"Cloud Computing": A Perspective Study

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PART I

BACKGROUND AND CONCEPTS

Introduction:

- Coined in late of 2007
- Currently emerges as a hot topic due to its abilities to offer flexible dynamic IT infrastructures, QoS guaranteed computing environment and configurable software services

Why is Cloud Computing Distinct?

- **User-centric interfaces**

Cloud services should be accessed with simple and pervasive methods. In fact, the Cloud computing adopts the concept of Utility computing.
Utility Computing: users obtain and employ computing platforms in computing Clouds as easily as they access a traditional public utility.
In detail, the Cloud services enjoy the following features:
(1) The cloud interfaces do not force users to change their working habits and environments.
(2) The cloud client software which is required to be installed locally is lightweight
(3) Cloud interfaces are location independent and can be accessed by some well established interfaces like Web services framework and Internet browser

CONTINUE…

- **On-demand service provisioning**

The computing Clouds provide resources and services for users on demand. User can customize and personalize their computing environments later on, for example, software installation, network configuration, as users usually own administrative privileges.

- **QoS guaranteed offer**
  - The computing environments provided by computing Clouds can guarantee QoS for users.
  - The computing Cloud renders QoS in general by processing Service Level Agreement (SLA) with users – a negotiation on the levels of availability, serviceability, performance, operation, or other attributes of the service like billing and even penalties in the case of the SLA.

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- **Autonomous System**

The computing Cloud is an autonomous system and it is managed transparently to users. Hardware, software and data inside clouds can be automatically reconfigured, orchestrated and consolidated to present a single platform image, finally rendered to users.

- **Scalability and flexibility**

The scalability and flexibility are the most important features that drive the emergence of the Cloud computing. Cloud services and computing platforms offered by computing Clouds could be scaled across various concerns, such as geographical locations, hardware performance, software configurations. The computing platform should be flexible to adapt to various requirements of a potentially large number of users.

DEFINITION

At the current stage, the Cloud computing is still evolving and there exists no widely accepted definition. To help demystify the matter, the 2008 IEEE International Conference on Web Service (ICWS), held last September in Beijing, included a panel, "Cloud Computing and IT as a Service: Opportunities and Challenges." It featured presentation from three IT vendor giants – Microsoft, IBM, and Cisco – addressing industry perspectives and cloud computation initiatives.

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First, we give a broad introductory definition: cloud computing is a nascent business and technology concept with different meanings for different people.

- for application and IT users, it's IT as a service (ITaaS) – that is, delivery of computing, storage, and applications over the Internet from centralized data center
- for Internet application developers, it's an Internet – scale software development platform and runtime environment
- for infrastructure providers and administrators, it's the massive, distributed data center infrastructure connected by IP networks

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Users move out their data and applications to the remote "Cloud" and then access them in a simple and pervasive way. This is again a central processing use case. Similar scenario occurred around 50 years ago: a time sharing computing server served multiple users. Until 20 years ago, when personal computers came to us, data and programs were mostly located in local resource of the history. 50 years ago, we had to adopt the time-sharing servers due to limited computing resources. Nowadays, the cloud computing comes into fashion due to build complex IT infrastructure. User have to manage various software installations, configurations and upgrades. Computing resources and other hardware are prone to be outdated very soon. Therefore outsourcing computing platforms is a smart solution for users to handle complex IT infrastructures.

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Based on the broad definitions provided we propose an definition of "Cloud Computing" as follows:

A computing cloud is a set of network enable services providing scalable, QoS guaranteed, normally personalized, inexpensive computing infrastructures on demand, which could be accessed in a simple and pervasive way.

THREE-LAYER CLOUD ARCHITECTURE

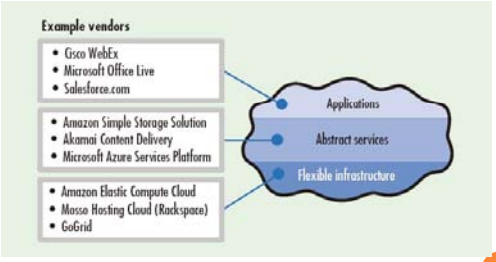
To illustrate this definition, let's look at a three-layer cloud architecture

- **top layer (application layer)**
Top layer applications delivered on demand in the software-as-a service (SaaS) model.

- **middle layer (platform layer)**
Middleware providing application services and a platform-as-a-service (PaaS) runtime environment for cloud applications.

- **bottom layer (infrastructure layer)**
A flexible infrastructure of distributed data center services connected via Internet Style Networking.

EXAMPLE PRODUCTS FOR EACH LAYER



FUNCTIONAL ASPECTS OF CLOUD COMPUTING

Conceptually, users acquire computing platforms or IT infrastructures from computing Clouds and then run their applications inside. Therefore, computing Clouds render users with services to access hardware, software and data resources, thereafter an integrated computing platform as a service in a transparent way:

- **Hardware as a Service (HaaS)**

Hardware as a Service was coined possibly in 2006. As the result of rapid advances in hardware virtualization, IT automation and usage metering and pricing, users could buy IT hardware, or even an entire data center, as a pay-as-you-go subscription service. The HaaS is flexible, scalable and manageable to meet your needs.

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- **Software as a Service (SaaS):**

Software or an application is hosted as a service and provided to customers across the Internet. This mode 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.

An early example of the SaaS is the Application Service Provider (ASP). The ASP approach provides subscriptions to software that is hosted or delivered over the Internet. Microsoft's "Software +Service" shows another example: a combination of local software and Internet services interacting with one another. Google's Chrome browser gives an interesting SaaS scenario: a new desktop could be offered, through which applications can be delivered (either locally or remotely) in addition to the traditional Web browsing experience.

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- **Data as a Service (DaaS)**
  - Data in various formats and from multiple sources could be accessed via services ny users on the network. User could, for example, manipulate the remote data just like operate on a local disk or access the data in a semantic way in the Internet.

    Amazon Simple Storage Service (S3) provides a simple Web services interface that can be used to store and retrieve, declared by Amazon, any amount of data, at any time, from anywhere on the Web.
  - The DaaS could also be found at some popular IT services, *e.g., Google Docs.*

    Elastic Drive is a distributed remote storage application which allows users to mount a remote storage resource such as Amazon S3 as a local storage device.

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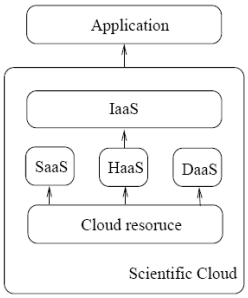
- **Infrastructure as a Service**

Based on the support of HaaS, SaaS and DaaS, the cloud computing in addition can deliver the Infrastructure as a Service (IaaS) for users. Users thus can on-demand subscribe to their favorite computing infrastructures with requirements of hardware configuration, software installation and data access demands.

RELATIONSHIP BETWEEN SERVICES



ENABLING TECHNOLOGIES BEHIND CLOUD COMPUTING

A number of enabling technologies contribute to Cloud computing, several state-of-the-art techniques are identified here:

- **Virtualization technology**
  - Virtualization technologies partition hardware and thus provide flexible and scalable computing platforms.
  - Virtual machine techniques, such as VMware and Xen, offer virtualized IT-infrastructures on demand.
  - Virtual network advances, such as VPN, support users with a customized network environment to access Cloud resources.

Virtualization techniques are the bases of the Cloud computing since they render flexible and scalable hardware services.

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- **Orchestration of Service flow and workflow**

  Computing Clouds offer a complete set of service templates on demand, which could be composed by services inside the computing Cloud. Computing Clouds therefore should be able to automatically orchestrate services from different sources and of different types to form a service flow or a workflow transparently and dynamically for users.

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- **Web service and Service Oriented Architecture (SOA)**

  Computing Cloud services are normally exposed as Web services, which follow the industry standards such as WSDL, SOAP. The services organization and orchestration inside Clouds could be managed in a Service Oriented Architecture (SOA). A set of Cloud services furthermore could be used in a SOA application environment, thus making them available on various distributed platforms and could be further accessed across the Internet.

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- **Web 2.0**

  Web 2.0 is an emerging technology describing the innovative trends of using World Wide Web technology and Web design that aims to enhance creativity, information sharing, collaboration and functionality of the Web. The essential idea behind Web 2.0 is to improve the interconnectivity and interactivity of Web applications. The new paradigm to develop and access Web applications enables users access the Web more easily and efficiently. Cloud computing services in nature are Web applications which render desirable computing services on demand. It is thus a natural technical evolution that the Cloud computing adopts the Web 2.0 technique.

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- **World-wide distributed storage system**

A Cloud storage model should foresee:

- A network storage system, which is backed by distributed storage providers, offers storage capacity for users to lease. The data storage could be migrated, merged, and managed transparently to end users for whatever data formats.

  Examples are Google File System and Amazon S3.

  Another example is Mashup which is a Web application that combines data from more than one source into a single integrated storage tool. The SmugMug is an example of Mashup, which is a digital photo sharingWeb site, allowing the upload of an unlimited number of photos for all account types, providing a published API which allows programmers to create new functionality, and supporting XML-based RSS and Atom feeds.

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- A distributed data system which provides data sources accessed in a semantic way. Users could locate data sources in a large distributed environment by the logical name instead of physical locations. Virtual Data System (VDS) is good reference.

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- **Programming Model**

  Users drive into the computing Cloud with data and applications. Some Cloud programming models should be proposed for users to adapt to the Cloud infrastructure. For the simplicity and easy access of Cloud services, the Cloud programming model, however, should not be too complex or too innovative for end users.

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For example, MapReduce is a programming model and an associated implementation for processing and generating large data sets across the Google worldwide infrastructures. The MapReduce model firstly involves applying a “map” operation to some data records – a set of key/value pairs, and then processes a “reduce” operation to all the values that shared the same key. The Map-Reduce-Merge method evolves the MapReduce paradigm by adding a “merge” operation. And Hadoop which is a framework for running applications on large clusters built of commodity hardware. It implements the MapReduce paradigm and provides a distributed file system – the Hadoop Distributed File System. The MapReduce and the Hadoop are adopted by recently created international Cloud computing project of Yahoo, Intel and HP.

STRATEGIES:

- **Microsoft: Software plus Services**
- **IBM: Transformation through Customer Implementations**
- **Cisco: Evolving Interoperability**

MICROSOFT: SOFTWARE PLUS SERVICES

Microsoft is building its cloud infrastructure to give current Windows and .NET users a seamless experience, whether they’re deploying an application on site or delivering it as a service from the cloud. Microsoft’s chief software architect Ray Ozzie coined the term “software plus services” to emphasize a strategy for enabling enterprise users to keep some applications on the ground. Microsoft didn’t formally announce the Azure Services Platform until a month after the ICWS conference, but the overall architecture and strategy had been in development under the codename Red Dog since 2007. The Azure platform is hosted in Microsoft data centers through Microsoft’s Global Foundation Services, which correspond to the infrastructure layer in Figure1. The platform’s operating system, Windows Azure, provides a development, service-hosting, and service-management environment. The initial set of developer services includes Web application hosting in addition to the company’s scalable storage for unstructured, structured, and queue data. Third-party developers don’t have to use these services to create cloud applications, but Microsoft designed them to make it easier for millions of Microsoft developers worldwide to do their work. Several Microsoft SaaS applications already run on the Azure platform, such as Live Mesh, HealthVault, and Events Online. Hewlett-Packard and several other companies are gearing up their development on the Azure platform as well.

IBM: Tramsformation through Customer Implementations

IBM launched its Blue Cloud initiative in November 2007 to help corporate data centers operate “more like the Internet.” The company scored significant commercial successes in 2008, including Wuxi Software Park in China and iTricity in the Netherlands. These customers are leveraging Blue Cloud to build dynamic infrastructures that provide ITaaS to their end users. The Blue Cloud was introduced as a way to connect and provision the proliferating array of end-user devices and sensors and to rapidly develop and deploy applications and services for delivery over networks. The IBM panel presentation included a slide comparing times for traditional deployments of eight IT management tasks to times for IBM’s cloud computing automated deployments. As part of the commitment IBM has made to develop technologies that meet geographically specific business requirements, the company has built IBM Cloud Labs all over the world—serving both public organizations and private enterprises. It has also invested in academic initiatives to support research and foster next generation Internet skills it sees as critical to cloud computing’s future, particularly in parallel programming.

CISCO: EVOLVING INTEROPERABILITY

- Cisco sees virtualization and automation as the key enabling technologies of cloud computing. As both the internal cloud fabric and delivery mechanism to users, the network plays a central role in enabling clouds with the security, performance, flexibility, and other SLA (service-level agreement) capabilities that enterprise customers require. Virtualization-aware networking, 10GE, and unified fabric technologies are a few examples of a longer list of network-based technologies that will enable enterprise-class clouds to interoperate. In addition, Cisco provides Web 2.0-based collaboration products. For example, it moved into the cloud applications layer in 2007 when it purchased WebEx, the world’s largest videoconferencing service at that time. WebEx Connect is a subsequent cloud application that uses Cisco data center technology to let users share presentations, applications, documents, and desktops. It includes Web-Ex’s full-motion video and integrated audio in a multimedia environment. With respect to Cisco’s focus on enabling enterprise-class clouds and cloud interoperability, Cisco sees three of those areas needing significant improvement to enable the cloud for enterprise customers:
- Security must better ensure data privacy and isolate network traffic through partitioning.
- Performance guarantees and SLA enablement in general must address latency and QoS (quality-of-service) issues.
- Interoperability requirements must support customer choice and additional agility—for example, in workload mobility.

As the IT industry works to solve these problems, cloud adoption will occur in phases: from the stand-alone clouds in place today, to enterprise-class clouds with enhanced security and SLA capability, and finally to full interoperability across cloud infrastructures—that is, the intercloud.

FURTHER RESEARCH ASPECTS

- Cloud computing software platform

  As cloud computing software platform is the heart of a cloud computing system, it will require considerable further research.
- Collaboration applications

  Such means of collaboration as chat, instant messaging, Internet phone calling, etc. will be added to various popular applications.
- Application and data integration across clouds

  The research on these subjects can leverage the available EAI, EII, and ESB technologies.

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- Continuing work on multimedia transmission and data mining

  Transmitting the bulky multimedia data across the network will continue to be a challenge, and it needs further research to speed up cloud computing. Further, as more data gets pushed to the clouds, including user-created data, the need to analyze such data to derive business-useful knowledge will increase. The data mining and machine learning communities will need to address this need.

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- Service Management

  As the clouds proliferate and the users start plugging into multiple clouds, the problems of discovering and composing services that have been subjects of research in the service-oriented architecture context will need to be revisited in the cloud computing context.

OPPORTUNITIES AND CHALLENGES

- **Opportunities:**

  The traditional IT model requires business users to make a front-loaded investment in software and hardware as well as a life-cycle investment in professional staff to maintain servers and upgrade software. IT services in the cloud shift much of this expense to a pay-as-you-go model and so offer significant cost advantages.

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- **Opportunities:**

  Using cloud infrastructure services, companies can redirect resources to more long-term strategic business development. Cloud-based software and services subscriptions can handle security, archiving, and business continuity.

  Early cloud computing offerings, such as Amazon Elastic Compute Cloud (EC2)—appealed primarily to the consumer and small-medium business (SMB) space, where the benefits of not having to establish an IT infrastructure—let alone one that scales on demand—far outweigh any shortcomings.

OPPORTUNITIES AND CHALLENGES

- **Challenges:**

  ITaaS is a highly disruptive concept for enterprise users, who have less to gain and more to lose by outsourcing IT. Cloud service providers trying to serve this space must implement enterprise-class capabilities at multiple levels both in the network and at the end points. Key business and technical challenges include cost, security, performance, business resiliency, interoperability, and data migration.

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- **Challenges:**

  Cloud computing is still in early development. Market researchers, financial analysis, and business leaders all want to assess its potential markets and business impact. According to IDC, a market research firm that recently surveyed IT executives, CIOs, and other business leaders, IT spending on cloud services will reach US$42 billion by 2012. However, as with any disruptive technology and transitional business model, there is no definitive assessment of cloud computing's market opportunity. We believe its long-term business impact could be even larger.

PART II

CONSTRUCT A COMPUTING CLOUD

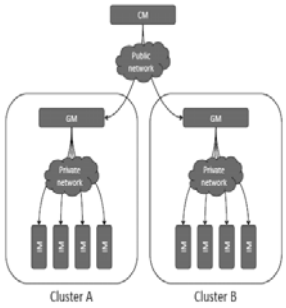

Figure 1. EUCALYPTUS *employs a hierarchical design to reflect underlying resource topologies.*

IM: Instance Manager controls the execution, inspection, and terminating of VM instances on the host where it runs.

GM: Group Manager gathers information about and schedules VM execution on specific instance managers, as well as manages virtual instance network.

CM: Cloud Manager is the entry-point into the cloud for users and administrators. It queries node managers for information about resources, makes high-level scheduling decisions, and implements them by making requests to group managers.

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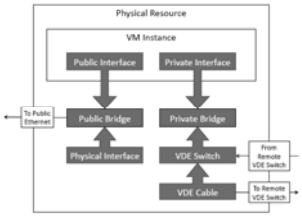

Figure 2. *Each instance is assigned a public interface connected to the physical Ethernet, and a private interface connected to a VDE virtual Ethernet.*

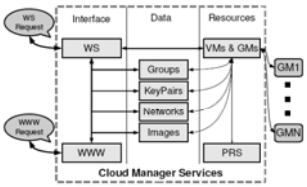

Figure 3. *Overview of Cloud Manager services. Dark lines indicate the flow of user requests while light lines correspond to inter-service system messages.*

QUESTION AND ANSWER:

Question: According to the definition of Cloud Computing, what is the three-layer cloud architecture? What are the functions of them? Could you give me some example for each layer?

Answer:

(1) top layer (application layer)

Top layer applications delivered on demand in the software-as-a service (SaaS) model. E.g. Salesforce.com

(2) middle layer (platform layer)

Middleware providing application services and a platform-as-a-service (PaaS) runtime environment for cloud applications. E.g. Amazon Simple Storage Solution

(3) bottom layer (infrastructure layer)

A flexible infrastructure of distributed data center services connected via Internet Style Networking. E.g. Amazon Elastic Compute Cloud