CLOUD COMPUTING: ISSUES, OPPORTUNITIES AND CHALLENGES

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ABSTRACT

Cloud computing is evolving as significant technology trend for online and on demand IT resource sharing. Cloud computing allows entrepreneurs to develop, deploy, market and sell Cloud applications worldwide without having to invest in expensive IT computing infrastructure, all these along with increase in business agility. It focuses on delivery of reliable, secure, fault-tolerant, sustainable and scalable infrastructures for hosting Internet-based application services. Its overwhelming benefits include low IT overhead, reduction in overall project expenditure, greater flexibility, on demand services and pay-per-use billing model. Manifesting itself as the descendant of several other computing technologies such as Service Oriented Architecture, distributed & grid computing and virtualization, Cloud computing inherits their advancements and limitations. This paper presents key considerations related to Cloud computing, issues, opportunities and challenges involved in it.

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1. INTRODUCTION

Cloud computing is a paradigm that makes IT resources available on demand over the Internet as subscription based service in a pay-as-you-go model just like utility services such as electricity, gas, telephone etc. Cloud consumers need to pay only for the computing services they use. In addition, consumers no longer need to invest heavily in IT infrastructure or encounter difficulties in building and maintaining complex IT resource. The IT resources mainly fall into three categories: (i) *Application* in the form of Software as a Service – SaaS (ii) *Environment* in the form of Platform as a Service – PaaS (iii) *Infrastructure* in the form of Infrastructure as a Service – IaaS.

In SaaS, a complete application is offered as service on demand. The service is hosted on Internet so that it runs on a server and accessed through web interface. (E.g. Salesforce (www.salesforce.com) and Google Apps (www.google.com/a)). In PaaS approach, encapsulated software layer (such as an application server) is offered as a service. (E.g. Sun GlassFish™(glassfish.java.net)). IaaS refers to the sharing of hardware resources (such as compute and storage) where multiple consumers use existing resources which can be scaled up or down as per requirement (E.g. Joyent(joyent.com)).

Clouds [1] intend to control the next generation data centers by building them as a network of virtual services so that users can access and deploy applications from anywhere on demand at viable expenses depending on consumers' Quality of Service requirements [2]. Developers are no longer required to make large capital outlays in the hardware and software infrastructures to deploy their services or human expense to operate it [3]. It offers significant benefit to IT companies by freeing them from the low level task of setting up basic hardware and software infrastructures and thus enabling more focus on core business.

The rest of the paper is organized as follows. Section 2 gives an architectural overview of Cloud environment followed by Cloud computing issues in section 3. In section 4 and 5, opportunities and challenges in Cloud computing are illustrated, respectively. We conclude and leave with the future scope of the work in section 6 with a list of references at the end.

2. ARCHITECTURAL OVERVIEW OF CLOUD

According to article [19], Cloud computing is divided among stack. Figure 1, figure 2 and figure 3 illustrate the stack from various perspectives. A Cloud *client* consists of computer hardware and/or software that rely on Cloud computing for application delivery.

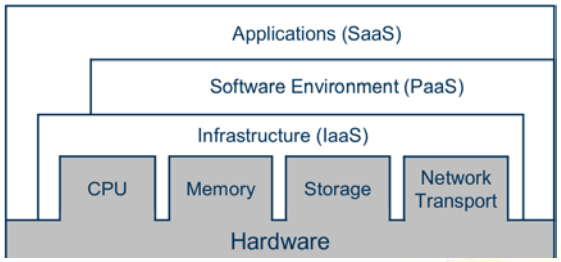

Figure 1: Cloud Computing Overview

Cloud *application* services deliver software as a service over the Internet, eliminating the need to install and run the application on the customer's computers and making maintenance and support simple. Key characteristics include:

- Network-based access to software
- Centrally managed activities enable customers to access applications remotely on the Web
- Application delivery that typically is closer to a one-to-many model including structure, costing, collaborating and administrative characteristics
- Centralized feature updating, which obviates the need for downloadable patches and upgrades.

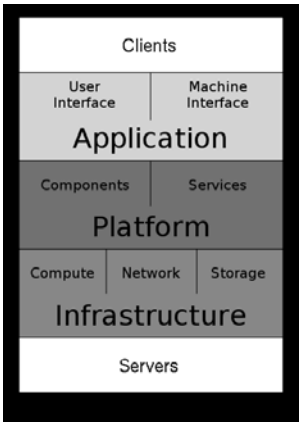

Figure 2: Cloud Computing Stack

Cloud *platform* services or "Platform as a Service (PaaS)" delivers a computing platform 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.

Cloud *infrastructure* services or "Infrastructure as a Service (IaaS)" delivers computer infrastructure, typically a platform virtualization environment, as a service. Clients buy servers, software, data center space or network equipment as a fully outsourced service. The service is typically billed on a utility computing basis and amount of resources consumed (and therefore the cost) will typically reflect the level of activity. It is an evolution of web hosting and virtual private server offerings.

The *server* layer consists of computer hardware and/or computer software products that are specifically designed for the delivery of Cloud services. Table 1 illustrates Cloud's layered architecture from Sun [6] perspective.

Table 1: Layers of Cloud Architecture

Services	Web Services, API, Storage (E.g. Google Maps API)
Applications	Web based applications (E.g. Google Apps)
Middleware	Virtual Hosting (E.g. AMP,

	GlassFish)
Operating System	Rent an OS (E.g. DNS Server)
Virtual Servers	Rent a virtual server
Physical Servers	Rent a computer grid (E.g. HPC Applications)

Reference [7] describes Cloud as a layered architecture as shown in figure 3.

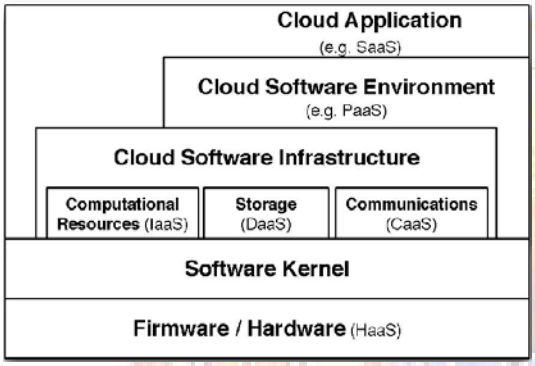

Figure 3: Five Layer Cloud Computing

Cloud Application Layer: Users access the services provided by Cloud through this layer on pay-per-use basis. It exports the user work to application data centers. Google Apps and Salesforce CRM systems are its examples. *Cloud Software Environment*: Cloud developers use this layer to implement and deploy their applications on Cloud using programming environment and API provided by Cloud providers. Google Apps Engine and Salesforce Apex System are its example. *Cloud Software Infrastructure*: It provides resources to other higher level layers to construct new environment or applications. It provides three types of resources: Computational (e.g. Amazon's EC2), Storage (e.g. Amazon's S3) and Communication (Microsoft CSF) resources. *Software Kernel*: It provides interface with physical servers. It can be implemented as an OS kernel, hypervisor, virtual machine monitor, and/or clustering middleware. Globus and Codor are its examples. *Hardware and Firmware*: It is the actual physical hardware that forms the backbone of the Cloud. IBM's Morgan Stanley's Computing Sublease is its example.

One of the key features of Cloud computing is that the infrastructure is programmable and all the developers need to do is configure and interconnect the virtual components through API specified by Cloud providers. The main benefits provided by Clouds are reductions in run time & response time, minimizing the risk involved in deploying actual hardware, reductions in entry cost, and increase in innovation pace.

3. ISSUES IN CLOUD

Traditional security issues (Confidentiality, Integrity and Availability) still play the same role in Cloud computing environment. Following questions need to be answered before migrating from desktop to Cloud. *Confidentiality* – Who controls the data? How reliable it is? *Integrity* – Can my data be tampered with? If yes, how do I come to know about that? *Availabity* – What if I want to transfer my data or to get backup of my data? How do I get my data back if I want to change the Cloud service provider?

Apart from these traditional security issues, there are other business concerns also - Compliance, Policy and risk [4]. *Compliance* – Are there any regulations (e.g. Data Protection Act in UK) to control how and where the data is stored? *Policy* – Costomer's policy must address all legal issues applicable to his enterprise. *Risk* – What if the service provider goes bust ? One risk in selecting a major service provider is that what if the provider is hacked or infacted with virus. *Open source standard* is also an issue of importance to the growth of Cloud computing, and open source software has provided the base for many Cloud computing implementations.

If a client is uncertain of whether Cloud is suitable for him or not, Dargha [5] provides some key consideration for adopting Cloud. He gives an illustrative scoreboard where one can put some numbers as per his own business needs and depending on the final score he may decide whether moving to Cloud is suitable, not suitable or moderate.

Cloud computing is at an early stage in its development, and one of the consequences of this is a lack of authoritative business standards which leads to issues to do with lock-in (and lack of transferability within the Cloud). As discussed above, open source standards are likely to be the solution to the issue.

4. OPPORTUNITIES IN CLOUD

Cloud computing shifts much of the major expenses to a pay-as-you-go model and so offer significant cost advantages. E.g., Microsoft's Exchange Online services provide access to email, calendars, and contacts at very low rate. Using Cloud infrastructure services, companies can redirect resources to more long-term strategic business development.

INPUT (2009) projected that, overall US federal IT spending will grow at a compound annual rate of 3.5%, reaching $90 billion by 2014. INPUT forecasts that federal Cloud computing-related spending will grow almost eight times as fast, with a growth rate of approximately 30% annually. Market Research Media (2009) projects a 40% CAGR (compound annual growth rate) for Cloud.

Joshi [9] states that Cloud computing enables economies of scale leading to large redundancy levels and wide geographical footprints. For Examples Amazon's EC2 supports two regions while AT&T's provides five "super IDCs". These can be leveraged through techniques such as virtual machine migration and cloning to provide better fault tolerance and disaster recovery, especially for operators of smaller applications that may not have been able to afford such capabilities.

New security and reliability services can be enabled or strengthened by virtue of being located in the Cloud. For example, popular Cloud-based email services such as Gmail amplify manual feedback from some users to provide automatic spam filtering for all users. Managed Cloud services that include OS level support can result in improved reliability and security due to consistent centralized administration and timely application of patches and upgrades.

Rayport and Heyward [8] urged the Obama administration, "It's high time to ensure that the Cloud's promise as an opportunity for U.S. wealth generation, job creation, and business and technology leadership does not pass our country by."

As far as deployment is concerned, normal IT tasks such as, servers assignment, software installation, configuring network and security parameters, backup/recovery/installing OS, regulating OS parameters and allocating IT resources dynamically, requires 14-24 days to deploy whereas it requires less than 6 hours in case of Cloud.[18]

It is clear that the opportunity for those who effectively utilize Cloud computing in their organizations is great. However, these opportunities are not without risks and barriers. It is

believed that the value of Cloud computing can be fully realized only when Cloud providers ensure that the Cloud is open.

5. CHALLENGES IN CLOUD

An environment with a few large Cloud infrastructure providers increases the risk of common mode outages and also provides highly visible targets for attackers. Community driven sites have noticed a number of outages and security vulnerabilities over the last few years affecting hundreds of Internet sites.

Sharing of Cloud resources can expose Cloud applications to increased risk levels. For example, on April 26 2008, Amazon's Elastic Cloud (EC2) had an outage across several instances due to a single customer playing abnormally, thereby triggering a performance degradation bug in Amazon's distributed firewall.

Problem detection and diagnosis become difficult as multiple administrative domains between the application and infrastructure operators decrease end-to-end system visibility and error propagation information. Apart from this, Cloud infrastructure providers may not provide full disclosure regarding the cause of outages or other detailed infrastructure design information. The hosting of data on outsourced and shared infrastructure that may be in a different legal jurisdiction than the owner of the data has serious legal and privacy implications. Act (HIPAA) of 1996 and the Telecommunications Act of 1996 may create obstacles to the applicability of Cloud solutions in the financial, healthcare and telecom industries.

Other major challenge [14] is that case law involving information stored in the Cloud is nearly non-existent. The enterprise must take measures to legally protect intellectual property and secure title over its information. In any event, the business must ensure that its security and legal requirements are made part of the contract and that it conducts periodic audits to ensure the vendor is meeting the requirements. [10] presents challanges and opportunities for adoption and growth of Cloud computing as shown in following table 2.

Table 2: Challanges and Opportunities of Cloud Computing

Challenges	Opportunities
Availability of Service	Use Multiple Cloud Providers to provide Business Continuity; Use Elasticity to Defend Against DDOS attacks
Data Lock-In	Standardize APIs; Make compatible software available to enable Surge Computing
Data Confidentiality and Auditability	Deploy Encryption, VLANs, and Firewalls; Accommodate National Laws via Geographical Data Storage
Data Transfer Bottlenecks	FedExing Disks; Data Backup/Archival; Lower WAN Router Costs; Higher Bandwidth LAN Switches
Performance Unpredictability	Improved Virtual Machine Support; Flash Memory; Gang Scheduling VMs for HPC apps
Scalable Storage	Invent Scalable Store
Bugs in Large-Scale Distributed Systems	Invent Debugger that relies on Distributed VMs
Scaling Quickly	Invent Auto-Scalar that relies on Machine Learning; Snapshots to

	encourage Cloud Computing Conservationism
Reputation Fate Sharing	Offer reputation-guarding services like those for email
Software Licensing	Pay-for-use licenses; Bulk use sales

6. CONCLUSION AND FUTURE WORK

Cloud computing is a new and promising paradigm delivering IT services as computing utilities. It promises significant benefits, but today there are security, privacy and other barriers that prevent widespread enterprise adoption. In addition, the cost benefits for large enterprises have not yet been clearly demonstrated. In this paper, we have discussed various Cloud computing aspects such as architecture, issues, challanges and opportunities.

Cloud platforms don't yet offer the full spectrum of an on-premises environment. For example, business intelligence as part of the platform isn't common, nor is supported yet for business process management technologies such as full-featured workflow and rules engines. This is all but certain to change; however, as this technology wave continues to roll forward.

While we are optimistic about the future of Cloud Computing, we would have to look into several other issues like billing units, relative prices of different resources, network bandwidth pricing etc. Several other challenges need to be addressed to realize the vision of marketoriented global Cloud. We also need to address regulatory and legal issues, which go beyond technical issues.

Although Cloud Computing providers may face many challenges as discussed above, it is believed that over the long run, providers will successfully navigate these challenges. Another interesting possible future work could be use of open source and free ware software to implement part of Cloud infrastructure to reduce its operating cost and in turn cost reduction for consumers.

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