AC 2009-1819: EXAMINING THE IMPLICATIONS AND CHALLENGES IN CLOUD COMPUTING ENVIRONMENTS: AN EXPLORATORY STUDY

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Abstract

Commercial enterprises are increasingly utilizing cloud computing as a solution to fluctuating capacity challenges. Cloud computing offers the possibility of on-demand capacity, allowing commercial enterprises to “tweak” their network infrastructure based on increased or decreased demand. Pay-per-use of cloud computing allows not only tremendous cost advantage; it also provides complete flexibility for launching or testing new products or services. Benefits, such as greater utilization efficiencies and worldwide accessibility of data and applications, are sometimes offset by “perceived” loss of control of personal data. Commercial entities such as, IBM, Google and Microsoft are already utilizing cloud computing. These companies, along with many others, face multitudes of challenges at the critical junction of hosted infrastructure and the cloud. Some of these challenges include, but not limited to, resource allocation, usage of virtual machines and bandwidth requirements. Along with these challenges, one of the largest challenges is of the legal status and jurisdiction. Recent legal precedents could provide potentially devastating outcomes for companies looking to adopt cloud computing as part of their network infrastructure. These legal precedents create difficult propositions for corporations from security and compliance audit standpoints. This paper explores various implications in regards to, infrastructure, data security and privacy. The paper also explores how various laws and government directives around the globe affect the relatively new concept of cloud computing. The paper also explores inclusion of cloud computing studies to existing computer networking coursework.

What is Cloud Computing?

Almost 30 years ago, computer manufactures were working to develop a computer that would no longer rely on another system to produce an output. As a result, thick clients were developed to work independently of centralized computer systems. Clients have since grown to be vastly independent, but with the popularity of the internet, we have grown to appreciate the centralization of data and resources. Cloud computing refers to the word ‘cloud’ as the internet. Cloud computing is a style of computing in which we use the internet to access resources and applications to enhance the usability of computing systems. The idea of cloud computing incorporates multi-computing systems and services that offer an infrastructure that reduces the power needed to run client software independently. Cloud Computing and its services hide the complexity of the application and resource management by centralizing the application and taking the workload off the client. Cloud computing can be loosely defined as, an environment where any type of IT resource may be provided as a resource. Like a commercial utility company, these IT resources are shared among thousands of users and thus

distributing investment and maintenance costs. Using resources hosted on cloud, customers are able to access applications and associated data from an outsourced provider. Internal IT department would serve the organization by managing access to cloud providers and ensuring that these vendors provide adequate security, scalability and reliability³. Organizations would certainly relinquish some operational control; however, the gains would be measurable in flexibility. For example, if demand for IT resources surges, add these resources from cloud provider and pay only for usage. In Contrast, if a company experiences slowdown, scale down the resources and pay less. Seasonal businesses would certainly benefit from allowed flexibility.

What are the uses of Cloud Computing?

Cloud computing provides many types of services. Web-based services, Software as a Service, Virtual Infrastructure as a Service, Physical Infrastructure as a Service, Software Platform as a Service, and Application Components as a Service all form this growing computing architecture. The most prevalent, by far, is the Web-based services in which we access most commonly by web-browsers. Two other services, however, are becoming increasingly prevalent in the role of everyday computing. Software as a Service (SaaS) is providing simplicity of development, installation, and management along with a new approach to licensing software. This licensing provides predictable payments, little to no upfront costs, scaling, and is subscription based. Virtual Infrastructure as a Service provides virtualization of computing systems, enabling developers to access and modify the computer resources needed. Companies such as Amazon provide services that enable developers to change resources on the fly using only a few lines of code. Virtual Infrastructures are typically built on large mainframes that store large amounts of data, providing access to many developers¹.

SaaS is a way in which computer software is distributed and run. The application runs directly from an interface, such as internet explorer, thus eliminating the need for installation, updates, and storage of the application. Many cloud computing services have been running for several years. For instance, users have been using applications like Yahoo Mail, Hotmail, and Gmail. Each provides access to the same resource from various locations. Using these clients, email can be retrieved via cell phones, PDA's, laptops, and many other computing systems irrespective of platforms. This provides a convenience of access and would otherwise slow the rate of communication. As software becomes a service, businesses are no longer tied to large investments made when purchasing software up front. The most common service provided by cloud computing today is Web-Based services. Websites such as YouTube, MySpace, FaceBook, and Microsoft Office Live, host web-sites offering services. Software as a Service however, provides a web-application through the internet and uses a new type of subscription based licensing model. This model is growing rapidly due to its flexibility for application development and cost¹¹.

A service that has taken popularity among developers is that of Virtual Infrastructure as a Service. This service includes access to virtual servers, data-storage,

and system configuration, via the internet. One of the most well known Virtual Infrastructure as a Service applications, in use today, is the Amazon Elastic Compute Cloud (Amazon EC2). This service allows access to computer systems via web-services. It allows full root access and control of a system. The word elastic refers to the flexibility in developer needs. This means the cost is dependent on the needs of the application. In some cases, this may provide cheaper costs to developers because it cuts the upfront costs for a complete system, such as server hardware and software. Maintenance on the data-centers that host this environment is handled by the host and therefore also reducing the cost for the developer. Pricing is handled through several factors including, processor speed, storage amount, data transfer, and other management services such as IP addressing. These computing environments also have several operating system choices available. Again, price can vary on the operating system and other software of choice.

An additional advantage to Virtual Infrastructure as a Service is that it eliminates the occurrences of server sprawl that many large organizations tend to have. Server sprawl is defined as an affect of many under-utilized low-end servers that often only support one application. Businesses should try to maximize their return on investment by utilizing as much of the servers as possible and reduce the number of servers to support.

Various Types of Cloud?

Utility computing: Utility computing is where a service provider makes computing resources and infrastructure management available to the customer as needed, and charges them for specific usage rather than a flat rate. Like other types of on-demand computing (such as grid computing), the utility model seeks to maximize the efficient use of resources and/or minimize associated costs¹².

Web services in the cloud: A client company will pay to use application programming interfaces, or API's, of a software program they want to use (infoworld.com). They will then use these programs over an internet connection. While the company will pay less through this approach for much of the same functionality, many times they will only receive a partial version of the program rather than a full or advanced version of the software they wish to use. An example of this type of cloud service is Google Maps, map software that will allow you to view maps from around the world¹⁰.

Platform as a service: In this form of cloud computing a company will build or design their own application that will run on the vendor's servers. These applications are then available for all end users at the company who requires the software. While this form of cloud computing certainly cost effective, the development and capabilities of the applications are restricted by what the provider's servers and infrastructure is able to handle. An example of this type is the new Google Apps Engine¹⁰.

Managed service providers: Managed service providers offer backend technology support to various businesses via the Internet. These include, network monitoring, remote data backup, and network security, but can also include other more new age technology services such as Virtual Private Networks and Voice Over Internet Protocol

services.. An example of this type of application would be Google's email security and archiving service, Postini.

Service Commerce Platforms: Using this form of cloud computing users will be able to purchase various services using the Internet. Examples of these services include, travel or secretarial services.

Internet integration: This method really is how other cloud methods are supported and integrated with the internet environment. It allows companies to integrate multiple SaaS services such as those provided by Salesforce.com and eAutomate, and it also offers enterprises the wherewithal to blend cloud services into their traditional IT resources¹³.

Benefits of Cloud Computing?

Cloud Computing environments offer good levels of failover, redundancy and overall resiliency of resources without any significant infrastructure investment. One of the potential benefits all forms of cloud computing can offer is **centralization of resources**. By combining several IT services into one set of resources money can be saved in a few ways. Most notably is by improving utilization by consolidating demand for underutilized services. Each of the smaller companies would have an individual demand for certain services such as tech support maintenance. They would need to employ a minimum number of people to provide the service and enough excess to handle peak demand. By pooling these services, resources would likely be larger than an individual company's resources but smaller than the sum total of the individual groups. Also by averaging the demand of several projects, peak resource requirements can potentially be minimized. For example, if a company has daily need of 20 units of computing power but a peak of 50 units on certain days of the year. They would have to be capable of handling the 50 units plus some margin for error at all times in order to maintain normal operation during peak usage. If 4 such companies were to pool resources they would likely never need more than 150 units of computing power. The 150 would come from two companies at peak needing 100 units, two at average needing 40 units and 10 for safety. If they ran as individuals the sum of their demand would be about 220 with only a 5 unit margin for error. By averaging out the peaks the third party it department attains a cheaper cost of service by only providing what is demanded by the clients.

Scalability is yet another realized benefit of the cloud computing environment. Since there is one company managing several IT systems, traffic can be measured and a smoother more constant expansion can be achieved. This dampening effect is usually only reserved for big business but can become available to smaller users when resources are pooled.

Another benefit of cloud computing would be the ability to run on **multiple platforms**. Since services are being provided over the internet the data is independent of the hardware on the end user's side of the connection. What this means is that the only capability the end user needs is simply internet connectivity and a device capable of interacting and displaying web data. Since many modern mobile devices can access the internet you can potentially access and manage your IT service from anywhere any time with varying degree of functionality.

Also being **software independent** would also free up both the software provider and user to use their preferred operating system and native desktop environment. Attempts to run multiple operating systems within an information system have only had limited success in the past since conventional information systems would have to support both architectures simultaneously. Since web based applications are designed to run through browsers the software on the end user's machine is largely irrelevant. This would allow for great ease in implementing work at home projects, a great asset in transit intensive metropolitan areas.

Challenges with Cloud?

While in most circumstances, cloud computing is more cost efficient than dealing with in-house equipment, there are some deep concerns in relation to data security, infrastructure concerns and privacy protections. Some critics also argue that the benefits of cloud computing, greater efficiency and greater accessibility, are mostly offset by the implications of users losing control over personal data.

As popularity increases among Software as a Service and Virtual Infrastructure as a Service, companies with highly confidential information must secure their data. The company choosing the host will be the one held responsible for the loss of confidential data, so it's important that they choose a host that is secure. Gartner defines following seven cloud computing security risks⁷.

- 1. Privileged user access:** Since the computer application is now hosted by an outside organization, it's important to know the securities and oversight the host provides with its employees. Employees often have access to the client's data, which could be a potential leak of information.
- 2. Regulatory compliance:** Assure that the host undergoes audits and contains the proper security certifications.
- 3. Data Location:** Provider should commit to storing and processing data in specific jurisdictions. Providers should also make contractual commitment to obey local privacy requirements on behalf of the customer.
- 4. Data segregation:** Assure that data is properly encrypted and tested to assure that irreversible mistakes are not made.
- 5. Recovery:** Make sure accommodations are made for complete recovery in the event of a failure. Also, the time of recovery should be minimal.
- 6. Investigative support:** In most cases, logging for illegal activity is provided, but ensure there is proper investigation support to eliminate any types of illegal behavior.
- 7. Long-term viability:** Guarantee ease of your host's replacement, by checking procedures for transferring data and configurations to another host, in the case the host were needed to be replaced.

Outages pose one of the biggest challenges. In August 2008 Google experienced 3 outages of its enterprise e-mail system, Apps Premier Edition (Cain). Outages not only hurt the involved company, it hurts the cloud computing market as a whole by validating claims that cloud computing is inferior and has greater down time than conventional

systems. These outages further show that the information sensitive companies need to be hesitant when implementing cloud computing solutions.

Another drawback is uniqueness. Many companies have invested a lot of time and money into their IT departments and have reaped great rewards from this innovation. Many of these companies would be reluctant to adopt a completely new IT infrastructure.

Corporations must also consider WAN costs. How much extra bandwidth you'll need to cover the additional throughput required for SaaS depends greatly on the types of applications needed, but network failover and connectivity are the key components. Any disruption would have a potentially devastating effect on business. Although high speed Internet links aren't inexpensive, mounting communication costs could eat into cloud savings.

Laws and governmental directives

Many of these challenges arise at the junction of internal infrastructure and the cloud. Although, these are all valid and interesting questions, even larger questions are arising on the horizon is that of jurisdiction and legal status. Are data and resources in the cloud on the same legal footing as in internal data center?

Turns out that currently, they are not on the same legal footing. Unfortunately, the legal precedents being set around the country are potentially devastating for enterprise adoption of cloud computing. The executive branch is repeatedly taking the position that data stored in the cloud does not have the same assumptions of privacy and due process as does data stored in your own infrastructure. The very fact that you put the data "out there" somehow strips any "expectation of privacy" This could be the most important factor in cloud computing adoption by corporate America⁸.

According to a recent survey conducted by Center for Democracy and Technology, despite the growing number of people using cloud services such as hosted e-mail and online photo storage, many consumers don't understand the privacy and security implications. So far, U.S. courts have generally ruled that private data stored in the cloud doesn't enjoy the same level of protection from law enforcement searches that data stored on a personal computer does.

As for privacy concerns, laws such as HIPAA and EU data directive restrict use of certain personal information. HIPAA makes no specific statements regarding outsourcing of data. It simply requires that a company get assurance from any third parties handling its data that the data will be appropriately safeguarded. Corporations adopting cloud computing resources could be negatively and legal penalized depending on how and where the Cloud Computing provider operates, since the local jurisdiction may not permit these laws to have any effect².

Summary

As far as placing limitations on what to deploy on the cloud, many experts agree to follow "context versus core rule." Core business practices provide competitive advantage in the market place. Context practices are internal activities such as, HR services and payroll. Both core and context can be divided into mission-critical applications and non-mission-critical ones. If the business practice is context and non-mission-critical, then always put it in the cloud. If it is context and mission-critical, it is likely you should make it cloud-enabled. However, if it is core and non-mission-critical, you may want to think about keeping it behind the firewall; if it is core and mission-critical, then definitely keep it behind the firewall³.

As with any new technology, transformational change is always difficult, however, today's dynamic environment demands new approaches to delivering and conducting business functions. Cloud computing is bound to lead the market, and IT organizations will not be able to ignore it. Simple ability to buy CPU time, storage, and application function in a Software as a Service type model in the same ways that companies now buy electricity, rent warehouses, and simply hire various services is bound to revolutionize corporate budgets and fiscal planning¹.

Companies with significant existing IT investments will be much more gradual in their adoption of Cloud computing, since they often have higher security/compliance, scalability, and reliability requirements. Cloud services would be more popular with Small to medium sized businesses (SMB) or startups, since they potentially might not have the time or money to build infrastructure given the nature of their business. As Cloud environments mature, most organizations will migrate some applications to this platform. Although to attract business, Cloud providers must not fall victim to data security breaches or continue to experience significant downtime. Like other transformational technologies, Cloud Computing is entering the market not with a bang, but via a slow and steady progress of functionality.

Cloud computing also offers another resource for innovation in computer networking curriculum. Existing computer networking curricula is already crowded with legacy technologies. As described in this paper, use of cloud computing is growing substantially and has tremendous potential to grow further. Network Administrators would play a very important role in procurement, adaption and configuration of cloud computing technologies for any size business. Adding cloud computing technologies as a networking curriculum innovation would not only enhance already crowded networking curricula, it also has potential to attract and retain quality students.

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