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Mobile Cloud Computing: The potential, Challenges & Applications

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Abstract

Mobile cloud computing is an technique or model in which mobile applications are built, powered and hosted using cloud computing technology. A mobile cloud approach enables developers to build applications designed specifically for mobile users without being bound by the mobile operating system and the computing or memory capacity of the Smartphone. Mobile cloud computing centered are generally accessed via a mobile browser from a remote web server, typically without the need for installing a client application on the recipient phone. This concept is also sometimes referred to as MoClo, a combination of Mobile Cloud. Mobile Cloud Computing (MCC) has revolutionized the way in which mobile subscribers across the globe leverage services on the go. The mobile devices have evolved from mere devices that enabled voice calls only a few years back to smart devices that enable the user to access value added services anytime, anywhere. MCC integrates cloud computing into the mobile environment and overcomes obstacles related to performance (as battery life, storage, and bandwidth), environment (e.g. heterogeneity, scalability, availability) and security (e.g. reliability and privacy).

1. Introduction

Cloud computing is defined as the trend in which resources are provided to a local client on an on-demand basis, usually by means of the internet.

At the same time, Cloud Computing has emerged as a phenomenon that represents the way by which IT services and functionality are charged for and delivered. NIST (National Institute of Standards and Technology, USA) definition [3] from September, 2011 released in its “Special Publication 800-145” of Cloud Computing is:

“Cloud Computing is a model for enabling convenient, on-demand network access to a shared pool of configurable resources (e.g. networks, servers, storage, applications and services) that can rapidly be provisioned and released with minimal management effort or service provider interaction.”

It can be thought as a combination of the cloud computing and mobile environment. The cloud can be used for power and storage, as mobile devices don’t have powerful resources compared to traditional computation devices. Today, there are already lots of good examples of MCC applications including Gmail, Google Maps, and such applications. However, the most of applications still do most of the calculation and data storage on the mobile devices themselves, not in the cloud.

The general architecture is as depicted in Fig 1 below

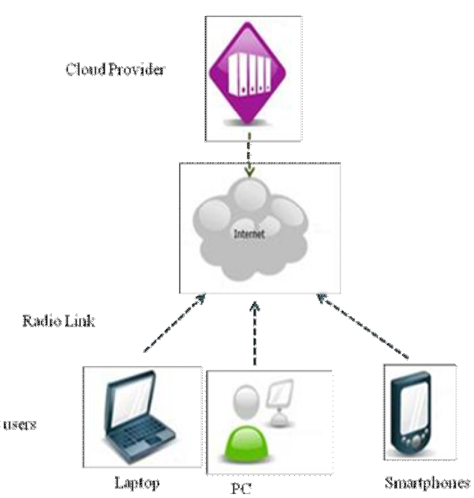

Fig: 1. Mobile Cloud Computing

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Delivering cloud services in a mobile environment brings numerous challenges and problems. Mobile devices cannot handle complicated applications due to their innate characters. Also, it is impossible that a mobile device is always online, the offline solution of the device need be considered as well. The absence of standards, security and privacy, elastic mobile applications requirement may obstruct the development of Mobile Cloud Computing. In order to understand the challenges and provide further scope for research, an understanding of this novel approach is essential. This paper introduces the basic model of MCC, its background, key technology, challenges, current research status and future research perspectives.

2. Background

From a simple viewpoint mobile cloud computing can be thought of as infrastructure where data and processing could happen outside of the mobile device, enabling new types of applications such as context-aware mobile social networks. As a result, many mobile cloud applications are not limited to powerful smartphones, but to a broad range of less advanced mobile phones and, therefore, to a broader subscriber audience. MCC can be simply divided into mobile computing and cloud computing. The mobile devices can be laptops, PDA, smartphones and so on, which connect with a base station or a hotspot by a radio link such as 3G, Wi-Fi or GPRS. Although the client is changed from PCs or fixed machines to mobile devices, the main concept is still cloud computing. Mobile users send service requests to the cloud through a web browser or desktop application. The management component of cloud then allocates resources to the request to establish connection, while the monitoring and calculating functions of mobile cloud computing are implemented to ensure the QoS until the connection is completed.

The cloud model as defined by NIST promotes availability and is composed of five essential characteristics, three service models and four deployment models.

2.1 Essential distinctiveness

On-demand self service: A consumer can unilaterally stipulation computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service provider.

Broad network access: Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms like mobile phones, laptops, PDAs etc.

Resource pooling: The provider's computing resources 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. The customer does not have control or knowledge over the exact location of the provided resources. Examples of resources include storage, processing, memory, network bandwidth and virtual machines.

Rapid elasticity: Capabilities can be rapidly and elastically provisioned, in some cases automatically, to quickly scale out and rapidly released to quickly scale in.

***Measured Service*:** Cloud systems automatically control and optimize 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).

2.2 Service Models

Software as a Service (SaaS): The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through a thin client interface such as a web bro wser (e.g., web-based email). The consumer does not manage or control the underlying cloud infrastructure with the possible exception of limited user-specific application configuration settings.

Platform as a Service (PaaS): The capability provided to the consumer is to deploy onto the cloud infrastructure consumer- created or acquired applications created using programming languages and tools supported by the provider. 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 application hosting environment configurations.

Infrastructure as a Service (IaaS): The capability provided to the consumer is 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. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems; storage, deployed applications, and possibly limited control of select networking components (e.g. host firewalls).

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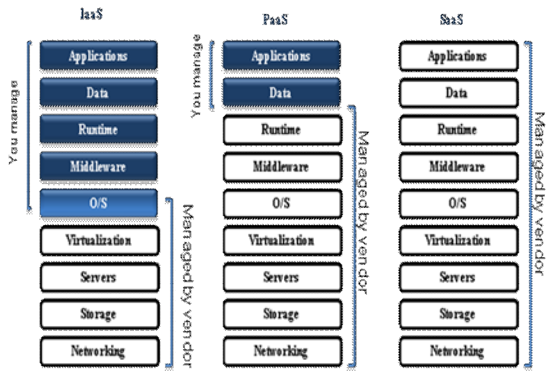

Fig: 2. shows this

2.3 Operation Models

Private Cloud: The cloud infrastructure is operated solely for an organization. It may be managed by the organization or a third party and may exist on premise or off premise.

Community Cloud: The cloud infrastructure is shared by several organizations and supports a specific community that has shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be managed by the organization s or a third party and may exist on premise or off premise.

Public Cloud: The cloud infrastructure is made available to the general public or a large industry group and is owned by an organization selling cloud services.

Hybrid Cloud: The cloud infrastructure is a composition of two or more clouds (private, community, or public) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portabilit y (e.g., cloud bursting for load-balancing between clouds).

Fig: 3. below illustrates Public, Private and Hybrid cloud deployment example.

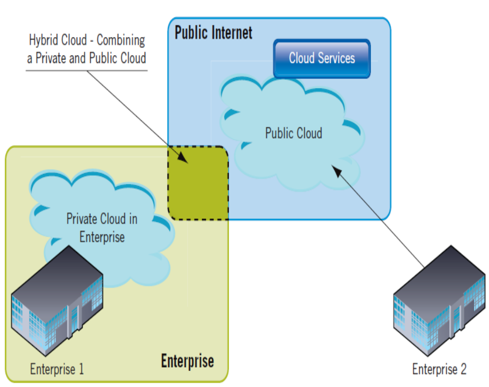

Fig: 3. Public, Private and Hybrid Cloud deployment

3. Architecture

An overview of basic Mobile Cloud Computing was presented in the previous section. A general architecture in a broader sense was as depicted in Fig 1. A more detailed representation will be presented in this section. Fig 4 presents a typical Mobile Cloud Computing architecture [8].

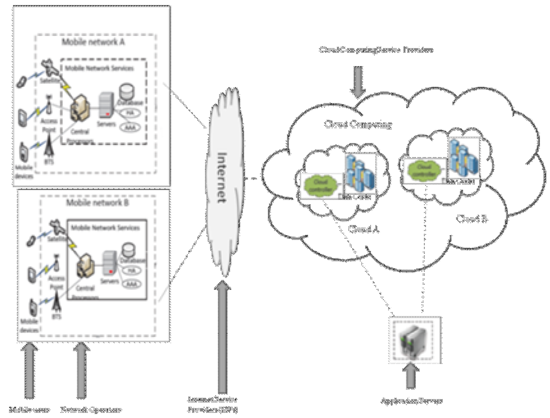

Fig: 4. Mobile Cloud Computing Architecture

The Mobile Cloud Computing architecture is basically shown in the Figure. The main architecture is composed from the components: mobile users, mobile operators, internet service providers (ISP), cloud service providers, respectively [3].

Mobile devices generally mobile phones communicate with the mobile networks with the help of base stations, access points and/or satellite. The information sent from the mobile devices are operated on the central processors, servers and database on the mobile network provider side. The main communication is composed from both stakeholders. Generally, the mobile network provider is like a middleware with SOAP or RESTful WS services and delivers the service result taken from the cloud providers to the mobile client. There are also different applications of MCC by using the cloud services without using network provider, directly through the internet [3]. The mobile network operator delivers the mobile clients' requests to the cloud through the internet. In the cloud, cloud controllers process the requests to navigate to corresponding cloud services to provide mobile users. The architecture provides effectiveness by using the advantages of the cloud computing. We focus on a layered architecture which commonly demonstrates the effectiveness of Cloud Computing model in terms of user's requirements. The service model has been explained earlier in this section. Fig 5 below gives an overview of the layered architecture or cloud stack and who uses these.

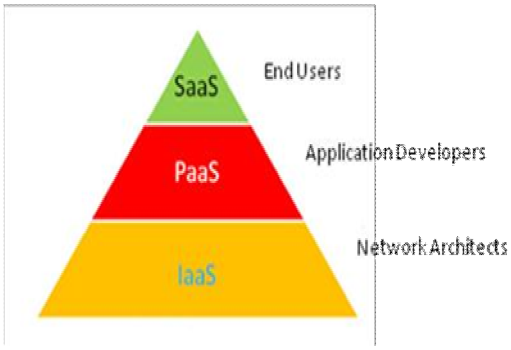

Fig: 5. Cloud stack

4. Challenges In Mobile Cloud Computing

As mentioned in the previous section, Mobile Cloud Computing has many benefits and good application examples for mobile users and service providers. On the other hand, as mentioned in some parts, there are also some challenges related to cloud computing and mobile networks communication. This section gives some explanation about these obstacles and solutions.

Mobile Side Challenges

In the mobile network side, main obstacles and solutions are listed below:

Low Bandwidth: Bandwidth is the one of important issues in mobile cloud environment because mobile network resource is much smaller compared with the traditional networks. Therefore, P2P Media Streaming for sharing limited bandwidth among the users who are located nearby in the same area for the same content such as the same video. By this method, each user transmits or exchanges parts of the same content with the other users, which is resulted in improvement of content quality, especially for videos.

Availability: Network failures, out of signal errors, or high traffic related poor performance problems are main threats to prevent users to connect to the cloud. But there are some solutions to help mobile users in the case of any disconnection from the clouds. One of them is Wi-Fi Based Multihop MANET. It is a distributed content sharing protocol for the situation without any infrastructure. In this mechanism, nearby nodes are detected in case of the failure of direct connection to the cloud. In this case, instead of having a link directly to the cloud, mobile user can connect to the cloud through neighboring nodes. Although there are some considers about security issues for such mechanisms, these issues can also be solved.

Heterogeneity: There are types of networks which are used simultaneously in mobile environment such as WCDMA, GPRS, WiMAX, CDMA2000, and WLAN. As a result, handling like heterogeneous network connectivity becomes very hard while satisfying mobile cloud computing requirements such as connectivity which is always on, on-demand scalable connectivity, and the energy efficiency of mobile devices. This problem can be solved 10 by using standardized interfaces and messaging protocols to reach, manage and distribute contents.

Pricing: Using multiple services in mobile requires with both mobile network provider and cloud service provider. However, these providers have different methods of payment and prices for services, features and facilities. Therefore, this has possibility of leading to many problems like how to determine price, how the price could be shared among the providers or parties, and how the subscribers can pay. As an example, when a mobile user wants to run a not free mobile application on the cloud, this participates three stakeholders as one of them is application provider for application licence, second one is mobile network provider for used data communication from user to cloud, and third one is cloud provider for providing and running application on the cloud.

Computing Side Challenges

In the cloud side, main obstacles and solutions are listed below:

Computing Offloading: As mentioned previous parts, offloading is one of the key features of MCC to improve the battery life time and to increase the applications' performance by using the cloud . Although this solution is very useful in the means of process power and storage, it can be ineffective in some situations. For example, the mobile devices can consume more energy for an application by using the cloud rather than local processing. For a critical threshold, using the mobile device instead of cloud might be more effective. Therefore, a problem arises that the optimum way of trade-off between the communication and calculation costs have to be estimated or calculated for mobile applications. The communication cost mainly depends on the size of transmitted data and the bandwidth of network, while the computation cost can be defined by the means of computation time. The optimal decisions of a program partitioning can be made at a runtime dynamically, by using and operating cost algorithms.

As an example, an approach for deciding which components of Java programs should be offloaded can be given. In this approach, a Java program is divided into methods and uses several parameters like size of methods or line of codes to calculate execution 11 costs for these methods. Then, this approach compares the local execution costs of each method with the remote (cloud) execution costs to make an optimal execution decision.

Security: Trust is the main issue of the subscribers in the mobile platform. When it comes to MCC, this issiue gains more importance as the stakeholders increase in the cloud environment for protecting user privacy and data/application secrecy. One of the security issue is mobile device users, other one is the data privacy and security. As mobile users, there are several security threats like malicious codes like virus, worm, and Trojan horses and privacy concerns when thinking of integrated global positioning system (GPS) devices that can lead subscribers to be tracked. To overcome this issue, there is security programmes can be runned on mobile devices to prevent illegal threats, but these programs use big portion of mobile device resources while running. Therefore there is some approaches moves threat detection capabilities from mobile devices to cloud. For example, Cloud AV platform provides a multiple service based on both cloud and mobile device for malware detection . A simple and lightweight part of the application runs on the mobile device and it communicates with the major component of the application in the cloud. Detection capabilities are moved to the cloud, as the mobile agent application sends file parts in the background to the cloud server application

Authentication: Although both application developers and mobile users benefit from storing and processing a large amount of data/applications on a cloud, they should be careful of dealing with the data or applications in terms of rights and authentication. Users have tendency of using small passwords while accessing external resources, so there is need for more secure authentication mechanisms. As an example of authentication method, TrustCube can be given. It is a policy based cloud authentication mechanism using open standards and it integrates various types of authentication.

Data Access: While cloud services are increasing, the number of data resources on the cloud rapidly increases. Therefore, dealing with these data resources in the means of storing, managing or accessing becomes very challenging. Cloud storage providers like Amazon S3, every input-output operations executes jobs generally, in file level which increases the cost of data communication and processing for mobile clients. There are some solutions that providing an efficient and less costly way of block level based I/O algorithms instead of file level. In this solution, not all the file transmitted, instead data blocks are transmitted, in case of necessity, which is very useful by the means of time and network communication cost. 13 In addition, to increase data access efficiency, mobile devices can use local storage as cache for specific parts of cloud service to increase access speed and reduce network necessity. Here, there is also a problem, as we cannot store large data on the mobile device storage cache, so some data management or data selections mechanisms have to be applied to determine which parts or amount of data can be cached or used from cloud. There are several other issues related to implementation of MCC. A few of them have been listed below:

4.1 Absence of standards

Inspite of the various advantages of Cloud computing over the conventional computing techniques, there is no accepted open standard available. Portability and interoperability is also impossible between different cloud computing Service Providers (CCSP). This prevents the service providers to widely deploy and quickly develop Cloud computing. Customers are reluctant to transform their current datacenters and IT resources to cloud platforms owing to a number of unsolved technical problems that exist in these platforms. Some of the problems existing due to a lack of open standards are the following:

- **Limited scalability:** Owing to the rapid growth, none of the CCSPs can meet all the requirements of all the users.
- **Unreliable availability of a service:** Dependence on a single CCSP's service can result in a bottleneck in the event of a breakdown of a service.
- **Service provider lock-in:** Absence of portability makes it impossible for data and application transfer among CCSPs, consequently customer is locked to a CCSP.
- **Unable to deploy service over multiple CCSPs:** Absence of interoperability makes it impossible for application to be scaled over multiple CCSPs.

In view of the afore mentioned disadvantages, B.Rochwerger et al. have introduced a solution called Open Cloud Computing Federation (OCCF) in [21], that solves the problems of interoperability and portability among various CCSPs. However, the move to a common cloud standard is impossible because most of the cloud computing firms have their own APIs and for setting those up lots of funds were spent. The OCCF thus lacks a practical realization mechanism. A possible approach is to have a Mobile Agent Based Open Cloud Computing Federation (MABOCCF) mechanism as introduced by Chetan S. et al. in [22].

4.2 Access Schemes

MCC will be deployed in a heterogeneous access scenario in terms of Wireless Network Interfaces. Mobile nodes access the Cloud through different radio access technologies viz. GPRS, WLAN, LTE, WiMAX, CDMA2000, WCDMA etc. Mobile Cloud Computing requires the following features:

- MCC requires an “always-on” connectivity for a low data rate cloud control signaling channel
- MCC requires an “on-demand” available wireless connectivity with a scalable link bandwidth
- MCC requires a network selection and use that takes energy-efficiency and costs into account

Access management is a critical aspect of MCC. A possible solution is to use context and location information to optimize mobile access, as proposed by A.Klein et al. in [23]. Deploying MCC utilizing the context information, such as device locations and capabilities and user profiles, can be used by the mobile cloud server to locally optimize the access management.

4.3 Security

Mobile devices today have all the functionalities of a standard computer. This, like for the standards computers, poses a security threat to the mobile devices as well. The threat detection services run on the mobile devices to combat these security threats, warrant intensive usage of resources, both in terms of computation and power. A possible solution is to move these detection services to the cloud. It saves the device CPU and memory requirements with increased bandwidth as the price to be paid. This approach has the following benefits:

- Better detection of malicious software
- Reduced on-device resource consumption
- Reduced on-device software complexity

4.4 Elastic Application Models

Cloud computing services are scalable, via dynamic provisioning of resources on a fine grained, self-service basis near real-time, without users having to engineer for peak loads. This requirement particularly manifests in Mobile Cloud Computing due to the intrinsic limitations of mobile devices. For example, the iPhone 4s is equipped with 800 MHz CPU, 512 MB RAM allowing about 8 hrs of talktime and 14.4 Mbps speed on HSDPA 4G network, [24]. Compared to today’s PC and server platforms, these devices still cannot run compute-intensive applications. Thus, an elastic application model is required to solve the fundamental processing problem.

5. Applications Of Mobile Cloud Computing

Mobile applications have been used widely and have a huge share in a global mobile market, because of the millions of subscribers, hundreds of networks providers and cloud providers. There are several mobile applications that started to use CC advantages; in this part some typical examples are briefly explained.

- Mobile Commerce

Mobile commerce is the ability to provide commerce using a mobile device, such as a mobile phone, a Personal Digital Assistant (PDA), a Smartphone, or other emerging mobile equipment such as dashed mobile devices [5]. The m-commerce applications fulfill many tasks that require mobility functions like mobile transactions and payments, mobile messaging, and mobile ticketing. Some services and products are mobile ticketing, Mobile vouchers, coupons and loyalty cards, Location-based services, Mobile banking, Mobile brokerage, Mobile marketing and advertising [5].

As the m-commerce have several products and applications, there are various challenges like low network bandwidth, high complexity of mobile device configurations, and security/privacy. As a result, m-commerce applications are navigated into cloud computing environment to solve these problems. Some security solutions are based on PKI (public key infrastructure). This mechanism uses an encryption-based access to ensure subscribers’ private and secure access to the cloud stored data.

Mobile Healthcare Medical applications in the mobile environment called as mobile healthcare applications and used for medical treatment, patient tracking, etc. The purpose of applying MCC in medical applications is to decrease disadvantages of traditional medical applications like small physical storage, security and privacy, and medical errors.

Mobile healthcare provides these facilities:

- Health monitoring services for patients to be monitored at anytime and anywhere through internet or network provider.
- Emergency management system for emergency vehicles to reach or manage vehicles effectively and in time, in case of receiving calls from incidents and accidents.

- Healthcare mobile devices for detecting pulse-rate, blood pressure, and level of alcohol integrated with a system to alert in case of emergency.
- Store healthcare information of patients to use in medical experiments or researches.

Mobile healthcare applications provide users easiness and quickness by accessing resources at any time, from anywhere. By the help of cloud, mobile healthcare applications offer a variety of on-demand services on clouds rather than standalone applications on local computers and servers. However, there have to be proposed solutions to protect participant's health information to increase the privacy of the users, as have to be done in the traditional applications.

- Mobile Learning

Mobile learning is learning across contexts and learning with mobile devices. Its design is based on electronic learning (e-learning) and mobility. Traditional m-learning applications have limitations because of high cost of devices and network, low network transmission rate, and limited educational resources. Cloud-based (mobile learning) m-learning applications are introduced to solve these problems. As an example, with the help of powerful processing ability and cloud's large storage capacity, the applications provide learners with much richer services in terms of data (information) size, faster processing speed, and longer battery life.

- Mobile Gaming

Mobile games tend to be small in scope and often rely on a simple play rather than graphics, because of the lack of processing power of the mobile devices. Mobile game is a potential market generating revenues for service providers, because games can completely offload which means that huge computing resources like graphic rendering can be operated on the cloud, the clients can only deals with the interface of the game on their mobile devices. This paradigm brings many advantages like energy saving, increasing game playing speed because of cloud's processing power.

While the performance for the games increase in case of steady communication infrastructure, on the other hand, the costs of network communication is a parameter to prevent gamers

6. Conclusion

Mobile Cloud Computing, as a development and extension of Cloud Computing and Mobile Computing, is the most emerging and well accepted technology with fast growth. The combination of cloud computing, wireless communication infrastructure, portable computing devices, location-based services, mobile Web etc has laid the foundation for the novel computing model. In this paper we have given an overview of Mobile Cloud Computing that includes architecture, benefits, key challenges, present research and open issues.

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