Demystifying Cloud Computing

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Abstract. Cloud computing is a new terminology that was added to IT jargon in early 2007. Still, people overuse this idiom to refer to things that may not relate to its actual definition and scope. Is it all about web hosting? Is it an old thing in new clothes? Why should organizations consider it? IT, business, and academia folks ask about cloud computing with the intent to understand it better. This paper tries to demystify cloud computing by simplifying its terms to readers with different IT interests.

Introduction

Over the last three years, many IT professionals, business managers, and researchers have started to talk about a new phenomenon called cloud computing. Each of these groups defined cloud computing differently according to their understanding of its offerings [1]. Although there was no agreement about what precisely constituted cloud computing, it still offered a promising paradigm that could enable businesses to face market volatility in an agile and cost-efficient manner.

Recently, a concise definition of cloud computing has emerged: To outsource IT activities to one or more third parties that have rich pools of resources to meet organization needs easily and efficiently [2]. These needs may include hardware components, networking, storage, and software systems and applications. In addition, they may include infrastructure items such as physical space, cooling equipments, electricity, fire fighting systems, and human resources to maintain all those items.

In this model, users are billed for their usage of remote IT infrastructures rather than buying, installing, and managing them inside their own datacenters. This structure gives users the flexibility to scale up and down in response to market fluctuations. For instance, a business enters the market with a new website that is initially unknown to customers, but eventually becomes popular with hundreds of thousands of requests per day. With cloud computing, businesses may start with a minimum set of IT resources and allocate additional services during peak times. Moreover, website owners can easily dispose unused IT resources during non-peak/recession times enabling them to reduce overall costs.

Typically, cloud computing adopts the concept of utility computing to give users on-demand access to computing resources in a very similar way to accessing traditional public utilities such as electricity, water, and natural gas. In this framework, clients follow a pay-as-you-go model that provides access to as much or as little computing resources as needed whenever needed from anywhere. Hence, organizations are no longer obliged to plan ahead and highly invest in computing resources to accomplish business goals.

History of Cloud Computing

The idea of cloud computing is not actually new as it goes back several decades. It was pioneered by Professor John McCarthy, a well-known computer scientist who initiated time-sharing in late 1957 on modified IBM 704 and IBM 7090 computers [3]. McCarthy expected that some corporations would be able to sell computing resources through the utility business model. Soon enough, different organizations paid for their use of computing resources (storage, processing, bulk printing, and software packages) available at service bureaus.

Over the past two decades, different implementations tried to leverage similar computing models including:

- **Web Hosting:** This service allows individuals and organizations to host their websites on spaces provided by datacenters of other companies. In web hosting, service providers offer different hosting options to clients. Offerings range from free web hosting for personal uses or shared web in which tens of websites are hosted on the same server, to dedicated servers that give each client his own server with full control over it.
- **Application Service Provider (ASP):** A paradigm where software companies offer applications for remote access by clients through networks for monthly fees [4]. ASP model exempts clients from the burden of buying, installing, and maintaining prepackaged solutions and underlying hardware infrastructures by shifting these tasks to providers.
- **Volunteer Computing:** Many research experiments that depend on high volume computing processes meet their needs by exploiting idle computing resources available through volunteers [5]. This paradigm provides researchers with access to supercomputer-like performance in a cost-effective manner.
- **Online File Sharing:** Websites enable Internet users to share their files online. For example, Flicker customers can manage and share their photos over the Internet. In this model, shared files are hosted on public spaces that Internet clients can access whenever and wherever needed.

• **Social Networks:** A variety of websites connect users interested in specific subjects. Examples are YouTube, Wikipedia, Blogger, Facebook, and MySpace. All these networks allow their users to share their ideas and resources such as presentations, videos, games, and small computer applications in an easy and efficient manner.

Definition and Characteristics

A cloud is an on-demand computing model composed of autonomous, networked IT (hardware and/or software) resources. Service providers offer clouds with predefined quality of service (QoS) terms through the Internet as a set of easy-to-use, scalable, and inexpensive services to interested clients on a subscription basis.

These attributes characterize cloud computing:

• **On-demand Computing Model:** Organizations are no longer required to own their datacenters to cover their IT needs; i.e., they can access giant pools of resources offered by providers in a way similar to accessing public utilities.

• **Autonomous:** Clients are unaware of the technical complexities of offered services. Some of these aspects include used technologies, physical location(s), networks, cooling structures, and number of human resources who manage the services.

• **Predefined QoS:** Cloud providers state QoS terms in their service level agreements to inform clients about expected level of service. QoSs give clients the chance to choose from available providers who can fulfill their technical needs.

• **Internet-based:** The name cloud originally came from the cloud shape that is widely used in the IT field to graphically represent the Internet. It means that all cloud services are hosted beyond client boundaries and delivered over the Internet.

• **Easy-to-use:** Cloud providers offer easy-to-use interfaces that enable clients to make use of their services. These interfaces include both GUI forms for administrators and APIs for developers as well.

• **Scalable:** Clients are not limited with fixed amounts of resources. Rather, they can scale up or down their usage according to fluctuating needs. This goal is accomplished through methods that allow clients to dynamically create, upload, and install their virtual machine images either by code or GUI screens.

• **Inexpensive:** Cloud computing gives small-and-medium-sized enterprises (SMEs) that cannot afford their own datacenters a significantly lower-cost option. This savings results from the fact that resources owned by providers are shared among several clients rather than being solely dedicated to specific client.

• **Subscription-based Model:** Clients subscribe to services they are interested in, and they are billed (usually at the end of the month) according to use.

Architecture

As illustrated in Figure 1, the architecture of cloud computing is like a pyramid composed of four layers listed from bottom to top as follows [6]:

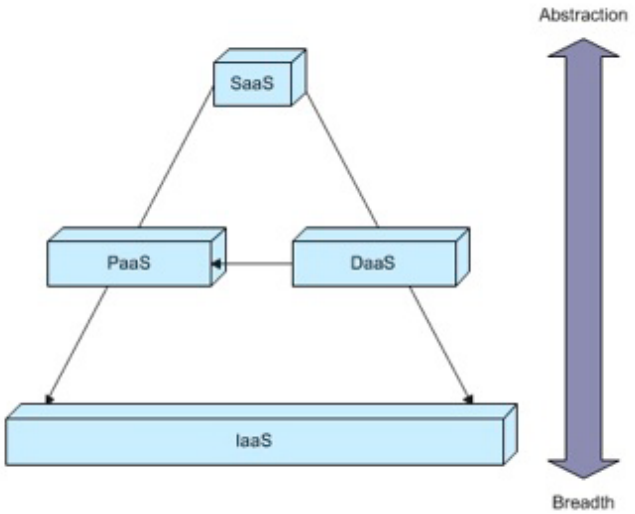
• **Infrastructure-as-a-Service (IaaS):** Represents the base of the pyramid without which the whole architecture cannot exist. IaaS provides hardware such as CPUs, memory, storage, networks, and load-balancers. Examples of IaaS providers include Amazon, Rackspace, and GoGrid.

• **Platform-as-a-Service (PaaS):** Supplies users with development and administration platforms that provide on-demand access to available hardware resources. Many PaaS platforms are available to enable access to IaaS resources. Examples of PaaS platforms include Amazon Web Services, Google App Engine, Windows Azure, and Force.com.

• **Data-as-a-Service (DaaS):** Frees organizations from buying high-cost database engines and mass storage. This service offers database capabilities for storing client information. Examples of DaaS include Amazon Simple DB, Amazon RDS, Google BigTable, and Microsoft SQL Azure Database.

• **Software-as-a-Service (SaaS):** The ultimate form of cloud resources that delivers software applications to clients in terms of accessible services. With SaaS, clients subscribe to applications offered by providers rather than building or buying them. Developers can also enrich their applications by integrating SaaS services into them. SaaS services may be designed to access cloud databases through a DaaS layer, or they may be designed to access hardware resources only through a PaaS layer. Examples of SaaS solutions/providers include Google Apps, Microsoft Online Services, and Salesforce.

Figure 1: Cloud Computing Architecture



Enabling Technologies

As illustrated in Figure 2, different technologies converged and worked together to enable the emergence of cloud computing, including:

• **Broadband:** High-speed Internet access enabled systems and data to reside in one continent while users access them from different continents. Furthermore, it increases accessibility to large data files such as images, videos, audios, and other

binary and large objects. The ability to do so has given organizations the flexibility required to overcome economic constraints in order to accomplish their goals. For example, many enterprises choose to host their information systems in less expensive datacenters in developing countries in Asia, Africa, and Eastern Europe to reduce their IT costs.

• **Grid Computing:** A distributed computing model that tends to gather underutilized computing resources available in organizations to process computing-intensive tasks faster [7]. This model has given organizations like Amazon the idea to lease unused resources (both processing units and storage) to clients in need of them.

• **ASP:** In the mid 1990s, ASP came to the surface as a business model that enabled organizations to access applications hosted by third parties, freeing them to focus on their business instead of being distracted by IT complexities. In fact, this model was not widely adopted due to two reasons [8]. First, it was unacceptable to organizations that had already invested in complex and expensive systems to reinvest in other new systems. Second, SMEs with no experience of outsourcing did not like to take chances until best practice scenarios were presented by bigger adopters. In this context, it is worth mentioning that although this model failed to survive, it opened the door to organizations outsourcing their applications to third parties.

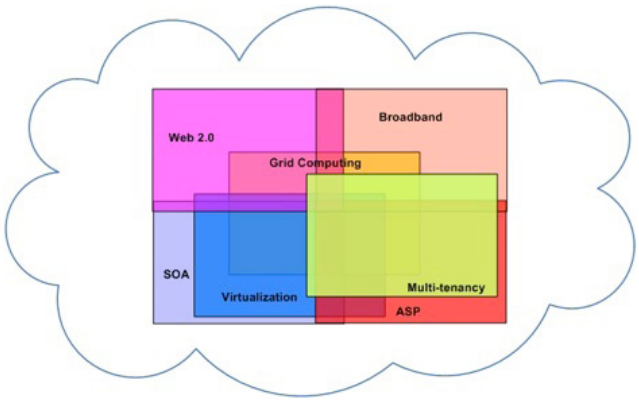
• **Service-Oriented Architecture (SOA):** The idea of SOA is to turn functionalities of both existing and new applications into a set of granular components [9]. SOA has encouraged software vendors to offer their products as services that clients can use/reuse and compose together to fulfill business requirements in an agile manner. This agility applies to cloud computing as well making it easier to access available hardware and software resources.

• **Web 2.0:** The last 10 years has seen many advances in web technologies. Innovations included different data formats and forms of accessibility to information available on the Internet such as RSS, Blogs, Portals, Wikis, XML, Web Services, and other mashups [10]. These techniques helped organizations to offer their information as sets of services that allow others to easily access them to mix and match underlying functionalities in their own websites/applications.

• **Multi-tenancy:** A software architecture that allows software vendors to offer a single instance of one or more of their systems to different tenants (clients). Multi-tenancy represents an evolution of the ASP model that offers similar services at lower costs. The savings mainly come from sharing the same software instance and underlying infrastructures by clients rather than dedicating resources to each single one. Technically, this model depends on a single database that stores tenant information with virtual separation between them. The separation is usually made by partitioning data into different sets of records, each of which is marked with the account ID of a corresponding client.

• **Virtualization:** Hardware virtualization is a technology that organizations are widely adopting to enable better utilization for available computing resources. Virtualization is accomplished by installing monitor software known as hypervisor that allows multiple operating systems to be installed concurrently on the same machine with total isolation from each other [11]. Additionally, many hardware capabilities were added to processors to allow better support for full virtualization. With virtualization, physical hardware resources are assigned to each running instance as required, enabling different clients to access them in a cost-effective manner. Virtualization is usually used as a substitute for multi-tenancy due to its ease of implementation and lower costs.

Figure 2: Convergence of Cloud Computing Enabling Technologies



Moving to the Cloud

Migrating to cloud computing is not a trivial task. The cloud is a different model that both techies and non-techies are not used to working with. Therefore, organizations should be well-prepared for this shift. As illustrated in Figure 3, successful migration process should contain the following steps:

• **Education:** Early adopters should first learn about the basics of cloud computing. Many workshops, conferences, magazines, forums, and case studies are now available to give beginners (both IT and non-IT practitioners) materials and information needed to understand this new paradigm.

• **Needs Assessment:** Cloud computing is by no means a silver bullet, but might be a way to help businesses overcome the limitations of on-premises solutions. Projects should not be driven by the hype; rather, organizations should know exactly why they are moving to cloud computing and what is expected from the switch. It is important that implementers know which parts of their datacenters should migrate to the cloud. It is equally important that they know if this migration is a strategic or tactical decision.

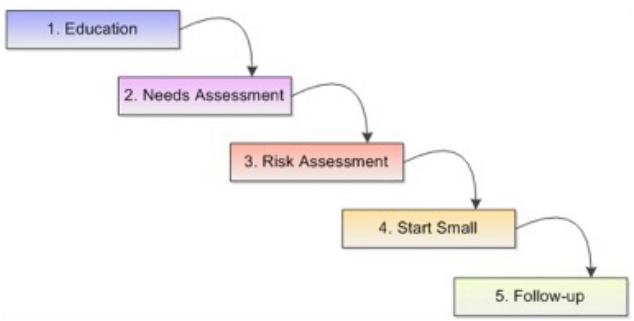
• **Risks Assessment:** As described in the "Cons" section, cloud computing is not a risk-free technology. Adopters should analyze the pros and cons of utilizing cloud computing versus on-premises model in reference to their needs to make sure that risks do not outweigh the benefits.

• **Start Small:** Implementers should not ship all IT projects to the cloud at once–it is not an all-or-nothing decision. Rather, they should start with one small project like those used by small

offices/departments. Implementers will need to learn how to use resources and services of selected provider(s). Developers should learn provider's APIs to allow their applications to dynamically scale up or down their usage in accordance with actual needs. Administrators should know how to manage and monitor used services. In practice, first implantation will come out with a list of lessons learned that can be usefully applied to future projects. This strategy will help organizations get hands-on experience as well as minimize risks associated with the decision to adopt a new technology.

• **Follow-up:** The purpose of this phase is to improve the overall quality of implemented projects. Organizations should assess their projects to decide whether to keep on using cloud option or not. If adopters decide to retain cloud computing, they should continuously review their implementations and decide which parts should stay on the cloud and which should not. During this phase, new cloud projects may be implemented, more data may move to the cloud, and some projects/data may move back from the cloud.

Figure 3: Cloud Computing Migration Steps



Case Studies

A number of case studies have been published both on providers' websites and in technical reports to give new adopters an inside look at some scenarios that led enterprises to adopt cloud computing and the benefits gained from that turn. A small list of cloud computing examples in different sectors is presented below [12]:

In SMEs:

• Razorfish, a digital advertising agency, needed to improve its ability to quickly respond to customers demands to support both highly visible web campaigns and high volume short run campaigns. Razorfish employed Rackspace infrastructure solutions to be able to build micro sites, web pages, and blogs more cost effectively. Cloud computing allowed Razorfish to set up web hosting space in 24 to 48 hours rather than 6 to 8 weeks for about $3,000 to $5,000 rather than tens of thousands of dollars.

In Large Enterprises:

• JohnsonDiversey, a global provider of commercial cleaning solutions for business, was motivated to move to the cloud for two reasons. First, to allow better collaboration and integration between its systems that was hard to accomplish with its legacy on-premise systems. Second, inefficiencies resulted from storage limitations. JohnsonDiversey adopted a number of cloud solutions such as Gmail to replace in-house e-mail; Google Docs to replace Microsoft Office environment; Google Sites for team collaboration; and Oracle CRM On Demand for remote sales force. Cloud solutions allowed JohnsonDiversey to cut operating costs of e-mail and collaboration environment by 70%; reduce bandwidth consumption for messaging and collaboration by 20%; and increase user satisfaction by more than 25%.

In Government:

• Japan's Ministry of Economy, Trade and Industry needed to build a public web application to enable clients to exchange old appliances for credits toward new appliances and merchandise. This application was planned to work fine for high-scalability requirements to support potentially large transaction volumes–40 million consumers were expected to access the site at peak times. The ministry was able to build the needed application in only three weeks by utilizing Salesforce.com sites and a Force.com API.

Pros

Cloud computing as a business and technical model derives many of its benefits from other terminologies such as economies of scale, distributed computing, and SOA. These benefits are on hand to both providers and clients.

Provider Benefits:

• **Better Hardware Utilization:** In most organizations, hardware resources rarely operate at full capacity; consequently, the value of these resources is extremely minimized versus the cost paid to obtain them. Cloud computing can help organizations with large investments in hardware resources to lease unused parts to others.

• **Higher Revenues:** It gives specialties that never existed before in the market the chance to run new businesses that make high incomes. Furthermore, the ability to lease unused hardware resources gives organizations the ability to make extra profits that could be exploited to run and enhance their IT infrastructure.

• **Bigger Software Markets:** Software vendors can deliver their applications in a form of services to their clients at lower costs on a subscription basis. This feature could encourage clients to increase their use of these applications, which in turn, would minimize the rate of software piracy, allowing providers to gain higher revenues.

• **Activities Monitoring:** Providers are able to monitor actions and activities performed by their clients. In doing so, providers can promote other services and products to clients with opportunities to make more money.

• **Better Release Management:** SaaS providers are freed from sending different patches, releases, and upgrades to each single client separately. Given that all software applications are being hosted on provider servers, updates can be instantly and automatically applied without client intervention.

Consumer Benefits:

• **Reduced Costs:** Cloud computing enables SMEs to have low cost startups by allowing them to rent resources offered by cloud providers instead of having their own sets. Also, large enterprises can take advantage of cloud computing as a tactical solution to face seasonal peaks without spending big sums to acquire resources that will be idle for most of the time. Operational expenses including salaries and energy costs are equally reduced for both small-to-medium and medium-to-large corporations.

• **Reduced Setup Time:** Organizations can acquire and operate necessary resources in almost no time versus much time needed to plan, buy and install their own resources.

• **No Installation/Upgrade Hassles:** With on-premises, organizations spend much time and effort to setup and run IT resources. Conversely, cloud computing put all these complexities on provider sides enabling clients to easily operate hardware and software appliances. Additionally, fixes and upgrades are all made by providers giving their clients the chance to focus on the business.

• **Higher Scalability:** Organizations can effortlessly install any number of hardware/software instances wanted by business. Additionally, clients can freely delete unused instances to save costs. This elasticity gives adopters two main advantages over on-premises models. First, it frees organizations from spending high up-front costs on IT resources that may not be fully utilized in the future. Second, it allows them to face occasional spikes by flexibly adding more resources at whatever time needed.

Cons

Cloud computing is still in its early years. Organizations usually prefer to adopt proven methodologies that come with success stories and best practices from previous adopters. Some of the risks of adopting cloud computing include:

• **Standards:** Cloud computing lacks the standards needed for loose coupling between providers and clients. Each client should use APIs offered by providers in order to allow its application to make use of available services. That is to say, each provider has its own technologies and standards making it impossible for clients to move from one provider to another.

• **Dependability:** The first question that every client usually asks about adopting cloud computing is, "Is the cloud provider going to be around in future?" Can they get their mission critical information, and is there a way to use it somewhere else? Organizations do not want to invest in IT solutions that may depart with important information if cloud providers decide to leave the market.

• **Transparency:** Because providers have full control over cloud resources, they can make changes to the infrastructure and services without notifying their clients. These issues must be stated in SLAs to guarantee continuity and reliability of solutions used by the clients.

• **Security:** Organizations cannot imagine hosting mission critical information beyond their borders. They believe that losing physical access to and control of servers that host such information means losing information itself. Such an issue makes sensitive information vulnerable to security breaches and surveillance activities of intelligence agencies and/or business competitors.

• **Internet Connections:** Since cloud computing relies on the Internet to host information, having reliable, redundant, and high-speed Internet connections is critical to successful implementations. Although broadband is available to many parts of the world, some countries still do not have dependable access to the Internet. Another concern related to this point is that although small/micro organizations can have Internet access, they cannot afford having multiple Internet service providers for service availability and reliability. Saving money resulting from leasing resources rather than buying them can be lost on redundant Internet connections and bandwidth. These limitations undoubtedly make it impossible for some organizations to move to the cloud.

• **Availability:** This is a crucial requirement for business stability and success. Key cloud providers invest several hundred million dollars in their hardware resources to guarantee the high level of service provided to their clients. Redundancy of datacenters owned by providers is an essential strategy followed to assure reliability of offered solutions. However, availability and reliability of cloud services are not 100% guaranteed due to unmanaged circumstances. For instance, an Internet connection may be lost for some reason, server(s) crashes may happen on the provider side, human error may cause servers to go down, etc. Lack of availability encourages organizations to locally backup their information for emergency use during cloud outages. Of course, local backup may not be an affordable solution for smaller organizations as it adds more overall cost.

• **Legislation:** Laws related to cloud computing issues such as reliability of presented solutions, availability of providers, and secrecy of information, as well as providers' financial rights, are still missing. Moving to cloud computing depends a great deal on trust between providers and clients and vice versa. With strong and effective legislation, trust between cloud implementers can be built and sustained.

Alternative Models

Cloud computing is not the only available model in the market that allows organizations to host and run their systems/data on remote servers. Some competing models are briefly described below:

• **Dedicated Servers:** As its name indicates, different clients can lease servers dedicated for their use by hosting companies for defined a length of time. Clients define the specifications of needed servers or they choose from hardware packages with the ability to customize according to their needs (upgrade, downgrade, install applications, etc.). Usually, companies offer dedicated servers in different options; for example, they may entirely/partially manage these servers by their own staff or not. Technically, the main difference a cloud computing model and a dedicated server model is as follows: with dedicated servers, clients are billed for the period they leased the servers and not for the actual use, whereas, cloud computing adopts a utility model that allows clients to pay only for the resources they used during a fixed period.

• **Virtual Private Servers (VPSs):** This solution leverages the capabilities of hypervisors to provide clients with a less expensive form of dedicated servers. In this model, hosting companies split each physical server into a number of virtual instances to be used by different clients concurrently. Each of these instances can run any application that is supported by the host operating system. Clients can also link different VPSs together

to act as a farm/cluster to obtain higher performance needed by heavy traffic websites/applications. Although this model has many similarities with an IaaS layer, they are not identical. In the VPS model, physical servers are usually sold to many clients with no real isolation between them. Those clients are offered instances composed of limited hardware resources compared to IaaS offerings. Thus, these oversold servers can easily lead to poor performance or even system crashes.

• **Colocation Centers:** This model allows clients to host their servers without the burden of having their own datacenters. Co-location centers (aka colos) are being widely used by SMEs that cannot afford building huge and complicated datacenters. With colos, enterprises can easily locate their servers at datacenters powered with spaces, electricity, cooling systems, fire protection systems, communication links, and security strategies. In addition, some colos offer technical expertise needed to manage servers of clients who cannot hire required human resources.

Conclusion

This paper presented essential terms related to cloud computing with the aim to answer questions frequently asked by people who are in the computer field. These terms included its history, definition and characteristics, architecture, enabling technologies, key adoption steps, a number of success stories, benefits to both providers and clients, challenges to adopt, and finally a list of top alternative models.

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