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Cloud Computing

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*Abstract* — Looking towards the needs for data storage of today’s world, cloud computing has a great importance in IT industry, which may force the developers to make the service to be more secure, reliable, usable worldwide and on large scale and efficient too.

As the need for this service is worldwide, the IT industry needs to think it over a massive area of operation and usage. Following will be the challenges faced by Cloud developers:

* In order to scale cloud services reliably to millions of service developers and billions of end users the next generation cloud computing and datacenter infrastructure will have to follow an evolution similar to the one that led to the creation of scalable telecommunication networks.
* The next generation virtualization technologies must allow applications to dynamically access CPU, memory, bandwidth and storage (capacity, I/O and throughput).

The authors believe that the next generation cloud evolution is a fundamental transformation which will enable global service collaboration networks utilizing optimally distributed network and storage resources driven in real-time by business priorities.

*Index Terms* — API, Cloud Computing, Community Cloud, Grid Computing, Hybrid Cloud, IaaS, IT Services, PaaS, Private Cloud, Public Cloud, SaaS, Utility Computing.

# INTRODUCTION

P

roviding software as a service is not a new computing practice. Some companies, known as Application Service Providers (ASPs), were providing businesses with software programs as a service via the medium of the Internet during the 1990s.

However, such attempts at “utility computing” did not take off. This was largely attributed to lack of sufficient bandwidth. During that period broadband was neither cheap nor plentiful enough for utilities to deliver computing services with the speed and reliability that businesses enjoyed with their local machines. Then came Web services (especially those based on the XML-based SOAP1 message protocol) that represented a model of software delivery based on the notion that pieces of software applications can be developed and then published to a registry where they can be dynamically discovered and consumed by other client applications over different transport protocols (e.g., HTTP, TCP/IP, etc.) irrespective of the language used to develop those applications or the platforms (e.g., operation systems, Internet servers) on which they are implemented. This was a dramatic improvement over the services provided by ASPs which relied on proprietary (and hence un-portable) software.

However, Web services are nowhere near achieving the full potential that was hoped for. Nevertheless the technologies being implemented successfully (and commercially) by many of the big players such as eBay, Amazon and Google. Furthermore, the technology has also created the foundation for a new Enterprise Application Integration (EAI) paradigm known as Service-Oriented Architecture (SOA).The extensible XML-based nature of SOAP has enabled many organizations to expose some of their legacy and disparate systems as Web services in order to achieve total integration of their systems.

Most importantly, SOAP-based Web services are now being used in the delivery of some aspects of a new computing paradigm (namely cloud computing) which not only promises to deliver software remotely but also other computing-related functionality thanks also to other relatively new technologies such as virtualization2 and grid computing3.

# What is cloud computing?

Cloud computing is a used to describe a variety of [computing](http://en.wikipedia.org/wiki/Computing) concepts that involve a large number of computers connected through a communication [network](http://en.wikipedia.org/wiki/Computer_network) such as the [Internet](http://en.wikipedia.org/wiki/Internet) [1]. It is very similar to the concept of [utility computing](http://en.wikipedia.org/wiki/Utility_computing). In science, cloud computing is a synonym for [distributed computing](http://en.wikipedia.org/wiki/Distributed_computing) over a network, and means the ability to run a program or application on many connected computers at the same time.

The phrase is often used in reference to network-based services, which appear to be provided by real server hardware, and are in fact served up by virtual hardware, simulated by software running on one or more real machines. Such virtual servers do not physically exist and can therefore be moved around and scaled up or down on the fly without affecting the end user, somewhat like a cloud becoming larger or smaller without being a physical object.

Cloud computing providers offer their services according to several fundamental models. The following is a list of the three main types of services that can be offered by the cloud:-

•*Infrastructure as a Service (IaaS):* Products offered via this mode include the remote delivery (through the Internet) of a full computer infrastructure (e.g., virtual computers, servers, storage devices, etc.).

•*Platform as a Service (PaaS):* To understand this cloud computing layer one needs to remember the traditional computing model where each application managed locally required hardware, an operating system, a database, middleware, Web servers, and other software. One also needs to remember the team of network, database, and system management experts that are needed to keep everything up and running. With cloud computing, these services are now provided remotely by cloud providers under this layer.

*• Software as a Service (SaaS):* Under this layer, applications are delivered through the medium of the Internet as a service. Instead of installing and maintaining software, you simply access it via the Internet, freeing yourself from complex software and hardware management. This type of cloud service offers a complete application functionality that ranges from productivity (e.g., office-type) applications to programs such as those for Customer Relationship Management (CRM) or enterprise-resource management.

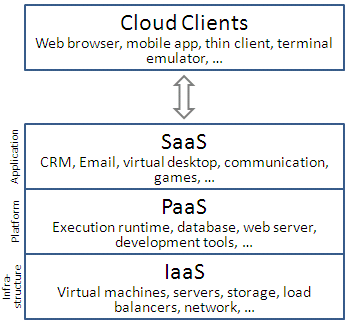


Fig.1. Structure of Cloud and its Services on the Cloud Platform

Before proceeding any further at this stage, a word of caution is necessary. One must not assume that cloud products offered by any of the above services are likely to work out-of-the-box. In some cases they might. Google Apps, a messaging and collaboration cloud platform from Google, is probably one good example of those out-of-the-box products (even though it does require some level of configuration nevertheless). Many of the products that are offered by those three types of cloud services will require some degree of programming (by the user or indeed the cloud provider) in order to access the functionality that exists in those services. Cloud providers will have created their own APIs (application programming interfaces) so that software developers can use them to create client applications in order to access that functionality. Currently, some of those APIs are proprietary; an issue which will be revisited later when examining some of the limitations of cloud computing. However, some are based on open source standards such as SOAP or REST.



Fig.2. Simplified structure of the main users of IT services in a typical university



Fig.3. Simplified structure of the main users of IT services in a typical university now using the services of cloud computing.

To demonstrate how those services can be utilized and the processes involved in their utilization (in a very simplified manner), a hypothetical example can be given. Take, for example, a typical university with an IT infrastructure that caters for the needs of students, teaching staff and management, research staff and software developers (e.g., Web developers). As illustrated in Fig. 1, demand for IT services in this environment is directed to the IT Services

Department (pictured in the middle) whose job is to:

• provide students and staff with software (e.g., email accounts, operating systems, productivity applications, malware detectors and cleaners, etc.) and hardware (e.g., PCs, Servers, etc.).

• provide researchers and postgraduate students with the required special software and hardware to run experiments that are likely to involve a great deal of processing and computation;

• provide Web developers with the development tools needed to write and host Web applications.

Many aspects of this arrangement can be migrated to the cloud as demonstrated in Fig. 2. For example, students, administrative staff and lecturers can be made to use the services of providers of SaaS and IaaS clouds. These services will be ideally accessed through thin clients.Any software launched by these groups of people resides on the servers of the SaaS cloud provider and is accessed online. Any requirement for disk space or additional hardware (e.g., a virtual PC or a virtual Server) is executed immediately online by the IaaS cloud provider. The same situation applies to the developers’ category in this scenario. Developers can now use all the software they need for their development online and all the hardware for hosting their applications through a PaaS cloud provider. Finally, researchers whose projects require a great deal of processing power and/or additional server capacity can do so at the click of a button through an IaaS cloud provider.

# Advantages

Cloud computing relies on sharing of resources to achieve coherence and [economies of scale](http://en.wikipedia.org/wiki/Economies_of_scale), similar to a [utility](http://en.wikipedia.org/wiki/Utility_computing) (like the [electricity grid](http://en.wikipedia.org/wiki/Electrical_grid)) over a network. At the foundation of cloud computing is the broader concept of [converged infrastructure](http://en.wikipedia.org/wiki/Converged_infrastructure) and [shared services](http://en.wikipedia.org/wiki/Shared_services).

The cloud also focuses on maximizing the effectiveness of the shared resources. Cloud resources are usually not only shared by multiple users but are also dynamically reallocated per demand. This can work for allocating resources to users. For example, a cloud computer facility that serves European users during European business hours with a specific application (e.g., email) may reallocate the same resources to serve North American users during North America's business hours with a different application (e.g., a web server). This approach should maximize the use of computing powers thus reducing environmental damage as well since less power, air conditioning, rack space, etc. is required for a variety of functions. With cloud computing, multiple users can access a single server to retrieve and update their data without purchasing licenses for different applications.

The term "moving to cloud" also refers to an organization moving away from a traditional [CAPEX](http://en.wikipedia.org/wiki/Capital_expenditure) model (buy the dedicated hardware and depreciate it over a period of time) to the [OPEX](http://en.wikipedia.org/wiki/Operating_expense) model (use a shared cloud infrastructure and pay as one uses it).

Proponents claim that cloud computing allows companies to avoid upfront infrastructure costs, and focus on projects that differentiate their businesses instead of infrastructure. Proponents also claim that cloud computing allows enterprises to get their applications up and running faster, with improved manageability and less maintenance, and enables IT to more rapidly adjust resources to meet fluctuating and unpredictable business demand. Cloud providers typically use a "pay as you go model." This can lead to unexpectedly high charges if administrators do not adapt to the cloud pricing model.

# Cloud Clients

Users access cloud computing using networked client devices, such as [desktop computers](http://en.wikipedia.org/wiki/Desktop_computers), [laptops](http://en.wikipedia.org/wiki/Laptop), [tablets](http://en.wikipedia.org/wiki/Tablet_computer) and [smart phones](http://en.wikipedia.org/wiki/Smartphones). Some of these devices – cloud clients – rely on cloud computing for all or a majority of their applications so as to be essentially useless without it. Examples are [thin clients](http://en.wikipedia.org/wiki/Thin_clients) and the browser-based [Chrome book](http://en.wikipedia.org/wiki/Chromebook). Many cloud applications do not require specific software on the client and instead use a web browser to interact with the cloud application

# Deployment Models

Deploying cloud computing can differ depending on requirements, and the following four deployment models have been identified, each with specific characteristics that support the needs of the services and users of the clouds in particular ways .

*•* ***Private Cloud***: The cloud infrastructure has been deployed, and is maintained and operated for a specific organization. The operation may be in-house or with a third party on the premises.

*•* ***Community Cloud***: The cloud infrastructure is shared among a number of organizations with similar interests and requirements. This may help limit the capital expenditure costs for its establishment as the costs are shared among the organizations. The operation may be in-house or with a third party on the premises.

*•* ***Public Cloud***: The cloud infrastructure is available to the public on a commercial basis by a cloud service provider. This enables a consumer to develop and deploy a service in the cloud with very little financial outlay compared to the capital expenditure requirements normally associated with other deployment options.

*•* ***Hybrid Cloud***: The cloud infrastructure consists of a number of clouds of any type, but the clouds have the ability through their interfaces to allow data and/or applications to be moved from one cloud to another. This can be a combination of private and public clouds that support the requirement to retain some data in an organization, and also the need to offer services in the cloud.

# Challenges in cloud computing

The current adoption of cloud computing is associated with numerous challenges because users are still skeptical about its authenticity. Based on a survey conducted by IDC in 2008, the major challenges that prevent Cloud Computing from being adopted are recognized by organizations are as follows:

***A. Security****:* It is clear that the security issue has played the most important role in hindering Cloud computing acceptance. Without doubt, putting your data, running your software on someone else's hard disk using someone else's CPU appears daunting to many. Well-known security issues such as data loss, phishing, and bonnet (running remotely on a collection of machines) pose serious threats to organization's data and software. Moreover, the multi-tenancy model and the pooled computing resources in cloud computing has introduced new security challenges that require novel techniques to tackle with. For example, hackers can use Cloud to organize bonnets Cloud often provides more reliable infrastructure services at a relatively cheaper price for them to start an attack.[9]

***B. Costing Model****:* Cloud consumers must consider the tradeoffs amongst computation, communication, and integration. While migrating to the Cloud can significantly reduce the infrastructure cost, it does raise the cost of data communication, i.e. the cost of transferring an organization’s data to and from the public and community Cloud and the cost per unit of computing resource used is likely to be higher. This problem is particularly prominent if the consumer uses the hybrid cloud deployment model where the organization's data is distributed amongst a number of public/private (in-house IT infrastructure)/community clouds. Intuitively, on demand

Computing makes sense only for CPU intensive jobs.

***C. Charging Model****:* The elastic resource pool has made the cost analysis a lot more complicated than regular data centers, which often calculates their cost based on consumptions of static computing. Moreover, an instantiated virtual machine has become the unit of cost analysis rather than the underlying physical server. For SaaS cloud providers, the cost of developing multitenancy within their offering can be very substantial. These include: re-design and redevelopment of the software that was originally used for single-tenancy, cost of providing new features that allow for intensive customization, performance and security enhancement for concurrent user access, and dealing with complexities induced by the above changes. Consequently, SaaS providers need to weigh up the trade-off between the provision of multitenancy and the cost-savings yielded by multi-tenancy such as reduced overhead through amortization, reduced number of on-site software licenses, etc. Therefore, a strategic and viable charging model for SaaS provider is crucial for the profitability and sustainability of SaaS cloud providers. [9]

***D. Service Level Agreement (SLA)****:* Although cloud consumers do not have control over the underlying computing resources, they do need to ensure the quality, availability, reliability, and performance of these resources when consumers have migrated their core business functions onto their entrusted cloud. In other words, it is vital for consumers to obtain guarantees from providers on service delivery. Typically, these are provided through Service Level Agreements (SLAs) negotiated between the providers and consumers. The very first issue is the definition of SLA specifications in such a way that has an appropriate level of granularity, namely the tradeoffs between expressiveness and complicatedness, so that they can cover most of the consumer expectations and is relatively simple to be weighted, verified, evaluated, and enforced by the resource allocation mechanism on the cloud. In addition, different cloud offerings (IaaS, PaaS, and SaaS) will need to define different SLA Metaspecifications. This also raises number of implementation problems for the cloud providers. Furthermore, advanced SLA mechanisms need to constantly incorporate user feedback and customization features into the SLA evaluation framework.

***E. What to migrate****:* Based on a survey (Sample size = 244) conducted by IDC in 2008, the seven IT systems/applications being migrated to the cloud are: IT Management Applications (26.2%),Collaborative Applications (25.4%), Personal Applications (25%), Business Applications (23.4%),Applications Development and Deployment (16.8%), Server Capacity (15.6%), and Storage Capacity (15.5%). This result reveals that organizations still have security/privacy concerns in moving their data on to the Cloud. Currently, peripheral functions such as IT management and personal applications are the easiest IT systems to move. Organizations are conservative in employing IaaS compared to SaaS. This is partly because marginal functions are often outsourced to the Cloud, and core activities are kept in-house. The survey also shows that in the time of three years, 31.5% of the organization will move their Storage Capacity to the cloud. However this number is still relatively low compared to Collaborative Applications (46.3%) at that time.

***F. Cloud Interoperability Issue****:* Currently, each cloud offering has its own way on how cloud clients/applications/users interact with the cloud, leading to the "Hazy Cloud" phenomenon. This severely hinders the development of cloud ecosystems by forcing vendor locking, which prohibits the ability of users to choose from alternative vendors/offering simultaneously in order to optimize resources at different levels within an organization. More importantly, proprietary cloud APIs make it very difficult to integrate cloud services with an organization's own existing legacy systems (e.g. an on-premise data centre for highly interactive modeling applications in a pharmaceutical company).The primary goal of interoperability is to realize the seamless fluid data across clouds and between cloud and local applications. There are a number of levels that interoperability is essential for cloud computing. First, to optimize the IT asset and computing resources, an organization often needs to keep in-house IT assets and capabilities associated with their core competencies while outsourcing marginal functions and activities (e.g. the human resource system) on to the cloud. Second, more often than not, for the purpose of optimization, an organization may need to outsource a number of marginal functions to cloud services offered by different vendors. Standardization appears to be a good solution to address the interoperability issue. However, as cloud computing just starts to take off, the interoperability problem has not appeared on the pressing agenda of major industry cloud vendors.

# Conclusion

Although Cloud computing can be seen as a new phenomenon which is set to revolutionize the way we use the Internet, there is much to be cautious about. There are many new technologies emerging at a rapid rate, each with technological advancements and with the potential of making human’s lives easier. However, one must be very careful to understand the security risks and challenges posed in utilizing these technologies. Cloud computing is no exception. In this paper key security considerations and challenges which are currently faced in the Cloud computing are highlighted. Cloud computing has the potential to become a frontrunner in promoting a secure, virtual and economically viable IT solution in the future

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