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Introduction to Cloud Computing

Abstract

This paper describes cloud computing, its main characteristics and the models that are currently used for both deployment and delivery. It examines the benefits and business issues with using the cloud, and how they can be addressed. It describes some of the early adapters of cloud computing, together with their experiences.

KEYWORDS: Cloud Computing, Deployment and Service Delivery Models

Introduction

Cloud computing, in general terms, is anything that delivers hosted IT services over the Internet, and allows consumers to access services and data via any device with Internet access. What distinguishes cloud computing from traditional computing is that: it is sold on demand; it is flexible (the user can consume as much or as little as they need); and the service is managed by the provider.

An example of cloud computing is *Google Mail*. This uses a device and an Internet connection to access the service. The server and e-mail management software reside on the cloud (Internet) and are managed by the cloud service provider, Google.

The rapid growth in cloud computing is attributable to the use of a more efficient cost model, which provides centralised storage, memory, processing, and bandwidth on a pay-per-use basis. The model allows users to reduce capital expenditure (CAPEX) in tandem with the growth of operational expenditure (OPEX) and is a genuine attempt to provide computing as a utility service, similar to electricity and water.

Gartner has forecast that worldwide cloud services revenue will reach $68.3 billion in 2010, a 16.6 percent increase from 2009 revenues of $58.6 billion. The cloud computing industry is expected to have strong growth up to 2014, when worldwide cloud services revenue is projected to reach $148.8 billion [1].

Meanwhile, in Ireland where the jobs market is in a downturn, Microsoft Ireland predicts that Ireland could create almost 20,000 jobs by rebranding itself a world leader in cloud computing [2]. The cloud could be worth €9.5 billion to the Irish economy by 2014.

The sections that follow describe: the different cloud computing models, the benefits and business issues of cloud computing, and the experience of companies who have already moved to the cloud.

Cloud Computing Models

This section discusses cloud computing deployment and delivery models.

Cloud Computing Deployment Models

There are four primary cloud deployment models: public, community, private, and hybrid (see Figure 1).

1. Public Cloud

Public cloud infrastructure is owned by an organisation selling cloud services to the general public or to a large industry group. Two examples are *Amazon Web Services (AWS)* and *Microsoft Azure*.

2. Community Cloud

Community cloud infrastructure is shared by several organisations and supports a specific community that has shared goals, mission, security requirements, policies, and compliance considerations. An example is *Google Gov*.

3. Private Cloud

Private cloud infrastructure is owned or leased by a single organisation and it is operated solely for that organisation. Intel, Hewlett Packard (HP) and Microsoft have their own internal private clouds.

4. Hybrid Cloud

Hybrid cloud infrastructure consists of two or more clouds (public, community, or private) that remain unique entities but are bound together by standardised or proprietary technology that enables data or application portability.

Figure 1: Cloud computing deployment models
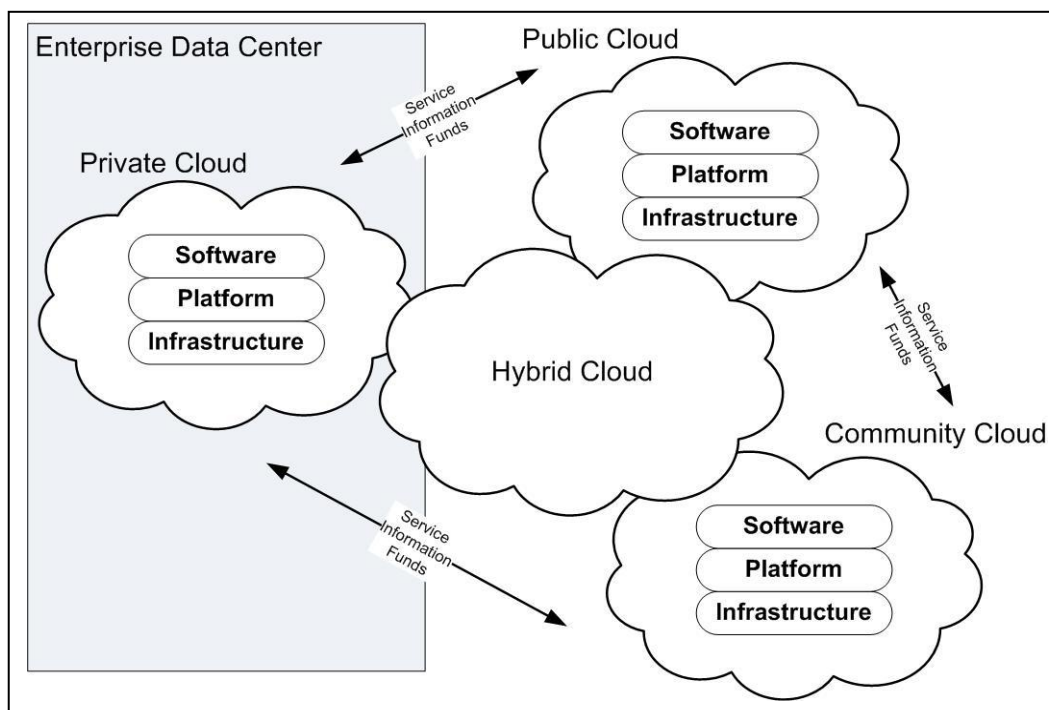
Source: Maik Lindner SAP

Advantages and Disadvantages of the Deployment Models

A public cloud typically delivers all of the cost reductions associated with a move from a CAPEX to an OPEX cost model. However, public clouds pose a risk to areas such as security and data access because the cloud infrastructure is shared with other businesses.

A community cloud spreads the cost over fewer users than a public cloud. This option is therefore more expensive, but it can offer a higher level of privacy, security and policy compliance.

Users of private clouds have to buy, build, and manage their clouds so they do not benefit from the lower up-front capital costs and the elimination of hands-on management costs. Private clouds reduce the risk to security and data access because the owner has complete control of the infrastructure.

A hybrid cloud allows an organisation to select the correct combination of cloud deployment models to suit their needs. For example, an organisation can take advantage of the scalability and cost-effectiveness of the public cloud for non-critical applications and data. It can use a private cloud to eliminate security and data access risks to protect critical applications and data.

Cloud Computing Delivery Models

The cloud-based ecosystem allows for a wide range of service delivery models. The services offered today can be broadly divided into three major categories [3] (see Figure 2).

1. Infrastructure-as-a-Service (IaaS)

Provides on demand virtual server instances with unique IP addresses and blocks of storage. Instead of the user purchasing servers, software, data centre space and network equipment, they buy these resources as a fully outsourced service. *Amazon Web Services* is an example of IaaS.

2. Platform-as-a-Service (PaaS)

Provides a way to rent hardware, operating systems, storage and network capacity over the Internet. It allows the user to rent virtualised servers and associated services for running existing applications or developing and testing new ones. *Force.com* (a subsidiary of Salesforce.com), *GoogleApps* and *Microsoft Azure* are examples of PaaS.

3. Software-as-a-Service (SaaS)

The supplier provides an application to customers as a service on demand. It includes the hardware infrastructure and the software product, and it interacts with the user through a front-end portal. SaaS is a very broad market: with initial offerings for Sales Force Automation (SFA) and Customer Relationship Management (CRM); this has now been extended to billing, invoicing, inventory control, and database processing [4]. *Salesforce CRM* is an example.
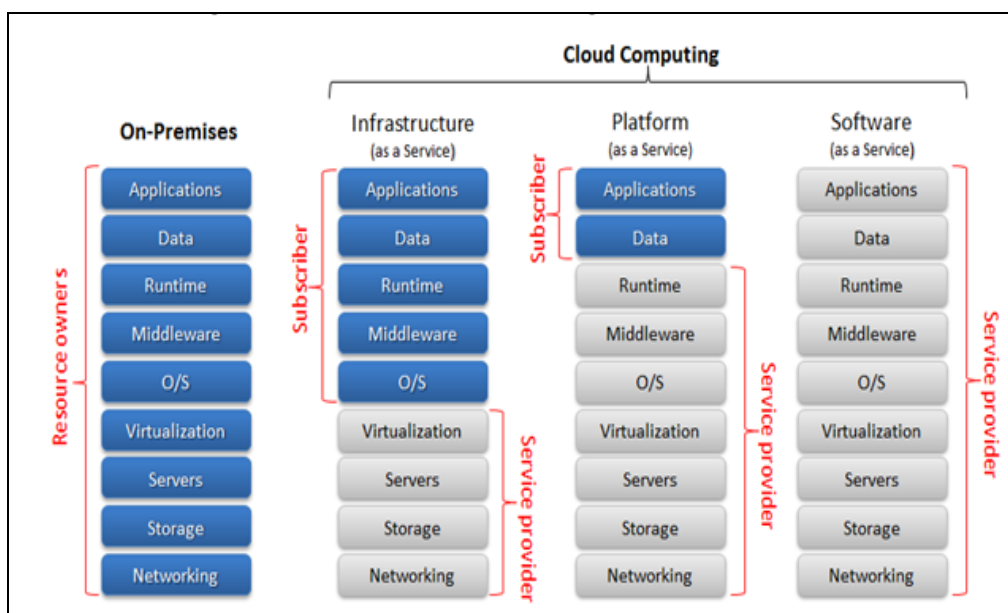
Benefits of Cloud Computing

The benefits for companies adopting cloud computing can be categorised as cost, functional, and resource.

Cost Benefits

- *CAPEX versus OPEX:* Cloud computing provides the opportunity to switch from a CAPEX to an OPEX cost model. This allows companies to eliminate start-up costs and take advantage of the pay-per-use model.

- *Software:* There is the opportunity to eliminate the purchase of expensive software applications, as most requirements can be delivered on a pay-per-use basis (e.g. *Microsoft BPOS*) or in some instances for free (e.g. *Google Docs* suite).

- *Scalability and Flexibility:* Cloud computing offers the ability to increase or decrease capacity as required. Organisations can add and reduce capacity (e.g. computing power, data storage) as their load dictates.

- *Agility and Adaptability:* New applications can be deployed relatively quickly using cloud computing services, whereas it can take weeks or months with the traditional enterprise model. In many cases, users can purchase cloud services with a credit card and begin to use them almost immediately.

Functional Benefits

- *Instant Software Updates:* Web-based application updates happen automatically and are available whenever the cloud is subsequently accessed.

- *Increased Response / Reduced Life Cycle Time:* Businesses save time across the life cycle as cloud computing becomes functional faster than traditional systems. Thus, businesses use less time and money at each stage of their life cycle.

- *Enterprise Level Quality of Service:* Network outages can send an IT department scrambling for solutions, but with cloud computing the company's selected vendor must comply with the agreed SLA and provide immediate support and a response to any emergency situations.

Resource Benefits

- *Easier Group Collaboration:* Multiple users can easily collaborate on documents and projects because information is hosted in the cloud and not on individual computers; all that is needed is a computing device and an Internet connection to share information with peers.

- *Freeing Up Internal Resources:* Staff are no longer required for routine maintenance tasks so they can be released for other high priority work.

- *Remote Access and Increased Mobility:* Access to information and documents is instantly available from the cloud. Employees can access information remotely using devices such as laptops or smart phones.

Business Implications of Cloud Computing

As cloud computing advances, a number of business implications need to be understood in order to take full advantage of the benefits.

Maturity of the Organisation

The ability of the outsourcing organisation, in particular its IT department, to formulate a clear strategy and vision of what it wants to accomplish will be key to success. This will largely depend on the maturity of the organisation and its ability to address the enterprise architecture, identity management, and the engagement of both stakeholders and suppliers. If an organisation has little experience in these areas it will need to either increase its internal expertise or look for outside help to ensure success.

Security

Cloud computing stores data in the cloud and as such the outsourcing company needs to know: *How secure is the cloud? Can unauthorised users gain access to confidential data? What happens if there is a system failure?* Established cloud computing providers indicate that data is secure, however, it is too early to be completely confident of the provider's security controls and protocols.

Many companies still remain cautious about entrusting their important data to third parties. In a May 2010 survey of small business owners conducted for *Bloomberg-Businessweek.com* by the professional social networking site *LinkedIn*, 75percent of the 65 respondents cited security as their biggest concern over cloud-based applications. In another recent survey of 169 corporate data centre managers conducted by Gartner, 85 percent of the respondents cited "security" as a factor that might inhibit them from deploying cloud-based applications [5]. Some of the security issues identified were [6]:

- *Privileged user access:* Sensitive data processed outside the enterprise brings with it an inherent level of risk – because outsourced services bypass the physical, logical and personnel controls internal IT departments exert over in-house programs.

- *Data location:* When using the cloud, companies probably do not know where their data is hosted.

- *Data segregation:* Data in the cloud is typically in a shared environment alongside data from other customers. Encryption is effective but isn't a cure-all. According to Gartner, encryption accidents can make data totally unusable, and even normal encryption can complicate data availability.

Data Ownership

One common fear about data in the cloud is what happens to it once it leaves the building. Outsourcing companies probably will not completely lose track of data in the cloud, but they are likely to lose some level of control over who accesses the data, when they access it, and for what purpose [7]. Few companies are putting critical data into public clouds partly because they are nervous about doing so, and partly because their structured and unstructured data has not yet been converted to function well in a services-oriented environment such as the cloud [8].

Increased Risk

Many increased business risks have been identified. The most commonly cited risks in the literature are:

- *Lock-in and Interoperability [9]:* Today, each service offering has a unique method of interacting between the cloud and applications, data, and clients. Once the decision is made to move to the cloud, it becomes very difficult to use multiple vendors and to seamlessly integrate legacy and cloud services.

- *Standard Architecture [10]:* Currently there is no standard open architecture defined for the cloud. Each of the major cloud providers (*Amazon Web Services*, Salesforce's force.com, *Google App Engine*, and *Microsoft Azure*) impose architectures that are different to the common architectures currently used for enterprise applications.

- *Enterprise Support and Service Maturity [11]:* Cloud computing services may not provide the levels of reliability, manageability and support required by large enterprises. Many services are aimed primarily at Small and Medium Businesses (SMBs) and at public consumers, rather than at large enterprises.

- *Reduced Functionality of Hosted Applications:* Existing web-based applications do not provide full features as compared to their desktop-based equivalent. For example, a lot more can be done with *Microsoft PowerPoint* than with *Google Presentation's* web-based offering.

- *Return on Investment [12]:* The exception is that external cloud computing can reduce costs for large enterprises and SMBs. However, the cost advantages for large enterprises may not be as clear as those for SMBs, since many large enterprises can reap the benefits of significant economies of scale in their own internal IT operations.

- *Requirement for Internet Connectivity:* Cloud computing is impossible without an Internet connection. In areas where Internet connections are inherently unreliable, there will be issues with low-speed connections such as that found with dial-up services, which will make cloud computing difficult to run. Even on a fast connection, web-based applications can sometimes be slower than accessing a similar software program on a desktop PC.

Early Adopters of Cloud Computing

This section outlines the experiences of the early adopters of cloud computing. Both success stories and problems encountered are described.

Success Stories

Current research [13] [14] has produced a rich and varied range of success stories. Table 1 details some representative examples to illustrate the diversity of the solutions available.

Table 1: Success achieved by early adopters of cloud computing

Company	Company Overview	Experience Detail	Comment
Eli Lilly	Eli Lilly is a leading innovation-driven pharmaceutical corporation. They develop a growing portfolio of pharmaceutical products by applying the latest research from their worldwide laboratories. They employ approximately 42,000 people worldwide and market their medicines in 143 countries.	Eli Lilly is currently using cloud computing and collaboration to speed up the time it takes to develop new medicines. By using *Amazon.com's* EC2 offering, Eli Lilly is able to take advantage of dynamic provisioning to scale computing environments up and down to meet the changing needs of its researchers' workloads.	Before exploring cloud computing, their researchers were fully utilising a 1,024-CPU Linux cluster. By shifting this research to the cloud, Eli Lilly's scientists are now able to work at a higher level of experimental throughput, and they undertake analytics that weren't possible previously.
Major League Baseball (MBL)	The MLB is an organisation that operates the National League and the American League which is the highest level of professional baseball in the United States and Canada.	During the 2007 season the MLB wanted to add a chat product, so that fans could chat about the playoff races. It was a big, ambitious project and their IT department did not have the data centre capacity or the time to order new machines. Consequently, MLB worked with a company called Joyent in California that provided hosting using virtual zones and virtual storage.	The MBL needed 30 machines. Joyent provided the requirement in a couple of days instead of the month or two that it would have taken to get someone to ship and install all of these machines. At launch, another 15 machines were ordered with twice as much memory and processors, as well as performing upgrades to the existing machines. When the World Series was over, the installation was scaled down to a skeleton crew of machines.
Taylor Wimpey	Taylor Wimpey, formed by the merger of Taylor Woodrow and Wimpey in July 2007, is one of the largest British-based house building companies.	In 2008 Taylor Wimpey moved its 1,800 staff onto *Google Apps* for e-mail and other services. The construction division has embraced software as a service by adopting *Google Apps Premier Edition* to improve mobility and flexibility for its workers. Staff are now using *Google Mail* along with the *Docs*, *Calendar* and *Sites* services, all of which is hosted by Google, removing the need to install or maintain the technology on site.	The company predicts it will save around GBP 1m in terms of up-front costs with each of the 1,800 licenses costing just GBP 25 per year for 25 GB of storage. These costs are also predictable due to Google not charging extra as new features are added.
Hasbro	Hasbro is an American multinational toy and board-game company. It is one of the largest toy makers in the world.	In 2009 Hasbro used Digitaria to help them produce an online marketing campaign around the first-ever *Monopoly Here and Now: World Edition*. The campaign web site allowed game-lovers worldwide to vote for their city to be included in the game's new edition. Looking for an economical solution, Digitaria used *Amazon Web Services* and open source software to produce the site's back-end infrastructure from a single Amazon EC2 image. With this, they created and launched a new database, application server, caching server, and load balancer instances all within a matter of days.	The Monopoly game web site was launched and during the 4 weeks of online voting, Digitaria received an incredible, unanticipated amount of global press coverage. Fortunately, Digitaria scaled to meet the unexpectedly high demand because it was hosted on Amazon EC2. Furthermore, using *Amazon Web Services* cost Digitaria half of what it would have cost in a traditional data centre.

Problems Encountered

Some of the early adopters of cloud computing have had negative experiences. Table 2 details some representative examples.

Overall, research findings show that:

- Cloud computing failures are not common and examples were difficult to find.

- Even though the problems are published as being 'cloud failures', it could be argued that the underlying cause was neither cloud computing nor the underlying technology.

- Most problems caused limited down time, and in most instances the services were back within a few hours.

Table 2: Problems encountered by early adopters of cloud computing

Company	Company Overview	Experience Detail	Comment
T-Mobile [15]	T-Mobile is a German mobile phone service provider owned by Deutsche Telekom. It operates several GSM networks in Europe and the United States. Globally, T-Mobile has some 150 million subscribers, making it the world's eighth largest mobile phone service provider by subscriber.	In October 2009, subscribers to *T-Mobile Sidekick*® mobile devices were informed that their personal data (contact information, calendars, notes, photographs, notes, to-do lists, video game scores and other data) had been lost. T-Mobile had outsourced the management of the cloud computing function for the *Sidekick*® devices to Microsoft's subsidiary, *Danger, Inc*.	This incident was one of the most publicised recent cloud failures but the underlying cause was human error, as no data backup was taken prior to a Storage Area Network upgrade which subsequently failed.
Heroku [16]	Heroku is an online *Rack, Platform as a Service* company, based in San Francisco, California. As one of the very first cloud service providers, it has been in development since June 2007. The company recently reported over 103,000 applications running on its service. In December 2010 Heroku was acquired by *Salesforce.com*.	At the start of the year Heroku started off with a nasty surprise. On 02 January 2010, all of the specialised, high-capacity Amazon EC2 instances that run its popular application and development service disappeared instantaneously and without warning. Twenty-two virtual machines suddenly vanished, leaving Heroku's estimated 44,000 running applications in the lurch.	Amazon blamed a routing device in its Virginia data centre, and the service was back up in an hour.
Google [17]	Google is a multinational corporation that has invested in Internet search, cloud computing, and advertising technologies. Google hosts and develops a number of Internet-based services and products and employs more than 25,000 people worldwide. Due to its widespread use – particularly for free services such as *Gmail* – Google has had many documented outages.	In May 2009, performance of *Google Search* and *Google News* slowed to a crawl, while an outage seemed to spread from *Gmail* to *Google Maps* and *Google Reader*.	Within a few hours, the outages were cleared.
		In February 2009, Google's *Gmail* had a highly publicised two-and-a-half-hour outage which came just a week after Google acknowledged that some users had experienced problems getting results from *Google News* searches over a timeframe of more than 14 hours.	Within a few hours, the outages were cleared.
		In December 2008, Google confirmed that there was a technical problem with *Google Talk* and the web-based *Gmail chat* system. One day earlier in the month, messages created by a "subset" of users were left unsent because of glitches in the messaging system.	Within a few hours, the outages were cleared.

Concluding Remarks

This paper has presented an overview of cloud computing. It has focused on: the deployment and services models; and the experiences (both successes and problems encountered) of early adopters of cloud computing. As a follow on to this paper, research is currently under way to apply the IT Capability Maturity Framework (IT-CMF) in order to help companies that have moved, or are about to move to a cloud computing environment.

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