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DELIVERY SERVICES MODEL OF CLOUD COMPUTING: A PERSPECTIVE OVERVIEW

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Abstract. *Cloud computing is a consequence of economic, commercial, cultural and technological conditions that have combined to cause a disruptive shift in the IT industry towards a service-based economy. It is a style of computing where massively scalable IT-enabled capabilities are provided as a service over the network and give rise to the "As a Service" business. The evolution of Cloud computing can handle massive data as per on demand service. Supporting this transition is a range of technologies from clustering to virtualization. This study presents an expanded delivery services model of Cloud computing for enterprise and business. The characteristics and the challenges of Cloud computing are analyzed and discussed. The offerings from some Cloud service providers are also outlined.*

Keywords: Cloud computing, Virtualization, Cloud infrastructure, Cloud services, Everything-as-a-Service

1. **Introduction.** In the IBM technical white paper of Cloud computing, the concept of Cloud computing has developed from earlier ideas such as grid and utility computing, and aims to provide a completely Internet-driven, dynamic and scalable service-oriented IT environment, which can be accessed from anywhere using any web-capable device [6]. With the Cloud computing technology, user's computer no longer has to do all the heavy computing process or data storage. The network of servers that make up the Cloud handles them efficiently and rapidly based on pay-as-you-go policy. Both on-demand service and software as a service play a role in the evolution of this emergent computing technology. Since 2003, Cloud computing has been evolved from internal IT system to public service and is already rooted in search engine platform design [5]. Cloud computing refers to both the applications delivered as services over the Internet and the hardware and system software in the datacenters that provide the services. The datacenter of hardware and software is what we call a Cloud [1]. The Cloud-based service can be public, private or a combination of the two, sometimes referred to as a hybrid Cloud. Five key technical features of Cloud computing cited in the literature are large-scale computing resources, shared physical and virtualized resource pool, high scalability and elastic, dynamic resource scheduling and general purpose [13].

Nowadays, Cloud computing has become a trend, drawing a lot of interest from both academia and industry. Several projects have started, for example, the RESERVOIR project [23], Amazon Elastic Compute Cloud [17], IBM's Blue Cloud [19], Google's App Engine [18], Microsoft Azure [20], Nimbus and Stratus [21,23] and OpenNEbula [22]. HP, Intel and Yahoo recently announced the creation of a global, multi-data center, open source Cloud computing test bed. Three major Cloud computing styles based on the

underlying resource abstraction technologies are briefly reviewed in the following. The Amazon style is based on server virtualization technology. Amazon released Xen-based Elastic Compute Cloud (EC2), CloudFront, Simple Storage Service (S3), Simple DB and Simple Queue Service (SQS) in early 2006 under the name Amazon Web Service (AWS) [3,16]. AWS is more than a collection of infrastructure services. With AWS one has the flexibility to choose whichever development platform or programming model that makes the most sense for the problems one is trying to solve. The Google style is based on technique-specific sandbox. Google published several papers from 2003-2008, which outline a kind of "Platform as a Service" Cloud computing. The platform is called Google App Engine released to public as a service in 2008 [7]. Google App Engine is an environment for developing and deploying web applications on Google's infrastructure. It enables users to build Web applications with Google's APIs and SDKs across the same scalable systems, which power the Google applications [15]. The Microsoft style uses Window Azure Hypervisor as the underlying Cloud infrastructure and .NET as the application container, which was released in 2008 with the name Microsoft's Window Azure. In 2010, Microsoft released several new features on Windows Azure, including virtual machine role, remote desktop access, extra small instance, Windows Server 2008 R2 compatibility, updates to the SDK and Windows Azure Tools for Microsoft Visual Studio, and more [4].

The work in this paper is motivated by a problem discussed by Litoiu et al. [11] regarding what the main motivation of Cloud computing is. The authors considered Cloud computing's main motivation is economics. Based on this sense, Cloud computing refers to the trend away from services provided by software running on client's computer, toward services provided across the Internet with data stored in centralized data centers. Thus, Cloud computing is becoming a new platform for enterprise and personal computing. Typical examples are that Gmail provides email in the Cloud and that Flickr provides photo albums in the Cloud. In this regard, it is a new style of computing where massively scalable IT-enabled capabilities are provided as a service over the network and give rise to the "As a Service" business. This study therefore presents an expanded delivery services model of Cloud computing for enterprise and also outlines the offerings from some Cloud services providers.

The rest of this paper is organized as follows. In the next section, we outline the general Cloud computing layered architecture and present the Cloud scenario and the core Cloud services. Then, in Section 3, we present an expanded delivery services model of Cloud computing for enterprise. Section 4 describes the characteristics of Cloud computing. The challenges of Cloud computing are presented in Section 5. Section 6 outlines the offerings of some Cloud services providers. Finally, the conclusions with the future direction of work are given in Section 7.

2. General Cloud Computing Architecture.

Cloud computing is a set of network enabled services, providing scalable, Qos guaranteed, normally personalized, inexpensive computing infrastructures on demand, which could be accessed in a simple and pervasive way [8]. According to this definition, Cloud computing refers to the practice of delivering software and infrastructure as a service on a pay-as-you-go basis. The general Cloud computing architecture that defines four distinct layers from physical hardware to end user applications is shown in Figure 1. This layered architecture of Cloud computing includes hardware layer, system middleware layer, user-level middleware layer and user application layer.

The hardware layer is the Cloud resources including hundreds or thousands of processors and data storages providing the horse power of the Cloud. This physical layer is

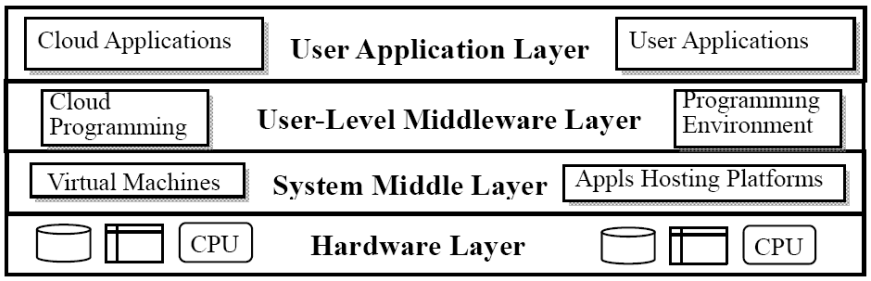

FIGURE 1. Cloud computing layered architecture

managed by the system middle layer whose objective is to provide an executable environment or platform for applications and to maximize the use of all hardware resources. The run-time environments are created by using hardware virtualization technology. Hardware level virtualization complete isolation of applications and share all resources by means of virtual machines. The system middle layer provides a wide set of services to the upper layers. Thus, together with the hardware layer the system middle layer presents applications hosting platforms or virtual machines for user's applications in the Cloud. The services delivered by the system middle layer are accessed only through the upper user-level middleware layer. The user-level middleware layer provides programming environment and programming tools for application developments in the Cloud. As a result, Cloud computing offers users with services to access hardware, software and data resources, and integrates computing platform as a service in a transparent way [14]. Instead of installing packaged software applications on their computers, people and businesses will use their web browsers to access a wide range of Cloud services available on-demand over the Internet.

There are diverse dimensions to classify Cloud computing, and one commonly used category is the services [12]. From the service type's view, Cloud service providers offer services can be classified as Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) [8,9]. The NIST (The Information Technology Laboratory of the National Institute of Standards and Technology) describes it as three delivery models. IaaS virtualizes the hardware equipment and offers computing services such as CPU, memory and storage. PaaS offers platform services, such as web, application and database servers and an executable programming environment. Programmers use this layer to code, test, debug and run many kinds of applications. SaaS consists of various services offered to the end users. Each end user should pay a subscription. Figure 2 shows three levels of Cloud computing based on service models. Taken together, these are often referred to as the SPI stack or the core of Cloud computing.

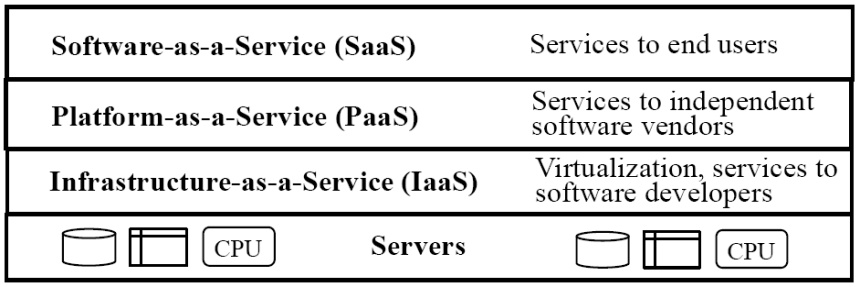

FIGURE 2. The SPI stack – the core of Cloud computing

2.1. **Infrastructure as a service (IaaS).** IaaS delivers computer infrastructure, typically a platform virtualization environment as a service. This is the lowest level provided by the Cloud computing paradigm. IaaS is a provision model in which an organization outsources the equipment used to support operations, including storage, hardware, servers and networking components. The service provider owns the equipment and is responsible for housing, running and maintaining it. The client typically pays on a per-use basis. An important advantage is that users always using the latest technology and customers can achieve a much faster service delivery and time to market. Some examples of IaaS are Amazon S3/EC2, Microsoft Windows Azure, VMWare vCloud, GoGrid, Layered Technologies, Flexiscale, etc.

2.2. **Platform as a service (PaaS).** PaaS delivers a computing platform and solution stack as a service, often consuming Cloud infrastructure and sustaining Cloud applications. It facilitates deployment of applications without the cost and complexity of buying and managing the underlying hardware and software layers. Users thus can on demand subscribe to their favorite computing platforms with requirements of hardware configuration, software installation and data access demands. The sizing of the hardware resources demanded by the execution of the services is made in a transparent manner. Compared with conventional application development, this strategy can sharply reduce development time by offering hundreds of readily available tools and services. A well-known example is the Google Apps Engine. The Google Apps Engine enables users to build Web applications with Google's APIs and SDKs across the same scalable systems. Some other examples of PaaS are Microsoft Azure Services Platform and ORACLE/AWS.

2.3. **Software as a service (SaaS).** SaaS was coined in a conference in 2005 and then popularized by Salesforce.com with its "No Software" motto. Salesforce.com helped define the market and continues to be a leader with their hosted CRM solution. The trend is for on-premises software vendors to provide a Cloud based solution. Later, several other examples have come to market, including the Google Apps offering of basic business services including email and word processing. The basic concept of SaaS is that software or an application is hosted as a service and provided to customers across the Internet. This mode transfers programs to millions of users through browser and eliminates the need to install and run the application on the customer's local computers. SaaS therefore alleviates the customer's burden of software maintenance, and reduces the expense of software purchases by on-demand pricing. Gartner predicts that SaaS based enterprise applications will grow from 10% in 2010 to 14% in 2014. Today Google is one of the strongest backers of this approach, with such products as Gmail, Google Reader and Google Docs. Some other examples of SaaS are Salesforce CRM, Oracle CRM on Demand and Microsoft Online Services.

3. **Expanded Delivery Services Model of Cloud Computing.** Recently, there are a number of other Cloud services emerging, such as storage as a service, communications as a service and network as a service, for some researchers have a classification of their own. Some experts said that the next wave of Cloud computing is "Everything as a Service". As "Everything as a Service" evolves, we have an opportunity to reshape the computing industry forever and, more importantly, create more dynamic services that enrich our everyday lives and improve how we do business. XaaS is a collective term said to stand for "Everything as a Service". The acronym refers to an increasing number of services that are delivered over the Internet rather than provided locally or on-site. XaaS is the essence of Cloud computing. However, when it comes to Enterprise Cloud Computing, more to the three SPI layers is needed. Here we present an expanded delivery services

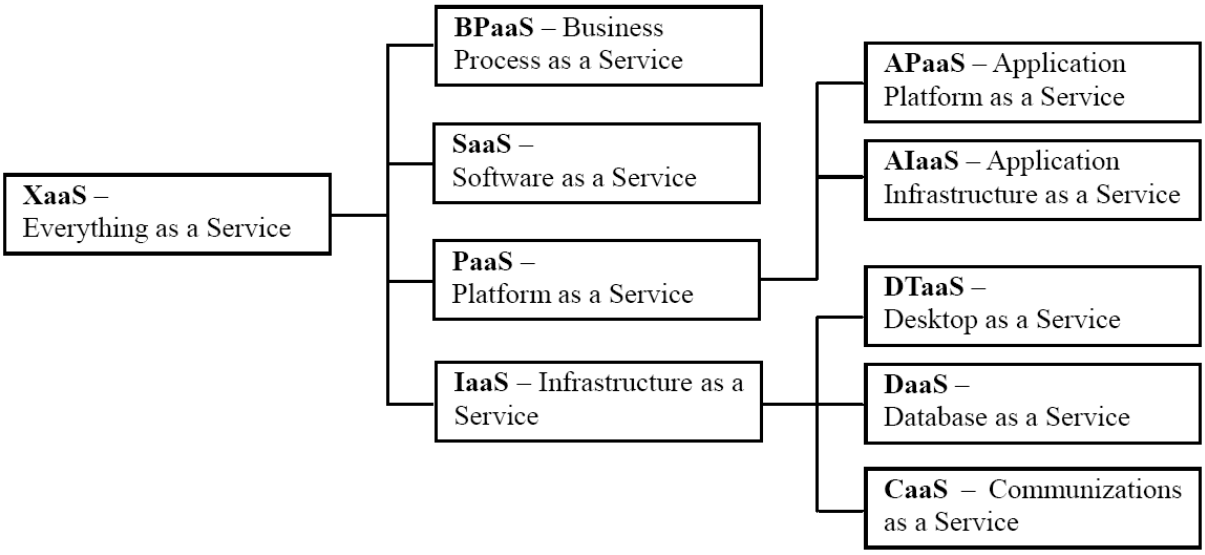

FIGURE 3. The proposed expanded delivery services model of Cloud computing

model of Cloud computing and describe its related Cloud services below. Figure 3 shows the proposed expanded delivery services model of Cloud computing.

3.1. **Business process as a service (BPaaS).** The idea of BPaaS is that the Web Service Platform is going to be based on a supplier, provider, value-adder and consumer supply chain. Suppliers are actually organizations who are hoisting their internal business processes into the Cloud via a provider. The provider controls the Cloud layer, and ensures there is a scalable, Service Level Agreement (SLA) managed environment for the provision and consumption of Business Process Services via the Cloud. An SLA is a part of a service contract where the level of services is formally defined. In Cloud computing, SLA between consumers and providers emerge as a key aspect. BPaaS provides the complete end-to-end business process management needed for the creation and follow-on management of unique business processes.

3.2. **Application infrastructure as a service (AIaaS).** Some experts consider this model to provide application middleware, including application servers, ESB (Enterprise Service Bus) and BPM (Business Process Management). An ESB is a software architecture construct which provides fundamental services for complex architectures via an event-driven and standards-based messaging engine (the bus). Developers typically implement an ESB using technologies found in a category of middleware infrastructure products, usually based on recognized standards. BPM is a management approach focused on aligning all aspects of an organization with the wants and needs of clients. It is a holistic management approach that promotes business effectiveness and efficiency while striving for innovation, flexibility, and integration with technology.

3.3. **Application platform as a service (APaaS).** According to Gartner, "APaaS is a development and deployment environment for Cloud-based applications, offered to IT organizations as a service". Gartner is a leading analyst/research house based in the United States that provides opinions, advice and data on the global information technology industry. APaaS is a part of a fundamental and discontinuous change in the application platform market. It is a step toward greater industrialization of IT, to predictable, dependable, professionally managed, plentiful and agile information resources.

APaas provides application servers with added multitenant elasticity as a service. In fact, the PaaS model includes both AIaaS and APaaS.

3.4. **Communizations as a service (CaaS).** CaaS is an outsourcing model for enterprise communications. Such communications can include voice over IP, instant messaging, collaboration and videoconference applications using fixed and mobile devices. Outsourcing communications make sense for small and medium sized businesses. The cost of the infrastructure required to support the required services is high. The CaaS vendor is responsible for all hardware and software management and offers guaranteed Quality of Service. CaaS allows businesses to selectively deploy communications devices and modes on a pay-as-you-go basis.

3.5. **Database as a service (DaaS).** DaaS is the latest entrant into the "as a Service" realm and becomes increasing popularity. DaaS provides traditional database features, typically data definition, storage and retrieval, on a subscription basis over the web. Today all major database platforms are virtually available in the Cloud. DaaS solutions provide full access to database logic, tables, views, programming and user interface functionality. Two real-world examples of DaaS are Salesforce.com's Force.com, which provides data services in its toolkit for building applications, and Amazon's SimpleDB, which provides an API for creating data stores which can be used for applications or pure data storage.

3.6. **Desktop as a service (DTaaS).** DTaas represents a new paradigm of desktop applications and results in a virtual desktop delivered on demand. DTaaS, also called virtual desktop or hosted desktop services, is the outsourcing of a virtual desktop infrastructure to a third party service provider. DTaaS applications can be delivered from the Cloud or just delivered from the organization's data center. Local applications can be delivered remotely using technology from VMWare or Citrix. DTaaS transforms Windows desktops into an on-demand service that can be accessed by any user, on any device, anywhere, with unparalleled simplicity and scalability. Whether workers are using tablets, smartphones, laptops or thin clients, DTaaS can quickly and securely deliver virtual desktops and applications to them with a high-definition user experience. Examples of vendors are ThriveNetworks Desktop Management, VMWare Virtual Desktop and Citrix XenDesktop.

4. **The Characteristics of Cloud Computing.** Cloud computing distinguishes itself from other computing paradigms, like Grid computing and Internet computing, in the following characteristics. With these characteristics, Cloud computing is the promising paradigm for delivering IT services as computing utilities [9].

4.1. **Virtualization technology.** Virtualization technology partitions hardware and provides flexible and scalable computing platforms [10]. The resources that users required come from Cloud instead of visible entity. Users can complete all they want through net service using a notebook, a PC, or even a mobile phone. For example, Amazon's Cloud computing is based on server virtualization technology. Amazon released Xen-based Elastic Compute Cloud (EC2), object storage service (S3) and structure data storage service (SimpleDB) during 2006 and 2007, under the name Amazon Web Service (AWS). Since then, AWS becomes the pioneer of Infrastructure as a Service (IaaS) provider and the current leader of Cloud provider based on the IaaS model. Virtualization technology is therefore well suited to a dynamic Cloud infrastructure providing sharing, manageability and isolation.

4.2. **Scalability.** The scale of Cloud is large and can extend dynamically to meet the increasingly requirement. Cloud services and computing platforms offered by Cloud computing could be scaled across geographical locations, hardware performance and software configurations. For example, Amazon, IBM, Microsoft and Yahoo, they each have more than hundreds of thousands servers. The computing platforms are then flexible enough to adapt to various requirements of a potentially large number of users.

4.3. **On-demand self-service.** Cloud computing provide resources and services for users on demand. Cloud is a large resource pool that users can buy according to their needs. A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service's provider. Users can thus customize and personalize their computing environments. In a nutshell, Cloud is just like running water, electric, and gas that can be charged by the amount that you have used.

4.4. **User-centric interfaces.** Cloud computing services are accessed with simple and pervasive methods. Cloud interfaces do not force users to change their working habits and environments. Instead, users employ computing platforms as easily as they access a traditional public utility. Cloud interfaces are location independent and can be accessed by web services framework and Internet browser. The computing environment provided by Cloud computing can guarantee quality of services for users.

4.5. **Security.** Corporate information is not only a competitive asset, but it often contains information of customers, consumers and employees that, in the wrong hands, could create a civil liability and possibly criminal charges. All companies must ensure adequate security for the storage and processing of data they venture into the Cloud or maintain traditional processing centers. Security concerns may be magnified by the dynamic nature of the Cloud environment. Thus Cloud computing must provide dependable and secure data storage center, preventing such as data loss, hacking or stealing.

5. **Challenges of Cloud Computing.** Even though Cloud computing has gained popularity as the emergent technology, businesses are still evaluating its feasibility and efficiency for their working environments. Armbrust et al. [2] provide a ranked list of ten obstacles to the growth of Cloud computing. Each obstacle is paired with an opportunity, a thought on how to overcome the obstacle, ranging from straightforward product development to major research projects. The first three affect adoption, the next five affect growth, and the last two are policy and business obstacles. The ten obstacles to Cloud computing are availability of service, data lock-in, data confidentiality and auditability, data transfer bottlenecks, performance unpredictability, scalable storage, bugs in large distributed systems, scaling quickly, reputation fate sharing and software licensing. The Internet Data Centers (IDC) also gives several obstacles of Cloud computing, including availability, security, performance unpredictability, hard to integrate with in-house IT, and lack of customizability [15].

According to a study by Launchpad Europe, a company that helps emerging firms with global business expansion, security is the chief obstacle to Cloud computing adoption. Nearly half of organizations say they have no plans to use any Cloud computing technologies in the next year, the security concerns are the chief reason why. In the survey, thirty-eight percent of respondents said their top priority when considering Cloud vendors was "security of the Cloud infrastructure". The reason is clear. With Cloud computing, data is stored and delivered across the Internet. The owner of the data does not control and typically does not know the location of the data. The owner's data could possibly

reside on the same resources as a competitor's application and data. The data owner has to rely on the Cloud provider's assurance that no unauthorized access takes place. In a multitenant environment, it may be very difficult for a Cloud service provider to offer the level of isolation and guarantee that an environment is dedicated to a single customer. Access control for business data is also of utmost importance. Access control prohibits unauthorized access to the data and applications and provides authorization schemes for multiple applications. Therefore, Cloud service providers must provide a secure virtual execution environment that is isolated for other applications running in the same infrastructure.

In addition, a group of experts has worked on a report that outlines the future directions and open issues of Cloud computing research. The report was presented and discussed on January 26, 2010 in Brussels, Belgium [25]. One of the open research issue is that Cloud technologies and models have not yet reached their full potential and many of the capabilities associated with Clouds are not yet developed and researched to a degree that allows their exploitation to the full degree, respectively meeting all requirements under all potential circumstances of usage. In fact, many aspects are still in an experimental stage where the long-term impact on provisioning and usage is as yet unknown. As a result, plenty of as yet unforeseen challenges arise from exploiting the cloud capabilities to their full potential, affecting some particular aspects deriving from the large degree of scalability and heterogeneity of the underlying resources.

6. **Some Cloud Service Providers.**

Cloud computing offers users with services to access hardware, software and data resources, and integrates computing platform as a service in a transparent way. Typical Cloud service providers deliver common business applications online that are accessed from another web service or software like a web browser, while the software and data are stored on servers. The offerings from five cloud service providers including Amazon, Google, Microsoft, GoGrid and Eucalyptus are summarized as follows [2,4,13,14].

6.1. **Amazon web services.**

The Amazon Web Services (AWS) are a collection of remote computing services (also called web services) that together make up a Cloud computing platform, offered over the Internet by Amazon.com. Since early 2006, Amazon Web Services (AWS) has provided companies of all sizes with an infrastructure web services platform in the Cloud. With AWS you can requisition compute power, storage, and other services-gaining access to a suite of elastic IT infrastructure services as your business demands them. Amazon's Cloud services offerings consist of following services:

1. Elastic Compute Cloud (EC2)
2. SimpleDB
3. Simple Storage Service (S3)
4. Relational Database Service (RDS)
5. CloudFront
6. Simple Queue Service (SQS)
7. Elastic MapReduce
8. Elastic Block Store (EBS)

From a developer's perspective, there are three important sections on the AWS home page: Explore Products, Signup, and Developers. The Infrastructure Services section under Explore Products lists all the core platform services offered by AWS. The Sign Up Now button lets you sign up for the AWS, and the Developers section has links to developer sign-up, technical documentation, the AWS management console, community

forums, and the Amazon Machine Images (AMI). AMIs are preconfigured virtual machine images for running in Amazon's web services.

6.2. **Google.** Google is the leader in search services on the Internet and has a significant presence and properties in advertising, collaboration, e-mail, and social networking sites. Google has massively scaled data centers with customized caching algorithms that host the fastest search engine in the world. The company has extended this massively scalable infrastructure for hosting communication and collaboration platform called "Google Apps" and an application platform called "Google App Engine" for developing and deploying web applications. The main services offered in Google Apps are Gmail, Google Talk, Google Calendar, Google Docs, and Google Sites. Google App Engine is an environment for developing and deploying web applications on Google's infrastructure and let users run their web applications on Google's infrastructure. App Engine also provides a datastore that supports simple create, retrieve, and delete functions. Developers can access the datastore from within App Engine web applications to store and query data. With App Engine, you only pay for what you use. There are no set-up costs and no recurring fees. The resources your application uses, such as storage and bandwidth, are measured by the gigabyte, and billed at competitive rates.

6.3. **Microsoft's windows azure.** Microsoft announced its official entry into the Cloud services arena with the Windows Azure platform in 2008. Microsoft's Windows Azure Platform is a Cloud platform offering that "provides a wide range of Internet services that can be consumed from both on-premises environments and the Internet". The Windows Azure platform today has four parts: Windows Azure, SQL Azure, Windows Azure AppFabric and Windows Azure Marketplace. All four of these components run in Microsoft data centers located around the world: two in North America, two in Europe, and two in Asia. Developers using the platform can control which data center runs their applications and stores their data, giving them the ability to place both closer to their users. Windows Azure is the operating system in the Cloud for running applications and storing data on computers in Microsoft data centers. It forms the core platform for all the other Azure Services. SQL Azure is the database engine providing relational data services in the Cloud based on SQL Server. AppFabric is the middleware component that consists of services like ServiceBus and Access Control. Windows Azure Marketplace is an online service for purchasing Cloud-based data and applications. Windows Azure has five main parts: Compute, Storage, Fabric controller, Content delivery network (CDN) and Connect. As their names suggest, the Compute service runs applications while the Storage service stores data. The third component, the Fabric controller, provides a common way to manage and monitor applications that use this Cloud platform, and also handles updates to system software throughout the platform. The CDN speeds up global access to binary data in Windows Azure storage by maintaining cached copies of that data around the world. The last component, the Connect, allows creating IP-level connections between on-premises computers and Windows Azure applications.

6.4. **GoGrid.** GoGrid is a Cloud hosting service that enables automated provisioning of virtual and hardware infrastructure over the Internet. GoGrid Cloud hosting allows user to build scalable Cloud infrastructure in multiple datacenters using dedicated and Cloud servers, elastic F5 hardware load balancing, and Cloud Storage with total control through automation and self-service. The GoGrid Cloud service offers Windows and Linux virtual machine images preconfigured with the most frequently used software components. It also offers Cloud storage and free hardware load balancing between virtual machine instances using Big IP's F5 load balancer. The service is very similar to the Amazon EC2

service offering with some feature differences. GoGrid is an Infrastructure as a Service (IaaS) Cloud provider. Configuring and managing infrastructure in the GoGrid Cloud is similar to managing infrastructure in a corporate data center or with a dedicated server or colocation service provider. GoGrid infrastructure is accessed and operated using standard network protocols and IP addresses over the Internet. No new technical skills or specialized equipment is required to get started.

6.5. **Eucalyptus.** Eucalyptus is an acronym for "Elastic Utility Computing Architecture for Linking Your Programs To Useful Systems". It is an open-source software infrastructure for implementing Elastic/Utility/Cloud computing using computing clusters and workstation farms. Eucalyptus began as a research project in the field of high performance computing (HPC) under the direction of Professor Rich Wolski in the Computer Science Department at the University of California, Santa Barbara. In January 2009, a company named Eucalyptus Systems, Inc. was founded to support the commercialization of the Eucalyptus Cloud computing platform. With Eucalyptus, customers make more efficient use of their computing capacity, thus increasing productivity and innovation, deploying new applications faster, and protecting sensitive data while making savings in capital expenditure. Eucalyptus enjoys several interesting features, such as compatible interfaces with Amazon's EC2, simple installation, deployment and management, support virtual privet network for users. Eucalyptus provides Amazon EC2's compatible interfaces. The interface compatibility with EC2 reduces the cost of learning a new interface when moving from a private to a public Cloud. It enables users to adopt popular management tools for private Cloud computing and to develop skills using the same techniques that they would deploy on Amazon's popular public Cloud.

Remark 6.1. *According to an article [26], Windows Azure beats Google, Amazon and GoGrid found to be the fastest Cloud service in independent test. From Table 1, produced by Compuware in January 2011, we can see that Windows Azure is top in performance ranking. The Google App Engine is narrowly beaten into second place, followed by GoGrid. Table 1 shows average response times globally on Windows Azure were 10.229 seconds, followed by 10.263 on Google App Engine. The data is taken from Gomez Last Mile tests, which analyze the average last mile response times from across the globe, accessing PCs of over 100,000 users who have signed up for the service in 168 countries. Tests are carried out every five minutes, using an application carrying out the same multiple step commands. Note that: Response time is the total time elapsed while downloading both web pages in the multi-step test transaction from a Tomcat web server hosted on each server.*

Table 1. Cloud provider global performance ranking

Cloud Provider Global Performance Ranking in January 2011		
Cloud Provider	Ranking	Average response times (sec)
Window Azure	1	10.229
Google App Engine	2	10.263
GoGrid	3	10.605
Amazon EC2	4	10.678

7. **Conclusions.** Cloud computing is a style of computing where massively scalable IT-enabled capabilities are provided as a service over the network. It emerges as a new computing paradigm to support the maximum number of user and elastic service with the minimum resource. The evolution of Cloud computing can handle massive data as

per on demand service. At this moment in time, IT is in transition from "as a product" to "as a service" for common workloads and activities. Thus Cloud computing is a complex infrastructure of software, hardware, processing, and storage that is available as a service. By means of virtualization technologies, Cloud computing offers to end users a variety of services covering the entire service stack from the hardware to the application level. The NIST describes IaaS, PaaS and SaaS as three delivery models. However, when it comes to Enterprise Cloud Computing, more to the three layers is needed. This paper presented an expanded delivery services model of Cloud computing, describes the characteristics of Cloud computing and discusses the challenges of the future of Cloud computing. Cloud computing would be a win-win strategy for the service provider and the service consumer. The advantages of Cloud computing are satisfying business requirements on demand, lowering the cost and energy-saving and improving the efficiency of resource management. However, some challenges to be further studied are security and privacy, the continuity of service and service migration.

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