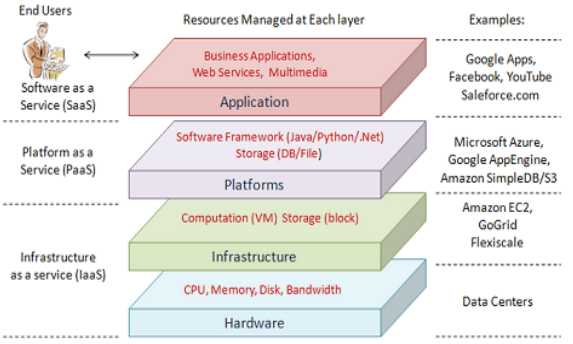

Fig. 1 Cloud computing architecture

Hardware layer: It manages the physical resources of the Cloud, including physical servers, routers, switches, power and cooling systems.

Infrastructure or Virtualization layer: It creates a pool of storing and computing resources by partitioning the physical resources using virtualization technologies such as VMware [12], Xen [13], and KVM [14].

Platform layer: It is composed of operating systems and application frameworks. Its aim is to minimize the burden of deploying applications directly in VM containers.

Application layer: It consists of the actual Cloud applications. In contrast to traditional applications, Cloud applications can leverage the automatic-scaling feature to achieve better performance, availability and lower operating cost [7].

Next, the main features of Cloud computing are described.

3.4 Cloud computing features

On-demand self-service: A consumer can be unilaterally provided of computing capabilities information such as server time and network storage, without requiring human interaction with each service provider.

Broad network access: Capabilities are available over the network and can be accessed through standard mechanisms by heterogeneous thin or thick client platforms such as mobile phones, tablets, laptops, and workstations.

Resource pooling: The provider's computing resources are pooled in order to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to the consumer demand. There is a sense of location independence in that the customer has not control or knowledge over the exact location of the provided resources but he may be able to specify location at a higher level of abstraction (e.g., country, state, or datacenter). Examples of resources are storage, processing, memory, and network bandwidth.

Rapid elasticity: Capabilities can be elastically provisioned and released, in some cases, to scale rapidly outward and inward commensurate with demand. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be appropriated in any quantity at any time.

Measured service: Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported, providing transparency for both the provider and consumer of the utilized service [11].

4. CLOUD TYPES

There are three kinds of Cloud computing services, which vary according to who owns and manages them. Next, these are described.

***Private Clouds or internal Clouds*:** It exclusively offers Cloud services for business or organizations that prefer to keep their data in a more controlled and secure environment.
***Public Clouds or external Clouds*:** It is the most popular type of Cloud computing that offers services that are available to the general public.

Hybrid Clouds: A hybrid Cloud is composed of several public Clouds, private Clouds and/or community Clouds. It offers more flexibility than both public and private Clouds [15]. In Hybrid clouds, part of the service infrastructure runs in private Clouds while the remaining part runs in public Clouds.

5. CLOUD SERVICES

Cloud computing services are classified in three service models: Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a service (IaaS). Nowadays, there are many Cloud Computing providers of each one of the aforementioned models. Some of them are presented below.

5.1 SaaS

SaaS offers already created applications running on a Cloud infrastructure such as: Web-based email, alternatives of typical office applications as word processors, to mention but a few. This model eliminates the need to install and run the application on the customer's local computers therefore applications can be accessed through networks from various clients such as Web browsers, and mobile phones [16], [17].

Examples of SaaS providers are: Zoho [18], AtTask Inc. [19], NetSuite [20], Bloomfire Inc. [21], Smartsheet [22], SalesForce [23], and Google Apps [24], among others. Next, the aforementioned SaaS providers are described.

Zoho: It was founded by Sridhar Vembu in 1996. It offers a comprehensive suite of award-winning on-line business, productivity and collaboration applications. Customers use Zoho Applications to run their business processes, manage their information and be more productive while at the office or on the go, without having to worry about expensive or outdated hardware or software [18].

AtTask Inc: It was founded by Scott Johnson, Jason Fletcher, and Nate Bowler in 2001. AtTask is the SaaS leader in project management solutions and the only provider of Collaborative Work Management. It helps organizations empower their knowledge workers by leveraging the combined power of social collaboration, empowerment, accountability, visibility, and recognition, making it possible for people to take ownership of their work and perform at a higher level, creating an environment that fosters productivity, motivation, and results [19].

NetSuite: It was founded by Evan Goldberg in 1999. NetSuite was one of the earliest SaaS offerings on the market, and its main purpose is to provide integrated business management software to midsize organizations. NetSuite provides a set of features such as customer relationship management (CRM), order fulfillment, inventory, accounting and finance, product assembly, Ecommerce, website management, and employee productivity [25].

Bloomfire Inc.: It was founded in 2010. It incorporates the best features of content management, file sharing, social business, and learning management software to create a collaboration tool perfect for the modern workforce. It allows capturing, displaying, saving, and sharing information, connecting people who have knowledge with those who need it, in order to improving team productivity [21].

Smartsheet: It was founded in 2005 by former executives of CRM company Onyx Software [26]. This is privately held Software as a Service (SaaS) known for its award winning online project management, collaboration, and file sharing features. It is broadly used to track and manage diverse types of work including: team projects and task lists, customer information, sales pipelines, event schedules, and business processes.

SalesForce: It was founded in 1999, and offers a suite of online programs for customer relationship management(CRM) and other business-oriented tasks [27].

Google Apps: It provides several Web applications with similar functionality to traditional office software (word processing, spreadsheets, among others), but also enables users to communicate, create and collaborate in an easy and efficient way. All applications are kept online and they are accessed through a Web browser, users can access their accounts from any internet-connected computer, and there is no need to install anything extra locally [1].

In Table 1 a comparison of providers aforementioned is presented. This comparison was carried out according to the software and price.

TABLE 1. SaaS providers

Provider	Software	Pricing
Zoho	- Collaboration applications: chat, commentBox, docs, discussions, mail, meeting, Projects, share, wiki. - Business applications: Assist, Marketplace, Books, People BugTracker, Recruit, Challenge, Reports, Creator, Site24X7, CRM, Sites, Invoice. - Productivity Applications: Calendar, Sheet, Notebook, Show, Planner, Writer.	- Free plan available (3 apps, 2 users, 1000 records, 2 reports 200 MB storage) - Basic $15/month (3 users, 6000 records, 5 reports, 500MB storage scheduler) - Professional $45/month (10 users, unlimited apps, 20000 records, unlimited reports, 2GB storage, payment module, scheduler, backup) - Enterprise $175/month (50 users, unlimited apps, 100000 records, unlimited reports, 7GB storage, payment module, scheduler, backup) - Free Trial available
AtTask, Inc.	Project Management, Project Reports & Dashboards, Resource Management Team Collaboration, Portfolio Management, Time Management. Help Desk & Issue Tracking, Product Integration, Gantt Chart, Process Improvement.	AtTask offers four license types: Full User, Team Member, View Only, and Requester. Each license type varies in terms of accessibility and functionality.
NetSuite	ERP/accounting, order management/ inventory, CRM, professional services automation (PSA), and Ecommerce	$499 base per month + $99 per user per month. Starting from $499.00/month Pricing model Subscription Free Trial Available
Bloomfire, Inc	Content management, file sharing, social business, and learning management software	- Bootstrap 10 users $99.00/month - Startup 25 users $199/month - small business 50 users $299/month - Free Trial Available
Smartsheet	Project management and collaboration, file sharing.	- Professional a user + unlimited collaborators, 10 or 50 sheets, 3 or 15 GBfile storage $15.95/month. - Team 3 to 200 users+ unlimited collaborators,50 sheets per user, 15 GB file storage per user $49.95/month - Free Trial available
SalesForce	Customizable applications, mostly Customer Relationship Management (CRM) services.	- Contact manager $5/user/month(contact management for up to 5 users) - Group $15/user/month(Basic sales & marketing for up to 5 users) - Professional $65/user/month(complete CRM for any size team) - Free trial available
Google Apps	Email, Calendar, Documents editing and creation, Mobile access, Uptime Guarantee	- Free plan available - Paid $9/app/month - premier $500/account/month

The use of the aforementioned providers depends of the user requirements On the other hand, there are providers such as Zoho and Google Apps that are some of the most used today and they offer a free plan with a variety of available software.

5.2 PaaS

PaaS provides a development environment as a service where applications are developed using a set of programming languages and tools. These services may include development, integration, testing or resources storage to complete the life-cycle of services [28], [29].Examples of PaaS providers are: AppEngine [30], Aneka [31], Force [32], Microsoft Azure [33], Heroku [34], Amazon Elastic MapReduce [35], CloudFoundry[36], among others. Next, the aforementioned PaaS providers are described.

AppEngine: It is a PaaS offering, which provides Python and Java support. AppEngine allows building scalable Web applications without the need for complex underlying hardware and software layers. Google abstracts those layers and lets fully concentrate on the application [37].

Aneka: It is a .NET-based application development Platform-as–a-Service (PaaS), which offers a runtime environment and a set of APIs that enable developers to build customized applications by using multiple programming models such as Task Programming, Thread Programming and MapReduce Programming. Also, Aneka provides a number of services that allow users controlling, auto-scaling, reserving, monitoring and billing the resources used by their applications. One of key characteristics of Aneka PaaS is to support provisioning of resources on public Clouds such as Windows Azure, Amazon EC2, and GoGrid [38].

Force: It is an enterprise Cloud computing platform offered by Salesforce. It allows service venders developing and delivering stable, secure and scalable applications. Two key technologies of Force.com are multi-tenancy and metadata. The idea of the Force.com Cloud solution is that it should take care of all common underlying requirements so that users need only focus on the design of their applications [1].

Microsoft Azure: The Azure Service platform is Microsoft's PaaS offering. Azure is based on the .Net language. It has a dedicated API to store and retrieve data called SQL Services. The underlying system for these SQL Services is Microsoft SQL Server. Although not all functionalities of Microsoft SQL Server are exposed via the API, the user can run transactions and use a restricted SQL query language [39].

Heroku: It is a very powerful Web-based platform which provides support for Ruby, JavaScript and Java Web applications. It directly deploys within a PaaS environment allowing quick migration from the development to deployment stage. It also contains a real time collaborative editor for use with up to five people [40].

Amazon Elastic MapReduce: It is an Amazon Web Service (AWS) that uses Hadoop to provide a MapReduce functionality. In the background itself relies mostly on two other AWS services: Elastic Compute Cloud (EC2) and Simple Storage Service (S3)[41].

CloudFoundry: CloudFoundry is an open-source platform-as-a-service environment offered by VMware that provides the environment to host multiple languages and frameworks in an open stack of software applications that can run on both outside and inside the firewall. The main features of CloudFoundry are: Choice of developer frameworks, Choice of application infrastructure services, and Choice of Clouds [42].

In Table 2 a comparison of the aforementioned providers is shown.

TABLE 2. PaaS providers

	Programming language	*Frameworks*	*Persistence options*	*Pricing*	*Use*
AppEngine	Python, Java (App Engine for Java supports many JVM languages, including BeanShell, Groovy, Scala, JRuby, Jython, and Rhino)	Restlet, Vaading, itsNat, Sweet, Struts 2, Spring MVC, Sinatra, Wicket, Lift, JSF 1.1, GWT, Tapestry, Grails, Slim3, Play Several frameworks based on Phyton e.g. Django, CherryPy, Pylons, web.py, and web2py.	Big Table	Maximum 500 MB storage and 10 apps free for developer	Web applications
Aneka	.NET	Spring .NET framework	RDBMS, SQL Express, MySQL and flat files.	----------	.Net enterprise applications, Web Applications
Force	Apex	----	Own object database	----------	Enterprise Applications
Microsoft Azure	NET, PHP, Java	----	Table/BLOB/ queue storage, SQL Services	Maximum 10 web sites free	Enterprise applications, Web applications
Heroku	Ruby, Java, Python, Scala, Clojure , Node.js	Rails, Sinatra, ramaze, camping, Spring, Grails, Play, Tapestry Twisted, Django	PostgreSQL, Amazon RDS MySQL, SQLite, PostgreSQL, MongoDB, CouchDB	Maximum 5 MB in disk for DB and 50MB for all files including GIT repositories	Web Applications
Amazon Elastic MapReduce	Hive and Pirg, Cascading, Java, Ruby, Perl, Python, PHP, C++	mrjob	Amazon S3	Free 5 GB of Amazon S3 storage, 20,000 Get Requests, 2,000 Put Requests, and 15GB of data transfer out each month for one year	Data Processing
CloudFoundry	Java, Ruby, Scala, Python, PHP, Node.js	Spring, Rails, Sinatra, Grails Lift,	PostgreSQL, MySQL, MongoDB, Redis	service is available immediately at CloudFoundry.com in beta and is free to use. (Pricing will be announced after an extended beta period)	Web applications

AppEngine is one of the most used platforms today because it offers support for a great variety of languages and frameworks for Web applications. However, if a user requires .Net language support would have to choose Aneka or Microsoft Azure. On the other hand, there are providers e.g. CloudFoundry that is still in its beta version, but promises to be a great provider, which is integrating a great variety of languages and frameworks.

5.3 IaaS

IaaS allows managing a large set of computing resources, such as storing and processing capacity and running applications inside virtual machines (VMs) [43].

Examples of IaaS providers are: Amazon E2C [44], Flexiscale [45], GoGrid [46], Joyent [47], Rackspace [48], Arsys [49].

Amazon E2C: It opens Amazon's large computing infrastructure to its users. The service is elastic in the sense that it enables the user to extend or shrink its infrastructure by launching or terminating new virtual machines (instances) [50].

Flexiscale: It is a complete rebuild of Europe's first Cloud computing platform using Flexiant's

revolutionary Cloud technology. The FlexiScale architecture is modular and can accommodate different implementations of its functionality. Virtual Iron is used which is built on the top of Xen Hypervisor and works as an external management layer for the virtual servers [51].

GoGrid: It hosts Linux and Windows virtual machines managed by a multi-server control panel and a RESTful API. It shares many common characteristics with Amazon in the classic Cloud computing areas such as: support for multiple operating systems through its own image management, and load balancing and Cloud storage support [46].

Joyent: It provides hosting, infrastructure, and application services for clients looking to run collaborative applications for their users. Joyent offers compute on demand and Web application virtualization and it helps to successfully scale social network websites such as: LinkedIn and Facebook [52].

Rackspace: It provides compute instances similar to Amazon EC2 and VM role of Azure, which are referred as "Cloud Servers". Rackspace also provides a managed service level for Cloud Servers. As part of the managed service, Rackspace is responsible for applying software and security patches for operating system and middleware [53].

Arsys: It is a European provider of ICT services, including Internet presence, Managed Hosting, Cloud Computing Solutions and ICT Infrastructure. Arsys is placed among the leading European companies in technology and innovation [49].

In Table 3 a comparison of the aforementioned providers is presented.

TABLE 3. IaaS providers

Provider	*Operating system*	*Virtualization*	*Pricing*	*24/7 support*	*Hybrid hosting*
AMAZON E2C	Linux, Windows	Xen Xen Xen	$0.080-$3.580 per hour (vary for different Instance and Regions)	No	No
FLEXISCALE	Linux, Windows	Linux KVM VMware	$17.00-$28,866.00 (it depends of units bought 1,000-2,000,000)	Yes	Yes
GOGRID	Linux, Windows	VMware	.PAY-AS-YOU-GO $0.06/hour(based on running server with 0.5GB of RAM) .PRE-PAID PLANS $0.02/hour(based on Enterprise Cloud plan and servers with 0.5GB of RAM)	Yes	Yes
JOYENT	SmartOS, windows		$0.085/hour-$2.80/hour or $62.05/ month-$2044/month	Yes	Yes
RACKSPACE	Linux		$0.022/hour-$2.64/hour	Yes	Yes
ARSYS	Linux, Windows		2 cents/hour or €10/month or €109.92/year	Yes	Yes

Some providers such as Amazon E2C, Flexiscale and GoGrid use Xen and they have support for operating systems such as Linux and Windows. GoGrid and Flexiscale unlike Amazon E2C, provides technical support included in each account and available 24 hours a day, 7 days a week (24/7 support) and hybrid hosting that allows using a combination of Cloud (virtual), dedicated (physical), and collocated servers connected via a private dedicated network; Other providers such as Rackspace and Arsys use VMware, both have 24/7 support and hybrid hosting. With regard to the price providers e.g. Rackspace, Amazon E2C and GoGrid offer pay-as-you-go.

6. CONCLUSIONS AND FUTURE WORK

Cloud computing has had a great impact in recent years. This new style of computing offers services via internet allowing users to access to programs and development platforms through different devices such as: laptops, smartphones to mention but a few. Cloud computing provides different services at different levels, Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service(SaaS). In recent years, a variety of IaaS, PaaS and SaaS providers have emerged, these providers aim to offer their services to small and large businesses, developers and others potential users. The analysis presented in this paper shows the current more popular SaaS, PaaS and IaaS providers. Also, a comparison with the main features of providers was presented. This comparison showed that some providers offer free plan available, however the use of these lack of features and provide limited, others offer full use of their services but a fee is required . This analysis helps users to select one cloud computing provider according to their needs and budget.

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