Cloud Computing
Advancements and Challenges - A Management Perspective

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***Abstract*—In Cloud Computing users access computing resources such as Processing Capability, Computing Memory, Storage Memory, Network resources, etc as a service. In other words Cloud Computing could be termed as 'IT as a Service'. Though there have been many advances in Cloud Computing, it is still not fully developed and is yet to mature.**

Cloud computing model offers tremendous opportunities for both the providers as well as consumers. The technology is sure to change how business is done and managed, across enterprises and across boundaries.

This paper discusses the recent advancements and challenges in Cloud Computing from a Management Perspective.

Keywords— Cloud Computing; IT as Service; IT Management

I. INTRODUCTION

In the beginning computers were human. Then they took the shape of metal boxes, filling entire rooms before becoming ever smaller and more widespread. Now they are evaporating altogether and becoming accessible from anywhere [1].

Cloud computing allows computer users convenient and easy access to fully featured applications, software development and deployment environments and computing infrastructure such as processing power and data storage.

The Cloud computing model promises massive cost savings and increased agility. It is critical that government and industry begin adoption of this technology taking full advantage of the reduced cost and increased speed. However, Cloud computing technology challenges many traditional approaches to data centre and enterprise application design and management in terms of security, interoperability, and portability issues.

A. Objective

The IT industry has the habit of introducing esoteric words and applying them everywhere. 'Cloud' is no exception and is being talked about across the industry. Though there is lot of talk going on, there is still lot of confusion and lack of understanding on what specifically is Cloud computing.

This paper attempts to analyse and understand Cloud Computing specifically looking at the Advancements and Challenges from a management perspective.

B. Relevance

The relevance of this study is better understood in the following context. In the internet realm, every minute, there are 204 million emails being sent, 61,000 hours of music being listened, 20 million photos being viewed, 3 million photos being uploaded, 100,000 tweets being sent, 6 million Facebook pages being viewed with 277,000 Facebook logins and 2 million plus Google searches being done [2]. The above volumes are happening because of the Cloud computing technology.

Also, "The rise of the Cloud is more than just another platform shift that gets geeks excited. It will undoubtedly transform the IT industry, but it will also profoundly change the way people work and companies operate. It will allow digital technology to penetrate every nook and cranny of the economy and of society." [1].

"The emergence of the phenomenon commonly known as Cloud computing represents a fundamental change in the way information technology (IT) services are invented, developed, deployed, scaled, updated, maintained and paid for." [3].

II. LITERATURE REVIEW

Cloud computing represents a convergence of two major trends in information technology (a) IT efficiency and (b) business agility. In IT efficiency, the power of modern computers is utilised more efficiently through highly scalable hardware and software resources. In business agility, IT is used as a competitive tool through rapid deployment, parallel batch processing, use of compute-intensive business analytics and mobile interactive applications that respond in real time to user requirements [3].

A. Definition

National Institute of Standards and Technology (NIST) of United States Department of Commerce defines Cloud Computing as "Cloud computing is a model for enabling ubiquitous, 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." [4].

They continue to state that the Cloud model, which promotes availability, is composed of five essential

characteristics, three service models, and four deployment models.

1) Essential Characteristics

The essential characteristics of a Cloud as detailed by them are as below:

a) On-demand self-service

A Cloud allows a consumer unilaterally provision computing capabilities, such as processing power, memory, processor time and network storage, as needed automatically without requiring human interaction with each service provider.

b) Broad network access

A Cloud is available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, tablets, laptops, and workstations).

c) Resource pooling

In a Cloud the computing resources of the provider are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. There is a sense of location independence in that the customer generally has no control or knowledge over the exact location of the provided resources but may be able to specify location at a higher level of abstraction (e.g., country, state, or data centre). Examples of resources include storage, processing power, memory, and network bandwidth.

d) Rapid elasticity

The Cloud resources are elastically provisioned and released, in some cases automatically, scaling rapidly outward and inward based on the demand. The resources available for provisioning often appear to be unlimited to the consumer and can be appropriated in any quantity at any time.

e) Measured service

Cloud systems automatically control and optimise resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported, providing transparency for both the provider and consumer of the utilised service.

2) Service Models

The Cloud service models put forward by NIST (2011) are as below. Here, the Cloud infrastructure is the collection of hardware and software that enables the five essential characteristics of Cloud computing. The Cloud infrastructure can be viewed as containing both a physical layer and an abstraction layer. The physical layer consists of the hardware resources that are necessary to support the Cloud services being provided, and typically includes server, storage and network components. The abstraction layer consists of the software deployed across the physical layer, which manifests the essential Cloud characteristics. Conceptually the abstraction layer sits above the physical layer.

a) Software as a Service (SaaS)

In the SaaS model, the consumer uses the applications of the provider running on a Cloud infrastructure. These applications are accessible from various client devices through either a thin client interface, such as a web browser (e.g., web-based email), or an application program interface. The consumer does not manage or control the underlying Cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities except limited user-specific application configuration settings.

Some examples are Google Docs, Salesforce CRM, SAP Business by Design.

b) Platform as a Service (PaaS)

In PaaS model, the consumer is allowed to deploy onto the Cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, services, and tools supported by the provider. Here again, the consumer does not manage or control the underlying Cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly configuration settings of the application-hosting environment.

Some examples are Force.com, Google App Engine, Windows Azure (Platform).

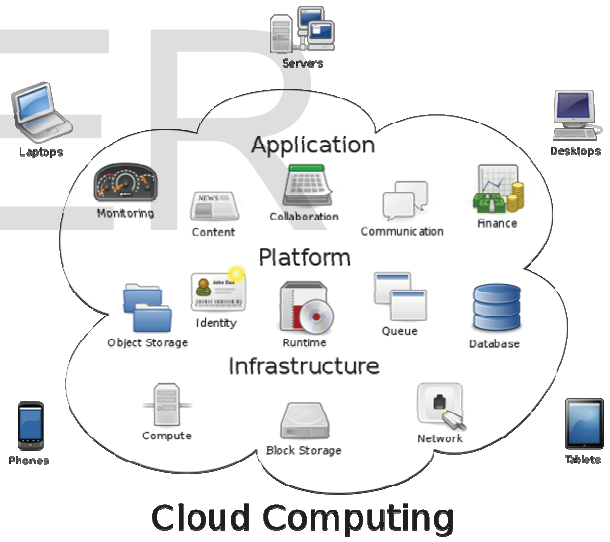

Fig. 1. Cloud Computing Service Models

c) Infrastructure as a Service (IaaS)

In the IaaS model, the consumer is allowed to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. As in other models, the consumer does not manage or control the underlying Cloud infrastructure but has control over operating systems, storage, and deployed applications; and possibly limited control of select networking components (e.g., host firewalls).

Some examples are Amazon EC2, Zimory, Elastichosts, Amazon S3, SQL Azure.

3) Deployment Models

Following are the deployment models detailed by NIST:

a) Private Cloud

In a private Cloud, the Cloud infrastructure is provisioned for exclusive use by a single organization comprising multiple consumers (e.g., business units). It may be owned, managed, and operated by the organization, a third party, or some combination of them. It may exist on or off their own premises.

b) Community Cloud

In this case, the Cloud infrastructure is provisioned for exclusive use by a specific community of consumers from organizations that have shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be owned, managed, and operated by one or more of the organizations in the community, a third party, or some combination of them. It may exist on or off their premises.

c) Public Cloud

In this deployment model, the Cloud infrastructure is provisioned for open use by the general public. It may be owned, managed, and operated by a business, academic, or government organization, or some combination of them. It exists on the premises of the Cloud provider.

d) Hybrid Cloud

Here the Cloud infrastructure is a composition of two or more distinct Cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability (e.g., Cloud bursting for load balancing between Clouds).

TABLE I. ROLES OF CLOUD ENVIRONMENT

Providers	Providers	They offer Clouds to Customers.
	Resellers or Aggregators	They aggregate Cloud environments from one or more providers and offer customised or enhanced Clouds to Customers.
Developers	Adopters or Cloud Software/Service Vendors	They exploit the Clouds from providers or resellers to provide their own software applications to Customers. They provide software as a service.
	Tool Providers	They provide tools to manage or configure Clouds.
End Users	Users/Consumers	They use the Cloud offering and are the end customers of the above.

4) Roles of Cloud Environment

In order to better understand the Cloud model, it is important to understand the roles that are common to the Cloud environment, which are listed in Table I. The different roles could be broadly classified into 3, the providers, the developers and the end users.

III. ADVANCEMENTS

While the Cloud computing may take many years to evolve completely, it offers many advancements.

A. Scalability

Cloud computing provides almost instantaneous scalability of computing resources for enterprises. This is helping many small enterprises utilise highly computer intense business analytics to compete with their larger competitors. This was not available to smaller enterprises because of the huge costs, which were not affordable to them. Similarly Cloud computing has brought huge opportunities for third world countries who could not otherwise afford such computing resources on their own [3].

B. Business Continuity & Innovation

Cloud computing provides instantaneous access to huge computing power helping enterprises achieve better business continuity as they are able to scale their services based on customer demand with increasingly accurate and up to the last minute information. Enterprises are able to provide better service to customers with ability to do trend analysis on past purchase history, buying trends, etc. and other business analytics.

Businesses are also able to innovate and achieve better results as Cloud offers no barriers for compute intensive business analytics. Cloud computing services allow an organization to control when, where, and how employees have access to the organization's computer systems, all managed over a simple web-based interface [3].

C. Capex to Opex

Cloud computing also reduces the need for upfront investment on IT infrastructure. Thus the Capital Expenditure (Capex) in purchasing and implementing huge computing infrastructure is reduced to the minimum. All the required infrastructure and computing solutions are available on the Cloud on demand allowing companies to use and pay per use for the utilised resources. Thus cost of IT has changed to a Operating Expenditure (Opex). Earlier even with huge Capex in IT companies used to run out of available resources, but with advent of Clouds, this has changed allowing companies to achieve better efficiencies with minimal and manageable IT Opex [3].

Apart from IT Capex, cost of maintenance of IT systems also are reduced in the Cloud environment, as the in house infrastructure gets reduced to the minimum.

D. Utility Computing

In 1961, John McCarthy, an American Computer Scientist predicted that “computation may someday be organized as a public utility”. Cloud computing seems to lead to that realisation where just like other utilities such as electricity, water, telephone, etc. computing is made easily available on demand and is charged based on usage [3].

In such a model, users access services based on their requirements without regard to where the services are hosted

or how they are delivered. Similar to accessing content from different websites without being bothered about where those sites are actually being hosted and how the content is made available, consumers are able to use computing power without being bothered about the underlying infrastructure or the complexity [5].

IV. CHALLENGES

The primary challenge of the Cloud environment is that of provisioning and management of the available resources. This becomes more and more complex because of the increasing amount of heterogeneous resources, increasing amounts of data, resulting communication volumes and processing power requirements, interoperability and portability requirements.

Virtualising the environment is a typical solution for realising at least some aspects of the above requirements. Virtualisation allows treating each user's environment separately and thus isolating the code and data assigned to the user. However, virtualisation is just one potential solution and it may lead to other issues and concerns which may not be desirable. For example such virtualisation of individual user environment of a small lightweight application with large number of users may create unnecessary overheads [7].

A. High Availability

In Cloud computing maintaining high availability of a service is one of the challenges. However, this is an increasingly difficult challenge as the service could depend on one or more underlying services from different service providers. A disruption on any of these underlying services could disrupt the service. Solution to this problem is to maintain alternate or redundant services on different Clouds. However, as most of the Cloud implementations are proprietary, interoperability is extremely difficult and practically impossible in the current Cloud environments [6].

B. Heterogeneous

Current Cloud offering are all heterogeneous in nature. Each Cloud is implemented differently and there is very little support for portability or interoperability. This locks in the user to one particular Cloud vendor without any chance of moving to another. This forced lock-in chases away many potential Cloud users.

Another major issue caused by this is the restriction in usability. Because of the heterogeneity users are not able to combine capabilities of different Clouds. This again is another deterrent to many who consider switching to a Cloud environment.

Thus if Cloud providers work together improving their federation and inter operability, that may attract more users to the Cloud. Such federation and inter operability may also improve price/cost savings for end users.

C. Security & Privacy

A Cloud environment could be utilising services and infrastructure from different service providers. In this context, implementing end to end security solutions is a major challenge as that would demand all the participating service providers to implement common security standards and practices, which would not be practical because of the underlying heterogeneous environment of the Cloud. Thus, "a Cloud provides "global" data hosting, possibly across multiple legal jurisdictions, raising compliance issues for both users and providers" [7].

In any computing environment data get transferred between systems and services. In a Cloud environment, these data exchanges may happen between different services on different Clouds running on different infrastructure. There is a risk of these exchanges getting intercepted during the exchanges. Moreover, based on the data exchange traffic it would be possible to predict or infer on business practices. There is also concern of the Cloud providers themselves snooping on the data of the consumers.

D. Elastic Scalability

Elastic scalability is still a major challenge in Cloud environments. While more and more objects are generally created based on user requests, those do not replicate utilising shareable components.

E. Resource Utilisation

Resource utilisation is another major challenge in Cloud environment. Optimal use of resources is still not achieved in Cloud environments. Which user is using what resource is still not being metered properly. Resources are still over and under utilised, and code and data are not effectively distributed, let alone adapted to the infrastructure [7].

F. Development & Management

In a Cloud environment a single service could depend on one or more service providers and a service could be part of one or more applications. There could be multiple such services which an application may utilise. Managing and ensuring the availability of all such services is a major challenge. The application providers have to constantly check on the different services in order to ensure the expected performance levels of their Customers. This is all the more difficult and challenging in the current Cloud environments as providers seldom provide customisable service monitoring mechanisms.

In order to better manage this challenge, Cloud providers should provide better service discovery by implementing service directories which would provide the details of the services offered and customisable monitoring mechanisms.

G. Data Management

The amount of data consumed, produced and distributed increases constantly much faster than the underlying infrastructure. This increases the challenge of data management with respect to replicating, distributing, localising and routing while compensating for the bandwidth and latency limitations.

Application hosted in a Cloud environment is accessible to multiple users at the same time. This is not restricted to

multiple applications or services being hosted on the same physical server, but could also involve actual sharing of code and data, or at least of parts of this code and data [7].

Managing consistency of data in a multi-tenant environment with a number of concurrent users could be quite complex. Though there is sharing of programs, data and resources, the data of the individual tenant has to be maintained secure and private. While the data and program has to be isolated for each tenant, it has to be shared also for better collaboration in the Cloud environment.

H. Programming Models

In order to best utilise the advantages of a Cloud environment, Cloud aware applications has to be developed and managed significantly different from traditional software applications of yesteryears.

Clouds are generally not easy to use to program for, let alone allow easy conversion of existing applications into the respective environment [7]. Thus it is very difficult to convert an existing proprietary application to Cloud environment directly, but the only option is to develop it afresh for the Cloud environment. However, current programming models do not really utilise the potential of Cloud computing.

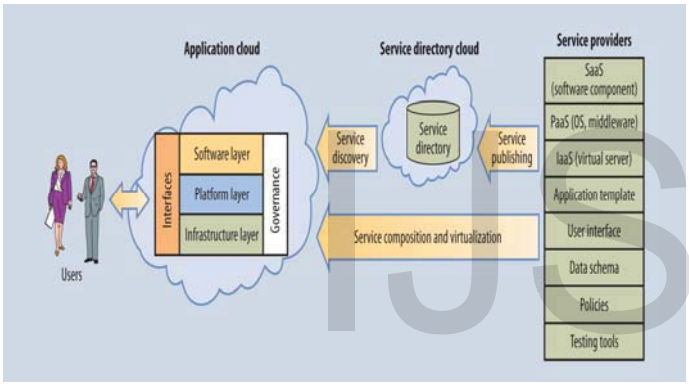

Fig. 2. Cloud Application Model

As in the traditional software development methodologies, Cloud based software development also starts with requirements engineering. During this phase, the application developer develops a business model, works with the customer to analyse, clarify, and refine requirements. Then a design of a workflow for the business model is made and decomposes the service requirements. These service requirements are then sent to the Service broker to find out the availability of the required services. The service requirements are then aligned to the available services. If any essential service is not available, request for creating that new service is conveyed. Once all required services are in place, the application developer publishes the application and tests the same in the Cloud environment [8].

V. CONCLUSION

Cloud computing is an information technology service model where computing services (both hardware and software) are delivered on-demand to customers over a network in a self-service fashion, independent of device and location. The resources required to provide the requisite quality-of-service levels are shared, dynamically scalable, rapidly provisioned, virtualised and released with minimal service provider interaction. Users pay for the service as an operating expense without incurring any significant initial capital expenditure, with the Cloud services employing a metering system that divides the computing resource in appropriate blocks [3].

Cloud computing model offers tremendous opportunities for both the providers as well as consumers. The technology is sure to change how business is done, across enterprises and across boundaries. As in any new technology, Cloud environment is also evolving and there are many holes to be caped before it matures and is accepted as the next utility service.

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