CLOUD COMPUTING IN MOBILE TECHNOLOGIES

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***Abstract*—Cloud Computing is the most promising technology in the beginning of the 21st century. It can provide critical services for managing business, reduction of IT expenditures, and the expenditures for hardware and software maintenance. Cloud Computing is of upmost importance for the IT industry of every country. It provides a way to share distributed resources and services that belong to different organization. This article gives an overview of its service categories, deployment models and its use in mobile technology.**

***Index Terms*—Cloud Computing, IaaS, PaaS, SaaS, Mobile Cloud Computing, Vurtual Structure**

I. Introduction

Cloud Computing, seen as the great network-tech break through, might bring us to the ”cloud society” after the PCs and the Internet brought people to the ”network society”. In the scheme of Cloud Computing, all the everyday usage of PCs will be transferred into the clouds (virtualized mass-computational servers which cooperate on the Internet), all we need is an access to the Internet and then we can perform any work on the cloud.

Cloud Computing is the latest evolution in the delivery of computing power. It lowers the point of entry, permitting access to computing power previously only available to the largest organizations. It also permits smaller organizations to leverage fully-managed computing infrastructures, reducing the requirements for highly skilled IT staff.

Cloud Computing refers to applications delivered as services over the Internet and also the hardware and systems software in the data centers that provide those services. In general, Cloud Computing is web-based processing, whereby shared resources, software, and information are provided on demand to computers, smartphones, and other similar devices [1].

Cloud Computing is also a new style of computing in which dynamically scalable resources are provided as virtualized services. This allows service providers and users to adjust their computing capacity depending on how much is needed at a given time, or for a given task [1]. Figure 1 presents an overview of how Cloud Computing is organized on platforms like Google [2], Salesforce [3], Amazon [4], Axios Systems [5], Microsoft [6], Yahoo [7], Zoho [8].

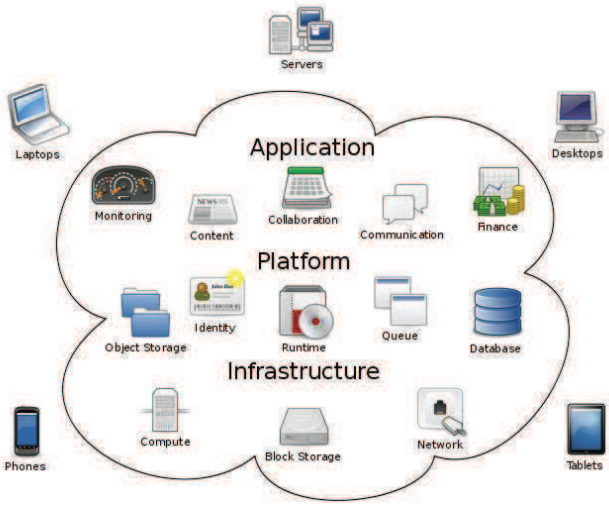

Fig. 1. Cloud Computing Overview

II. History

Computing has evolved significantly over the last 60 years. In the early days, a large central computer would be used by an entire company. This gradually evolved to departmental computers in the 1970s and later personal computers in the 1980s and 1990s.

Although Cloud Computing is a new term, as a concept it was predicted by computer scientist John McCarthy in the 1960s. McCarthy stated: ”Computation may someday be organized as a public utility.” [9]. McCarthy had the foresight to predict what we today refer to as Cloud Computing. In the mid-1960s, Intel co-founder Gordon E. Moore famously predicted that the number of transistors (or computing power) that could be inexpensively placed on an integrated circuit would double every two years. This is commonly known as Moore’s law [10].

By the late 1990s, Moore’s law had guided computing to heights beyond many organizations predictions. Much of this demand was fueled by the now popular World Wide Web (WWW), which brought an age of networking and collaboration that had not been seen before.

In mid-2000s, a lot of companies had discovered that, their largest IT purchases were often left idle and only fully utilized

during peak demand. These organizations were very large IT or academic organizations. For example, Amazon had a lot of processing power to be able for huge demand of web transactions and were thinking how to scale the solution in order to exploit the available resources.

The researchers were wondering how to leverage the latent processing power and find optimal solutions. In 2007, Google, IBM, Carnegie Mellon, MIT, Stanford University, UC Berkeley, the University of Maryland, and the University of Washington collaborated to begin research into Cloud Computing.

III. Cloud Computing Service Layers

Cloud Computing providers provide different kinds of services to Cloud Computing consumers. In order to understand the different layers of service, it is important to understand how they would relate in a non-Cloud Computing scenario as shown at Figure 2.

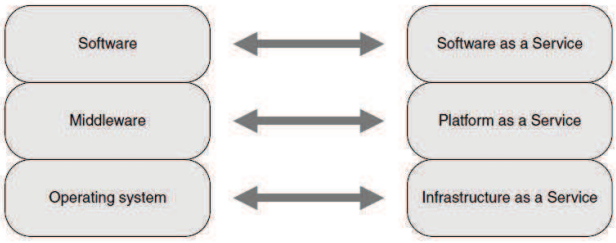

Fig. 2. Cloud Computing Services Categories

The kind of service being provided has many implications on the provider, including how they address concerns such as security, resiliency, compliance, and multitenancy. Cloud Computing services fall into one of the categories presented on Figure 2. We briefly discuss their characteristics in the following subsections.

A. Infrastructure as a Service

Infrastructure as a Service (IaaS) providers allow their customers access to different kinds of infrastructure. The provider typically provides this service by dividing a very large physical infrastructure resource into smaller virtual resources for access by the consumer. Sometimes the service provided is a complete virtual machine with an operating system. In other instances the service provided is simply for storage, or perhaps a bare virtual machine with no operating system.

IaaS providers are often service providers to other cloud providers. One of the most popular IaaS providers is Amazon [4] who provides their EC2 (Elastic Compute Cloud) IaaS. Other also successful providers are GoGrid [11], Joyent [12], AppNexus [13].

B. Platform as a Service

Platform as a Service (PaaS) providers extend the software stack provided by IaaS to include middleware. Middleware generically refers to software such as a DB2 database, or runtime environments such as a Java Runtime Environment (JRE) or a Websphere application server.

This middleware is a prerequisite to running more sophisticated applications, and provides a rich operating environment for the application to exploit. A popular example of a PaaS is Microsoft's Windows Azure platform [14].

C. Software as a Service

Application as a Service, or Software as a Service (SaaS) providers as they are more commonly known, typically provide a rich web-based interface to their customers. SaaS providers typically increase the capacity of their systems through scale up or scale out methods - depending on the characteristics of the application.

Typical SaaS applications can scale up to a lot of instances. Due to this requirement they are usually moved to larger platforms as their capacity requirements grow.

SaaS applications that scale out are typically run on large clusters of servers. As additional capacity is required, the provider adds additional machines to the cluster. Popular examples of SaaS include GoogleApps [15] and Salesforce [3].

IV. Cloud Computing Deployment Models

Cloud Computing has a number of different deployment models. A deployment model is a particular method of delivering a service. In the case of Cloud Computing, these are unique methods of deploying a Cloud Computing service. Deployment models often have particular characteristics that suit them to appropriate workloads. The most commonly used deployment models are as follows.

A. Private

In a private cloud, the Cloud Computing services are provided by an internal organization for use by other internal organizations. The provider in this case is most often the internal Information Technology (IT) or Information Systems (IS) department. Consumers vary, but typically these consumers are consumers of other IT services.

As both the consumer and provider are internal organizations, private clouds allow the consumer greater control over quality of service provided by the cloud. Private clouds generally provide the most control, as both provider and consumer are part of the same organization. This control comes at a price, as the organization ultimately bears the full cost of the cloud infrastructure.

B. Community

Community clouds have membership in one or more organizations. Community clouds are often groups of individuals and organizations collaborating for the purpose of a particular mission or concern. This might be an industry consortium, an awareness group, or another group altogether.

C. Public

Public clouds are clouds where the provider delivers a cloud service to any customer who wishes to access it. Unlike a private or community cloud, there are no provisions regarding the consumer's ownership or cause in using the cloud, it is simply provided for any customer who wishes to support the payment model.

One challenge of public clouds is the assurances regarding quality of service. In many instances, today's cloud providers offer little in compensation for missed service level agreements (SLAs). Most often, the only compensation offered is the reimbursement of fees paid by the consumer. For many organizations, the business impact of application downtime can be magnitudes above the cost of the cloud service.

D. Hybrid

Hybrid clouds are not a separate deployment model, but rather an intersection of two or more - for example, a private SaaS application that is based on a public IaaS. Hybrid clouds are usually focused on leveraging the economies of scale present in public cloud offerings, but also on driving workloads that have more stringent quality of service requirements. For this reason, in many cases hybrid clouds are internal clouds, which turn to the capacity of public clouds for peak demand.

V. Mobile Cloud Computing

The mobile devices (smartphones, computers, etc) are increasingly becoming important part of the human life as most efficient and most proper communication tools. The mobile device users accumulate wide experience of different services from mobile applications (iPhone Applications [16], Google Applications [15] etc.) which work on devices and/or on remote servers through wireless networks.

A. Opportunities and threats

Mobile Cloud Computing is the usage of Cloud Computing in combination with smart mobile devices. Cloud Computing exists when tasks and data are kept on the Internet rather than on individual devices, providing on-demand access of data. Applications are run on a remote server and then sent to user.

Due to the advanced improvement in mobile browsers thanks to Google [2] and Apple [17] over the past couple of years, nearly every mobile should have a suitable browser according to the need. This means that the developers will have a much wider market and they can bypass restrictions created by mobile operating systems.

Mobile Cloud Computing gives new companies chances for mobile network providers also. Several operators as Vodafone [18], Orange [19] and Verizon [20] have started to offer Cloud Computing services for different companies [21].

The quick progress of the mobile computing is a powerful trend in the development of the IT technology, but also for the commerce and the industry in general. The mobile industry is going through significant transition from being voice-centric to data-centric, from consumers spending 90% of their time talking to being engaged on mobile data services 80% of the time.

With the emergence of the smartphones, the mobile operators are being gradually cut out of the value added services space with most of the revenues shifting to rest of the ecosystem. Mobile Cloud Computing provides an opportunity to leverage their network infrastructure assets and their consumer relationships to open up new revenue streams.

A huge advance in breaking through was the production of tablets, mobile devices which can exploit 3G and wireless connections to Internet to access the cloud from one side and the relatively small screen with high resolution and multi-touch pad capable to do processing as a standalone personal computer. These devices are also known as cloud devices although they present typical mobile devices with increased computing capability.

The reach GUI offered with multi-touch pad, high resolution and other gadgets make these devices a good alternative for the desktop PC, since you can use it as you move. All you need is just an Internet browser to access the cloud and make these devices all you need to access the workplace or find all relevant information.

B. Benefits and Impact

Cloud Computing shifting the course of computing away from physical hardware with locally managed sotware platforms towards virtualized, cloud based services. This provides users with instant access to virtually unlimited computing resources and at the same time allows providers to deploy complex Infrastructure As A Service (IAAS).

Cloud Computing is not only related to personal computers, it also affects and heavily impact the mobile technology. MCC provides the mobile device users with data processing and storage of services in the cloud. The mobile devices do not need a powerful configuration (processor speed and memory capacity) because all complicated computer modules can be processed in the clouds [22]. The offered logo is "All you need is just a browser".

The offered technology of cloud devices (tablets) make possible to have access to all resources and communicate with others for all everyday activities.

C. Architecture

MCC as a typical example for mobile applications by which data processing and storage are moved from mobile devices to powerful and centralized computing platforms located in clouds. These centralized applications are accessed over the wireless connection based on a thin native client or a web browser on the mobile devices.

From MCC concept, the general architecture of MCC is shown on Figure 3 [23].

The mobile devices presented on Figure 3 are connected with the mobile networks through base stations (Base Transceiver Station (BTS), access point or via satellite) which establish and control communications and functional interfaces between the networks and the mobile devices. The request and

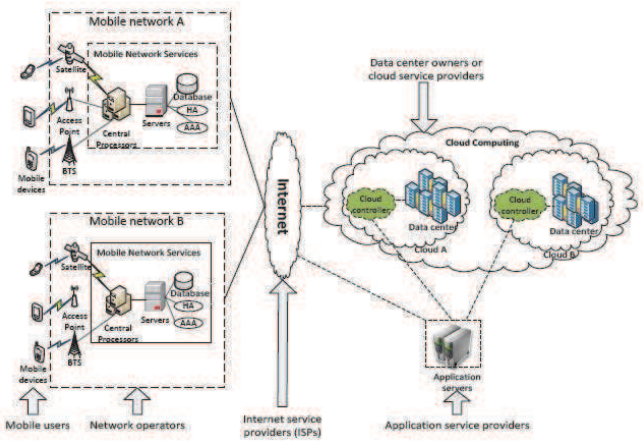

Fig. 3. Mobile Cloud Computing (MCC) architecture

information from the mobile device users (ID and location) are transmitted to the central processors which are connected to servers providing mobile network services.

Using this architecture, the mobile operators can provide services to mobile device users as AAA (for authentication, authorization, and accounting) based on Home Agent (HA) and to the subscriber's data stored in the databases. After that the requests of the subscribers via the Internet are delivered to the cloud. In the cloud, cloud controllers process the requests and provide the mobile device users the proper cloud services. These services are developed with the concepts of utility computing, virtualization, and service-oriented architecture (e.g.,web, application, and database servers).

D. Advantages of Mobile Cloud Computing

Cloud Computing is known to be a promising solution for mobile computing due to many reasons, mobility, communication, and portability. In Mobile Cloud Computing, cloud services converge with Mobile Multimedia Broadcasting (MMB).

Mobile Cloud Computing more or less requires an "everything-as-a service" concept where software, platform, and database services are really all required to be in the cloud to provide small devices with reasonable battery-life quick access to information and the ability to manipulate large quantities of data.

MMB services currently use push technology and the desired end result is always to meet the personalized demand of users a quickly as possible. However, when many users are trying to access the same information at the same time and/or a large amount of users need fast access to network storage, or processing capabilities, the ability to provide this information quickly and efficiently becomes a challenge due to the ignorant MMB [24].

The battery-life of mobile devices is a constant struggle. Mobile Cloud Computing has significantly improved the battery-life of mobile devices. However, it can be argued that the perfect balance of what is performed and stored in the cloud versus what is performed and stored on the mobile device to offer the most reasonable battery-life is still to be found.

Storage capacity is also a constraint for mobile devices. MCC is developed to enable mobile users to store/access the large data on the cloud through wireless networks. Amazon Simple Storage Service (Amazon S3) and Image Exchange are examples which utilizes the large storage space in clouds for mobile users. MCC also helps reducing the running cost for compute-intensive applications that take long time and large amount of energy when performed on the limited-resource devices[23].

Locatopn Based Computing acts as a typical SaaS in mobile computing. A user can trigger an application or event based on location information. For example, marketing related content to be delivered to those found on a particular location, or paying parking fee by mobile phone based on location. Typical frequently used application is the gps navigation based on location information.

Today's pervasive and ubiquitous applications are based on usage of wireless sensor networks and usage of location based computing. SaaS applications on mobile devices can even make decisions based on location and various sensor stimuli when found in a particular area.

E. Mobile Devices and Cloud Computing

Long time ago, many analyst groups began reporting on the significant market share being established by Cloud Computing. Cloud Computing will completely transform future of mobile applications development, and their use. Cloud Computing will dramatically reduce the requirement of advanced handsets for running mobile applications.

A mobile database system (MDS) provides full database and mobile communication functionality. It allows a mobile user to initiate transactions from anywhere and anytime and guarantees their consistency preserving execution. Multimedia libraries have enormous amount of information for communication in audio, video, text, graphics, animation form [25].

F. Deployment Models and Service Layers at MCC

This section presents MCC deployment models and service layers. As in Cloud Computing, MCC also consists of three deployment models and each of them targets corresponding user group, Public, Private, Hybrid cloud. They have the same characteristics as non-mobile Cloud Computing deployment models mentioned in Section IV.

However, there are some differences in the MCC service layers. Mobile SaaS is used much more for applications instead of browsers. This is opposite to non-mobile SaaS which is primarily web based and requires usage of internet browser.

The rise of mobile devices is changing the meaning of SaaS which used to be synonymous with do it in a browser. Using mobile SaaS is more likely to use "do it in an app".

Mobile PaaS is expected to be the next big thing. It is a platform that allows companies to mobilize everything easily,

mobilize their sales, their internal operations, their partner networking, their whole IT strategy.

Good mobile SaaS can offer, mobile application which will be easy to access, Marketplace to buy everything that is available, a mobile platform that will allow companies to build custom applications for their existing systems, virtual mobile desktop, etc. This represents the basic features of MCC service layers.

VI. Conclusion

Cloud Computing is an emerging technology supporting business and satisfies customer needs. Users run applications in shared environment. When a user uses any application on the Cloud, just logs in, customizes it, and starts using it. That's the power of Cloud Computing.

In Mobile Cloud Computing both the data storage and the data processing happen outside of the mobile device i.e. when we combined concept of Cloud Computing in mobile environment. In MCC scenario all the computing power and data storage move into the mobile cloud. MCC will not provide benefits only to the smart phone users but will help a broader range of mobile subscriber.

It is estimated that by the end of 2014 the number of mobile cloud users will be over a billion. Smartphone applications will be transferred from the device to the cloud. Cloud Computing offers endless possibilities, but also faces great challenges. Key challenge for Cloud Computing is the availability of the network because the services will be provided through Internet.

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