Impact of Cloud Computing: Beyond a Technology Trend

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***Abstract**: Cloud Computing is being widely promoted as the next enterprise computing paradigm and a solution to most current enterprise IT problems. IT experts are making bold predictions about Cloud Computing and IT vendors are making major investments to implement infrastructure for delivery of Cloud Computing services, while IT users express concerns about various aspects of this new enterprise computing model. In this paper we consider Cloud Computing in a historical context of evolution of enterprise computing and briefly review the benefits and challenges of Cloud Computing. We then discuss the likely impact of wide adoption of Cloud Computing on both the providers and consumers of Cloud Computing services, and argue that Cloud Computing represents a continuation of existing trend towards centralization of IT resources resulting in increased specialization and ultimately leading to most end user organizations abandoning IT ownership.*

Keywords: Cloud Computing, SaaS, IaaS, PaaS, SOA

1 Introduction

The main idea of Cloud Computing is not new and can be traced back to the concept of Utility Computing popularized by Nicholas Carr who generated extensive debate following the publication of his articles *IT does not Matter* [1], and *The End of Corporate Computing* [2] where he argues that the traditional (on-premise) model of enterprise computing is unsustainable in the long run and will be replaced by a utility model, similar to that used in electricity generation and distribution. Carr argued that “As information technology's power and ubiquity have grown, its strategic importance has diminished. The way you approach IT investment and management will need to change dramatically”, and that “After pouring millions of dollars into in-house data centers, companies may soon find that it’s time to start shutting them down. IT is shifting from being an asset companies own to a service they purchase”. The analogy with the emergence of electric utilities at the beginning of the twentieth century is remarkably accurate (at least up to a point), and so is his prediction of the transformation of enterprise IT from a fragmented, underutilized and capital intensive on-premise model to a centralized Cloud Computing utility model. But, this simple analogy is rather limited as there are important differences between IT services and electricity supply (or other types of utility services) [3, 4]. More specifically, the complex interaction between business and IT services that often produces innovative business solutions makes it difficult to achieve high levels of standardization (in particular in the case of software services), limiting the ability to leverage economies of scale. To gain strategic advantage using IT services delivered from a utility-style data centre, companies must be able configure IT services to effectively support innovative solutions and business models. It can be argued that the utility model applies well to virtualized IT infrastructure services build using commodity hardware components, but not to software services that are closely coupled to business processes and can be highly specialized.

To fully appreciate the need for a new enterprise computing paradigm we need to put Cloud Computing into a historical context of the evolution of enterprise computing. The present enterprise computing environment is the result of more than four decades of evolution resulting in a highly complex and heterogeneous environment characterized by the coexistence of several generations of architectural approaches and related technologies. Successive generations of enterprise computing architectures have evolved in response to business requirements with organizations attempting to support their increasingly sophisticated business processes using the most up-to-date hardware and software platforms. Notwithstanding major advances in hardware and software technology, enterprise computing is regarded by many as inflexible, costly and associated with poor return on investment. Most current IT systems have been acquired and organized according to specific business functions they support into separate information processing *silos*. This leads to duplication of data and application functionality, and results in high integration costs. Importantly, such environments are excessively complex and inflexible making it difficult for organizations to respond to changing business requirements in a timely manner. According to [5], “Today we have IT infrastructures and enterprise architectures that are just too costly to maintain and difficult to impossible to change. As business needs change, including upturns and downturns in the economy, IT is having an increasingly harder time adjusting to meet the needs of business.”

Furthermore, over the last four decades enterprise computing has undergone progressive decentralization of IT resources (initially in the form of client/server computing and later as a result of deployment of applications over the internet) in the drive for increased scalability to accommodate very large user populations. As the cost of computer hardware decreased, organizations acquired large numbers of computers, initially mini computers and later Personal Computers (PCs). The widespread proliferation of PCs and later various types of servers into the corporate computing environment during the 1980s and 1990s made enterprise computing environment more difficult to control, significantly increasing administration costs. Along with the introduction of multiple hardware platforms came a variety of software, some developed in-house, but mostly purchased from software vendors in the form of various types of packaged software and ERP (Enterprise Resource Planning) systems. In majority of organizations this process of introducing new hardware and software was poorly controlled and contributed to the present high complexity of enterprise computing environments and high demand for integration services, and consequently excessive TCO (Total Cost of Ownership). In retrospect it is clear that decentralization, while delivering many benefits, also produced a situation where IT resources are poorly utilized, difficult to administer and expensive to maintain.

Service-Oriented Architecture (SOA) has been widely promoted as the architecture capable of addressing the business needs of modern organizations and at the same time reducing TCO of enterprise IT. Many organizations view SOA as an architectural solution to the problem of integration of legacy applications, improving responsiveness and flexibility of IT solutions as well as increasing hardware utilization. However, there is increasing evidence that many companies are not willing to make substantial investment required for the transition to SOA, and there is disillusionment among some experts who are beginning to argue that SOA has failed to deliver on its promise [6, 7]. While SOA is well-suited to today’s dynamic computing environment, adopting new enterprise architecture addresses only a part of the problem that organizations face when implementing IT solutions, as in the final analysis, enterprise applications must be implemented using hardware and software technologies provided by IT vendors and deployed by IT professionals. The success of such projects depends on numerous factors that include the stability of technology platforms, correctness of the analysis, and not least on the level of expertise and skills of IT architects, application designers and developers. Numerous studies indicate that the success rate of such IT projects conducted by user organizations is unacceptably low. For example, a recent CHAOS Summary 2009 report by The Standish Group based on a survey of 400 organizations concludes that only 32 percent of IT projects were considered successful, 24 percent of IT projects were considered failures, and the rest (44 percent) were considered challenged (finished late, over budget, or with fewer than the required features and function) [8]. This poor performance indicates that end-user organizations are not well-equipped to manage the development, customization and operation of complex enterprise applications. IT is not core competency for such organizations and often represents a substantial drain on resources that could be better utilized on core business activities. Rapidly evolving technology and continuously changing business requirements are making it increasingly more difficult for end user organizations to maintain pace with new developments and to acquire the necessary technical skills to conduct implementation projects.

The present trend towards re-centralization and consolidation of computing resources into large data centers is a response to decades of decentralization and represents an effort to regain control of enterprise IT. The administration and management of centralized computing environments is significantly less expensive, and typically associated with high-levels of security, data integrity, and system availability. Most of the limitations of the early mainframe-based data centers have been overcome by multi-processor architectures that use inexpensive commodity processors and storage devices configured as blade servers to achieve high levels of scalability at acceptable cost. Virtualizations, statistical multiplexing and sophisticated resource management with on-demand provisioning further increases utilization and reduces TCO. While some large organizations have been able to take advantage of such technological developments to optimize the use of their IT resources, and in some cases re-invent themselves as technology providers renting out spare capacity of their data centers (e.g. Amazon.com), most user organizations are looking towards various types of outsourcing solutions to avoid the costs associated with ownership of IT infrastructure and enterprise applications.

In summary, most user organizations today face three fundamental issues:

1) complex, inflexible, under-utilized and expensive IT infrastructure
2) poorly integrated, expensive to deploy and customize on-premise software
3) need to maintain costly internal IT expertise and pay for external consulting assistance

Cloud Computing is regarded by many as new enterprise computing model with the potential to address all of the above issues. According to IDC, spending on IT cloud services will grow almost threefold over the next five years [9]. IT companies are investing hundreds of millions of dollars building large data centers designed to deliver various types of software and infrastructure services, but many users express concerns about security, data lock-in, increased dependence on service providers, and a number of other issues that are likely to slow the adoption of Cloud Computing [10].

In this paper we briefly review the basic Cloud Computing models and related technologies (section 2), and then discuss the benefits and challenges of Cloud Computing (section 3). In the final section (section 4) we conclude by discussing the likely impact of wide adoption of Cloud Computing on both the providers and consumers of Cloud Computing services.

2 Cloud Computing Models and Technologies

As many other concepts in IT, Cloud Computing lacks a precise definition and this can create confusion and lack of understanding of potential benefits and challenges associated with adopting this model. Most definitions are too broad and high-level allowing almost any IT service delivered from a remote data centre on a pay-per-use basis to fit under the Cloud Computing *umbrella*. Consider, for example the frequently quoted NIST (National Institute of Standards and Technology) definition: “Cloud computing is a pay-per-use model for enabling available, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, services) that can be rapidly provisioned and released with minimal management effort or service provider interaction." [11]. Most authors classify Cloud Computing services into three distinct categories: SaaS (Software as a Service), IaaS (Infrastructure as a Service), and PaaS (Platform as a Service), and two types of deployment models: Public clouds (public cloud is shared by multiple companies), and Private clouds (private cloud is used exclusively by a single organization), although agreement about this classification is not universal. Some experts exclude PaaS, some insist on multitenancy and automatic provisioning as preconditions for Cloud Computing, and others dismiss the concept of a private cloud [12]. There is also a discussion about the minimal size of a cloud and other aspects of the model. Although the basic Cloud Computing models (IaaS, PaaS, and SaaS) share a number of common characteristics and are often used in combination, it helps to consider each model separately when discussing their role in enterprise computing today.

2.1 Infrastructure as a Service

IaaS is a basic Cloud Computing service that addresses the need for a scalable, cost-effective IT infrastructure, and is typically provided directly to users in the form of virtualized operating system instances and cloud storage (but can also include other types of services such as message queuing and database services), or delivered as an integral component of PaaS or SaaS services (e.g. Salesforce.com CRM SaaS applications are implemented using a scalable infrastructure services and can be complemented with additional application components developed using Force.com PaaS development environment). Cloud infrastructure services rely on low-cost, commodity storage and server components, and highly scalable virtualized resources that use statistical multiplexing to significantly increase resource utilization, typically to above 80%. According to some estimates, the combination of statistical multiplexing and savings achieved by placing data centers in geographical locations with low cost of electricity, labor, property, and taxes can reduce costs by a factor of 5-7. As a result, infrastructure services can be offered at relatively low cost; for example Amazon EC2 Services offer 1.0 - GHz x86 ISA (Instruction Set Architecture) instance for 10 cents/per hour, and Amazon S3 storage charges are $0.12 to $0.15 per gigabyte-month [12]. A number of major vendors have entered the IaaS market, including Amazon.com, Microsoft, Google and Yahoo with a range of service offerings, leveraging their massive data centers. Amazon.com offers infrastructure services that include storage services - Amazon Scalable Storage Service (Amazon S3), compute services - Amazon Elastic Compute Cloud (Amazon EC2) and, database management services - Amazon SimpleDB [13]. Microsoft offers cloud services under the Azure Platform [14], that include Windows Azure (Windows operating system instances), Microsoft SQL Azure (cloud-based database build on SQL*Server), and Windows Azure platform AppFabric (framework to connect cloud and on-premise applications and services).

2.2 Platform as a Service

PaaS services address the need for a reliable, secure and scalable development environment that can be rapidly configured and deployed without extensive technical expertise. An example of a Cloud Computing platform service is Google App Engine for Java intended for developers of consumer-oriented Web applications [15], and the recently released enterprise version Google App Engine for Business that targets enterprise application developers and provides secure and scalable environment (including the ability to host SQL databases) for enterprise-level applications [16]. Using this platform, Java developers can rapidly develop and deploy Java and J2EE applications to the cloud without having to provision servers, configure databases and server-side technologies. Google App Engine services include authentication, authorization, data persistence and task scheduling and use standard Java technologies so that existing Java applications can be ported to the cloud without major modifications. Other examples of PaaS services include the Force.com platform [17] that allows developers to build applications compatible with Salesforce.com suite of business application and leverages the scalability of the underlying multitenant architecture. Third-party developed applications can be made available to users via the AppExchange, a marketplace for Salesforce applications and services that users can evaluate and purchase. AppExchange applications are developed using the

Force.com platform and are relatively easy to integrate with other applications within the same ecosystem. Integration with other types of cloud services (e.g. AWS) or legacy applications is implemented using Web Services and REST APIs. Another example of a platform service is the Oracle Database 11g on Amazon EC2 Cloud that provides a number of popular AMIs (Amazon Machine Images) for the Oracle Database 11g database, dramatically reducing the time and skills required to configure an Oracle database instance. Fast and secure backups of Oracle databases can be made to Amazon S3 service, avoiding data transfer the costs [18].

2.3 Software as a Service

The SaaS model has its origins in the Application Service Provider (ASP) model that emerged in the late 1990s, but was largely unsuccessful due to a lack of suitable technological infrastructure for hosting complex enterprise applications in a scalable and secure manner. Essential pre-requisite for delivering SaaS services to a large user base with diverse application requirements is a multitenant architecture that is able to accommodate a large number of different versions application components tailored to specific requirements of individual end-user organizations, and share physical and logical resources among different end-user organizations in a secure manner. Database virtualization plays a key role in large-scale SaaS applications, allocating individual end-user organizations to logical (virtual) databases that coexist within a single physical database instance and at the same time maintaining confidentiality of information. This significantly reduces administration overheads associated with maintaining the database (i.e. database backup and recovery, etc.), and provides a secure environment for individual user organizations. Examples of successful SaaS services range from comprehensive CRM applications offered by Salesforce.com [19] to office and collaboration applications provided by Google Apps [20]. Google Apps includes messaging via Gmail and Google Calendar and collaboration services via Google Docs, Google Video, Google Sites and Google Secure Data Connector (SDC). SDC allows access to corporate data residing behind a firewall and enables the creation of web applications that have access to both private as well as public data in a secure manner by allowing the validation and authorization of requests.

3 Benefits, Risks and Challenges of Cloud Computing

A key characteristic of Cloud Computing is that services can be rented on a pay-as-you-use basis, enabling client organizations to adjust the level of usage (e.g. amount of storage, number of servers, number of users, etc.) according to their current needs. This property (called elasticity) allows client organizations to manage their IT expenditure much more effectively than in situations where they directly own IT resources. From the point of view of service provider, the Cloud Computing business model generates ongoing revenues in the form of subscription fees and as the number of clients grows the service provider benefits from economies of scale as the incremental costs of adding new users is relatively low. The clients benefit from minimizing (or eliminating altogether) up-front costs associated with hardware and software acquisition and predictability of ongoing costs. Importantly, the responsibility for operation and upgrades is transferred to the provider resulting in rapid implementation and reduced demand for internal IT staff. However, it should be noted that the actual benefits that users gain by adopting Cloud Computing solutions can significantly vary according to the specific circumstances and type of service. For example, the benefits derived from service elasticity are particularly compelling in situations where demand varies widely or is unpredictable [10]. The frequently quoted Animoto example of the customized Web-based video presentation service [21] involves a massive increase in number of users (from 5,000 users per day to about 750,000 users in three days) over a short period of time. This scenario is not likely to be replicated in more traditional enterprise computing environments. Although demand for IT resources is often subject to seasonal variations, such rapid increases typically occur in start-up companies, or possibly on-line e-commerce websites. Similarly, not many enterprise applications are capable of taking advantage of parallelization to the extent demonstrated by the New York Times Time Machine (another frequently quoted Cloud Computing success story) that made 3.3 million of fully searchable articles of The New York Times available online using Amazon Web Services. Conversion of millions of newspaper articles and hundreds of thousands of large image (TIFF) data files was implemented on hundreds of machines simultaneously using in less than 36 hours [22].

Cloud Computing is associated with a number of well-documented challenges and potential risks. According to a recent IDC survey [23], security is regarded as the top Cloud Computing challenge (87% of respondents), followed by service availability (83% of respondents), and performance (83% of respondents). Other issues identified by the survey included concerns about higher costs (when compared to on-premise implementation) associated with the subscription model (81% of respondents), lack of interoperability standards (80% of respondents), data lock-in (80% of respondents), difficult integration with on-premise applications (77% of respondents), and limited customization facilities (76% of respondents). Business continuity and service availability has been identified as a significant inhibitor for Cloud Computing adoption [10], and although leading Cloud Computing service providers (e.g. Google, Amazon.com, Salesforce.com) use multiple data centres and network providers to maintain highly reliable services, typically limiting outages to a few hours per year (i.e. maintain availability above 99.9%), this can still be unacceptable for some user organizations. Of particular concern is the potential of service provider business failure or takeover by another company, as the level of dependence on the service provider is much greater than in on-premise implementations. Although Cloud Computing service providers are highly focused on data security and confidentiality, there are many applications that cannot be considered for cloud deployment because of regulations that affect location of data and stringent auditability requirements. Governance is another area of concern as responsibilities become divided among various parties (i.e. service providers, end users, and possibly a third-party) making the environment more difficult to audit and manage.

At a more technical level, Cloud Computing applications need to be designed to maximize the benefits and minimize the costs. This involves decisions about data placement as the cost of data transfer can be prohibitive ($100 to $150 per terabyte), and other architectural considerations. There are indications that many organizations are lacking the architectural pre-requisites for Cloud Computing and will not be able to take full advantage of this new approach [24]. The Cloud Computing subscription model is particularly attractive to SMEs (Small and Medium Enterprises) as little or no upfront capital expenditure is required, but in general, these organizations do not have the technical and management skills to be able to effectively integrate externally sourced services from a range of different providers and to incorporate these services into their existing enterprise architecture.

4 Conclusions

Recent convergence of important technological trends that include commoditization of hardware, hardware and software virtualization, ubiquitous network connectivity and SOA has created pre-conditions for a major shift in the way enterprise IT is implemented and delivered. Leading IT companies are facilitating this transition by making massive investments in infrastructure for delivery of Cloud Computing services and are actively promoting the benefits of this new model. It is also evident that IT user organizations have concerns about certain aspects of Cloud Computing, in particular data security, services continuity and provider lock-in. It is quite likely that many large organizations will take advantage of new data centre technologies and implement their own (private) clouds emulating the features of public clouds and deriving similar benefits without running the risks associated with external service providers. For example, the UK Government has announced a strategy to create a government cloud (G-Cloud) that will concentrate government computing power into a series of about a dozen highly secure data centers replacing more than 500 existing data centers with expected annual savings of £3.2bn [25]. Other large organizations with security concerns may follow a similar path towards Cloud Computing, consolidating their existing data centers and taking advantage of virtualization technologies to optimize hardware utilization and minimize costs.

Cloud Computing adoption rates for individual application types and industry sectors are likely to vary significantly. Adoption rates for relatively simple and stable enterprise applications such as CRM and office productivity applications are relatively high, while more comprehensive ERP-style enterprise application are not easily adapted to service-based delivery because of the extensive customization required for each use-user organization. Adoption of Cloud Computing is likely to be driven, at least initially, by SMEs and by new startups, with Cloud Computing acting as a catalyst for innovation. There is some evidence that new innovative startup companies are already taking advantage of Cloud Computing services to enable new business models. For example, the business intelligence and analytics company GoodData (www.gooddata.com) is using Amazon Web Services and Amazon CloudFront to deliver specialized BI (Business Intelligence) services.

Finally, Cloud Computing while being driven by technological advances is not purely a technological trend. It is primarily a manifestation of increasing maturity of the IT industry resulting in increased specialization and re-distribution of responsibilities among IT vendors, end-user organizations and various types of third-parties (e.g. systems integrators, etc.). Most enterprise applications in use today have been architected for low performance/high cost hardware platforms and low bandwidth networks. This type environment necessitates local deployment of applications and local storage of data, and consequently on-premise software and hardware. This results in poor hardware utilization and high TCO. A major component of this high TCO can be traced to inefficiencies associated with poor (*diluted*) IT expertise that needs to be transferred from the source (i.e. the IT vendor) to a large number of the end-user organizations. For example, a single new version release of an ERP system requires re-skilling of thousands of local experts employed by end user organizations, and may also necessitate hardware upgrades and additional software customizations. Apart from the high cost associated with this re-skilling process, given the fast rate of change, enterprise applications in end user organizations are almost never up-to-date with latest software releases. Similar arguments can be made for on-premise hardware technology. Fast and ubiquitous network connectivity combined with almost infinitely scalable computing platforms makes this enterprise computing model obsolete. This will lead to concentration of IT resources with IT providers resulting in increased specialization and ultimately leading to most end user organizations abandoning IT ownership altogether.

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