A Taxonomy of Cloud Computing

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Abstract- Today, computing becomes steadily more important and more used. Cloud computing has appeared as an accepted computing model for processing very large volume of data. Cloud computing is an unavoidable trend in the future computing development of technology. In this paper, we have discussed the computing taxonomy and their relationship with cloud computing. Then we have discussed the essential characteristics, layered service model architecture and deployment model of cloud environment. Last we have identified the several research challenges, cloud adoption challenges along with the applications of cloud computing. This paper is for those who have heard first time the term "cloud computing" and wants to know about its taxonomy. Also this paper will provide an idea of design challenges of cloud computing and help in identifying important research directions in this area.

Index Terms- Cloud Architecture, Cloud computing, Cloud computing issues, Distributed computing

I. INTRODUCTION

With the invention of internet, notion of computing has changed. Earlier only one processor was used for computing purpose. Later on, concept of parallel computed has accelerated the computing process. Parallel computing and distributed computing are ways of utilizing parallelism in computing to accomplish higher performance. Several processing elements are used to solve a problem. Grid computing, cluster computing, utility computing and cloud computing are some of the variations of distributed computing based on the functionality and features they are providing [1].

Today, computing becomes steadily more important and more used. The amount of data exchanged over the network or stored in a computer is constantly increasing. Thus, the processing of this increasing mass of data requires more computer equipment to meet the various needs of organizations [2]. Cloud computing is an unavoidable trend in the future computing development of technology. Its critical importance lies in its capability to provide all the users with high performance and consistent calculation. Cloud computing is the evolution of distributed computing, grid computing, and many other techniques. In cloud computing data is moving from desktop system to data centers. By means of virtualization technology, one physical host can be virtualized into multiple virtual hosts and use these hosts as a basic computing unit. [3].

In this taxonomy we have tried to elaborate cloud computing architecture along with its strength, weakness, challenges and applications in current scenario based on the current advances from academia. This paper is organized as follows: Section 2 discusses the overview of the cloud environment. Section 3 discusses the challenges for cloud environment. Section 4 discusses the advantages, disadvantages and applications of cloud environment.

II. CLOUD OVERVIEW

2.1 Definition

Cloud Computing refers to both the applications delivered as services over the Internet and the hardware and systems software in the datacenters that provide those services. The basic idea of cloud computing is managing and scheduling uniformly computing resources that are connected by a network, and constituting a computational resources pool which provides user service according to their needs. The network which provides resources is called "cloud". From the point of view of the user, the resources in the "cloud" can be extended unlimitedly, and can be assessed at any time, used according to need, and paid according to usage [4].

Cloud can also be defined as a type of parallel and distributed system consisting of a collection of inter-connected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources based on Service Level Agreements (SLA) established through negotiation between the service providers and consumers [5].

Cloud computing is Internet-based computing, whereby shared resources, software and information are provided to computers (hardware) and other devices on-demand, like the electricity grid [6].

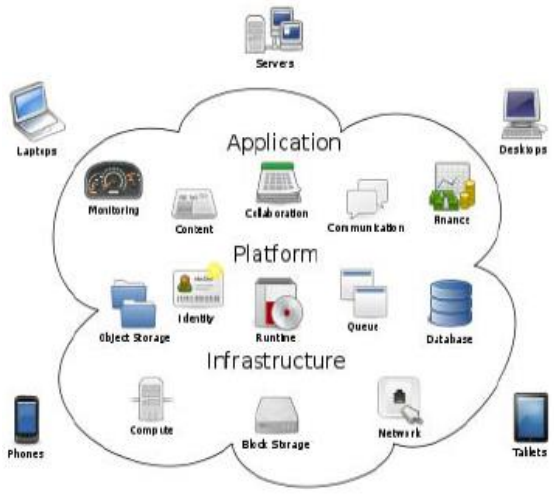

Figure 1: cloud computing [7]

National Institute of Standards and Technology (NIST) has defined the Cloud Computing model by describing its essential characteristics, three cloud services models and four cloud

deployment models as shown in figure 2 where its layered architecture is shown.

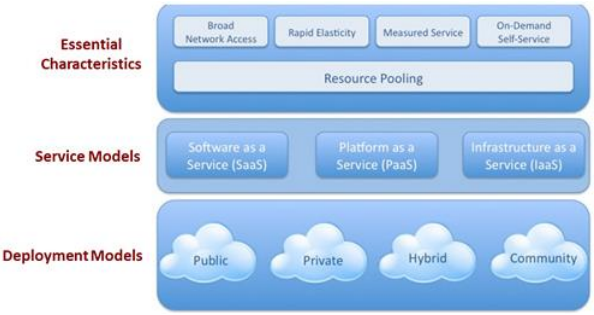

Figure 2: model of cloud computing [8]

2.2 Essential Characteristics

Essential characteristics of cloud computing system are as follows:

- Elasticity and Scalability: Elasticity is the ability to expand or shrink a computing resource in real time, based on the user's computing requirements. Cloud platform can be expanded or shrink dynamically according to the circumstances of the application and the number of the users.
- Virtualization: The most important characteristic is virtualization in cloud computing. With virtualization, one physical resource can be made to look like multiple virtual resources. Cloud computing provides resources to users through virtualization technology. Due to this feature provider can run multiple application and operating systems in a single physical machine by partitioning the available resources which results in reduction in hardware cost and optimization of workload.
- Large scale infrastructure: There are more than one million servers in Google's cloud computing platform, and more than hundreds of thousands of servers in IBM, Amazon, Microsoft, Yahoo and other cloud services platform. So, Cloud computing environment will give users super computing capabilities.
- Ubiquitous: The services provided by the cloud computing are not customized for a specific application. The users can choose different applications according to their needs. Different users can run different applications in the same platform. Also user can access the application from any place at any time where internet facility is available.
- Utility based pricing: When customers use a cloud infrastructure that utilizes more resources, they pay for this. However, when the peak load is over, the cloud infrastructure shrinks, or scales down, to the required resources. At this point in time, the customer is only paying the reduced infrastructure cost. They pay only for the resources they use [6].

2.3 Cloud service model architectures

There are three Cloud Services Models and these three fundamental classifications are often referred to as "SPI model" i.e. software, platform or infrastructure respectively.

- Cloud Software as Service: In the software as a service model, the same software is provided to different customers via Internet. The software no longer resides on the consumer's workstation. Under the SaaS model, the software provider is responsible for the creation, updating, and maintenance of software, including the responsibility for licensing the software. Customers usually rent the software on per usage basis. A good example could be web-based email running on a cloud infrastructure. Typical examples for SaaS offerings are Google Apps such as Google Mail and Google Docs and Spreadsheets and Salesforce.com [6].
- Cloud Platform as Service: In this model, the computing platform is made available as a service. Customers can develop, test, and deploy their applications on the cloud. The user of the service is responsible for the creation, updating, and maintenance of the application. Customers of PaaS do not control the underlying infrastructure as SaaS users do, but control over the deployed applications. Typical examples of PaaS are Google App Engine which allows applications to be run on Google's infrastructure, Windows Azure, Engine Yard and Force.com [8].
- Cloud Infrastructure as Service: In the infrastructure as a service model, the consumer can provision fundamental computer resources such as processors, storage, and networking resources. An infrastructure provider (IP) makes an entire computing infrastructure available "as a service". Rather than purchasing servers, data storage, and networking equipment, customers rent these resources provisioned over a network. Infrastructure services are built on top of a standardized, secure, and scalable infrastructure. Amazon Web Services with its Elastic Compute Cloud (EC2) for processing and Simple Storage Service (S3) for storage and Joyent who provide a highly scalable on-demand infrastructure for running Web sites and rich Web applications are examples of IAAS.

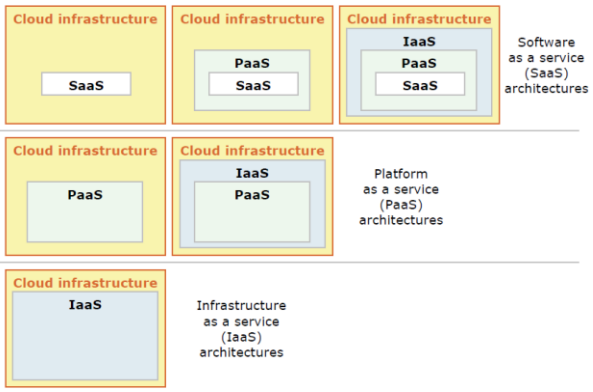

Figure 3: cloud service model architectures [6]

2.4 Cloud deployment models

The four cloud computing models are as follows:

- Public Cloud: A public cloud is one in which a third-party provider makes resources, such as applications and other computing resources, to the general public via the Internet. It is offered on a pay-per-usage model. The cloud service provider is responsible for setting up the hardware, software, applications, and networking resources. Public clouds do not imply that the user's data is public. In many cases, access control mechanisms are required before the user can make use of cloud resources. The advantage of public clouds is

that they allow client to build on-demand virtual systems on almost any scale with minimal in-house hardware [8].

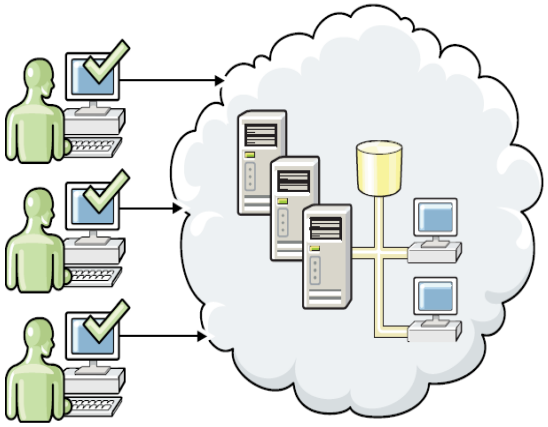

Figure 4: model of public cloud [6]

- Private Cloud: This type of the cloud is available exclusively for a single organization. Private Cloud intentionally limits access to its resources to service consumers that belong to the same organization that owns the cloud. The infrastructure is managed and operated for one organization only. The main aim is to uphold a consistent level of control over security, privacy, and governance. With a private cloud, computing resources are pooled and managed internally. This provides for greater efficiencies. Resources can be applied dynamically according to demand. A private cloud allows the enterprise to continue to follow workflow and security procedures. This ensures that the correct level of "code" is executing. These types of clouds are not burdened by network bandwidth and availability issues or potential security exposures that may be associated with public clouds. Private clouds can offer the provider and user greater control, security, and resilience. IBM Smart Business Development and Test Cloud is an example of a private cloud [8].

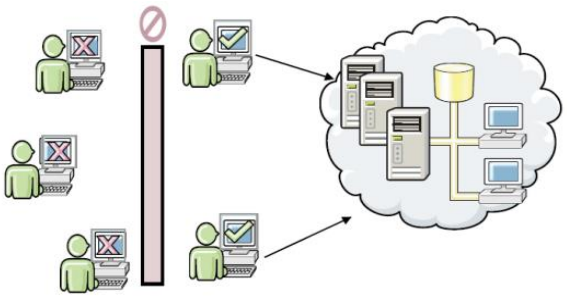

Figure 5: architecture of private cloud [6]

- Hybrid Cloud: Hybrid clouds are combinations of public and private clouds that work together. In this model, IT typically outsources noncritical information and processing to the public cloud, while keeping business critical services and data in their control. The hybrid cloud environment works to seamlessly integrate external applications on other private and public clouds, with your in-house processes.

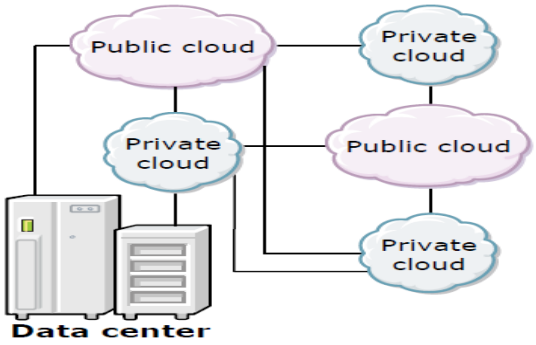

Figure 6: model for hybrid cloud [6]

- Community Cloud: A community cloud can be a private cloud purchased by a single user to support a community of users, or a hybrid cloud with the costs spread over a few users of the cloud. A community cloud is often set up as a sandbox environment where community users can test their applications, or access cloud resources [6].

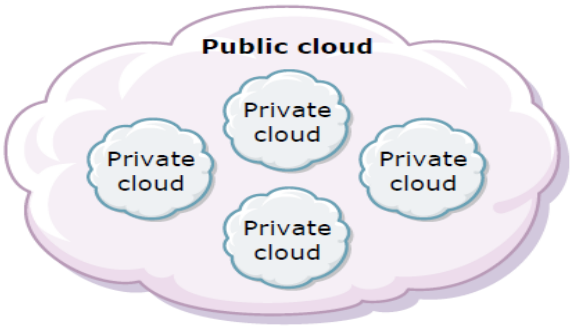

Figure 7: community cloud [6]

III. CHALLENGES

3.1 Research challenges

Although cloud computing has been widely adopted. But still its analysis is in its early stages, and some scientific challenges remain unsolved by the scientific community. Some main challenges are:

- Security: Due to dynamic scalability, service abstraction, location transparency, openness of cloud and shared virtualized resources by multi-tenant features of cloud computing models it is difficult to maintain data confidentiality, data integrity. So there is need of security model which will increase the consumer's trust in cloud computing service provider. Data security in cloud computing is a contractual and technical issue [10].
- Load Balancing: In cloud environment, servers are continuously monitored and when one becomes non responsive then a load balancing mechanism is called to avoid system failure. There is a need of efficient load balancing strategy which will ensure the virtualization, availability, even load distributions in data center and elasticity. This will improve the customer satisfaction level and help service provider to achieve scalability [11].
- Stored data management: There is an exponential increase in data stored across the network due to data outsourcing. So the stored data management has become a main challenge

for successful implementation of cloud computing. How can we distribute the data to the cloud for optimum storage of data while maintaining fast access [2].

- Automated service provisioning: Elasticity is the most important feature of cloud environment. Due to this feature resources can be allocated or released according to demand. How then can we use or release the resources of the cloud, by keeping the same performance as traditional systems and using optimal resources.
- Energy Management: Efficient utilization of energy is another big challenge in cloud environment. It has been estimated that the cost of powering and cooling accounts for 53% of the total operational expenditure of data centers**.** So cloud service providers are under huge pressure to decrease energy use. The objective is not only to cut down energy cost in data centers, but also to fulfill government regulations and environmental standards [12].

3.2 Adoption challenges

As Cloud Computing is still in its early development stage, so there are some issues associated its adoption in present form. These are:

- Security: Storing your data and installing your software at someone else's storage media and using someone else's CPU requires a trustworthy environment. So the security issues prevent the smooth adoption of cloud environment.
- Costing: Due to on demand and elastic nature of cloud environment, client can enjoy the services through the available interface. But client is not aware of the resources used by him. Non transparent cost model prevent the smooth adoption of cloud environment.
- Service Level Agreement: It is essential for client to obtain guarantees from cloud service providers on service delivery. These are ensured through Service Level Agreements (SLAs) finalized between the client and service providers. SLA should be defined in such a way that it has a suitable level of granularity i.e. there must be a balance between expressiveness and complicatedness, so that they can cover most of the clients expectations and is relatively simple to be implemented, and enforced by the resource allocation mechanism on the cloud. In addition, different cloud service models will need to form different SLA. This also raises a number of implementation problems for the cloud providers [13].

IV. PROS, CONS & APPLICATIONS

4.1 Advantages

- Pay as per usage: From client's perspective, utility-based payment model allows client to only use the amount of service they actually need, and only pay for the amount of service they have actually used. Also these services are available in uninterrupted manner.
- Zero upfront investment: From service provider's perspective, there is no requirement for up-front investment in hardware and software. It just leases resource from the cloud as per requirement and pay for the usage. So working expenditure is the only expenditure and maintenance headache is very less.
- Less Operational Cost: Flexibility and scalability of a cloud environment is also an added advantage for cloud and service provider. It enables easy and fast scaling of required computing resources on demand. This results in large saving as resources can be freed to minimize operating costs when service requirement is low.

4.2 Disadvantages

When a client wants to use cloud it requires an upfront investment in the combination of the client's infrastructure and applications with a Cloud.

- Due to unavailability of standards for the IaaS, PaaS, and SaaS interfaces, it becomes very difficult to choose cloud provider.
- Client has to depend on the promise of the service provider in context of availability, security, reliability, performance and Quality of the Service (QoS) of the resources.
- Client is not aware of the actual server on which his data is stored or processing.
- To use cloud's services, user has to transfer his own data on cloud. So due to transfer data back and forth there is a higher security and privacy risks related to data.

4.3 Applications

There are many different areas where cloud computing have applications. Some major areas in which cloud computing have applications are:

Data Processing Applications:

- Document processing: It can be used to convert very large collections of documents from one format to another (e.g., from *Word* to *PDF*), or encrypts the documents.
- Video trans-coding: It can be used to convert one video format to another. (e.g., from AVI to MPEG).
- Image processing: The image-processing application support image conversion (e.g., enlarging an image or creating thumbnails). It can also be used to compress or encrypt images.
- Data mining: It can support searching very large collections of records to locate items of interests.

Batch Processing Applications:

- Report Generation: It has applications in daily basis, weekly basis, monthly basis, and annual basis activity reports generations for organizations in retail, manufacturing, and other economic sectors.
- Processing, aggregation, and summing up of daily transactions for financial institutions, insurance companies, and healthcare organizations.
- Inventory management for large organizations.
- Bill processing and processing of payroll data.
- Keeping record of software development (e.g., nightly updates of software repositories).
- Automatic checking and verification of software and hardware systems [11].

V. CONCLUSION

Cloud computing is a latest technology extensively studied in present years. It is a model through which IT services are delivered and charged on the basis of usage.

But still present technologies are not developed enough to utilize its full capacity. There are many untouched issues in this domain, including security management, stored data management, load balancing, automatic service provisioning and energy management have just started to receive attention from academician and industry. So, we believe that still there is a wide scope of research in this field.

Our proposed taxonomy will help researcher to understand cloud computing architecture along with its strength, weakness, challenges and applications.

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