Cloud Computing: A new Era of Computing in the Field of Information Management

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***Abstract*—The fast developing era of computer technology has gone through the spectacular advances in computing storage, processing capabilities and networking technology, which have allowed the users to generate, process, and share huge volume of information with high reliability and efficiency. The need for processing and distribution of huge data leads to the development of cloud computing, which enables convenient, limitless, on demand network access to a shared pool of computing resources placed at different places. Numerous users and research organizations are now applying cloud-computing concepts for easy and efficient solutions to their computing and data sharing needs. This chapter provides the detailed discussions on the architecture of cloud computing, its advantages, and various potential applications in the field of Information Technology (IT), agriculture, library and education.**

Keywords-cloud computing; virtualization; public cloud; private cloud; hybrid cloud; infrastructure as a service; platform as a service; hardware as a service

I. INTRODUCTION

Though several definitions of cloud computing exist in the literature, the definition coined by the US National Institute of Standards and Technology (NIST) Information Technology Laboratory in 2009 is usually considered as an universally accepted standard one. According to NIST [5] "Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model promotes availability and is composed of five essential characteristics, three service models, and four deployment models. The emerging cloud abstracts infrastructure complexities of servers, applications, data, and heterogeneous platforms".

Cloud computing [1] emphasizes wide use of Wide Area Networks (WANs), i.e. the Internet, which allow interaction between cloud service providers and consumers. Service providers are expanding their offerings ranging from initial hardware and platforms to software services as well as the whole software applications. The logical diagram [12] of cloud computing mechanism is shown below. It mainly consists of three components viz; Infrastructure, Platform and Application and Users.

In brief Cloud computing is an "on demand service" in which shared resources, information, software and other devices are provided according to the clients requirement at a specific time.

Generally it consists of an application, a platform [9] and an infrastructure [12][13]. The infrastructure is distributed in nature. These distributed infrastructures are responsible for providing on-demand services. Services may be of software resources (e.g. Software as a Service, SaaS), physical resources (e.g. Platform as a Service, PaaS), hardware (e.g. Hardware as a Service, HaaS) or infrastructure (Infrastructure as a Service, IaaS).

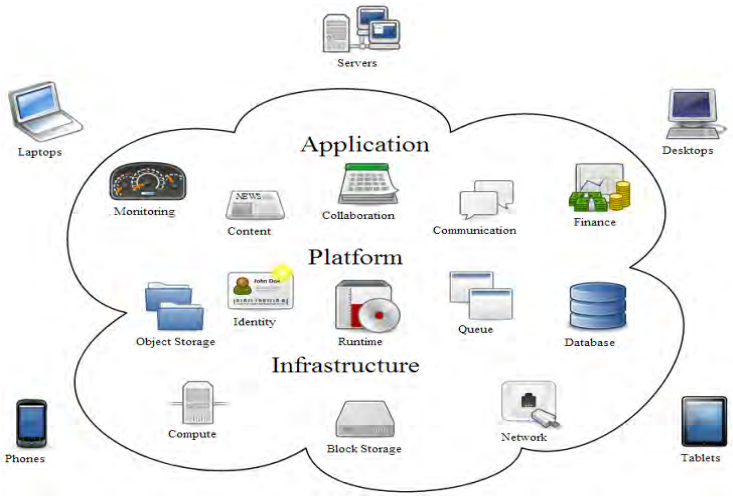

Figure 1. Cloud Computing logical diagram [1]

The rest of the paper has been organized as follows: Section II deals with components and environment of a typical cloud system, Section III reflects the infrastructure model of cloud, Section IV focuses on various layers of cloud computing models, Section V and VI highlights cloud computing benefits and challenges respectively followed by Section VII which deals with the future applications of clouds and finally the paper is concluded in Section VIII.

II. COMPONENTS OF CLOUD

A Cloud system consists of three major components such as clients, data center, and distributed servers. Each element has a definite purpose and plays a specific role.

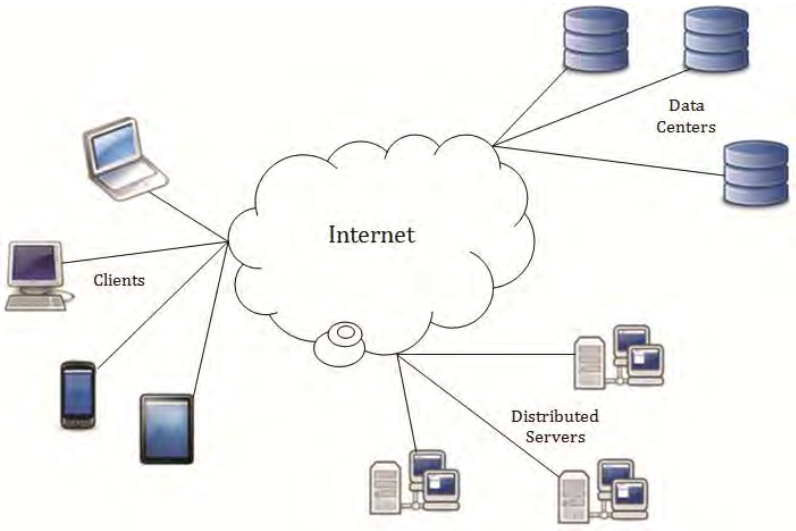

Figure 2. The components of a cloud solution

A. Clients

Clients are, in a cloud computing architecture are similar to the clients of everyday local area network (LAN). These are the computers which are residing on the desk of the end users. This is where the frontend applications are installed. They can be laptops, tablet computers, mobile phones, or PDAs. In short clients are the devices at the user side and used to manage client information. The physical specification brings the client into the following three categories:

- Mobile - Mobile devices include Smart phones, Tablets or PDAs.
- Thin – These are the dump terminals having no hard disk space rather it let the servers do all processing activities. It simply displays the information.
- Thick - This type of client is a regular computer, using a web browser like Firefox or Internet Explorer to connect to the cloud.

Today, the thin clients are the popular solution for implementing a cloud solution, because of the following characteristics.

- Low costs hardware – The hardware specification of a thin client is low cost in nature. It is because it doesn't have any storage and processing capabilities. It simply transmits the data to sever for processing.
- Failure points – As all the clients are managed by server therefore there is very less chance of infrastructure failure.
- Security - Since data is managed centrally by servers where the processing takes place therefore the clients are free from any attacks such as malwares and there is less chance for data to be lost if the client computer crashes or is stolen.
- Infrastructure Management – In case of a failure of client or if the client dies it is easy to replace the clients in the cloud infrastructure.
- Cost Effective – The last but not least, thin clients consume less power than thick clients which saves energy (which is a scarce resource when the clients are movable) and which in turn also cost effective to the users.

B. Data Center

The data center is the collection of servers where the applications to which the user subscribes are hosted. A data center server can be virtualized in nature where the software can be installed in the main physical server but appeared as separate server identity to the user. In this way, one can have half a dozen virtual servers running on one physical server.

C. Distributed Servers

It is not necessary that the data center always contains only one server in one place. Sometimes, servers are placed in geographically disparate locations in the globe. But from the end user perspective it seems that data is coming from a central server. In this approach if one server is down or instantly not available to a client request, may be due to congestions etc., the other servers activate to cater the clients. In order to provide seamless service to the client, the data in these servers are synchronized frequently.

III. INFRASTRUCTURE MODELS OF CLOUD

There are many variations for cloud computing architectures starting from a standard enterprise application deployment model to the application model which is deployed throughout the globe. All these variations can be categorized as Public, Private and Hybrid Clouds.

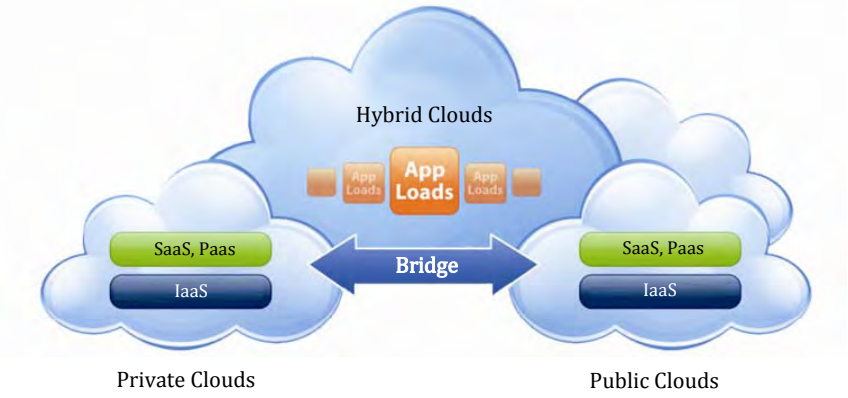

Figure 3. The infrastructure models of clouds

The terms public, private, and hybrid does not emphasize on location. The whole Internet can be considered as public clouds whereas the private clouds are typically limited to an organization.

It is entirely depends upon the organizations to decide which cloud computing model to adopt. For an instance, a user which requires very cost effective solution might be interested in a public cloud because it helps to avoid the need for procuring additional equipment to solve the short term needs.

A. Public clouds

Public clouds [4][13] are run by third parties and located outside the customer premises. These infrastructures provide a way to reduce customer risk and cost by providing a flexible and readymade solution. In public cloud infrastructure, the applications from different customers are generally mixed together on the cloud's servers. Therefore most of these public cloud servers are virtual in nature.

The main benefits of public clouds are the ability to scale up and scale down on demand, and the infrastructure risks are always borne by the cloud service providers.

B. Private clouds

Private cloud systems are exclusively maintained by the client. The private cloud infrastructures are implemented only when security is the main concern. In this scenario, the organizations own the infrastructure and should have control over application deployment. Private clouds are more expensive than that of public clouds and the risk of infrastructure is always borne by the owner.

C. Hybrid clouds

Hybrid clouds combine both public and private cloud models. It introduces the complexity of application distribution both across a public and private cloud. This infrastructure is beneficial for the customers who are dealing with small data sets.

IV. LAYERS OF CLOUD COMPUTING MODELS

As the cloud computing model gains popularity, it is important to understand the service layers that define it. Each layer of the cloud computing model exists conceptually on the foundation of the previous layers and provides services to the adjacent layers, as it is in the case of OSI (Open Systems Interconnections) model of computer network.

Within this model, there are three different service layers which are used to specify Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). Additionally, there are three layers viz; Hardware layer, Virtualization layer and the Client layer that are not provided as user services. The Hardware Layer and the Virtualization Layer are owned and operated by the cloud services provider while the Client Layer is supplied by the end users.

A. The Hardware Layer

The hardware layer is also known as the server layer. It represents the physical hardware that provides actual resources that make up the cloud. As in most of the cases, the hardware service is provided by the cloud service provider, it seems to be the least important layer in the cloud infrastructure. This layer can be made redundant by utilizing multiple hardware platforms to make the system fault tolerant.

B. The Virtualization Layer

This layer is also known as the infrastructure layer. The virtualization layer is the result of various operating systems being installed as virtual machines. It is a very useful concept in context of cloud systems. It is the software implementation of a server to execute different programs like a real machine. Virtualization enables an user to use different services of a cloud. The remote data center provides different services in a full or partial virtualized manner.

C. Infrastructure as a service (IaaS)

The infrastructure layer [9][10] builds on the virtualization layer by offering the virtual servers as a service to users. The clients are billed for these virtual servers but not for the actual hardware. This reduces the cost of unnecessary hardware procurement physical servers or data storage systems.

D. Platform as a service (PaaS)

This layer provides an operating system platform for hosting various applications. PaaS solutions [9] are basically the development platforms for which the development tool itself is hosted in the Cloud through IaaS and accessed through a browser.

With PaaS, developers can build Web applications as per their native systems and to deploy those applications in the cloud virtualized server without any specialized systems administration skills.

E. Software as a service (SaaS)

If the users do not want to develop the cloud application, the SaaS layer [4][9][10] is the solution. The users simply procure a service, such as email or CRM (Customer Resource Management). Billing can be based on utilization of these services. In this case, it is a simple way to get the application functionality that the users need without incurring the cost of developing that application.

F. The Client

This is also known as end user layer where the users interact with the cloud. In cloud computing, the users generally access cloud resources through networked client devices, such as desktop computers, laptops, tablets and smart phones. Examples are thin clients, mobile, thick clients and the browser-based Chromebook etc. However, many of these applications do not require specific software on the client and instead use a web browser to interact with the cloud application.

V. CLOUD COMPUTING BENEFITS

In order to get the optimum benefit from cloud computing, developers or the users must be able to port their applications to the cloud system. The benefits of porting applications in a cloud server include low processing/ response time, low risk of infrastructure deployment, low cost of implementation and high pace of innovation.

A. Low processing time

In comparison to a single server, the processing speed of cloud servers will be much higher. For example running a large batch job in 100 of cloud servers is much faster than that of running the same batch in a single server.

B. Low response time

As the cloud servers are the collection of high speed parallel processors, the response time [16][17] to a request will also be significantly low.

C. Low risk of infrastructure

Infrastructure risk [16] can be reduced by adopting a cloud solution. For a public cloud [4], the risk of infrastructure is solely borne by the cloud service provider and the client simply billed for the deployment. In case of any infrastructure failure, it is the service provider who will provide instant support to the customer and thus reducing the risk of purchasing and deploying physical servers by the customers.

D. Lower cost of implementation

Since the infrastructure [4][6] is not purchased rather it is rented in case of a public cloud, the cost of implementation can be controlled to the extent of the capital investment to be almost zero. Moreover, most of the cloud applications are readymade, which reduces the cost and time of developing a custom application.

E. High pace of innovation

Cloud computing can help to increase the pace of innovation. The low cost of entry to new markets helps to level the playing field, allowing start-up companies to deploy new products quickly and at low cost. This allows small companies to compete more effectively with traditional organizations whose deployment process in enterprise data centers can be significantly longer. Increased competition helps to increase the pace of innovation and with many innovations being realized through the use of open source software, the entire industry serves to benefit from the increased pace of innovation that cloud computing promotes.

VI. CHALLENGES OF CLOUD COMPUTING

Organizations are increasingly aware of the business value that cloud computing brings and are taking steps towards transition from the traditional solution to the cloud solution. A smooth transition need a thorough understanding of the benefits as well as challenges involved. The adoption of cloud computing is not free from challenges. Some of the most important issues are as follows.

A. Security and Privacy

The main challenge to cloud computing is how it handles the security and privacy concerns of businesses. In case of a public cloud the valuable enterprise data reside outside the corporate firewall [4][7][15] which is a serious security issue. Various attacks such as hacking would affect multiple clients even if only one site is attacked in a cloud infrastructure. These risks can be mitigated by using security applications, encrypted file systems, data loss software, and buying security hardware to track unusual behaviour across servers.

B. Service Delivery and Billing

It is difficult to assess the costs involved due to the on-demand nature of the services. Budgeting [2][17] and assessment of the cost will be very difficult unless the provider has some good and comparable benchmarks to offer. The service-level agreements (SLAs)[17] of the provider are not adequate to guarantee the availability and scalability. Businesses will be reluctant to switch to cloud without a strong service quality guarantee [8].

C. Interoperability and Portability

Businesses should have the leverage of migrating [8] in and out of the cloud and switching providers whenever they want, and there should be no lock-in period. Cloud computing services should have the capability to integrate smoothly with the on-premise IT.

D. Reliability and Availability

Cloud providers still lack round-the-clock service; this results in frequent outages. It is important to monitor the service being provided using internal or third-party tools. It is vital to have plans to supervise usage, performance, robustness, and business dependency of these services.

E. Performance and Bandwidth Cost

Using public cloud scenario organizations can save money on hardware infrastructure but they have to spend more for the bandwidth. Although bandwidth is a low cost for smaller applications but it can be significantly high for the data intensive applications. Delivering intensive and complex data over the network requires sufficient bandwidth. Because of this, many businesses are not interested for adopting the cloud solutions. Therefore, it is necessary to give serious consideration to these issues and the possible solution before adopting the technology.

VII. FUTUTURE APPLICATIONS

The application of cloud solutions has multiple applications in many areas viz., agriculture, IT industry, library etc. The detail application of cloud solution can be summarized as –

A. Cloud in Information Technology

In the current period of Information Technology cloud computing is opening an epoch of fundamental managerial changes of business organizations, with virtualized organizations by using web 2.0 tools [18], net PCs, mobile technology and various services. According to Fingar [14] - "the world shifts from using Information Technology (IT) for transaction and information management to a far more organic Business Technology (BT) for collaboration and interaction management." Therefore, in the future period it is no doubt Cloud computing will change the way IT professionals work, and the kinds of jobs they do. It will also bring a fundamental change in how managers think about business, coordinate tasks and people.

B. Cloud in Agriculture

Agriculture has traditionally been maintained by farmers' communities [11] where the sharing of knowledge is regarded as very important criteria of efficient farming. The collection and sharing of knowledge will definitely result in better overall efficiency and productivity. The application of Cloud computing in the field of agriculture will be Sales to customers and production planning for cultivated land. This can be performed together using the help of cloud computing. Similarly Management of all sorts of data [11] relating to cultivated land, including location, land rights, area, soil, and land characteristics can be integrated.

C. Cloud in Libraries

Cloud computing already set the foot prints in commercial sectors [14] and is now beginning to find a suitable place in library science.

Libraries may put more and more content into the cloud. Using cloud computing [3][4] user would be able to browse a physical collection of books, journals, CDs or DVDs etc. The user can also take out a book for scan a bar code into his tablet pc. All historical and rare documents would be scanned into a comprehensive, easily searchable database and would be accessible to any researcher.

D. Cloud in Education

The potential of cloud computing for improving efficiency, cost and convenience for the educational sector is being recognized by a number educational institutions. Due to economical factors such as budget crisis many educational institutions are also adopting cloud computing for paper less teaching learning process. Many universities also found cloud computing to be attractive to use in one of their courses which was focused exclusively on developing and deploying SaaS applications.

VIII. CONCLUSIONS

In this article a number of approaches to cloud computing are pointed out along with its architectural model. It has been seen that after so many years, cloud computing today is the beginning of "network based distributed computing" and is regarded as the technology of this decade. This paper also describes various advantages and challenges of cloud computing. In the same time various applications of cloud computing in the area of information technology, agriculture, library and education are outlined.

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