

Cloud Computing Architecture: A Survey and Research Directions

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Abstract--Cloud computing is a revolutionary technology that provides services on demand as pay per use basis. No need to concern about infrastructure and framework by the users as resources can be accessed from cloud according to requirements. Various cloud service providers for providing resources are Amazon, Microsoft, Google, IBM, Hewlett Packard, Yahoo, and Rackspace [1]. This paper gives introduction of cloud computing, features of cloud computing, architecture, deployment model and various recent research challenges.

Keywords--Cloud computing, Characteristics, IaaS, PaaS, SaaS, Challenges

I. Introduction

Cloud computing is an emerging, revolutionary, dynamic, internet based, distributed technology. It provides high reliability over internet with least cost as users don't require any software and framework for their applications. They just need to pay for the software, platform and resources to run their complex applications. It uses virtualized resources and provides these resources as a service through virtual machines concept [2]. Virtual resources are not actual physical resources but are images of actual ones to provide services to multiple users in distributed network environment. Cloud computing supports distributed as well as parallel systems [3]. In distributed environment requests can come instantaneously from any geographical location so cloud resources are organized in such a way to serve all these requests when they arrive.

Cloud is based on market oriented policy as it provides infrastructure to users to run their

applications with no concern regarding platform. Nowadays cloud is basically used for everything on internet from storage of data, multimedia to the processing of different applications, web browsing and social networking. Mainly it is used for storage of data [4]. As cloud is made up of large numbers of nodes which may be geographically distributed, when a request for data storage comes, that data can be stored at any node in cloud and user is not aware of it i.e. where his data has been stored. User's data can be stored anywhere on a single computer or on multiple computers in cloud environment. This cloud environment basically belongs to third party which provides services on demand.

Cloud can be divided in frontend and backend phases. At backend are the various data centers or servers where data has been stored which is not visible to user and at frontend are several users who use that data. Both frontend and backend together form the cloud which serves the users requests at faster rate [4]. Main advantage of cloud is its reduced cost as all framework, platform and services are provided by third party on pay per use basis allowing users to share cloud resources without investing too much in their installations. Cloud also provides high reliability and scalability as cloud is made of large no of servers, if anyone goes out of service others can handle its tasks maintaining reliability. Cloud is scalable as new nodes can be added easily when required. Cloud is an elastic model allowing users to increase their acquired resources in peak hours and release these resources when not required. Cloud computing proves to be very beneficial for IT industry as it helps even small enterprises to withstand in market by leasing various resources in cloud. Due to its innumerable benefits, number of big

companies have come to market like Amazon, Google, Yahoo, Microsoft, IBM etc., they provide powerful, efficient, reliable, flexible services at least price.

II. Characteristics of Cloud

Cloud computing has enormous features which distinguish it from already existing computing as listed below:

- *Utility services:* Cloud provides various utility services like hardware, software, storage, processing, framework and platform.
- *On-Demand-services:* Cloud provides services on demand as pay per use basis. Users don't have to concern earlier regarding installation of platform or framework [5].
- *Elastic Model:* Cloud services can be scaled up or scaled down depending upon need. During peak hours more resources can be leased and then released when no longer required.
- *Multitenant Model:* Multitenant means multiple users shares resources on pay per use basis. In this approach multiple users use same shared resources.
- *Broad Access:* Cloud computing is made up of large no of geographically distributed nodes and one can access its services from any location and at any time [6]. Cloud services are not bounded due to location, but have broader access.
- *Dignified Services:* Cloud provides dignified services by automatically optimizing the resources provided to the user depending on the capability [7].
- *Scalable:* Cloud is highly scalable environment as more and more nodes can be added to it according to requirements.
- *Reliable:* Cloud computing model is highly reliable as data is replicated on multiple nodes, if one node goes out of service other can handle its tasks.
- *Cost Efficient:* This model reduces cost by providing shared access to resources in cloud. Cloud environment can be allocated and de-allocated depending on need. When demand becomes lower, these resources can be de-allocated which leads to significant decrease in cost.

- *Virtualization:* virtualization is process of partitioning physical resources into virtual resources which can be shared among multiple users [8]. virtualization is fundamental technology of cloud computing through which cloud environment is provided to different users simultaneously.
- *Autonomous:* Cloud is self-managed system. It has ability to manage its resources automatically.
- *Client Server methodology:* Cloud is also based on concept of client and server. Servers are nodes in cloud which provide services and clients are users of these services.
- *Peer-to-Peer model:* Cloud is made of distributed nodes without any central authority and every node either service provider or service user are at the same level.

Five most important features are shown in figure 1.

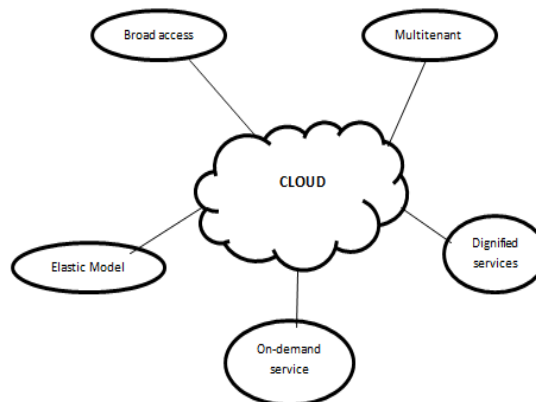


Fig. 1. Cloud Computing Features

III. Architecture and Services of Cloud

Cloud computing services can be classified broadly in three categories IaaS, PaaS, SaaS. These services are divided among different layers. They are not provided on local computers but on centralized systems handled by third party. Architecture of cloud is shown in figure 2.

- Software as a Service

SaaS provides software and interface to the user as a service. Application services are provided to user without any control of underlying infrastructure [6]. Their underlying infrastructure is controlled by infrastructure providers. Users have to pay for the leased software for the specific time duration. Now users don't need to install these applications on their local computer, they just need an interface like web browser on their system. SaaS applications are platform independent and can be accessed from various devices like PDA, mobile phones, laptops, desktop etc. from anywhere. SaaS is mainly adopted by large organizations and government. Example of various SaaS is: Email system, database processing, Salesforce, Google Docs, Microsoft online, RackSpace, office software, social media, online games [7] etc.

- Platform as a Service

PaaS provides framework, platform and runtime environment for the development of new applications [2]. It provides development tools, application programming interface, software libraries etc. PaaS offers users high level of abstraction and provides the feature of multi-tenancy. Users have to concentrate on application development without concerning about hardware and software needed. It's the duty of cloud service provider to manage underlying infrastructure including network, servers, operating system. It cuts down the upfront and operational cost and makes the development quick and easy. PaaS is mainly adopted by large organizations. Google App engine, Windows Azure Platform, Force.com are popular PaaS services.

- Infrastructure as a Service

Underlying concept of IaaS is virtualization, where users can use network, storage, virtualized servers, and routers like resources provided by cloud service provider. These resources are provided to users as virtual machine instances and users can control, manage, start, stop and configure these instances. As compared to PaaS, IaaS provides more flexibility to the users by allowing them to deploy any software on top of operating system. SaaS is mainly adopted by large organizations, small and medium enterprises and individual users. Examples of IaaS services are: Google Apps, Azure VMs.

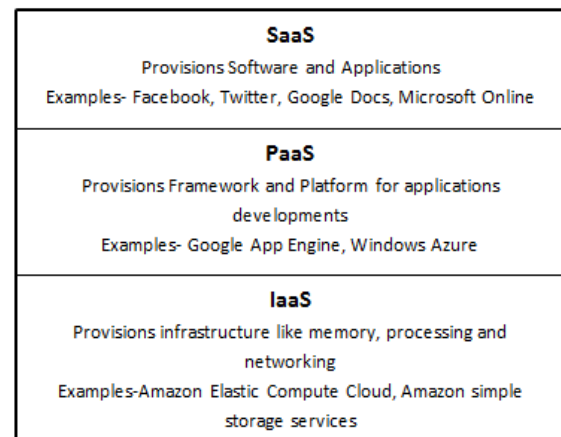


Fig. 2. Architecture of Cloud

IV. Deployment Paradigms

Depending upon various factors like low cost, high reliability, security etc. applications can be deployed on different clouds. Mainly four types of cloud deployment model exist:

- Public Cloud

Public cloud is available to general public for use. Mainly large organizations use this cloud, which can then be shared among individuals, small and large organizations. This cloud is best for consumers who want to develop and host new applications in the cloud. Public cloud offers various benefits like no initial investment, no need of infrastructure installation etc. But public cloud also has some shortcomings like least control over data, network and security. Examples of organizations that have public cloud are Google, Microsoft and Amazon etc.

- Private Cloud

Private cloud is also called as internal cloud, on-premise cloud. It is developed for exclusive use by a single organization. Private cloud is used by organizations that wants high security, control over data. This cloud can be run by the organization itself or a third party. Main benefit of this cloud is high security. Organizations having private cloud are St Andrews Cloud Computing Co-laboratory and Concur Technologies etc.

- **Community Cloud**

Community cloud is shared by multiple organizations and they have same policy and consideration. It is basically designed for specific requirements. Community cloud is best for organizations who want to share applications, data and cost. The open cirrus testbed is a community cloud.

- **Hybrid Cloud**

Hybrid cloud is mixture of the above three clouds. This cloud is best for organizations that want to use high security and control over data in private cloud and also want to cut-down cost by using public cloud. Hybrid cloud allow cloud bursting, private cloud can be burst up in public cloud when it needs more resources [6].

Deployment models are depicted in figure 3.

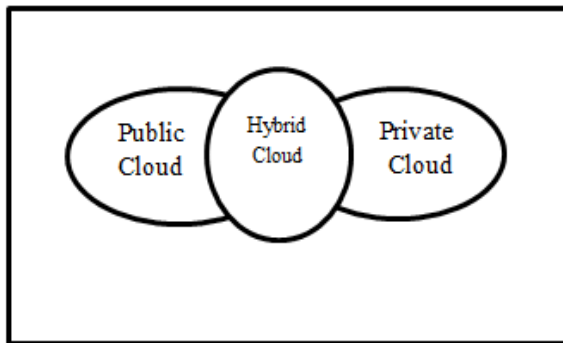


Fig. 3.:Deployment Model of cloud

V. Research Challenges

Cloud computing is an evolving technology, which is widely used for different applications over internet nowadays. Various research works are already carried out on cloud but some issues are still open to researchers. Here we give summarization of key research issues.

- **Mobile Cloud Computing**

Mobile cloud computing (MCC) is a quiet new area, which is developing vary rapidly.It is a combination of two technologies Cloud computing and Mobile networks. Its main idea is to make cloud services available on mobile devices, such that these services can be accessed on demand and from anywhere on mobile devices [9]. Various

applications of mobile cloud computing have been developed like Goggles Gmail, Maps, Navigation system for mobiles, voice search and many more for android. Here main challenge is how to combine these two technologies in seamless way, as each has their own flaws. Mobile devices have their own limitations like limited resources, limited power backup, limited processing and quality of wireless communication etc. which need to be concerned to access cloud. Various future research topics in this area are: which processes to execute in cloud and which on mobile devices, network handover delays, delivery time, security and privacy.

- **Security**

Data security is one of serious issue in cloud.Cloud services are provided by third party and it is the responsibility of cloud infrastructure provider to manage all security issues as cloud service providers merely provides security settings remotely without knowing their implementation details. So it's the responsibility of cloud infrastructure providers to achieve following security issues [10]:

- *Confidentiality*, data can be transferred and received securely.
- *Authenticity*, data is accessed by trustworthy person.
- *Auditability*, to check whether security settings have been altered or not [8].
- *Data Location*,as data can be stored anywhere in cloud. Users are not aware of data location.
- *Access monitoring*, who, when and where is accessing what data.

Security need to be applied at every architectural layer of cloud like IaaS, PaaS, SaaS [11]. Recently research works are carried out to develop more secure and effective protocols.

- **Load Balancing**

Cloud is made of large no of geographically distributed nodes and balancing the load on these nodes is major issue. Load balancing algorithms provide the mechanism of adjusting load according to the application and node capacity. Whenever a request comes to a node which is already having heavy load, this load needs to be transferred to some

other node with low load to improve throughput and minimize response time. This transfer in cloud is transparent to user and done by load balancers transparently [5]. Various load balancing algorithms already exist like First-Come-First-Serve, Round-Robin, Min-Min, Opportunistic load balancing algorithm. These algorithms are divided into two broad categories static and dynamic load balancing algorithms. Round-Robin scheduling algorithm comes under static. OLB (Opportunistic Load Balancing) and MM (Minimum-Minimum) algorithms come under dynamic. Static algorithms work only for already existing load, while dynamic also work for real time load requests. Developing dynamic load balancing algorithm, which gives better efficiency and performance by automating whole task in cloud, is still an open issue.

▪ **Energy Management**

Reducing power usage by nodes or data centers in cloud is an open challenge. In front of infrastructure providers it's a challenge to cut down power cost without reducing efficiency and performance of nodes. Energy-aware hardware architecture [8], job scheduling, network protocols, security protocols and turning off unused nodes are the ways to cut down power usage. Recently researchers are working towards maintaining a trade-off between energy conservation and performance.

▪ **Data Traffic Analysis**

Analysis of data traffic is an important issue. On basis of traffic analysis load can be optimized on data centers. Also network operator can use it to optimize network routes. Researchers are working in this area to develop efficient traffic analysis algorithms.

▪ **Data Recovery And Availability**

Cloud service providers must ensure availability of data at any time and at any location. If any data center gets crashed, there should be provision of data recovery. For this cloud service providers need to replicate data at different nodes so that data can be recovered at any time.

VI. Conclusion

Cloud computing provides tremendous computing capability over internet by provisioning of resources on demand. It has changed whole concept of computing, Now users don't need to make heavy investments in implementing infrastructure for developing an application. They can lease these resources on basis of demand from cloud service providers. Instead of various developments and facilities provided by cloud, still it has various hot research areas which need to be explored more in near future.

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