International Journal of Information Management 30 (2010) 109–116

Contents lists available at ScienceDirect

International Journal of Information Management

journal homepage: www.elsevier.com/locate/ijinfomgt

Cloud computing for education: A new dawn?

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ARTICLE INFO

Article history:

Keywords:
Cloud computing
Web services
Virtualization
Grid computing
Small and medium enterprises (SMEs)

ABSTRACT

Educational establishments continue to seek opportunities to rationalize the way they manage their resources. The economic crisis that befell the world following the near collapse of the global financial system and the subsequent bailouts of local banks with billions of tax payers' money will continue to affect educational establishments that are likely to discover that governments will have less money than before to invest in them. It is argued in this article that cloud computing is likely to be one of those opportunities sought by the cash-strapped educational establishments in these difficult times and could prove to be of immense benefit (and empowering in some situations) to them due to its flexibility and pay-as-you-go cost structure. Cloud computing is an emerging new computing paradigm for delivering computing services. This computing approach relies on a number of existing technologies, e.g., the Internet, virtualization, grid computing, Web services, etc. The provision of this service in a pay-as-you-go way through (largely) the popular medium of the Internet gives this service a new distinctiveness. In this article, some aspects of this distinctiveness will be highlighted and some light will be shed on the current concerns that might be preventing some organizations from adopting it.

1. Introduction

Providing 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 (Carr, 2009). Then came Web services (especially those based on the XML-based SOAP[1] 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.

The advent of Web services promised many exciting possibilities. Some of these promised possibilities initially received a great deal of attention and were a frequent subject of media discussions and futuristic scenarios (sometimes amounting to "hype") such as the ability to automate the process of discovery, binding, and invocation of Web services on the Internet without human intervention (Manes, 2004; Nakhimovsky & Myers, 2004). One technology analyst and author (David Chappell) in 2003 even doubted if there was a business case for Web services (Chappell, 2003).

However, Web services are nowhere near achieving the full potential that was hoped for. Nevertheless, the technology is being implemented successfully (and commercially) by many of the big players such as eBay, Amazon and Google (Iskold, 2006). 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 (Clark, 2007; Flinders, 2007; Mohamed, 2007).

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

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[1] SOAP is an XML-based and open source message transport protocol. It stands for Simple Object Access Protocol.

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doi:10.1016/j.ijinfomgt.2009.09.004

software remotely but also other computing-related functionality thanks also to other relatively new technologies such as virtualization[2] and grid computing.[3]

2. What is cloud computing?

There seems to be many definitions of cloud computing around. A study by McKinsey (the global management consulting firm) found that there are 22 possible separate definitions of cloud computing. In fact, no common standard or definition for cloud computing seems to exist (Grossman, 2009; Voas & Zhang, 2009). A more commonly used definition describes it as clusters of distributed computers (largely vast data centers and server farms) which provide on-demand resources and services over a networked medium (usually the Internet). The term "cloud" was probably inspired by IT text books' illustrations which depicted remote environments (e.g., the Internet) as cloud images in order to conceal the complexity that lies behind them.

However, by understanding the type of services offered by cloud computing, one begins to understand what this new approach is all about. The following is a list of the three main types of services that can be offered by the cloud[4]:

- 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.

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.[5]

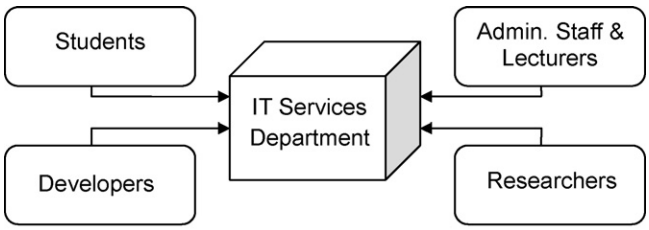

Fig. 1. Simplified structure of the main users of IT services in a typical university.

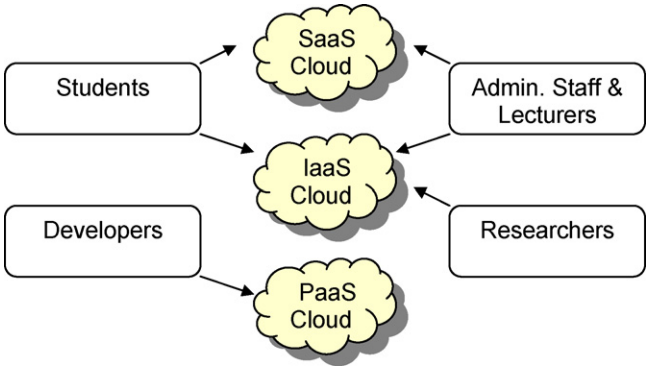

Fig. 2. Simplified structure of the main users of IT services in a typical university now using the services of cloud computing.

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.[6] 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

[2] Virtualization is the technology that enables the creation of a virtual (as opposed to actual) version of something e.g. an operating system, a server, a storage device or network resources.

[3] Grid computing is the technology that enables the sharing of tasks over multiple computers (joined together to form a supercomputer). These tasks can range from data storage to complex calculations and can be spread over large geographical areas.

[4] Some sources expand this list.

[5] REST, which stands for Representational State Transfer, is a style of programming which relies on well established protocols and standards (e.g., HTTP, URI, XML, etc.) to store, retrieve and process data.

[6] A thin client is a dumb terminal that is no more than a screen and a keyboard.

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.

Some analysts dispute the validity of attaching the title "new paradigm" to cloud computing arguing that this approach is largely dependent on existing technologies and approaches such as utility computing, distributed computing and centralized data centers. Cloud computing's only innovation, according to this view, is that it combines and integrates these approaches (Weinhardt, Anandasivam, Blau, & Stößer, 2009).

However, the notion of providing a wide array of computing-related services on the fly on a pay-as-you-go basis opens many opportunities for the providers of those services to exploit this expanding market which (according to Merrill Lynch) is worth 100 billion US dollars (Buyya, Yeo, & Venugopal, 2009). At the same time, it increases the options available to policy makers entrusted with the job of ensuring the efficient functioning of their organization's IT resources. On that basis, cloud computing probably represents a paradigm shift in the way IT (in its all aspects) is being viewed by commoditicising it in a manner that was not possible before.

3. Methodology

To demonstrate the viability of cloud computing for organizations (especially educational establishments) and its huge potential benefits, an introduction will be given in order to highlight the common economic issues associated with having an IT infrastructure. Furthermore, a number of general examples will be provided to demonstrate the emerging popularity of cloud computing with some educational and business establishments, and more focus will be applied on the recent experience of the University of Westminster with cloud computing as a case study.

4. Flexibility and cost

Economics, simplification and convenience of the way computing-related services are delivered seem to be among the main drivers of cloud computing (Erdogmus, 2009). Many see huge potential of the technology in reducing the cost of IT to organizations and freeing them from the expense and hassle of having to install and maintain applications locally (Leavitt, 2009). Providing IT services in the cloud shifts much of this expense to a pay-as-you-go model and consequently offers significant cost advantages according to one view (Lin, Fu, Zhu, & Dasmalchi, 2009). Furthermore, a great proportion of the costs of running an IT infrastructure comes from electricity consumption (needed to run hardware e.g., PCs, servers, switches, backup drives, etc.) and cooling (needed to reduce the heating generated by the hardware). Cloud computing is likely to reduce expenditure in this area and also reduce labor-related costs, as less people (e.g., technicians) than before will be required to run a cloud-based IT infrastructure.

5. The cloud is here already

Cloud computing is not just a concept technology that promises to deliver many exciting things. It is already a reality and there are many commercial implementations of it. For example, Amazon's Elastic Compute Cloud (EC2) offers a variety of services and it represents a virtual computing environment that allows users to use Web service interfaces in order to launch instances with a variety of operating systems, load them with customers' custom application environment and manage customers' network's access permissions. Amazon's other cloud, known as S3 (or simple storage service), provides a Web services interface that can be used to store and retrieve any amount of data, at any time, from anywhere on the Web. It provides developers with access to "the same highly scalable, reliable, fast, inexpensive data storage infrastructure that Amazon uses to run its own global network of Web sites", according to Amazon's description of this service.

A number of clouds serving different needs are also provided by Google. One popular service is Google Apps. Google Apps is a collection of Web-based messaging (e.g., Gmail, Google Talk, and Google Calendar) and productivity and collaboration tools (Google Docs: text files, spreadsheets, and presentations).

IBM has a number of cloud products under its Smart Business portfolio. They include Smart Market (a portal service to compare and manage different business applications that run in IBM's cloud environment), Smart Cube (an all-in-one appliance that has networking, storage, and office software built in), Smart Desk, (a dashboard software package that enables users to manage applications and services from the Market and Cube clouds). IBM is also trying to address the concerns of IT staff who claim that their top challenge is finding enough available resources to perform tests before moving new applications into production. IBM response was the introduction of Smart Business Test Cloud (designed, according to IBM, to reduce costs to organizations substantially) which includes a pre-integrated set of services, from planning through management, for a test environment implementation. Delivered through hardened services methods for the design and deployment of integrated cloud solutions, this cloud can leverage existing investments in hardware, software, storage, and virtualization management, or utilize the newly announced IBM Cloudburst (a complete IBM service management package) as the infrastructure solution.

Like other major vendors, Microsoft is also investing heavily in this new computing service delivery model and has introduced Azure, as its cloud offering. Azure has three components: Windows Azure (which provides developers with on-demand compute and storage to host, scale, and manage Internet or cloud applications), SQL Azure (which extends the capabilities of Microsoft SQL Server into the cloud as a Web-based distributed relational database) and Azure .Net Services (which include a set of Microsoft-hosted, highly scalable, developer-oriented services that provide key building blocks required by many cloud-based and cloud-aware applications).

The above examples are intended to provide an impression of the type of cloud services on offer by some of the major players in this field. There is no space here to list the many other cloud services that currently exist. However, some Web sites and blogs maintain a list of those suppliers which can be found easily by "google-ing" one's search. This, no doubt, is a manifestation of the growing number of cloud providers and vendors.

6. Education and the cloud

The high rate at which IT technology changes will continue to place a great deal of pressure on organizations' budgets. Continuous upgrades of software and hardware have become important items on many of those organizations' resource meetings and will continue to put pressure on the budgets of those organizations. This situation is likely to be made worse in the current difficult economic conditions, following the near collapse of the world's financial systems.

However, cloud computing services could provide many of those organizations with the opportunity to continue to take advantage

of new developments in IT technologies at affordable costs. Cloud computing is likely to be an attractive proposition to startup and small to medium enterprises[7] and educational establishments. The UK's National Computing Center (NCC) estimates that SMEs can reduce the total cost of ownership of technology using hosted solutions (Microsoft, 2009).

This view was reinforced by cloud vendor "Gooroo" in a survey which revealed that UK SMEs will embrace cloud computing in an attempt to reduce costs during the economic downturn. Over half (54%) of the survey's respondents indicated that they expected to be using cloud computing by the end of 2010 while 12% said that they were already using the technology. The majority of respondents (65%) said that a reduction in overall IT costs was the main driving force behind their adoption of cloud computing. The surveyed companies indicated that improved efficiency (50%), greater business flexibility (50%), easy set-up and management (46%) and access to key business applications from any location (42%) were among the cloud adoption drivers (Evans, 2009).

Indeed, cloud computing could also prove to be attractive to academic institutions. The global bailouts of the financial systems with hundreds of billions of tax payers' money are likely to impact on public spending in many countries. In the UK, for example, there are speculations that senior civil servants had been told to draw up contingency plans for 20% cuts in public spending. This situation is giving vice-chancellors cause for concern as they fear that their 8.5 billion pounds budget will be among the first to suffer, regardless of which party wins the next general election (Grimston, 2009).

Colleges and universities are always on the lookout to upgrade their software and IT hardware in order to attract students and keep pace with the rapid developments in digital technologies. Cloud computing could provide those institutions with the means to achieve those ambitions at prices they can afford. Furthermore, shifting responsibility to external providers for managing some aspects of their software and hardware infrastructures could also result in cost savings with relation to labor, as fewer IT services staff will be needed than before.

7. Cloud in the education

The potential of cloud computing for improving efficiency, cost and convenience for the educational sector is being recognized by a number US educational (and official) establishments. The University of California (UC) at Berkeley, for example, found cloud computing to be attractive to use in one of their courses which was focused exclusively on developing and deploying SaaS applications. Helped by a donation from Amazon Web Services (AWS), UC was able to move its course from locally owned infrastructure to the cloud. One of the main reasons was quoted as being the ability to acquire a huge amount of servers (needed for this course) in a matter of a few minutes (Fox, 2009).

For some universities, the availability of an awesome computing power through cloud computing for research purposes was welcome. Researchers at the Medical College of Wisconsin Biotechnology and Bioengineering Center in Milwaukee are making protein research (a very expensive undertaking) more accessible to scientists worldwide, thanks largely to renting processing time on Google's powerful cloud-based servers.

One of the major challenges for many laboratories setting up proteomics programs has been the need to obtain and maintain a computational infrastructure required for analyzing a vast flow of proteomics data generated by mass spectrometry instruments used in determining the elemental composition as well as chemical structure of a molecule. With cloud computing making the analysis less expensive and more accessible, it meant that many more users can set up and customize their own systems and investigators can analyze their data in greater depth than was previously attainable, thus making it possible for them to learn more about the systems they are studying (La Susa, 2009).

Major cloud computing providers such as IBM and Google are actively promoting cloud computing as tools for research. In 2007 Google and IBM announced a cloud computing university initiative designed to improve computer science students' knowledge of highly parallel computing practices in order to address the emerging paradigm of large-scale distributed computing. This year (2009), the National Science Foundation (NSF) awarded nearly $5 million in grants to fourteen universities through its Cluster Exploratory (CLuE) program to help facilitate their participation in the IBM/Google initiative. The initiative will provide the computing infrastructure for leading-edge research projects that could help us better understand our planet, our bodies and many other issues.

However, there is also an increasing number of educational establishments that are adopting cloud computing for economic reasons. One of those is the Washington State University's School of Electrical Engineering and Computer Science (EECS). Faced with budget cuts relating to current economic conditions, as well as continual pressure to do more with less, the EECS selected a cloud platform (namely vSphere 4) from VMware (a leading provider of virtualization technology) as it searched for the best platform to support a move to cloud computing. The vSphere 4 platform aggregates and manages IT resources as a seamless, flexible and dynamic service that offers nearly limitless scalability with greater reliability and better performance than a traditional IT environment.

The EECS claims that despite the challenging economic climate, cloud computing has actually enabled it to expand the services it offers to faculty and students rather than cut them back (DeCoufle, 2009).

Schools also seem to have bought the idea of cloud computing. For example, in order to rationalize costs, Kentucky's Pike County district introduced cloud computing to its schools (which have a population of 10,200 students). The platform is managed by ICC Technology Partners, a subcontractor of IBM. The schools are now using cloud computing to transform 1400 old computers (many were sitting on the floor), that were ready for scrap, into fully functioning virtual machines. This was possible because cloud computing eliminates the need for a hard drive on the local computer. In a cloud environment, the processing takes places at the server level, not locally at the desktop level. The desktop machine becomes simply a conduit, or dumb terminal, that receives processing power and software delivered from the server, or the "cloud". One of the biggest advantages of cloud computing for Pike County is having enough computers on location to do computer-based formative assessment which was problematic in the past due to the limited number of working desktop machines (Erenben, 2009). Pike County estimates that over a 5-year period, the cost of ownership for the hosted virtual desktop solution will be less than half of the cost of supporting the desktops on-premise. By hosting the desktops in IBM's data center, Pike County was able to avoid the additional infrastructure and staffing costs of administering the servers (Lambert, 2009).

Cloud computing is also finding its way in British academia. A number of UK higher education institutions, e.g., Leeds Metropolitan University, the University of Glamorgan, the University of Aberdeen, the University of Westminster, the London University's School of Oriental and African Studies (SOAS) and the Royal College of Art (RCA) have adopted Google Apps. Popular demand from students (many of whom were already abandoning the unreliable

[7] Defined by the European Commission as those with fewer than 250 employees and annual turnovers not exceeding 50 million euro and/or an annual balance sheet total not exceeding 43 million euro (European Commission, 2005, p. 5).

in-house email systems) and cost were said to be the main factors behind this move (Hicks, 2009).

Even Africa is embracing cloud computing. If you think that this poor continent, with its under-developed IT infrastructure, would be the last place to adopt cloud computing then you are likely to be disappointed. A number of African educational establishments have adopted cloud computing, largely due to their inadequate IT infrastructures and their inability to cope with the endless cycle of hardware and software upgrades.

Google has been very successful in targeting the East African educational market. For example, the giant cloud provider has partnered with a number of East African educational establishments (e.g., the National University of Rwanda, the Kigali Institute for Education, the Kigali Institute for Science and Technology, the University of Nairobi, the United States International University, the Kenyan Methodist University and the University of Mauritius) in order to provide Google cloud services (e.g., Gmail, Google Calendar, Google Talk and Google Docs and Spreadsheets) to their students. These universities were also helped by an existing World Bank grant that supports bandwidth subsidy in universities (Wanjiku, 2009).

Not far away, Microsoft is also helping Ethiopia rolling out 250,000 laptops to its school teachers, all running on Microsoft's Azure cloud platform. The laptops will enable teachers to download curriculum, keep track of academic records and securely transfer student data throughout the education system, without the extra cost of having to build a support system of hardware and software to connect them (Chan, 2009).

The ability of cloud computing to help African education, not only by reducing IT costs but also by making education more efficient than before, is likely to be a very powerful (and empowering) tool for the advancement of education in this under-developed continent.

8. The University of Westminster: case study

The University of Westminster (UOW),[8] which has more than 22,000 students, is one of a handful of UK educational establishments to embrace cloud computing. Interest in cloud computing began when the University's student email service began to look out-dated; an issue which was highlighted by a survey that showed that 96% of students were setting up their email accounts so that received emails were automatically forwarded to their external third party accounts. In 2007, the University started to look for an alternative option in order to address this issue. Google Apps (Education Edition) was that option. This platform can provide a whole campus with free email (with a capacity of 7.3 GB of disk space for each student), messaging, and shared calendars with no advertising for students or staff. Furthermore, the Google email system enables users to retain their domain names in the email. For example, a user whose email address is "davids@wmin.ac.uk" will continue to be able to use this email address. The Google platform also provides a suit of productivity applications (e.g., word processing, spreadsheet, presentation) with functionality that supports collaboration (i.e., users can share documents remotely) which can be potentially useful for students working on group-based assignments).

After a period of piloting, testing and user consultation, Google Apps was rolled out for the 2008/9 academic year. It was clear that the University's existing student email system was not looked upon very favorably by students who were abandoning it in favor of their personal email systems. One of the problems the University faced with students forwarding their University emails to their personal email accounts was that their personal email accounts were beginning to treat the forwarded emails as spam, bogus or rogue messages and were being blocked on many occasions. This meant that urgent and key emails from the University were not getting through to students.

Storage issues with network servers and email also meant that students were, more often than not, saving their work to USB memory sticks which are often prone to loss or misuse. The new Google system provided each student with up to 7.3 GB of email storage capacity, which meant the likely end of using USB memory sticks as students would now have plenty of storage space online to store their large graphics and multi-media files.

In addition to providing a good student experience, there were also economic reasons behind the University's decision to adopt of Google Apps. The cost of using Google Mail was literally zero. It was estimated that providing the equivalent storage on offer on internal systems would cost the University around £1,000,000 (in terms of installation, ongoing maintenance, upgrades, staff costs, licenses, servers, storage, etc.).

Furthermore, the spam issue associated with students' personal email accounts was no longer going to be a problem. Google Apps also provided the University with the option to use friendly names for email rather than use the traditional student ID number. Google Apps also enabled students to use their mobile devices in order to access their emails and saved documents remotely.

Interestingly, students using Google Apps can also retain their email addresses and continue to get access to their University work, stored online in Google Docs, after graduation. When asked by this author: "What does Google get out of this free service?", Catherine Titherton, IT Project Manager at UOW, replied: "A huge pool of tomorrow's business leaders familiar with Google Apps".

Despite the fact that Google Apps for Education is free, the University ensured that it followed policy guidelines when it rolled it out. For example, University records and Intellectual Property (IP) policy required that all calendar, teaching, research, legal and employment information be maintained on University-owned systems. Staff Google mail is provided for the purposes of collaborating with colleagues or students in the Google environment. However, Exchange/Microsoft Outlook (the university's old email system) remains the official staff email system. This was obviously a conscious decision by the University which was concerned about the legal implications of transferring the safe keep of their data to a third party.

9. Cloud concerns

Cloud computing, as indicated above, is an emerging computing service paradigm. And, like other new services of this scale and complexity, there are bound to be fears, uncertainties and concerns about the technology's maturity. The most important of those concerns can be identified as those relating to control, vendor lock, performance, latency, security, privacy and reliability.

In some cases, there is an outright rejection of this model. Richard Stallman, creator of the GNU operating system and founder of the Free Software Foundation, described cloud computing as a trap aimed at forcing people to buy into locked, proprietary systems that are likely to prove costly in the future. He once told the Guardian: "It's stupidity. It's worse than stupidity: it's a marketing hype campaign". This view was also echoed by Larry Ellison, the founder of Oracle, who criticized the rash of cloud computing as "fashion-driven" and "complete gibberish" and commented that it would be hard to make money in this technology which he sees as "lacking a clear business model" (Hasson, 2008; Johnson, 2008).

IT managers are likely to be wary of surrendering control of their resources to outside providers who can change the underlying tech-

[8] Most of the information collected for this study were obtained from UOW's IT Project Officer (Catherine Titherton) and from JISC (2009), "Outsourcing Email and Data Storage: Case Studies".

nology without customers' consent. Issues relating to performance and latency (evidenced by the temporary run-outs of capacity by some providers) are also cited as problematic.

Furthermore, there are also valid security and privacy concerns. A recent survey of chief information officers and IT executives by IDC (International Data Corporation) rated security as their main cloud computing concern and almost 75% of respondents said that they were worried about security. Recently, the Electronic Privacy Information Center (a not-for-profit organization), has filed a complaint with the US Federal Trade Commission (FTC) about the security standards of Google's cloud computing, arguing that Google does not encrypt information held on its servers (Marshall, 2009). Moreover, various governments, such as those in the European Union (EU), have privacy regulations that prohibit the transmission of some types of personal data outside the EU. This issue prompted companies such as Amazon and others to develop offerings using storage facilities located in the EU.

Organizations are likely to adopt a careful approach to cloud computing, as demonstrated by the University of Westminster's experience. A survey by EDUCAUSE[9] involving 372 of its member institutions revealed that a great proportion of the respondents with use cases that involved cloud-based services reported that data privacy risks and data security risks were among their top barriers to overcome (Goldstein, 2009).

Any large scale implementation of cloud services by educational establishments (or indeed any other organizations) may have to wait until law-makers begin to address the legal issues that relate to privacy and data protection in the context of cloud computing. However, until such time is upon us, cloud users and providers will need to be more creative in their approach to cloud computing in order to overcome such hurdles. Some of the main issues in the UK's Data Protection Act (DPA) of 1998 that might delay UK organizations from subscribing to cloud computing are security and the transfer of data outside the EU. However, some cloud providers are already building data centers in various locations in the EU in order to address this issue, and many are already using state-of-the-art encryption technologies. Other cloud providers have opted to be more practicable. Amazon, for example, has very recently launched a service known as virtual private cloud (VPC) designed to address this issue of security and control. Amazon's VPC allows organizations to connect their existing legacy infrastructures to Amazon's clouds via a virtual private network (VPN) connection.[10] Amazon's cloud customers can create their own Amazon isolated resources (i.e., virtual private clouds) within Amazon's cloud infrastructure and then connect those resources directly to their network servers using industry-standard encrypted IPsec VPN connections. In doing so, these customers will be able to extend their existing security and management policies within their IT infrastructure to their VPCs as if they were running within their own infrastructures. There are also efforts to address the issue of security by other stakeholders. A not-for-profit body, calling itself the Cloud Security Alliance (composed of noted experts in many fields) was established recently in order to promote the use of best practices for providing security assurance within cloud computing, and provide education on the uses of cloud computing to help secure all other forms of computing.

Another concern is vendor lock and failures. Currently, many cloud providers offer their services through proprietary APIs. Portability is likely to be increasingly important as the number of cloud providers increases. One solution would be to base those APIs on open source message standards such as SOAP or REST. In some situations this is already happening. For example, Amazon is making its S3 storage cloud available through both SOAP and REST and Microsoft ensured that its Windows Azure cloud also supports those standards. There are currently efforts by some organizations such as the Cloud Computing Interoperability Forum (http://www.cloudforum.org) to address this issue (Grossman, 2009).

Furthermore, failure of a cloud provider which owns data centers can have serious repercussions for end users who trusted their data with such provider. This issue may force potential cloud users to go for well established and large companies who are likely to be around for many years to come.

Lastly, reliability can also be a serious problem for cloud users. Salesforce.com, for example, left customers without service for 6 h in February 2008 while Amazon's S3 (simple storage service) and EC2 (Elastic Compute Cloud) suffered a 3-h outage in the same month a few days later and an 8-h outage in July of the same year by S3 (Leavitt, 2009). In early 2009, Google's Gmail (its Webmail service) went down for 3 h, thus preventing its 113 million users from accessing their emails or the documents which they store online as "Google Docs" (Naughton, 2009). Vendors often provide service credits for outages. However, those credits, according to a director of a US market research firm, are "cold comfort for sales opportunities missed and executives cut off from business information" (Leavitt, 2009).

10. A question of trust and tradeoff

Cloud computing may not be suitable for all organizations. For large companies, for example, loss of service as a result of cloud glitches would be a major concern, particularly if it impacts on their customers and results in substantial loss of sale opportunities and customer dissatisfaction. The issue of reliability with relation to cloud services will continue to be a problem. Similar glitches that befell the cloud services of Amazon and Google are likely to surface again as the number of cloud providers (and users) increase. However, for small companies (struggling to survive the current global economic downturn) and cash-strapped educational establishments, often used to similar glitches caused by their old in-house systems, cloud computing is likely to remain an attractive option due to its cost structure and flexibility.

Furthermore, evidence is also emerging to suggest that even large companies (contrary to conventional wisdom) are actually embracing cloud services. A recent report by Forrester (the independent technology and market research company), based upon a survey of small and large enterprises located in North America and Europe, revealed that large firms were more interested than small firms in leveraging IaaS (Infrastructure as a Service) external cloud capability (Golden, 2009).

Furthermore, a number of large companies are in fact already using cloud computing. One of those, for example, is Sanmina-SCI which has a turnover of 10.7 billion US dollars. Sanmina uses the Enterprise version of Google Apps which costs 50 $US per user per year (as opposed to 499 $US per one license for Microsoft Office Professional). Its Chief Information Officer (CIO), Manesh Patel, sees great advantage and value for money in using Google Apps for its ability in enabling collaboration among employees (such as those of Sanmina) scattered across the globe (King, 2008). Another large company which uses cloud services is the Schumacher Group which employs 750 people. The US company (which provides solutions for emergency and hospital medicine practices) relies heavily on a customer relationship management (CRM) service from Salesforce.com, to manage its 2500 independently contracted

[9] EDUCAUSE is a US-based non-profit organization whose mission is to promote the intelligent use of information technology in order to advance higher education.

[10] A virtual private network (VPN) is a private network that provides remote access to its resources through a public telecommunication infrastructure, such as the Internet.

emergency room physicians (King, 2009). EasyJet (the low-cost airline) is another large company to see benefit from adopting cloud computing. The company will be using Microsoft's Azure cloud in order to run its newly developed customer services platform, Halo, which it hopes will allow it to do away with service desks at airports. The company was originally considering investing in an entirely new data center to run Halo, but has now decided that using Azure will be a more cost-efficient alternative (Ferguson, 2009).

As indicated above, there are genuine concerns relating to the use of this new computing delivery service. However, despite these concerns an increasing number of companies (small and large) are beginning to see some real value in using the cloud. This, no doubt, is a vote of confidence by these companies in the future of cloud services. One needs to remember that cloud computing is a developing (albeit rapidly) computing service paradigm and many of the concerns which were highlighted in this article are likely to disappear as the technology matures. One author, Carr (2009), equated the rise of cloud computing to mass electrification and described, in some interesting details, how it shared many traits with electricity.

11. The green credentials of the cloud

The cost advantage of cloud computing is not just related to how much cloud users can save by not buying and installing hardware and software and using less power. Users of cloud computing are more likely to significantly reduce their carbon footprint. Research suggests that ICT is already responsible for 2% of global carbon emissions, and that its relative share will increase further. In the UK, for example, increasingly stringent regulations (such as the Carbon Reduction commitment and EU Energy Using Products Directive) are likely to put pressure on educational establishments to make ICT more sustainable (James & Hopkinsons, 2009). In an environment where there is increasing concern about institutions' carbon footprint and energy costs, virtualized services (such as those offered by cloud computing) may become especially appealing (Katz, 2008).

12. Conclusion

Cloud computing is an emerging computing paradigm which promises to provide opportunities for delivering a variety of computing services in a way that has not been experienced before. It was demonstrated in this article how organizations (both small and large) are already taking advantage of the benefits which this technology is bringing, not only in terms of cost but also efficiency and the environment. Several general examples of cloud users were provided and a case study of the University of Westminster was presented and explored in more details. It was argued in this article that educational establishments are likely to embrace cloud computing as many of them are bound to suffer from under-funding due to the global economic crisis. In some parts of the world, such as Africa, cloud computing is emerging as an empowering tool that is being used to advance the cause of education in this continent. Conventional wisdom dictates that cloud computing, as explained in this article, is unlikely to be suitable for some organizations (especially large ones). However, recent research and real-life examples suggest that this view may no longer be valid. Like many new technologies and approaches, cloud computing is not without problems. There are many concerns relating to its security, reliability and portability (to mention but a few).

Comparing the emergence of cloud computing to mass electrification, by one author, is probably foretelling of how popular this new computing paradigm is likely to be in the future. However, before that stage is reached, more work is required in order to address the concerns that currently prevent some organizations from embracing cloud computing. Some of the laws (e.g., UK's DPA) that govern issues of data protection and data security can be subject to different interpretations. This issue would be a good candidate for future research in order to critically examine the rationale that currently inhibits some organizations from taking full advantage of this revolutionary computing service paradigm.

Acknowledgement

The author is grateful for the useful comments and explanations provided by Catherine Titherton, IT Project Manager at the University of Westminster (UOW), with relation to her university's experience with cloud computing.

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