A Survey on Cloud Computing

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Abstract Cloud computing technology is the way to provide everything to clients as services through internet connection. Using this technology the clients would be able to rent the required services via web browsers. This study gives a proper definition to cloud computing, highlighted the related technologies, the essential characteristics, cloud architecture and components. Comparison among three service models (SaaS, PaaS, and IaaS) as well as deployment models: private, public, and community cloud has been given. Furthermore, the chapter includes information security requirements of public and private cloud according to different service models. The aim of this chapter is to giving the researchers a clear vision about this technology and the information security requirements for private and public cloud as well as the main security issues for future researches.

Keywords Cloud computing · Service models · Cloud architecture · Security requirements · Deployment models

1 Introduction

According to US NIST (National Institute of Standards and Technology), Cloud computing is a style of providing unlimited shared pool resources such as (Hardware/Software) to client as soon as requested through the internet, these resources can be automatically scaled up and down according to the client's demand [1–3].

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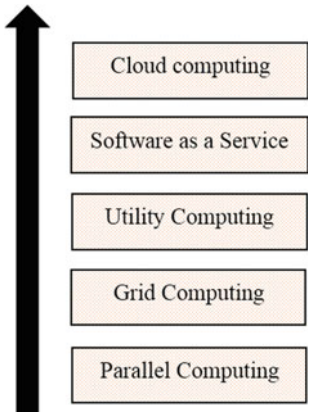

Fig. 1 Cloud computing evolution

Leonard Kleinrock which is the chief scientists of the original Advanced Research Projects Agency Network (ARPANET) made a prediction on 1969 by saying that "At this moment, computer networks still are in their early stages, however as they grow up and turn to be sophisticated, we will most likely notice the spread of 'computer utilities' including present electric and telephone utilities, which would service individual homes and offices throughout the country" [4, 5]. In 1990 the grid computing has been issued to allow the user to have computing power on request [6–8]. The cloud computing became famous and gained increasing attention when Google and IBM have cooperated to promote it in October 2007 [9–11]. Figure 1 depicts the cloud computing evolution.

The current chapter proceeds as follows: in Sect. 2 we have given a brief detail about some related technologies to cloud. Section 3 explains the five essential characteristics. Section 4 explains the components of cloud computing. Section 5 describes the Cloud computing architecture. Section 6 describes the different deployment models. Section 7 explained the security challenges in cloud computing. Finally, we conclude this chapter in Sect. 8.

2 Related Technologies

The paradigm of cloud computing has contribution of many technologies such as parallel computing, grid computing, utility computing, virtualization, Autonomic computing, Ubiquitous computing, Software as a service, web 2.0, distributed computing, and web 2.0. We will explain some of the technologies which related to cloud computing.

2.1 Parallel Computing

The concept of parallel computing is to divide the computing problem which is scientific into many small tasks, and run them at the same time on a parallel computer [12]. Usually, the parallel computing is used whenever need of high computing performance, such as in the field of energy exploration, military, medicine, and biotechnology. A parallel computer is a set of many homogeneous processing units, which are able to solve large computational problems faster through collaboration and communication [13, 14].

2.2 Grid

Grid is the technique which is used to shift the workload to the place which requires the computing resources that are remote and immediately available to be used. It is split the one main task into many subtasks to be executed in parallel, applications are also required by the grid to verify grid software interfaces [15].

2.3 Utility Computing

It provides the resources based on the client's demand and charging them according to the usage [16]. It uses a fully utility-based pricing scheme for making reasonable charges to clients. With the ability of providing the resources on-demand and fully based pricing scheme, the utility computing maximizes the use of resources and minimizes the cost of providing resources [5, 17].

2.4 Virtualization

The virtualization technology is presented since 40 years back but there was a limitation for the application of virtualization by the technologies, the limitation has been exposed to be depended by cloud computing as a major technology [6]. Virtualization is a technology that separates the underlying physical hardware and provides virtualized resources to the applications [5]. A typical server is capable of hosting a number of virtual machine instances, consequently giving the ability to customize the software on-demand. So this is the technology of providing the virtual server to the client-based on-demand such as VMware, vCloud, Amazon EC2, and others [6]. Virtualization is the basis of cloud computing, as it enables the pooling of computing resources from a group of server which is clusters and dynamically assigns the virtual resources to the client as required and reassigns

once unrequired [5]. The virtualization is attractive technology due to the ability of isolation and customization environments with little impact on performance [5, 18, 19].

2.5 Autonomic Computing

Presented in 2001 by IBM, it is constructed of many computing systems to make them able to do self-management such as automatic observations to external and internal and acting without any human interaction [20]. The main purpose of autonomic computing is to control over the complexity of computer systems. Also cloud computing has another powerful feature which is automatic resource provisioning in order to reduce the cost of resources rather than decreasing the complexity of the system [5, 21].

2.6 Ubiquitous Computing

The idea of Ubiquitous computing has been presented by Mark Weiser in 1988 as well as predicted that this method would be pervasive. In 1990, people got an extensive attention to the concept of pervasive computing and they started step by step exciting to Ubiquitous computing idea. Officially the concept has been proposed by IBM in 1999. In 1999, the first session has been held by IBM. In 2000, the first International Conference on Pervasive Computing has been held. Furthermore, the IEEE Pervasive Computing journal is founded in 2002 [22]. One of many significant goals in ubiquitous computing is to enable the computer equipment to feel the changes in surrounding environment and to modify the behaviors according to those changes. Radio network technology has been used in Pervasive computing in order to make users able to access the information without any limitations of place and time [13, 22].

2.7 Software as a Service

It is a web-based software application which is providing a software to subscribers, SaaS is a model of software attribution in which the applications have designed to be delivered through the network. This model almost priced in a package format such as monthly paying, this monthly paying will be cover the maintenance cost of applications, license fee and the cost of technical support. SaaS model can be considered as the best option to use the advanced technologies for the small and medium companies [13, 23].

3 Cloud Computing Characteristics

According to National Institute of Standard Technology (NIST, U.S. Department of Commerce), there are five essential characteristics of cloud computing mentioned below [24].

3.1 On-Demand Self-service

On-demand means that the clients can access to resources immediately as requested. Self-service means that the provision of resources will be automatically and without any human interaction [9, 25].

3.2 Broad Network Access

The resources of cloud computing are accessible and deliverable through the network and used by many client applications with a different type of platforms (such as mobile phone and PDAs) [2, 8, 24, 25].

3.3 Resource Pooling

The provider's resources are collected to be used by multiple clients using a multi-tenant type, with different resources which are assigned and reassigned dynamically according to client's order [2, 25].

3.4 Elasticity

The cloud computing has a unlimited number of resources, these resources can be provided from provider to clients at any time and quantity. The provided resource can be increased automatically when application load increase and vice versa [9, 25].

3.5 Measured Service

Although the resources of computing are shared and pooled by many different clients (such as multitenancy), the infrastructure of the cloud is having the ability to

use suitable mechanisms to measure what each individual client has used the resources [25]. The rate of hire is different from a cloud provider to another [8].

4 Cloud Computing Components

The three major components of cloud computing are: Clients, Data center, and distributed servers as shown in Fig. 2. Each component has a specific purpose and role. We will illustrate each of them as below [24].

4.1 Clients

It is the devices which are used by end-user to manage his resources in cloud, these devices could be desktop, laptop, smartphone, iPad, and so on. Thin client does not need to have a high-speed processor and big data storage, it needs to be able to run a web browser such as (Google Chrome, Firefox, and so on). The categories of clients could be divided into three types (thin clients, mobile, thick clients) [15, 24].

4.2 Data Center

The applications which are used by the clients of cloud computing are hosted in many numbers of servers, it could be a building or a room which it is not necessary to be in your place but must be accessible by the Internet. Multiple Virtual Machine (VM) can be run together on a single physical server known as a host, the number of VM will be limited to many factors such as type of the applications that are run on virtual server, speed, and size of physical server [15, 26].

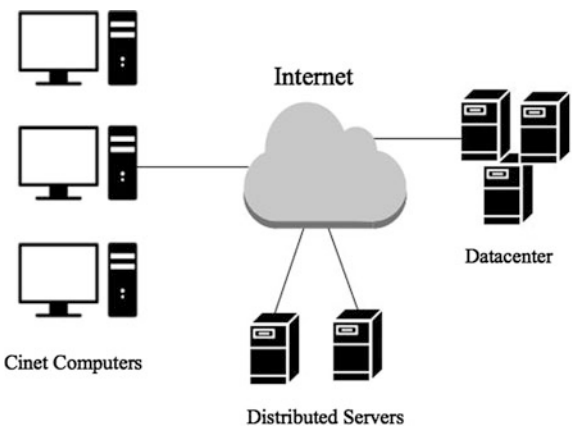

Fig. 2 Main components of a cloud computing solution

4.3 Distributed Servers

In order to provide the reliability and availability to servers, the cloud has distributed the servers in the different geographic area. In the case of failure in the specific server, then the other server will take the action, on the other hand, to increase the scalability when an extra server is needed then simply the new one will be added to the existing one [27].

5 Cloud Computing Architecture

5.1 A Layered Model of Cloud Computing

As Fig. 3 shows, the cloud computing contains a four layer of architecture design, each layer in cloud architecture having the flexibility to cooperate with above and below layers. We will illustrate all of them as below:

1. Application layer:
   The application layer is responsible for running the applications of cloud on the client's PC [15]. The applications in this layer can achieve the automatic-scaling to do a maximum performance [28]. The provider examples are force.com, Microsoft and IBM [29].
2. Platform layer:
   It refers to OS and software. By this service, the client can ensure that he can get an appropriate platform for his application to do his purpose like deployment, development, hosting of web application,and testing. The main goal of platform layer is to decrease the burden of deployment of the application to VM containers directly [29, 30].
3. Infrastructure layer:
   It is responsible for providing the user with hardware and software such as hard disk capacity, the size of RAM, CPU and so on. By the help of virtualization

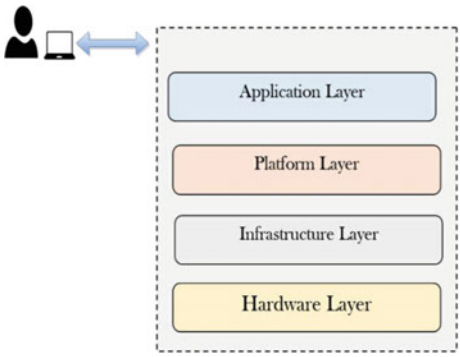

Fig. 3 Cloud computing architecture layers

technology, the infrastructure layer can be divided the physical resources to create the storage pool and computing resources like Xen, KVM, and VMware. Examples of these service providers are GoGrid, Layered technologies Joyent and Flexiscale [29, 30].

4. Hardware layer:
the purpose of this layer is to do the management for physical resources. The physical resources of the cloud are routers, cooling system, servers, switched, power equipment and so on. This layer is working for the servers of data centers which are connected together by a set of routers, switches, and many other equipment. So the main issues of hardware layer are traffic management, fault tolerance, cooling, and power management and hardware configuration [29, 30].

Each layer of above is able to evolve independently. This architectural modularity enables cloud computing to provide a huge number of application requirements whereas decreasing the maintenance and management overhead.

5.2 *Business Models*

Conceptually, every layer of the architecture described in the previous section can be implemented to the layer above as a service, conversely each layer can be acted as a customer for the below layer. As Fig. 4 shown the service models of cloud computing are consist of three services which are SaaS, PaaS, and IaaS.

1. The Software-As-a-Service Model: The provider allows the user to use provider's software, the software reacts with the user's interface [8, 9, 31]. By using cloud technology, client only has to rent the software via the internet connection, every client in the cloud which using the same software feel that it independently belongs to him only but in the fact it is shared on the same infrastructures [32]. By the technology of cloud, the user can use the software by either participation way or pay per use model. Preliminary statement is needed to find organization particular data for the service to be completely utilized and

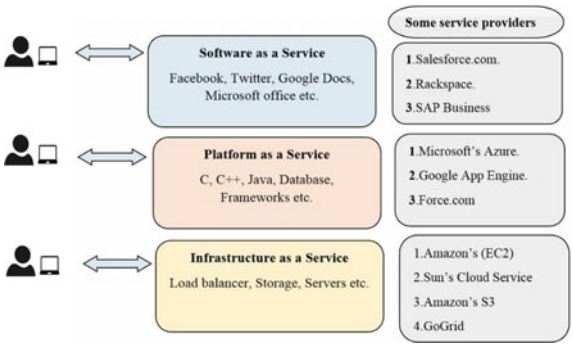

Fig. 4 Cloud computing service model

combine with other applications that are not part of the platform of SaaS. The application is handed over through internet to the organization's firewall [11].

2. The Platform-As-a-Service Model: It is used by the clients who are interested to develop the application because the providers are providing the development environment and toolkit [9, 11]. The development toolkits are hosted in the cloud and being used by the clients through web browser [11]. Developers will make the development of applications without taking care of the processor's ability and the size of memory which going to be used by the applications [9, 11]. PaaS is allowing the clients to use platform resources such as operating system support and software frameworks [8].
3. The Infrastructure-As-a-Service Model: As the name refers, it is providing the infrastructure as a service to clients, IT service or data center usage will be measured according to the usage time of CPU per hour, Storage usage and Data transfer per gigabyte [1, 28, 32]. It is provide virtualized resources on request [9]. In IaaS the client has a privilege to do many things like changing firewall rules, install a virtual disk on it, install a software package, on and off the server, and set access license [9, 32].

There are a lot of resources of cloud which cannot classify into IaaS, SaaS or PaaS such as Apple's App Store, online games, and Electric books on Amazon [28]. According to different factors such as service type, user control on, provider control in, flexibility/generality, difficulty level, scale and vendors the comparison among three service models SaaS, PaaS and IaaS has been done as shown in Table 1 [13, 33, 34]:

6 Cloud Computing Deployment Models

There are four types of cloud computing which are public, private, hybrid, and community, each type has different security risk and IT management. We are going to explain each of them as below.

6.1 Public Cloud

It can be reached by public people [8], the services are given by specific provider and mostly being used in the basis of pay per use, or might be offered as free services to clients [1, 9]. The resources are located in the physical location of service provider. It is maintained, owned, managed and operated by third-party vendor [1, 11]. The public cloud providers are: Amazon's AWS (EC2, S3 etc.), Rackspace Cloud Suite, and Microsoft's Azure Service Platform [1, 9].

Table 1 Comparison between SaaS, PaaS and IaaS

Classification	Service type	User control on	Provider control on	Flexibility/generality	Difficulty level	Scale	Level	Vendors
SaaS	Application with specific function	No thing	Application, data, runtime, middleware, O/S, virtualizations, servers, storage, network	Low	Easy	Small	User level	SalesForce.com, Google documents, Facebook.com, Gmail, Hotmail, Quicken Online, IBM®, WebSphere, Oracle on-demand, SAP, Netsuite
PaaS	Application hosting environment	Application, data	Runtime, middleware, O/S, virtualizations, servers, storage, network	Middle	Middle	Middle	Developer level	Google AppEngine, Microsoft Azure, Manjrasoft Aneka, Coghead, Force.com, Yahoo Developer Network, **MSFT,** Heroku, Mosso, Engine Yard
IaaS	Basic computing, storage, network resource	Application, data, runtime, middleware, O/S	Virtualizations, servers, storage, network	High	Difficult	Large	IT level	Amazon EC2 and S3, Nirvanix, Op source, Gogrid, RACKSPACE, IBM BlueHouse, Linode, VMWare

6.2 Private Cloud

The infrastructure of provider is supplied to the organization within its border and is used only by the members of the same organization, also it is not accessible by the other organization [11]. These enable to deliver some advantage of cloud computing like data security, flexibility, scalability, and reliability [9, 11]. The service should be provided behind the firewall to a limit number of people. The organization network and the administrator of data center must be a service provider because of the advance of virtualization and the distributed computing to provide their member in the organization [1]. It could operate, maintain and owned by the same organization [1, 8, 24].

6.3 Community Clouds

It is a set of above different types (private, public), It is used by a group of users which belong to different organizations or group of organizations for special purposes [24], by using Hybrid cloud will give the cloud users the ability to make a new cloud with new attached services. Community cloud could be located either on premise or off premise. For instance is Open Cirrus formed by HP, Intel, Yahoo, and others [9]. The responsibility to build, manage and operate the community cloud could be by one organization, a group of organizations, third-party or gathering of the three [24].

6.4 Hybrid Clouds

Hybrid is an assembly of two clouds or more of above three models (private, public or community) which are stay unique structure, but are limited to each other by standardized or proprietary technology that will make the data and application able to be mobility [9]. Due to a combination of private and public cloud, it allows the organizations to execute both non-core applications and core applications. It has more flexibility and power than public cloud and private cloud itself [8]. Comparison of deployment models: private, public and community cloud according to theoretical chapters based on their advantages and attributes have been given in Table 2. Additionally, the mandatory and optional requirement of security information for public and private cloud according to three service models (SaaS, PaaS, and IaaS) also illustrated in Table 3 [28, 32, 35–38].

Table 2 Comparison of deployment models

	Public	Private	Community
Description	• It is not dedicated to any specific organizations or client • Public clouds are less secure than other types • Reduce cost and risk by flexibly extending the IT infrastructure of consumers	• It is dedicated for a specific organizations or client • Usually the private clouds are installed and constructed by the third parties	• It is dedicated for many organizations that means the infrastructure will be shared among several organizations • It provides higher level of security, policy compliances and privacy
Attributes	• Location of infrastructure is located on the site of provider • Anyone can be consumer of public cloud and without any limitations • Provider is external	• Location of infrastructure is located on the site of consumer • Part or whole of enterprise is consumer of private cloud due to the purpose of confidentiality and security of their personal data • Provider is external or consumer's IT	• Location of infrastructure is located on-premises or off-premises • Members of community are the consumers of community cloud • Provider is external provider or community member
Advantage	• Not difficult to be used and not expensive as all application, storage capacity and bandwidth will be service provider responsibility • It is maintained, owned, managed and operated by third-party vendor • Scalable as the users are required • Only pay whenever we use, so that will not allow the resource to be wasted • Technical expertise is available 24/7	• A private cloud gives the organization high control over the infrastructure and computing resources • It is optimize and maximize the utilization of resources which are available in-house • Saving the cost of transfer the data from the organization's infrastructure to public cloud • It is more secure than public	• The Cost of install a community cloud is cheaper than individual private cloud, because of the division of costs between all participants • It can be constructed and managed either by one organization, a group of organizations, third-party or gathering of the three • Tools existing in community cloud can take the advantage of the information which stored to serve clients and the supply chain

Table 3 Information security requirements for public and private cloud according to three service models

			SaaS	PaaS	IaaS
Information security requirements	Private cloud	Identification and authentication	Mandatory	Optional	Mandatory
		Authorization	Mandatory	Optional	Optional
		Confidentiality	Mandatory	Mandatory	Optional
		Integrity	Mandatory	Mandatory	Optional
		Non-repudiation	Mandatory	Optional	Optional
		Availability	Mandatory	Mandatory	Mandatory
	Public cloud	Identification and authentication	Mandatory	Optional	Mandatory
		Authorization	Mandatory	Mandatory	Mandatory
		Confidentiality	Mandatory	Optional	Optional
		Integrity	Mandatory	Optional	Mandatory
		Non-repudiation	Mandatory	Optional	Optional
		Availability	Optional	Mandatory	Mandatory

7 Security Challenges in Cloud Computing

There are so many advantages of using cloud technology such as unlimited scalability, High performance, reduced upfront investment, Great availability, excellent fault tolerance capacity, and pay per use. On the other hand, the cloud has many disadvantage or risks attached with it. While the cloud is used by many different users and they are sharing the resources, then every user does not know who else is working in same server [39]. Usually, the cloud is located outside of organization's or company's firewall. This will lead to a significant effect on organization's decision toward migrating to cloud [40]. When client decides to migrate his work to the cloud, he must be aware of the challenges in cloud, there are many challenges in the cloud such as below [41–43]:

- Privileged User Access: The data leak risk is increased whenever the client's data got accessed outside the enterprise and the client unable to buy a new membership for verification.
- Data Location: When the user stored his data in cloud that means he might unable to know where the data are stored as well as unable to know from where the data are hosted.
- Investigative Support: If any illegal and inappropriate activity occurred in cloud computing along with client data, in that case, it is impossible to do a proper investigation regarding it.
- Data segregation: The client data exist in the same infrastructure which contain the other clients' data, which are using the services in parallel.

- Recovery: Because of some natural disasters or problems the data center or server will become ruined, the provider of the cloud will inform each client about his data condition.
- Availability: Many users willing to get the services of cloud but the company rang is not always available.
- Regulatory Compliance: The provider of cloud does not ever permits any audits from external and refuses to setup new security certificates to the network.

8 Conclusion

In this chapter, a proper definition has been given to cloud computing technology and various cloud architecture layers. Additionally, cloud service and deployment models are briefly discussed. Comparison of different models of cloud computing services, deployment models: private, public, and community cloud as well as information security requirements of public and private cloud according to different service models have been given. However, cloud computing has many characteristics such as on-demand self-service, broad network access, resource pooling, elasticity and measured service but it cannot be completely trusted. Finally, the main challenges and issues of cloud computing with regards to the security for further researches have been discussed in the chapter.

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