Cloud Computing: For A Better Tomorrow

Kent K. Pawar
Information Technology Department, St. Francis Institute of Technology (SFIT) College of Engineering, Borivli (W), Mumbai 400 103
Email: kent.pawar@gmail.com, Contact number: 9920323599

Abstract: *Cloud computing is a fast emerging paradigm for computing; that promises a greener, scalable, cost effective alternative to utilizing IT resources. Cloud solutions facilitate faster implementation of innovative ideas, thereby leveraging businesses and changing the way we design and deliver software, as well as the business models used. This paradigm shifts processing and storage activities from the client-side to the data centers. This paper gives an overview of the concept and its core technologies, along with its underlying characteristics, service layers and infrastructure models. The latter part will discuss case-studies of a sampled list of cloud services and providers, benefits and impact on customers, user concerns, mass acceptability, current research and future trends.*

Keywords: Cloud Computing, Cloud, Scalable, Elastic, IaaS, PaaS, SaaS, Virtualization, Cloud storage, Service provider, Vendor, Service models, Infrastructure models, Private cloud, Community cloud, Public cloud, Hybrid cloud, Cloud OS, GAE, AWS, S3, EC2, Windows Azure.

1. Introduction

Cloud computing is an emerging model of computing in which on-demand access to dynamically scalable(elastic), virtualized IT resources that are managed and provided as a service over a network (typically the Internet) through a web-browser or a provider-specific interface. Several recent technologies [1-10] (loosely or entirely) based on this model are accessed via the Internet to satisfy some of the diverse computing needs of users. Customers use cloud services (which are implemented as web applications) via a web browser, some of which that mimic (all or a subset of) the operations performed by their desktop counterparts, without having to install any additional software on their local machines. Such services often provide common business applications online that are accessed from a web browser, while the software and data are stored on the servers.

The first academic use of 'Cloud computing' appears to be by Prof. Ramnath K. Chellappa who originally defined it as a computing paradigm where the boundaries of computing will be determined by economic rationale rather than technical limits [11]. This concept is still evolving - so its definitions, architecture and characteristics will change and be refined over time. There is a significant confusion regarding the definition of the cloud [12]. Recently, NIST defined it 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 [13]." Simply put, a cloud dynamically provisions, configures, reconfigures, and de-provisions physical or virtual servers as needed by the customer [14].

A 'Cloud service provider' provides 'cloud services' through a complex network of linked data centers (acting as virtualized servers) and other resources that we collectively call the "cloud." The Cloud typically offers scaling up of capacity or capabilities on the fly via a shared, simple to use and subscription-based (or pay-per-use) computing and storage services. The effective cost of using these services is comparatively lower than having to invest in new infrastructure and licensing new software to implement the same required services on the local data centers of an organization.

So, Cloud computing, specifically enables Internet companies to rapidly scale up when there is a sudden increase in demand for their services; scale down, when there is decline in demand or to simply reduce operational cost. Companies are thus protected - to a certain extent - from the high cost and risk associated with development and deployment of a software product that does not meet their predictions, in terms of customer demand.

As Microsoft notes, it's not a new concept: Hotmail is an example of a cloud-based service, with the emails and processing software stored online as opposed to running an e-mail program on your computer [15]. Microsoft, Sun Microsystems, IBM, Amazon, Google and Yahoo are some of the major cloud computing service providers; some of which are investing millions of dollars into research.

If cloud computing is such a good idea, then why wasn't it considered earlier? Well, in the past barriers like bandwidth, loss of control, trust and feasibility all played a role in reasons for not considering a cloud service [16]. Today most of these challenges have been overcome, or

countermeasures are in place to resolve the challenges. Significant innovations in virtualization and distributed computing, as well as improved access to high-speed Internet and a weak economy, have accelerated interest in cloud computing. In the present, the downturn is shifting business perception of the cloud service and many companies both big and small are seriously considering, if not subscribing, to cloud services [12, 16].

1.1 Characteristics

There is no single definition or a standard set of characteristics defined for this model of computing; but there is a consensus among several leading companies and academic institutions which collectively agree on five essential characteristics, three service models and four deployment models [13].

Essential Characteristics

On-demand self-service: A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed in real-time through a service provider through a simple interface.

Ubiquitous network access: Cloud Services are available over the network or Internet, and accessed through standard Internet-enabled devices that may be based on thin or thick client architecture (e.g., mobile phones, laptops, and PDAs).

Resource pooling: The provider's virtualized resources are pooled to serve multiple consumers using a multitenant model. Customer demands are serviced in real-time; shared resources are dynamically assigned and reassigned to any user that places the demand – so no particular resource is permanently reserved. Examples of resources include storage, processing, memory, network bandwidth, and virtual machines.

Rapid elasticity: Computing capacity or storage and bandwidth capabilities can be automatically (without human intervention), rapidly and elastically provisioned, to scale up or down as the situation may demand. Enabling consumers to increase or decrease the rented capacity, proportional to demand or to effectively manage operational cost.

Consider a web service that requires a maximal 200 servers during the first 12 hours of the day and 400 servers during the next 12 hours when it receives its highest traffic. So the actual utilization over the whole day is (200 x 12 + 400 x 12) = 7200 *server-hours*. Assume that the company wants all its users to get the required satisfactory service, and thus employs the maximal (400) required servers. This cost the company 400 × 24 = 12000 *server-hours*. Indicating that the company pays for an extra 4800 server-hours; that is likely never to be utilized. Rapid elasticity will enable this company to increase or decrease the rented capacity, proportional to demand. So the company will just use and pay for the actually required 7200 *server-hours*. This is 1.7 times less then what the company currently spends, which translates to huge savings!

Measured Service: Cloud systems automatically control and monitor resource utilization at some level of abstraction appropriate to the type of service provided: storage, processing, bandwidth... Resource usage can be monitored, controlled, and reported providing transparency to both the provider and consumer of the utilized service. Consumers are then charged fees based on their usage.

1.2 Roles

This section describes the functions of three entity groups that use, develop, sell or provide Cloud computing technologies. It is recommended that you familiarize yourself with these terms, as they will be used frequently through out this article.

User/End user: A person or organization that utilizes cloud services.

Provider: Cloud-based service providers manage and may even develop cloud computing systems to deliver service to third parties (users).

Vendor (Facilitators): Vendors develop and then sell or offer their products and services for free, to facilitate the delivery, adoption and use of cloud computing.

2. Service models

Cloud computing is composed of three Service Models: Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS) and Software-as-a-Service (SaaS); where each model hosts a variety of different products for businesses and individuals around the world. These service models can also be viewed as service layers within the cloud computing architecture, or more correctly as layers of a Cloud computing stack.

2.1 SaaS

In SaaS, a complete application is offered as a cloud service. This application is developed by a vendor and hosted as a service on the cloud service providers system; at times, the vendor may be the service provider. A single instance of the application runs on the cloud which services multiple clients (referred to as multitenant architecture).

These applications are accessible from various client devices through a thin client interface such as a web browser or some provider-specific interface. The consumer does not directly manage or control the underlying cloud infrastructure; but may occasional use configuration settings to satisfy their needs.

SaaS is the only segment that has proven successful as a business model. Services can be anything from Web-based email to inventory control and database processing. Because the service provider hosts both the application and the data, the end user is free to use the service from anywhere.

Using business applications over the internet via cloud services, rather than from on-site servers helps companies to avoid maintenance costs, licensing costs and the costs of the hardware required for running servers on-site.

Table I list some well-established companies and their services, categorized on the basis of service model. The second field (not exhaustive), lists companies that offer the service for a fee or in some cases, free-of-charge.

TABLE I
CATEGORIZATION OF SERVICES ON THE BASIS OF SERVICE MODEL

Service model	Company (Product name and/or Description)
SaaS	Salesforce.com, Google (Google Docs), NetSuite, Taleo, Concur Technologies
PaaS	Google (Google App Engine), Amazon.com (EC2), Microsoft (Windows Live), Salesforce.com (Force.com), NetSuite (Suiteflex), Yahoo Pipes
IaaS	Google (Apps Engine, Managed hosting and development environment), IBM (Managed hosting), Amazon.com (Cloud storage)

2.2 PaaS

PaaS providers offer a platform for software development, which is provided as a service to its customers (developers). The platform consists of tools and APIs for every phase of software development and testing. Providers may also deploy their customer's applications as a service to other users, over their existing cloud infrastructure. The consumer does not manage or control the underlying cloud infrastructure of the provider, but can configure their deployed applications, application hosting environment and development environment as per their needs.

2.3 IaaS

IaaS delivers basic storage and compute capabilities as a service over the network. Servers, storage systems, switches, routers, and other systems are pooled (through virtualization technology) to handle specific types of workloads — from batch processing to server/storage augmentation during peak loads [17]. IaaS vendors provide the physical storage space and processing capabilities that allow for the all the services described above. The IaaS customer does not manage or control the underlying cloud infrastructure but can select the components that will be a part of the rented infrastructure: operating systems, storage systems [13]...

3. Infrastructure models

These models basically are the types of clouds that can also be called deployment models. Figure 1 shows typical architecture of a cloud system.

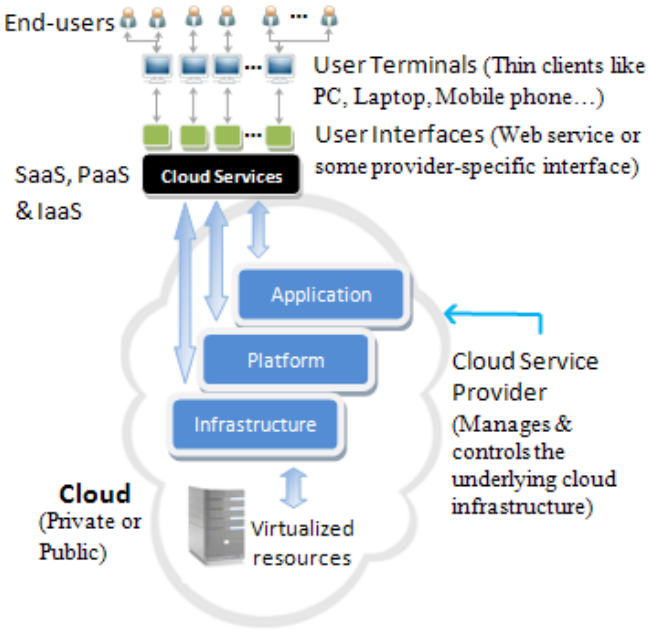

Fig. 1: Typical architecture of a cloud system

3.1 Private cloud (Internal cloud)

The cloud infrastructure is operated solely for an organization or a limited number of people. It may be owned and managed by an individual, organization or a third party; it may exist on premise or off premise. But, a private cloud is usually owned by the company that uses it. These clouds are typically built behind a company's firewall; thereby, keeping all the company's data in-house, secured and in full control of the in-house IT staffers. Private clouds are a good option for companies where data security is of critical importance [13, 17].

3.2 Community cloud

The cloud infrastructure is shared by several organizations

and supports a specific community that has shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be managed by the organizations or a third party and may exist on premise or off premise [13].

3.3 Public cloud (External Cloud)

The cloud infrastructure is owned by a third party organization renting cloud services to the general public over the Internet. These clouds are outside a customers/company's firewall. The public cloud is a pay-per-use storage utility. Currently, Amazon Web Services (AWS) [3, 4, 29] is the largest public cloud provider. The cloud storage service provider manages the storage infrastructure, pooling its capacity to accommodate the needs of multiple customers; so the customer is freed from having technical expertise managing the storage [13, 17].

Public Cloud services will mainly benefit small businesses, start-ups, users who need to use the internet often and the student community - that may have very little capital to invest in their own infrastructure. Large enterprises are not expected to use public services just yet, mainly due to the challenges described in section 8; but may invest in their own private clouds. Students could make use of a very simple-to-use, affordable thin client with internet connectivity that connects to some cloud services to remotely work and store data on it. This will serve as a good solution for the One Laptop per Child **(**OLPC) [18] initiative.

3.4 Hybrid cloud

The cloud infrastructure is a composition of two or more clouds (private, community, or public) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load-balancing between clouds) [13, 17].

4. Enabling Technologies for Cloud Computing

There are several technologies that act as the building blocks of Cloud services, many of which provide web 2.0 services. Some of these enablers are explained below.

4.1 Virtualization

Virtualization is a cornerstone design technique for all cloud architectures. In Cloud Computing, Virtualization allows servers, storage devices, and other hardware to be treated as a pool of resources rather than discrete systems, so that these resources can be allocated on demand [17]. The benefits of virtualization become obvious when you consider that, most of the time servers don't run at full capacity, resulting in unused processing power [19]. By using specially designed software (FreeVPS, Microsoft Virtual Server,Xen,…), an administrator can allow one physical server to act as multiple virtual ones (paravirtualization [17]) or even allow multiple servers to act as a single server (clustering [17]). Each virtual server acts like a unique physical device, capable of running its own OS. The technique is called server virtualization, which maximizes the throughput of individual physical servers and thus reduces the need for more physical servers.

4.2 Cloud Storage

Cloud storage is a utility-type service that provides multiple users access to a shared pool of storage capacity, which is accessed over an Internet connection [20]. Start-ups are expected to be among the biggest users of cloud storage, as savings are huge. Cloud storage, such as Amazon's S3 [3], is considered to be an example of IaaS.

Cloud storage best handles large volumes of unstructured data and archival material, such as credit card and mortgage applications or medical records. For now, public clouds can't reliably handle highly transactional files or databases that require consistently fast network connections. Any kind of online transaction processing is inapplicable [21].

Quite a few well-known companies offer some form of cloud storage that caters to a specific file types. A sampling of cloud storage vendors and their offerings:

Google Inc.'s Google Docs for documents, presentations and spreadsheets (which you can publish and edit online); Xdrive, MediaMax and Strongspace offer storage space for any kind of digital data; Web e-mail providers like Gmail, Hotmail and Yahoo! Mail that store e-mail messages with its embedded content (images, flash,…); Flickr and Picasa store digital images; YouTube hosts millions of user-uploaded video files …

5. Sampled list of cloud services

Advancements in internet technologies have made it possible to now deploy web application that could only have be deployed on desktop environments in the past. From switching to Hotmail from Outlook Express or switching to GoogleDocs from MS Word, many user preferences have changed with time.

Cloud services can offer its users vast processing capabilities and storage, but it can also offer much simpler web-based applications that you can sample right away

(many of which are free to use). We are all familiar with popular internet cloud services such as [1-10] and those mentioned in section 4.2. There are several other interesting services that are fast gaining popularity, some of which are discussed below.

5.1 Cloud OS (Cloud Operating system)

Users wanting access to simple cloud services can make use of Cloud Operating systems that will serve as your personal (remote) desktop on the cloud. Some of these apps act as an alternative to their desktop counterparts. Popular Cloud OS's such as EyeOS [6], iCloud [7] and g.ho.st [8] are offering more or less the same standard tools expected in any desktop environment, such as Office tools (word processing, spreadsheet, presentations, calendar,…), Games, File storage, Internet tools (RSS reader, Internet Browser, Email, FTP, IM), Multimedia tools (mp3 player, video player), Desktop Widgets, Application Development Tools and more.

EyeOS is a PHP based open source cloud desktop that you can download and run from your organizations Apache web server. iCloud, g.ho.st as well as EyeOS are offered as a free online service that requires you to signup for an account to use the desktop; enabling you access to the provided applications and your documents from any Internet connected computer.

A company called 'Good OS LLC' developed the "Cloud (OS)", which is a "browser based operating system" based on Linux for netbooks; a successor to company's Linux-based gOS [9]. Now, Google continues this trend by developing the "Google Chrome OS", which they describe as an "open source, lightweight operating system that will initially be targeted at netbooks and will be available for consumers in the second half of 2010" [22]. This OS is obviously aimed at users doing most of their work online. Speed, simplicity and security are the key aspects of Google Chrome OS. The OS will start up quickly and get the user onto the web, in a matter of seconds. Also, users won't have to deal with viruses, malware and security updates as most of the software will be available as a cloud service, which will be managed entirely by the service provider.

The overall architecture consists of a Google Chrome web browser running within a new windowing system on top of a Linux kernel. So most or all of the applications will be web-based and thus heavily dependant on Cloud infrastructure, rather than on-site computing via the OS. As a result the netbooks running Chrome OS are not expected to have high processing power or maximal storage capacity; thus making it a very affordable alternative to regular notebooks or laptops. The One Laptop per Child (OLPC) [18] project will definitely benefit from such advancements.

6. Sampled list of Cloud service providers

6.1 Google App Engine (GAE)

App Engine is primarily a free service that makes it easy to build scalable web applications using Google technology [2]. App Engine currently provides a SDK for Java and Python.

6.2 Amazon Elastic Compute Cloud (EC2)

Amazon Elastic Compute Cloud allows customers to rent computers on which to run their own computer applications [4]. EC2 provides scalable virtualized resources.

6.3 Windows Azure

Azure is Microsoft's new cloud computing platform that will allow developers to create, test and debug web applications using Microsoft development tools and deploy them across Microsoft's data centers [5, 23].

7. Benefits and impact of cloud computing on various fronts

The major needs that drive company's interest in clouds are – increasing efficiency, reducing capital costs and easing staffing issues [12]. Corporations adopting cloud services might save money on IT support as there will be lesser hardware to manage. Cloud storage centralizes storage of data; that makes backup, archiving and thus disaster recovery an effortless process. Upgrades, servicing and backup are performed by the provider. Cloud services cost less, are scalable, secure and reliable. Client-side investment will drop; on the provider-side, as there are few shared resources to maintain, costs are low compared to conventional hosting. It should be noted that software can be better protected from reverse engineering if it is implemented as a web service.

7.1 Impact on Mobile devices and their manufacturers

The advantages are huge when you consider mobile devices as the thin clients utilizing cloud services [24]. Should customers spend more on phones that are capable of running complex applications, when a web browser on the device could enable the user to access the same (or similar) services online? If there are no risks in using cloud services, customers will probably opt for the latter. This may pose a problem to mobile device manufacturers who spend millions to upgrade their devices. Cloud services can offer

much more complex facilities that could never be possible on these devices. So lower-end phones with support for web 2.0 compatible web browsers and internet connectivity will benefit the most from Cloud computing; which brings complex apps to the lower-end phones.

8. Concerns

The paradigm shift from on-site computing to computing on the clouds will affect few companies in different industries, including software companies, internet service providers and hardware manufacturers. Businesses offering computer repairs and maintenance to companies may suffer losses if their clients move towards cloud solutions, where the provider carries out the maintenance.

Primary concerns are that of security and privacy. People may feel uncomfortable with their confidential data being stored on third-parties' remote computers. Other concerns include risk of lock-in to cloud platform vendors, loss of control over cloud resources over public clouds, and reliability [25]. Developers need to know that currently, there are no standards for interoperability or data portability in the cloud. Some providers will not allow software created by their customers to be moved off the provider's platform.

Users had no freedom to install new applications and needed approval from administrators to achieve certain tasks. Overall, it limited both freedom and creativity. Richard Stallman, founder of the Free Software Foundation, believes that cloud computing endangers liberties because users sacrifice their privacy and personal data to a third party. He stated that cloud computing is "simply a trap aimed at forcing more people to buy into locked, proprietary systems that would cost them more and more over time [26]."

9. Research

There is no doubt that cloud computing is an emerging field and a topic of interest among researchers, in the computer science domain. Several well known companies (mainly Microsoft, Sun Microsystems, IBM, Amazon, Yahoo, and Google) are investing millions of dollars into research and development of cloud infrastructure. These companies have been building cloud-computing infrastructure and new software to support it, at a rapid pace to service the large number of potential users.

Scientists and researchers could tap into the available combined processing power of a cloud system to process their complex calculation. The development of EUCALYPTUS [27] is thus notable in this respect the scientific community. EUCALYPTUS is an open-source software framework for cloud computing that implements IaaS – developed by and for the research community. It provides a system that is easy to deploy atop existing resources, that lends itself to experimentation by being modular and open-source, and that provides powerful features out-of-the-box through an interface compatible with Amazon EC2.

Cloud services are backed by a massive array of data centers with possibly a couple hundred of servers managing petabytes of data, using hundreds of megawatts of power and costing millions (or billions) of dollars in capital and operational expenses. The downside of current clouds is that the infrastructure used to build them makes use of existing hardware and software technologies that were not designed for deployment at such a massive scale [28].

There is a dire need for research to be carried out in this field to produce new technologies that help reduce the cost of setting up and operating such cloud services, which will require advancements in hardware as well as software. As current cloud service infrastructures are built using the same systems that deliver today's Web 2.0 services, they are bound to be very expensive to maintain and less efficient, among other things in meeting the immense workload and resources that such services will soon require; as pointed out by Dan Reed, director of Scalable and Multicore Systems, who currently leads the new research organization called Cloud Computing Futures (CCF), Microsoft Research [28].

Reference [28] states, "The CCF is focused on reducing the operational costs of data centers (providing cloud services) and increasing their adaptability and resilience to failure." Besides these the group will strive to lower hardware costs, power consumption, and the environmental impact of such facilities. CCF has successfully experimented with a cluster of low-cost, energy-efficient and slower computers to provide cloud services as opposed to using faster, less energy-efficient servers that require a lot more maintenance (and cooling). They showed that overall power consumption can be reduced (in comparison with standard servers) while still delivering the same quality of service.

10. Future

Cloud Computing will have a huge impact on the way we design and deliver web services, as well as the underlying economics of how revenue is collected for using them. In the near future, the number of providers, vendors and the user base of cloud-based services are expected to increase [12]; there will then be a dire need for cloud interoperability - to shift the control from the provider to the customer. In June 2009, F5 Networks conducted a study examining the adoption of cloud computing by enterprise

IT managers and found that widespread enterprise adoption is eminent upon solving access, security and performance concerns; among other interesting reports [12].

As hardware costs continue to move downwards, it has become a bit of a custom for web companies to offer free (or cheaper) storage space for email, web hosting, social media (YouTube, Flickr) and other user-generated content based services. This trend along with the advancements in Cloud OS's (Refer section 5.1) will lead to the ultimate fantasy – you're desktop away from home, on the web; accessible from any terminal connected to the internet. Also, hardware manufacturers may develop a special range of cloud infrastructure based products.

Microsoft will soon release slimmed down versions of applications such as Microsoft Office which run entirely online. Customer concern for more security has resulted in a rise of VPN type technology like SSL VPN and other remote working solutions i.e. Terminal services and Citrix [16].

11. Conclusion

Cloud solutions enable faster implementation of innovative ideas. It will revolutionize the way we work and do business on the web. As several issues concerning cloud architecture still need to be resolved, companies adopting cloud solutions may opt to keep their critical and confidential data on their local data centers.

As any new technology brings along a few surprises, some unexampled services may come into existence. More and more companies will see cloud solutions as a quick and reliable way to cut cost and achieve other objectives, thereby ushering their organizations out of the current global economic slump. The acceptability of cloud computing by the masses will mainly depend on the consideration given to security and its economic practicality.

Cloud solutions are greener [16, 17, 28] as the underlying infrastructure of service providers are shared among several thousand clients; so fewer servers are required to deliver cloud services. Making it a more cost and energy efficient alternative as a unit of work is completed with far less electricity, less cooling and thus reducing maintenance and overall cost.

References

[1] Google Docs. [Online]. Available: http://docs.google.com

[2] Google App Engine (GAE). [Online]. Available: http://code.google.com/appengine/

[3] Amazon.com Inc.'s Simple Storage Service (S3). [Online]. Available: http://aws.amazon.com/s3

[4] Amazon Elastic Compute Cloud (EC2). [Online]. Available: http://aws.amazon.com/ec2/

[5] Windows Azure. [Online]. Available: http://www.microsoft.com/windowsazure/products

[6] EyeOS. [Online]. Available: http://eyeos.org/

[7] iCloud. [Online]. Available: http://icloud.com/

[8] "g.ho.st". [Online]. Available: http://g.ho.st/main.jsp?language=en

[9] gOS, Good OS LLC. [Online]. Available: http://www.thinkgos.com/cloud/index.html

[10] YouTube. [Online]. Available: http://www.youtube.com

[11] "Cloud computing - Emerging paradigm for computing". [Online]. Available: http://meetings.informs.org/Dallas97/TALKS/C20.html

[12] Cloud Computing, Survey results 2009. F5 Networks. [Online]. Available: http://www.f5.com/pdf/reports/cloud-computing-survey-results-2009.pdf

[13] NIST (2009). [Online]. Available: http://csrc.nist.gov/groups/SNS/cloud-computing/

[14] Greg Boss, Padma Malladi, Dennis Quan, Linda Legregni and Harold Hall, "Cloud Computing", IBM, 2007. [Online]. Available: http://download.boulder.ibm.com/ibmdl/pub/software/dw/wes/hipods/Cloud_computing_wp_final_8Oct.pdf

[15] John Lister (2009). MS Sets Cloud Computing Policy for Future Apps Online. [Online]. Available: http://www.infopackets.com/news/business/microsoft/2009/20091109_ms_sets_cloud_computing_policy_for_future_apps_online.htm

[16] Ricky M. Magalhaes (2009). Cloud Computing: The Past, The Present, The Future. [Online]. Available: http://www.windowsecurity.com/articles/Cloud-Computing-Past-Present-Future-Part1.html

[17] Jim Baty and Jim Remmell, Take Your Business to a Higher Level: Sun Cloud Computing (Sun Cloud Computing Primer), Sun Microsystems, 2009.

[18] One Laptop per Child **(**OLPC). [Online]. Available: http://laptop.org/

[19] Jonathan Strickland (2009). "How Server Virtualization Works". [Online]. Available: http://communication.howstuffworks.com/server-virtualization.htm.

[20] Jonathan Strickland (2009). "How Cloud Storage Works". [Online]. Available: http://communication.howstuffworks.com/cloud-storage.htm

[21] Julia King (2009). "5 key questions about cloud storage - A bird's-eye view of the technology and the factors to consider before storing your data in the

cloud." [Online]. Available: http://www.computerworld.com/s/article/340471/Cloud_Storage_Illuminated?taxonomyId=19&pageNumber=1

[22] “Introducing Google Chrome OS”. [Online]. Available: http://googleblog.blogspot.com/2009/07/introducing-google-chrome-os.html

[23] David Chappell (2009)."Introducing the Windows Azure Platform". [Online]. Available: http://www.microsoft.com/windowsazure/whitepapers/default.aspx

[24] Sarah Perez (2009). Why Cloud Computing is the Future of Mobile. [Online]. Available: http://www.readwriteweb.com/archives/why_cloud_computing_is_the_future_of_mobile.php

[25] Dion Hinchcliffe (2009). Eight ways that cloud computing will change business. ZDNET. [Online]. Available: http://www.majorcities.eu/pics/download/1_1247671028/ZDNET_Eight_ways_that_cloud_computing_will_change_business.pdf

[26] “Cloud computing is a trap, warns GNU founder Richard Stallman”, Guardian, 2008. [Online]. Available: http://www.guardian.co.uk/technology/2008/sep/29/cloud.computing.richard.stallman/

[27] Daniel Nurmi, Rich Wolski, Chris Grzegorczyk, Graziano Obertelli, Sunil Soman, Lamia Youseff and Dmitrii Zagorodnov, “The Eucalyptus Open-source Cloud-computing System”, Computer Science Department, University of California, 2009. [Online]. Available: http://vgrads.rice.edu/publications/pdfs/eucalyptus-ccgrid2009.pdf

[28] Rob Knies (2009). Peering into Future of Cloud Computing. [Online]. Available: http://research.microsoft.com/en-us/news/features/ccf-022409.aspx

[29] Amazon Web Services (AWS). [Online]. 2009. Available: http://aws.amazon.com/

[30] Michael Armbrust, Armando Fox, Rean Griffith, Anthony D. Joseph, Randy Katz, Andy Konwinski, Gunho Lee, David Patterson, Ariel Rabkin, Ion Stoica, and Matei Zaharia. “Above the Clouds: A Berkeley View of Cloud Computing”, February 10, 2009. [Online]. Available: http://www.eecs.berkeley.edu/Pubs/TechRpts/2009/EECS-2009-28.html