

# Mobile Cloud Computing

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**Abstract**— MCC stands for Mobile Cloud Computing which is defined as a combination of mobile computing, cloud computing, and wireless network that come up together purpose such as rich computational resources to mobile users, network operators, as well as to cloud computing providers. Mobile Cloud Computing is meant to make it possible for rich mobile applications to be executed on a different number of mobile devices. In this technology, data processing, and data storage happen outside of mobile devices. Mobile Cloud Computing applications leverage this IT architecture to generate the following advantages: 1) Extended battery life. 2) Improvement in data storage capacity and processing power. 3) Improved synchronization of data due to “store in one place, accessible from anywhere” platform theme. 4) Improved reliability and scalability. 5) Ease of integration. There are two types of applications of mobile cloud computing (MCC) that are almost similar. These are as follows: 1) Mobile Cloud application: It is defined as a model where processing is done in the cloud, and the storage is also in the cloud, and the presentation platform is the mobile device. For this, the internet connection should have to be reliable and cell-phone to run a browser. 2) Mobile Web Services: In Mobile Web Services mobile devices consume more network traffic. It may lead to some challenges for web services such as mismatch of resolution and details of desktop computers. The device needs to know about that service and the way it can be accessed to use any web-service so that the mobile device can transmit specific information about the condition of the device and the user.

**Keywords:** Mobile Cloud Application, Mobile Web Services

## I. 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.

One of the main benefits of cloud computing is reducing downtime and wasted expenditure for servers and other computer equipment. A given company is required to purchase the minimum amount of hardware necessary to handle the maximum points of stress on their system. Given situations where the strain and traffic are highly variable this leads to wasted money. For example, Amazon.com, a pioneer in cloud computing, at times used as little as 10% of their capacity so that they would have enough capacity to deal with those rarer high strain times.

In the case of mobile cloud computing an additional significant benefit is brought to the table. Many mobile devices have significant constraints imposed upon them because of the importance and desirability of smaller sizes, lower weights, longer battery life and other features. This often severely constrains hardware and software development for these devices. Cloud computing allows devices to avoid these constraints by letting the more resource intensive tasks be performed on systems without these constraints and having the results sent to the device. Thus, cloud computing

for mobile devices is a very appealing and potentially lucrative trend.

Several methods exist by which this trend can realize itself. First, methods have been proposed which aim to construct general systems for utilizing the cloud to help boost phone performance. This family of solutions can be referred to as general-purpose mobile cloud computing (GPMCC). Second, many individual applications used today with mobile devices such as smartphones employ cloud computing to a greater or lesser extent. There are multiple methods used and proposed by which the cloud can be leveraged. This can be referred to as application-specific cloud computing (ASMCC). Each of these two approaches has advantages and disadvantages and they are not mutually exclusive.

Cloud computing provides on-demand, scalable, device-independent and reliable services to its users. The aim of mobile cloud computing (MCC) is to use cloud computing techniques for storage and processing of data on mobile devices, and hence to reduce their limitations. The term MCC was introduced just after the concept of cloud computing that was launched in mid-2007. Since then, it has been drawing attention of organizations to reduce the development cost of mobile applications. It provides the mobile users and researchers a variety of mobile services at low cost. Here, we discuss the technologies that have led to the development of MCC.

Mobile devices (e.g., smartphone and tablet PC) are increasingly becoming an essential part of human life as the most effective and convenient communication tools not bounded by time and place. Mobile users accumulate rich experience of various services from mobile applications (e.g., iPhone apps and Google apps), which run on the devices and/or on remote servers via wireless networks. The rapid progress of mobile computing (MC) becomes a powerful trend in the development of IT technology as well as commerce and industry fields. However the mobile devices are facing many challenges in their resources (e.g., battery life, storage, and bandwidth) and communications (e.g., mobility and security). The limited resources significantly impede the improvement of service qualities. Cloud computing (CC) has been widely recognized as the next generation computing infrastructure. CC offers some advantages by allowing users to use infrastructure (e.g., servers, networks, and storages), platforms (e.g., middleware services and operating systems) provided by cloud providers (e.g., Google, Amazon). Cloud computing is known to be a promising solution for MC because of many reasons (e.g., mobility, communication and portability). In the following we describe how the cloud can be used to overcome obstacles in MC, there by pointing out advantages of MCC. (Salesforce) at low cost. In addition, CC enables users to elastically utilize resource in an on-demand fashion.

### A. What is Mobile Cloud Computing?

Mobile cloud computing (MCC) at its simplest, refers to an infrastructure where both the data storage and data processing happen outside of the mobile device. Mobile cloud applications move the computing power and data storage away from the mobile devices and into powerful and centralized computing platforms located in clouds, which are then accessed over the wireless connection based on a thin native client. Mobile cloud computing uses cloud computing to deliver applications to mobile devices. These mobile apps can be deployed remotely using speed and flexibility and development tools. Mobile cloud applications can be built or revised quickly using cloud services. They can be delivered to many different devices with different operating systems, computing tasks, and data storage. Thus, users can access applications that could not otherwise be supported. Mobile Cloud Computing or MCC is a combination of cloud computing, mobile computing, and wireless network, in order to bring rich computational resources to mobile users, network operators, as well as cloud computing providers. The underlying idea here is to make it possible for the rich mobile applications to be executed on a huge number of mobile devices.

### B. Why Mobile Cloud Computing?

Mobile devices face many resource challenges (battery life, storage, bandwidth). Cloud computing offers advantages to users by allowing them to use infrastructure, platforms and software by cloud providers at low cost and elastically in an on-demand fashion. Mobile cloud computing provides mobile users with data storage and processing services in clouds, obviating the need to have a powerful device configuration (e.g. CPU speed, memory capacity), as all resource-intensive computing can be performed in the cloud.

### C. Why do we need Mobile Cloud Computing?

Cloud Computing has been implemented and accessed by almost 89 percent of the population in the world today. The cloud has been adopted in each and every industry and the benefits have been acquired by enterprises and individuals. Many organizations have opted for cloud services to store their critical data because they now know how secure cloud can be.

Earlier, there were many questions raised against the technology and its application in businesses as everybody was skeptical regarding the security of data in the cloud. Throughout the years, cloud technology has proved everybody wrong and established how easily cloud can benefit storage and access to data from anywhere and from any device.

A specific space on the server allows you to store data and retrieve it whenever it is needed. This technology has saved a lot of costs, improved business efficiencies and provided a huge competitive advantage over organizations that do not use cloud services. Data on the cloud can be accessed remotely through any device which is connected to the internet which is one of the major benefits of this technology.

A relatively new term which is Mobile Cloud Computing is on the rise and the implementation and

popularity around it are rising. The very existence of mobile phones will drive the trend of mobile cloud computing.

## II. CHALLENGES AND ISSUES

### A. What are Challenges of Mobile Cloud Computing?

#### 1) Less Network Bandwidth

Carrying out deployment using MCCs requires the communication to be continuous. This means that a developer may face problems if the network being used is wireless. This is because wireless networks tend to be less reliable or possess low bandwidth. For example, 3G, Wi-Fi, or 4G networks. Therefore, the speed of the applications is much slower in comparison to wired networks. While 5G networks remain a ray of hope, it is much too early to decide its effectiveness.

#### 2) Service availability

Mobile users may attain a very low-frequency signal, hindering the speed, as well as the storage capacity of the application. Moreover, users also experience issues like breakdown, transportation crowding, and lack of coverage.

#### 3) Hardware Issues

Mobile phones, even with the latest technology, have a finite source of energy, i.e., batteries. Cloud-based apps increase the use of the battery and would, therefore, drain it much more quickly. This can hinder MCC development as the user base can potentially decline along with an increase of complaints regarding the impact on the battery life.

#### 4) Operating System Issue

The applications created using MCC will function on different operating systems. Therefore, the application must be compatible with operating system platforms like Android, iOS, and Windows Phone. To do so, the development team must possess knowledge regarding an IRNA or Intelligent Radio Network Access technique.

#### 5) Security Issues

The management and identification of threats have proved to be a challenging task. This is because MCCs function on a wireless network. Therefore, there are more chances of overlooking or the general absence of network information. Moreover, with multiple hand-offs within the architecture and a general lack of multilayer security, vulnerabilities are high.

The security related issues stem from vulnerabilities in the MCC architecture. With multiple users accessing the clouds there is a threat to the safety of data. Say if the security of one of the user data is breached then there are risks at other users as well.

- 1) Alteration of Networks: Mobile cloud computing is used in a different operating system driven platforms like Apple iOS, Android, and Windows Phone. So it has to be compatible with different platforms. The performance of different mobile platform network is managed by the IRNA (Intelligent Radio Network Access) technique.
- 2) Limited Energy source: Mobile devices consume more energy and are less powerful. Mobile cloud computing increases battery usage of mobile devices which becomes an important issue. Devices should have a long-life battery to access applications and other operations.

## B. What are benefits of Mobile Cloud Computing?

### 1) Flexibility:

Users can access data from any device and from anywhere in the world. All they need is access to the web.

### 2) Real-time Data Availability:

Data is updated almost instantly. Team members and team leaders have access to the most up-to date and accurate information possible.

### 3) Cost Efficiency

MCC does not require a great upfront investment. IT upfront investment costs are nil. Hardware costs are reduced. Low-tier mobile devices will have the same access and availability as devices with higher specs. This means organizations do not have to worry about increased user costs.

Typically, with cloud providers, service is pay-as-you-go. Businesses only pay for what they use. This model is also energy-efficient, further reducing costs.

### 4) Integrated Data

All of the data is stored and maintained on the same cloud architecture. This allows for quick integration of data points. The integrated data provides insight with accurate and real-time analytics. APIs allow for combined services that are not otherwise available. These allow a large number of applications to communicate with one another. These integrations can maximise productivity.

Mobile devices have lower performance compared to desktops. This is because mobile devices run on a limited power supply. This can severely limit the application performance of complex processes. The mobile app can offload the computations to the cloud platform for processing. Offloading enables the most humble devices to use any application available.

## 5) What are issues of Mobile Cloud Computing?

### a) Mobile communication issues:

- Low bandwidth: One of the biggest issues, because the radio resource for wireless networks is much more scarce than wired networks
- Service availability: Mobile users may not be able to connect to the cloud to obtain a service due to traffic congestion, network failures, mobile signal strength problems
- Heterogeneity: Handling wireless connectivity with highly heterogeneous networks to satisfy MCC requirements (always-on connectivity, on-demand scalability, energy efficiency) is a difficult problem.

### b) Computing issues:

#### Computation offloading:

- One of the main features of MCC
- Offloading is not always effective in saving energy
- It is critical to determine whether to offload and which portions of the service codes to offload
- Two types:
  - Offloading in a static environment
  - Offloading in a dynamic environment

### c) Security issues:

Protecting user privacy and data/application secrecy from adversaries is key to establish and maintain consumers' trust in the mobile platform, especially in MCC.

MCC security issues have two main categories:

- Security for mobile users
- o Securing data on clouds

## 6) Security for Mobile users:

- Mobile devices are exposed to numerous security threats like malicious codes and their vulnerability.
- GPS can cause privacy issues for subscribers.
- Security for mobile applications:
- Installing and running security software are the simplest ways to detect security threats. o Mobile devices are resource constrained, protecting them from the threats is more difficult than that for resourceful devices.

## C. Mobile Cloud Computing

### 1) Open issues in Mobile Cloud Computing:

#### a) Network Access Management:

- An efficient network access management not only improves link performance but also optimizes bandwidth usage.
- Cognitive radio can be expected as a solution to achieve the wireless access management.
- Can automatically changes its transmission or reception parameters, in a way where the wireless communications can have spectrum agility in terms of selecting available wireless channels opportunistically.
- Integrated with MCC for better spectrum utilization.

#### b) Quality of Service:

- How to ensure QoS is still a big issue, especially on network delay.
- Clone Cloud and Cloudlets are expected to reduce the network delay.
- Clone Cloud uses nearby computers or data centers to increase the speed of smart phone applications.
- The idea is to clone the entire set of data and applications from the smartphone onto the cloud and to selectively execute some operations on the clones, reintegrating the results back into the smartphone.
- A cloudlet is a trusted, resource-rich computer or cluster of computers which is well-connected to the Internet and available for use by nearby mobile devices with on one-hop wireless connection.
- Mobile users may meet the demand for real-time interactive response by low-latency, one-hop, high-bandwidth wireless access to the cloudlet.
- Can help mobile users overcome the limits of cloud computing as WAN latency and low bandwidth.

#### c) Pricing:

- MCC involves with both mobile service provider (MSP) and cloud service provider (CSP) with different services management, customers management, methods of payment and prices.
- This will lead to many issues.
- The business model including pricing and revenue sharing has to be carefully developed for MCC.

#### d) Standard Interface:

- Interoperability becomes an important issue when mobile users need to interact with the cloud.
- Web interfaces may not be the best option.
- It is not specifically designed for mobile devices.
- May have more overhead.

- Compatibility among devices for web interface could be an issue.

#### D. Mobile Cloud Computing

##### 1) Service Convergence:

- Services will be differentiated according to the types, cost, availability and quality.
- A single cloud may not be enough to meet mobile user's demands.
- New scheme is needed in which the mobile users can utilize multiple cloud in a unified fashion. o The scheme should be able to automatically discover and compose services for user.
- Sky computing is a model where resources from multiple clouds providers are leveraged to create a large scale distributed infrastructure.
- The mobile sky computing will enable providers to support a cross-cloud communication and enable users to implement mobile services and applications.
- Service integration (i.e., convergence) would need to be explored.

##### 2) Privacy issues in Mobile Cloud Computing:

- Location based services (LBS) faces a privacy issue on mobile users provide private information such as their current location.
- This problem becomes even worse if an adversary knows user's important information.

### III. ADVANTAGES AND LIMITATIONS

#### A. What are advantages of Mobile Cloud Computing?

##### 1) Extending battery lifetime:

- Computation offloading migrates large computations and complex processing from resource limited devices (i.e., mobile devices) to resourceful machines (i.e., servers in clouds).
- Remote application execution can save energy significantly. Many mobile applications take advantages from task migration and remote processing.

##### 2) Improving data storage capacity and processing power

- MCC enables mobile users to store/access large data on the cloud.
- MCC helps reduce the running cost for computation intensive applications.
- Mobile applications are not constrained by storage capacity on the devices because their data now is stored on the cloud.

##### 3) Improving reliability and availability:

- Keeping data and application in the clouds reduces the chance of lost on the mobile devices.
- MCC can be designed as a comprehensive data security model for both service providers and users:
  - Protect copyrighted digital contents in clouds.
  - Provide security services such as virus scanning, malicious code detection, authentication for mobile users.
- With data and services in the clouds, then are always(almost) available even when the users are moving.

##### 4) Dynamic provisioning:

- Dynamic on-demand provisioning of resources on a fine-grained, self-service basis
- No need for advanced reservation

##### 5) Scalability:

- Mobile applications can be performed and scaled to meet the unpredictable user demands
- Service providers can easily add and expand a service

##### 6) Flexibility

- Mobile cloud computing allows accessing data from anywhere in the world. As long as you are connected to the internet, you can access the application and mobile data from any mobile device.

#### B. Multiple Platform Support

- Mobile cloud computing offers multiple platform support. You can easily access and applications stored in the cloud, regardless of the platform.

##### 1) Cost-Efficient

Cloud computing is one of the most cost-efficient methods to be used and maintained. Mobile cloud computing has a minimal upfront cost depending on the usage. Also, there are no hefty fees charged for licensing and upgrades.

##### 2) Real-Time Data Availability

You can go real-time with the mobile cloud computing. Since all your data is managed externally, you can access and update your data in real-time on your mobile device. Documents can also be simultaneously managed by multiple persons.

##### 3) Backup and Recovery

Data backup and restoring is much easier when all your data is stored in the cloud. Cloud disaster recovery is a strategy that involves storing and maintaining copies of digital records in a cloud computing environment as a security measure.

#### C. What are Disadvantages of Mobile Cloud Computing?

##### 1) Data Security

Data security is one of the major concerns of cloud computing. Most of the time mobile users provide sensitive information through the network, and if it is not protected can cause major damages. You need to choose the most reliable service provider, who can keep your data totally safe and secure.

##### 2) Connectivity and Performance Issues

As mobile cloud computing depends on internet, this can affect your access and use. Sometimes you may feel that performance is not up to the mark. Hence, it is better to check the track record of your service provider before undertaking the service. In spite of keeping up high standards of maintenance, cloud service providers may face some serious dysfunction.

##### 3) Dependency and Vendor Lock-In

Sometimes it becomes difficult to migrate from a service provider and this is what it is called as 'Vendor lockin'. It is very important to check the terms & conditions and other options before picking a vendor as later it can become difficult to switch to some other provider.

With the emergence of cloud resources all the data processing and storage, the mobile users do not need high data processing and storage capabilities on their mobile devices. For top mobile app developers, developing apps for

mobile cloud is different than developing apps for native platforms like iPhone or android. Moreover, mobile app solution providers have started offering mobile browsers that allow users to access apps from the website eliminating the need to go to the App Store to download the app.

Here are some things you should consider before choosing the cloud computing service provider

Make sure you choose a cloud service provider that has an experience in the industry and familiar with most of the software that your company or you personally are using

Go for the cloud service provider who can handle robust bandwidth and data exchange in real-time

Before selecting a cloud service provider, look at the security and data policies, and terms of service

Select the cloud service provider who provides easy integration of current network resources into servers and cloud apps

Cloud service should be easy to manage, control and maintain with efficiency

Check the pricing plans before selecting the cloud service provider

The cloud service provider should offer reliable and flexible recovery option

You should also look for device diversity and location independence in cloud service

Despite its disadvantages, cloud computing still has some great potential for future. Mobile applications are becoming increasingly smart, people are using mobile to access documents, delivering presentations. Moreover, with the adoption of HTML5 standards by top app developers, it has now become easy to design apps that rely on the mobile cloud. With technology advancement, we can only hope that advantages may take over disadvantages and make our work much easier.

#### IV. APPLICATIONS OF MOBILE CLOUD COMPUTING

##### A. What are applications of Mobile Cloud Computing?

###### 1) Mobile Commerce:

- M-commerce allows business models for commerce using mobile devices.
- Examples: Mobile financial, mobile advertising, mobile shopping ...
- M-commerce applications face various challenges (low bandwidth, high complexity of devices, security ...)
- Integrated with cloud can help address these issues
- Example: Combining 3G and cloud to increase data processing speed and security level.

###### 2) Mobile Learning:

- M-learning combines e-learning and mobility
- Traditional m-learning has limitations on high cost of devices/network, low transmission rate, limited educational resources
- Cloud-based m-learning can solve these limitations
- Enhanced communication quality between students and teachers
- Help learners access remote learning resources
- A natural environment for collaborative learning

###### 3) Mobile Healthcare:

- M-healthcare is to minimize the limitations of traditional medical treatment (eg. Small storage, security/privacy, medical errors ...)
- M-healthcare provides mobile users with convenient access to resources (eg. medical records)
- M-healthcare offers hospitals and healthcare organizations a variety of on-demand services on clouds
- Examples:
  - Comprehensive health monitoring services
  - Intelligent emergency management system
  - Health-aware mobile devices (detect pulse-rate, blood pressure, level of alcohol etc)
  - Pervasive access to healthcare information
  - Pervasive lifestyle incentive management (to manage healthcare expenses)

###### 4) Mobile Gaming:

- M-game is a high potential market generating revenues for service providers.
- Can completely offload game engine requiring large computing resource (e.g., graphic rendering) to the server in the cloud.
- Offloading can also save energy and increase game playing time (eg. MAUI allows fine-grained energy-aware offloading of mobile codes to a cloud)
- Rendering adaptation technique can dynamically adjust the game rendering parameters based on communication constraints and gamers' demands

###### 5) Assistive technologies:

Pedestrian crossing guide for blind and visually-impaired  
Mobile currency reader for blind and visually impaired  
Lecture transcription for hearing impaired students

###### 6) What are Characteristics of Mobile Cloud Computing?

- 1) Portability - The Ability to move a device within a learning environment or to different environments with ease.
- 2) Social Interactivity - The ability to share data and collaboration between users.
- 3) Context Sensitivity - The ability to gather and respond to real or simulated data unique to a current location, environment, or time.
- 4) Connectivity - The ability to be digitally connected for the purpose of communication of data in any environment.
- 5) Individual - The ability to use the technology to provide scaffolding on difficult activities and lesson customization for individual learners.
- 6) Small Size - Mobile devices are also known as handhelds, palmtops and smart phones due to their roughly phone-like dimensions. A typical mobile device will fit in the average adult's hand or pocket. Some mobile devices may fold or slide from a compact, portable mode to a slightly larger size, revealing built-in keyboards or larger screens. Mobile devices make use of touch screens and small keypads to receive input, maintaining their small size and independence from external interface devices. The standard form of a mobile device allows the user to operate it with one hand, holding the device in the palm or fingers while executing its functions with the thumb.

Netbooks and small tablet computers are sometimes mistaken for true mobile devices, based on their similarity in form and function, but if the device's size prohibits one-handed operation or hinders portability, then it cannot be considered a true mobile device.

- 7) Wireless Communication - Mobile devices are typically capable of communication with other similar devices, with stationary computers and systems, with networks and portable phones. Base mobile devices are capable of accessing the Internet through Bluetooth or Wi-Fi networks, and many models are equipped to access cell phone and wireless data networks as well. Email and texting are standard ways of communicating with mobile devices, although many are also capable of telephony, and some specialized mobile devices, such as RFID and barcode.

## V. CONCLUSION

Mobile Cloud Computing is one of mobile technology trends in the future since it combines the advantages of both mobile computing and cloud computing, thereby providing optimal services for mobile users. According to Gartner, corporate employees using smartphones and tablets for business purposes represent about 75% of the mobile cloud app market. The mobile cloud app market is expected to exceed \$9 billion by 2014. With this importance, this paper has provided an overview of mobile cloud computing in which its definitions, architecture, and advantages have been presented. Next, applications models for implementing cloud computing in mobile devices are discussed. In the last section, several issues regarding MCC and steps which can be taken to overcome these issues are presented. Despite some drawbacks, cloud computing and mobile cloud computing have a very bright future as they have made it very easy to access data and applications over the cloud without the need of incurring huge costs associated with the technology. With the high increasing of data computation in commerce and science, the capacity of data processing has been considered as a strategic resource in many countries. Mobile cloud computing (MCC), as a development and extension of mobile computing (MC) and cloud computing (CC), has inherited the high mobility and scalability, and become a hot research topic in recent years.

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