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Cloud Computing Basics

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S. Srinivasan
Texas Southern University
Houston
Texas
USA

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*To my family:
Lakshmi, Sowmya, Shankar and Harish*

Preface

Cloud Computing has emerged as a cost effective alternative to managing complex computing systems. Traditionally organizations of all sizes required computer networks within their businesses. Managing a network requires specialized expertise which many businesses lack. In many cases network management was outsourced but it still required the attention of businesses since computing service was considered essential. This is where the emergence of Cloud Computing is trying to fill a void where companies would want to focus on their core strengths and let others deal with managing their computing needs. From the start the Cloud Computing model has been attractive because it offers the users the ability to grow incrementally and scale back when services were no longer needed. Moreover, a business could pay only for the services that they use. When there are so many businesses and people who want to use more sophisticated forms of computing services the Cloud Computing model fits well. At the same time it gives a major incentive to cloud providers to offer the necessary services by benefiting from economies of scale.

In this book under the Springer Briefs Series, I will present all the essential details that a potential user would want to consider before deciding on the use of cloud service. The book is divided into seven chapters. In Chapter 1, I will trace the history of the evolution of Cloud Computing as a viable service today and how it is helping entrepreneurs and small businesses have access to advanced services at a fraction of the cost. Chapter 2 will cover the details pertaining to the different forms in which one could use a cloud service. In particular, the reader will be able to understand the three basic types of service that the cloud service provider offers. These services offer varying levels of control to the user regarding their infrastructure. These are known as Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). Besides these three basic types, there are four different deployment modes in which cloud service is used. The most common form of cloud service is known as the Public Cloud. This is more like the Internet where there is nothing proprietary owned by the user. The Private Cloud is often used by large businesses that want to use the architecture of the Public Cloud but keep the computing resources all to themselves without sharing with others. The Private Cloud architecture is usually held in-house as a managed service. It can also be used as a hosted service. There are also two other models of cloud usage—Hybrid Cloud

and Community Cloud. The Hybrid cloud comes in two flavors—one in which the user owns a private cloud for much of their computing needs and uses a public cloud primarily for archival purposes. Another way of defining a hybrid cloud is one in which the user uses their computing resources for business critical applications and sensitive data and uses a public cloud for other general uses such as hosting a web site. The Community Cloud is more specialized in that it is used by a group of people with a common interest or a group of businesses that specialize in a particular industry such as automotive, health care or finance. Next I will describe how the cloud is used heavily today for storage and backup.

Chapter 3 discusses the many benefits that Cloud Computing offers as well as the drawbacks associated with the cloud. The details presented here would help a prospective cloud customer as to the things that they should look for in selecting a cloud service provider. Main expectations for the cloud customer are the service availability and the security and privacy of their data. To put things in proper perspective concerning the cloud service I will highlight some of the major outages in cloud service in the recent past so that businesses will be aware of some of the risks associated with a cloud service. Chapter 4 amplifies further on this theme where I describe about the major cloud providers and their services. In this chapter I provide detailed analysis of all the major cloud service providers and niche cloud service providers. In Chapter 5, I address the security aspects related to Cloud Computing. This is an important aspect of Cloud Computing that every user must be concerned with. In this chapter I describe the tools available to protect sensitive data in the cloud. Often businesses are faced with providing evidence to authorities about the compliance requirements such as HIPAA. This chapter will discuss the compliance aspects that a business must consider if it is necessary for them. In this regard I discuss about all the major federal laws in U.S. concerning data and privacy protection that a business may have to comply with as well as industry standards such as the Payment Card Industry Security Standards. Another important aspect that is discussed in this chapter deals with access control that is critical to security.

In Chapter 6, I provide the necessary details that a business would need from a cost and risk perspective in using cloud services. There is detailed discussion on the various types of risks that a business might face when moving their computing resources to the cloud. This discussion sheds light on how using a cloud service is similar to outsourcing. A detailed look at these two aspects shows the similarities and differences between the two types of services. Chapter 7 is the concluding chapter in the book which provides details on what businesses should look for in a Cloud Computing contract in order for them to know how reliable the service would be and how they could limit their liability. Extensive details are presented on what to expect from the cloud service provider and what remedy, if any, the cloud customer would have when a Service Level Agreement provision is violated. The material presented throughout the book focuses on making the cloud customers understand the complexities involved in dealing with the cloud and how they may already be dealing with a cloud service without their knowledge. My goal in this book is to present the material in a simple and easy to understand manner, with several examples highlighting the various topics discussed.

In each chapter I have provided extensive references to validate the points raised and for further exploration of ideas. Many of the web references provide currency of material as of the publication date. Each chapter has Review Questions. This book is aimed at the general business user for them to know the details about cloud computing and also as a learning resource for junior and senior college students in Computer Science and Information Systems programs. The author will be maintaining a companion web site for the book through the publisher which will provide content updates in the blogs. For instructors planning to use this book for classroom use there will be supplemental materials available consisting of PowerPoint Presentations for each Chapter, Question Bank and Answers to Questions. I have carefully checked the validity and accuracy of all the statements in the book. I have carefully proofread all the material in the book. It is very likely that some errors might have escaped my attention. I welcome feedback from the readers on any aspect of the book, including omissions, typos and errors of any type. Please send all communications to the author via email at mvmsrini@yahoo.com.

Houston, Texas
February 2014

S. Srinivasan, Ph.D.

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About the author



S. Srinivasan is the Associate Dean for Academic Affairs and Research as well as a Distinguished Professor in the Jesse H. Jones School of Business at Texas Southern University. Previously he was at the University of Louisville for 23 years building the Information Security program. This program was designated as a National Center of Academic Excellence in Information Assurance Education by the National Security Agency. He received the Ph.D. from the University of Pittsburgh in Pennsylvania. His research is focused on security and privacy.

He has published numerous papers in Mathematics and Computer Science as well as presented his research in international, national and regional conferences. Recently he edited a book on Cloud Computing Security. He has actively pursued external grants from federal and state agencies as well as private businesses for many years. He spent his sabbatical leave periods at multinational corporations such as Siemens, UPS and GE. He has volunteered extensively for the profession, community and public education causes. He co-directed the doctoral theses of three students. He has taught Mathematics, Computer Science and Information Systems courses at the undergraduate and graduate levels for over three decades. He serves on the Editorial Boards of some journals. He enjoys walking and reading.

Chapter 1

Cloud Computing Evolution

Abstract Cloud computing has emerged as a cost effective alternative to having reliable computing resources without owning any of the infrastructure. The growth of this technology mirrors the growth of computing in general. The options offered by cloud services fit the needs of businesses of all types. As a truly global technology, cloud computing is growing rapidly, albeit without any global standards. The benefits of cloud computing are too numerous to hold back adoption. At present the goal is to meet the business needs and as the technology matures it will accommodate changes emanating from global standards. As the first step in this direction many of the major cloud service providers are joining multiple consortia to develop the standards. This chapter addresses the history of the growth of cloud computing and the three basic service types—SaaS, PaaS, IaaS—that help businesses of all types. We identify the major cloud service providers and the cloud service types that they offer. We discuss the ways in which cloud computing is supporting entrepreneurial activities. Our analysis shows further that the advancements in communications technology is benefiting cloud computing and makes it a truly global service. Moreover, cloud computing technology is making a major contribution to e-commerce.

Keywords Cloud computing · Technology · Entrepreneurial · Storage · Global · Paradigm shift · Distributed service · Ecommerce

1.1 Introduction

Overall technology growth has been steady. This type of growth spans multiple areas—communications, devices, computing hardware, computing software, video creation, entertainment, etc. One such new technology in computing is Cloud Computing. It is not a revolutionary technology like the Internet was but packages some of the existing technologies in a more user friendly and cost effective way. The success of any new technology is measured by its acceptance by the intended users. As new technologies both telephone and television revolutionized their respective fields. It took telephones over 75 years to gain widespread use. On the other hand, television took only 13 years to gain widespread use. Personal computers which evolved from general computers took only 16 years to become common household item. The internet was launched in 1969 as ARPANET by the US government for use

Table 1.1 Summary of technology growth

Technology	Time to gain 50 million users
Telephone	75 years
Radio	38 years
Television	13 years
Personal Computers	16 years
Internet	4 years
Google Search Engine	3 months
YouTube	11 months
Facebook	2 years 10 months
Twitter	3 years

by a select group of research institutions. It grew slowly and gained global acceptance within a span of 4 years once the infrastructure was built. Newer technologies such as the Google Search Engine and YouTube took much shorter to attain critical mass. The Social Media giants Facebook and Twitter started out slow in growth but grew rapidly since then. Today, Google has over 540 million users, Facebook has over 1.3 billion users and Twitter has over 230 million users. Table 1.1 summarizes the time span of acceptance for the old and new technologies.

It is important to realize that the growth of certain technologies depend on the availability of the proper infrastructure. All modern technologies benefit from the availability of several enabling technology. In this sense cloud computing is a beneficiary since the internet is available globally and the communication technology has grown significantly. Because of the availability of higher bandwidth for communication the response time for applications running on a distant server is very low. This feature is known as low latency. Given the availability of these enabling technologies, cloud computing moved the computing infrastructure to the internet. Prior to the advent of cloud computing the server utilization rates were very low. Cloud computing took advantage of the wide availability of internet and the greater communication speed and leveraged the concept of virtual machines (VMs). A virtual machine runs on a physical hardware and since the server utilization rate has been very low, the VM concept was able to launch multiple VMs on a single physical hardware and increase the server utilization rate. This approach is the key to cloud computing where the infrastructure resides with an external provider and serves thousands of customers. Since the customer needs only an internet connection in order to use the cloud computing service, many cloud service providers are able to serve a global audience.

The cloud computing was initiated less than a decade ago. The web based company Amazon, which already had extensive experience running its business over the web, invested heavily in creating the infrastructure that businesses and individuals would need and took the chore of managing a computer system away from the businesses and ordinary users. Because of economies of scale, cloud computing is able to consolidate the services on the cloud and offer the services over the internet. Other companies that had a significant web presence already then launched their own cloud service. Thus grew the cloud services Google Apps, Microsoft Office

365, Windows Azure and Rackspace (Google Apps 2014, Windows Azure 2014). Over the past 5 years, based on customer concerns for privacy protection, the prevailing laws and industry standards many of the cloud services have enacted steps to provide reliable and secure cloud service. These large companies started offering a variety of cloud services that enabled innovation and the launch of several entrepreneurial cloud ventures such as Dropbox, Netflix and Flickr that used the cloud services of these major providers in order to provide their niche services. In the remaining sections of this chapter we will consider the various factors that have contributed to the growth of cloud computing.

1.2 Growth of Technology

Cloud computing today is benefiting from the technological advancements in communication, storage and computing. The basic idea in cloud computing is to take advantage of economies of scale so that IT services could be provided on demand with a decentralized infrastructure. This idea is a natural evolution from the IT time-share model of the 1960s and 1970s. Today, technology has advanced significantly and many more organizations have computing demands that are elastic in nature. Organizations large and small require reliable computing resources in order to succeed in business. Large businesses deal with complex systems where as Small and Medium sized Enterprises (SMEs) need access to affordable computing resources. Based on these aspects, some of the rationale for today's cloud computing needs can be summarized as follows:

- acquiring and managing the IT resources requires specialized skills
- maintaining a reliable IT infrastructure is expensive
- rapid technology advancements make it difficult to keep current the IT expertise
- internet has opened up many opportunities for individuals as well as small businesses
- number of entities requiring computing resources has grown exponentially
- SMEs' demand for computing resources varies significantly over time
- providing data security is a complex undertaking

In the above paragraph some of the major reasons as to why cloud computing would be advantageous to use has been identified. The phrase 'cloud computing' is used as a catch all for many types of online computing services. In this book we use the phrase 'cloud computing' in the way most businesses consider—computing over the internet with capability to grow or shrink resources on demand and pay only for the services used. Formally, we follow the definition of NIST developed by Mell and Grance. The NIST definition of 'cloud computing' is "Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing that can be rapidly provisioned and released with minimal management effort or service provider interaction" (Mell and Grance 2011). With this definition of cloud computing we analyze how businesses are using this new

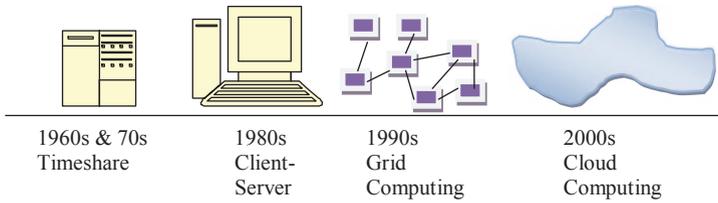


Fig. 1.1 Cloud computing timeline

tool. When a significant part of the business depends on a type of service that the business does not fully control, the question arises as to how the business can meet its obligations to its customers. As highlighted above, IT services are essential to the success of the business but it would be cost prohibitive for many businesses to manage an IT center with the required expertise and fluctuating demand on resources for processing and storage. Thus, a business using cloud computing must understand the security challenges that it would be responsible for and how cloud computing could help in this regard. More details on the security aspects of cloud computing are provided in detail in Chapter 5.

Before looking at the variations of technologies that led up to the concept of ‘cloud computing,’ let us first understand how this terminology came into use. It is difficult to attribute the first use of the phrase ‘cloud computing’ to anyone individual. However, it is safe to state that the first known recorded use of the term comes from a 1996 Business Plan by the erstwhile computer company Compaq. Since then Compaq merged with HP (MIT 2011). The phrase is also mentioned in the 1997 Trademark application by a company called NetCentric (Source Digit 2012). The company is now defunct. If any individuals were to be associated with the earliest use of the phrase ‘cloud computing’ it would be George Favoloro of Compaq and Sean O’Sullivan of NetCentric. Looking back at the evolution of the Internet, it was 1995 when the use of Internet became widespread. Thus, the above timeline of 1996 and 1997 fit well with the introduction of the ‘cloud computing’ concept. The person who could be credited for popularizing the phrase ‘cloud computing’ is Eric Schmidt, former CEO of Google. On August 9, 2006, at the Search Engine Strategies Conference in San Jose, CA, while referring to an emerging new computing model he said, “I don’t think people have really understood how big this opportunity really is. It starts with the premise that the data services and architecture should be on servers. We call it cloud computing—they should be in a “cloud” somewhere” (Schmidt 2006). This initial talk about this new concept was followed by an actual service called Elastic Compute Cloud (EC2) that was launched by Amazon Web Services on August 24, 2006 (Amazon 2012).

Researching the advancements in technology we are able to come up with the following timeline for the growth of cloud computing. Even though this technology has been around now for over a decade, only now it has become a mainstream technology. We show this timeline in Fig. 1.1 above.

Two of the important facilitators of cloud computing are the Internet and the bandwidth to move large volumes of data. Since the 1960s, cloud computing has

grown in many ways even though it was not known by that phrase in the early days. Since the Internet started to offer higher bandwidth in the mid-1990s, benefits of cloud computing for the public at large have evolved rather slowly. One of the major milestones for cloud computing was the launching of Salesforce.com in 1999. It pioneered the concept of delivering enterprise applications via an easy-to-use website. Today salesforce.com is known for its CRM application over the Internet. The next development was Amazon Web Services in 2002, which provided a suite of cloud-based services including storage, computation and even human intelligence through the Amazon Mechanical Turk. Then in 2006, Amazon launched its Elastic Compute Cloud (EC2) as a commercial web service that allows small companies and individuals to lease computers on which to run their own computer applications. Today, Amazon leads in cloud computing services to a vast array of small and medium sized companies and individuals.

The popularity of cloud services relies on the availability of reliable technology to support the service. In this connection the maturity of web in 2009 is noteworthy when Web 2.0 became widely available. Simultaneously, Google Apps provided several browser-based enterprise applications. This is a significant contributor to Software as a Service (SaaS) gaining greater foothold in the marketplace (Google Apps 2014). Besides Google, other companies such as Microsoft, IBM and Rack-space started offering cloud-based services (IDC Report 2012). A significant advantage of cloud-based services is the ability to use virtualization technology to offer each client their own computing infrastructure that appears dedicated but yet shared with other users. Availability of high-speed bandwidth has contributed to the reliability of cloud computing. As far as standards are concerned, they are still evolving with respect to cloud services. In order to reap the full benefits of cloud services the industry needs to adopt universal standards which will greatly enhance interoperability among the various providers.

1.3 A Paradigm Shift in Computing

Cloud computing is a significant shift in the way IT services are managed. Organizations large and small have managed IT services over the years with varying levels of investments. Today, with advancements in communication technology, many new options have opened up for existing businesses and new entrepreneurs want to use more of the capabilities of IT. These two aspects have spawned the significant growth of cloud computing, which gives the customer the ability to benefit from the pay-as-you-go model. Cloud computing has enabled the service providers to benefit from the economies of scale.

This change in service rendering is necessitated by the fact that today's workforce is increasingly mobile and consequently the need for access to remote resources is greater. Moreover, demand fluctuations for IT services are a reality. Businesses cannot afford to provision IT services to meet peak demand, which occur infrequently. Cloud computing provides an ideal solution to meet these needs without incurring significant cost in services provisioning.

Investments necessary to have a reliable IT service kept many prospective entrepreneurs from creating online ventures. On the web, businesses large and small look alike. Cloud computing is providing entrepreneurs the opportunity to try their ideas out, with IT services no longer holding them back as a barrier to entry. The major beneficiaries of cloud computing are small and medium sized businesses as this new concept provides them an opportunity to try out high-end services with no up-front cost, allowing them to use the pay-as-you-go model.

Large enterprises also stand to benefit from cloud computing, although of a different nature. Large enterprises manage data centers and the IT paradigm shift referred to earlier mean more in the context of accessing data from the data centers. In this context private clouds have been introduced where the benefits of storage management and elasticity in demand for computing services are the key drivers. Moreover, the cloud technology also offers high level of reliability and availability of systems without significant capital layout. Often, the benefits of cloud computing are realized by taking a hybrid approach. The hybrid approach gives the large organizations the ability to manage their IT centers and at the same time expand their computing capacity without large capital investment by utilizing the cloud resources. This is especially useful to meet seasonal peak demands with hybrid clouds. Organizations with seasonal high demands that could benefit from hybrid clouds are in the entertainment industry around holidays, sports networks with on-demand service and tax service providers.

In assessing cloud computing's appeal we should consider the usage levels of organizational servers. Server utilization level gives a good metric to see if the investment cost is worth it. The U.S. federal government started looking at the server utilization in its data centers several years ago. It is now widely reported that among all data centers in use the server utilization rate is between 6% and 20%. Even Google's server utilization rate is around 40%. One reason for the low utilization is the lack of virtualization and the need to use dedicated servers for multiple operating systems as well as separation of sensitive applications. Cloud computing is a natural fit to address the low utilization aspect because of higher level of virtualization. With multiple users sharing the computing resources, cloud computing has a very high level of server utilization (Hayes 2008).

Cloud computing architecture enables businesses to meet demand elasticity in computing resources. Business organizations have great difficulty in dealing with demand elasticity for cost considerations. A useful model to compare here is how networks manage elasticity in bandwidth demand. For cost reasons network bandwidth provisioning uses the Committed Information Rate (CIR) model. Likewise, cloud computing provides a similar feature in meeting demand elasticity in both storage and computing power. Without the ability to meet demand elasticity, businesses may end up with an underprovisioned service. In that case customers would abandon such services. Amazon's CEO Jeff Bezos highlights the success of extreme demand for computing power within a very short period of time from Animoto that Amazon was able to accommodate (Bezos 2008). This is a good illustration of high demand elasticity.

In the traditional model, the end user had control over the creation, maintenance and deletion of a document. In the cloud environment, the end user is spared the trouble of maintaining the computing system and reaps the benefits of the applica-

tion software. This is a positive aspect of cloud storage. However, it is not entirely clear to the end user that when a document is deleted it is going to be inaccessible from the storage system. There have been instances where the document lingered on in the storage system of the cloud provider. These types of issues are unique to cloud computing and thus are a departure from the standard expectation of a computer system. Thus, we note that a shift in approach is needed in order to have control over the online information.

Many large organizations are considering cloud based services as a cost-effective way to plan for disaster recovery. The main cloud service type being considered for this is Infrastructure as a Service (IaaS). Data backup is another service area in which cloud computing is gaining ground. The promise of these two services in the cloud has brought Microsoft and Iron Mountain together to offer data backup and recovery. The customer pays for this service based on the amount of storage used and the retention period for backup data. This service has the added benefit of offsite storage built-in that is essential for disaster recovery and backup because the cloud provider is remotely located relative to the customer. An essential component of efficient data backup is data de-duplication, also known as ‘intelligent compression.’ The de-duplication method allows for storing only one copy of the data and providing a pointer from all future occurrences of the same data. Data de-duplication can be performed at the file or block level. The latter is more efficient than the former. In typical email backups many users may have the same file as an attachment and so the same file is backed up multiple times. Using the de-duplication approach only one copy is saved and all other references point to the same copy. This is a typical file level de-duplication. Most often de-duplication is more efficient at the block level. In this approach each block of data is hashed using an MD5 or SHA-1 algorithm and the hash index is stored. Future hashes of blocks producing the same hash index are treated as duplicates and not stored. There are sophisticated methods available to detect hash collision, which is rare (Armbrust et al. 2010).

As noted, cloud computing provides a cost effective alternative for users to consider a centralized service that provides computing power, storage alternatives and high reliability. This is a paradigm shift in computing because with the introduction of Client/Server computing more businesses controlled their computing resources and data storage. However, the demand fluctuations for services and the greater need for remote access to data from multiple devices have made it more difficult for many organizations to keep with advancements in technology. This is where we notice a paradigm shift in what cloud computing could provide at a fraction of the cost. Cloud computing’s major benefit is the pay-as-you-go business model that it offers. This paradigm shift comes at the cost of security concerns because businesses are hesitant to lose control over where and how their data is stored. The Cloud Security Alliance and the Cloud Industry Forum are providing businesses with many resources to assess the cloud services prior to switching to cloud services (Cloud Security Alliance 2014, Cloud Industry Forum 2014).

Every business is noticing tremendous increase in data availability and the need to store the data. Anytime data is stored it comes with the associated cost of securing as well as backing up the data. This increased demand on the need to make the data available on a continuous basis is making data centers reach their capacity quickly. This