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A Survey on Communication Issues in Mobile Cloud Computing

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Abstract

Despite the expanding utilization of mobile devices, exploring their full resources is an issue due to their limited battery power, processing power and data storage. The integration of cloud computing with mobile devices solves these issues by offloading major computation in to the cloud. This paper provides a survey on Mobile Cloud Computing (MCC), which helps to understand the MCC architecture, communication issues and applications. An extensive survey is made of communication issues and different approaches are discussed to overcome the communication issues. Finally open research challenges are also provided which will be helpful for active researchers in the field of MCC.

Keywords: QoS, offloading, mobile, cloud, communication

Introduction

In recent years, mobile devices (e.g., tablet pcs, smartphones, etc.) have become a part of human life. Mobile devices are rich in various applications like Google apps, iPhone apps which run on a remote server and/or mobile devices connected through wireless networks. The possible services provided by the mobile devices are service and computing due to the advanced inbuilt sensors like GPS, pressure sensors, light sensors, accelerometer, and magnetometer. The greater utilization of these sensor requires more analysis of data leading to an increase in computation. Mobile computing [1] is the emerging trend in IT, industry and commercial fields. Mobile devices are facing many challenges in communications (security and mobility) and their resources (battery, storage and bandwidth) [2]. The constrained resources fundamentally obstruct the improvement in Quality of Service (QoS).

Cloud computing is treated as one of the emerging platforms for computations. Cloud computing offers services like infrastructure (servers, storage, and networks), platforms (Operating systems and middle-ware services) and software (application programs) to users. Cloud computing provides flexible and virtualized services based on user requirements. The scalability can be increased due to non-maintenance of servers and other required infrastructure. The cloud service providers provide services to the clients with minimum cost and in on demand fashion. The richness of cloud computing and the drawback of mobile computing has led to the development of a new environment called Mobile Cloud Computing (MCC). This paper presents the survey on MCC with the discussion of the paper concentrated more on the communication issues and applications of MCC.

Towards mobile cloud computing

Mobile cloud computing is the term evolved from the combination of mobile computing and cloud computing. It didn't take much time to introduce MCC after the introduction of cloud computing in mid-

2007. Most industries are concentrating on MCC to reduce the cost of applications in mobile devices by introducing the cloud concept in to it. Researchers are focusing on saving the energy of mobile devices which it is commonly called green IT [3]. As per the mobile cloud computing forum, MCC is defined as [4];

“The mobile cloud computing is a paradigm where the data storage and computation is performed external to the mobile device. Mobile device take the advantages of cloud computing and process the data in to the cloud to save the resources in the internal environment.”

The MCC is defined as the most efficient tool for accessing the applications and services over the internet and it is a combination of the mobile environment and cloud computing [5-7].

MCC architecture

Figure 1 shows the overview of MCC architecture. The MCC architecture is divided in to 3 layers such as mobile environment, wireless medium and cloud environment. The mobile environment contains the mobile devices that are connected to the sink nodes to maintain the communication between the mobile devices and network. The AAA (for authentication, authorization and accounting) policy is applied to establish the communication. As a next step, the mobile users request the services from the cloud; the requests are handled by the cloud through the internet services. The cloud forwards the mobile user request to the cloud services (application, web and data servers).

The architecture of cloud computing is defined with 4 layers with different contexts. The 4 layers are application, platform, unified resource and fabric [8]. The application layer is responsible for running the applications which are present in the cloud. The platform layer contains the specified tools for development software, middleware for supporting heterogeneous communication and is responsible for software development. The unified resource layer provides the virtualization of the resources. The fabric layer consists of the hardware environment such as storage and network. Aneka platform was introduced to build .NET applications in multi programming models to support developers [9,10]. Huang *et al*. [11], to support business models the authors introduced business oriented services to the cloud. They have developed a framework with a scalable, low cost and secure platform for web based services. But, the research is not concentrated on major QoS issues such as availability, security and reliability.

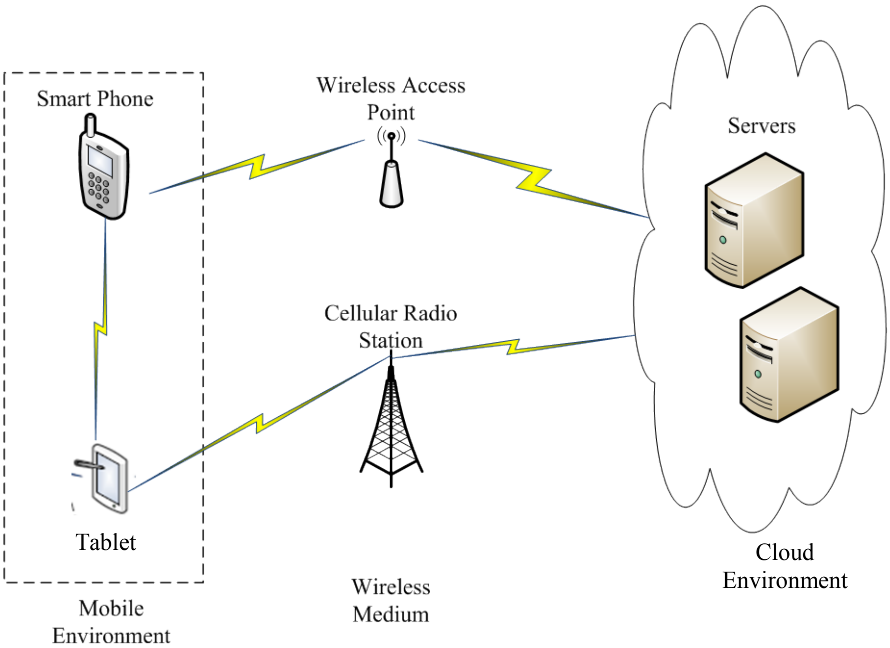

Figure 1 Architecture of mobile cloud computing.

Benefits of mobile cloud computing

To overcome the issues of mobile computing (mobility, bandwidth and portability) [12], cloud computing is a promising solution. The major benefits of integrating cloud technology to the mobile computing are given as follows.

Extending data storage: Data storage is one of the major constraints of mobile devices. MCC offers services to the users to utilize the data storage in the cloud. Amazon S3 is one example of cloud storage which provides storage as a service [13]. Facebook is one successful social networking sites that is utilizing cloud services in the mobile device [14]. Flicker [15] and ShoZu [16] are image storage application benefits from the MCC.

Improving computational capacity: Computing-intensive applications need more computational capacity, but the mobile devices are lack in the required level of processing power. MCC helps in reducing the cost of executing the application by synchronizing the cloud to the mobile device in terms of processing capacity. For example, the cloud can provide multimedia services [17], online gaming [18] or E-banking [19] for mobile devices. The examples which were discussed earlier consume a lot of time and energy when they are executed in a mobile environment, but they consume less time in the cloud environment.

Enhancing battery life: The major challenge in the face of mobile devices is limited battery power. Many solutions have been proposed to improve the battery life by enhancing the performance of the CPU and by managing the storage and screen resolution smartly [20-23]. These solutions require additional changes to the mobile devices and it results in new hardware and additional cost.

Computational offloading is a technique which can be implemented for migrating the complex and large computations from mobile devices to cloud servers. This will reduce the load on the mobile device and increase the performance of the battery. Several experiments were conducted using offloading techniques. The results obtained from the experiments showed that the remote execution of the application can save energy [24,25]. A mathematical model was introduced for the reduction of energy in mobile devices. They obtained up to a 45 % reduction in energy consumption [24]. The MAUI (Mathematical Arithmetic Unit and Interface) architecture was proposed in Cuervo *et al*. [26], for reducing energy in MCC. Their approach was to offload the mobile game components in to the VMs of cloud; it saved almost 27 % in the energy of the mobile device.

Enhancing reliability: The offloading of data and computation to the cloud makes the application more reliable. The data storage in servers creates backup and it will be helpful to reduce data loses on mobile devices. A comprehensive security model has been designed for the MCC for both users and providers. The model had proposed to control the unauthorized access of data from the MCC [27]. The cloud can provide services like authentication, malware detection and virus scanning to mobile users [28].

Communication issues in the mobile cloud computing

The MCC is a combination of both the mobile environment as well as cloud computing, it has many challenges regarding the mobile communication and data provisioning in the cloud. This section describes several research issues, research solutions and future directions in MCC.

Quality of service in MCC

In MCC, the mobile users are able to access the resources in the cloud to reduce energy consumption, but the mobile users faced many communication issues regarding the connection to the cloud. The issues are limited bandwidth, network delay, signal attenuation and network disconnection. **Figure 2** explains the QoS issues in MCC.

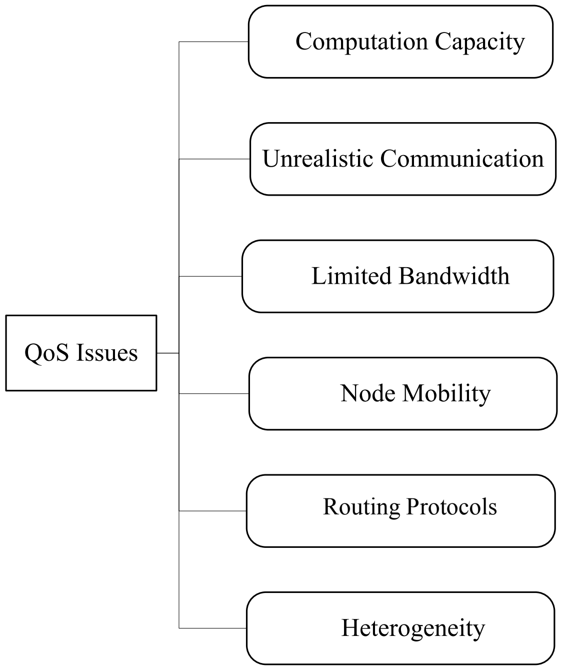

Figure 2 QoS issues in the mobile cloud computing.

The computation capacities in the mobile devices are limited and very poor when compared to desktops, laptops, etc. The computation capacity always affects the services of mobile cloud computing. Limited bandwidth always creates major problems in the communication of MCC. Jin *et al*. [29] proposed architecture to solve the bandwidth problem in MCC. They concentrated on sharing of limited bandwidth to the mobile users which are requesting from the same location and the same application. But, the limitation of the solution is that it cannot address the unfairness in the distribution of bandwidth. Mishra *et al.* [30] proposed a model for bandwidth shifting and redistribution in MCC. They followed an auction based model for distribution of bandwidth. Canepa *et al*. [31] proposed a mechanism for unrealistic communication, the model has the capacity to search unavailable nodes when the link is in a failure state. To address the network heterogeneity, the author in [32] presented an intelligent radio network access for heterogeneous networks. To solve the network delay in MCC, Intel researchers proposed a model called CloneCloud [33]. This approach manages to send the data to the nearest server; this brings a lot of advantages to the mobile platform to speed up the computation. To address the mobility management in MCC, Rahimi *et al*. [34] proposed a heuristic algorithm MuSIC to convert the mobility patterns into mobile usage patterns. A detailed survey on QoS issues is shown in **Table 1**.

Table 1 Related Work regarding QoS issues in MCC.

Issue	Papers	Techniques used
Limited bandwidth	[29,30,35,36]	power-efficient mobile P2P media streaming, Auction based mechanism, fmobile software, Machine to Machine (M2M) cloud
Availability	[37,38]	Distributed Application Processing Frameworks, CloneCloud
Heterogeneity	[39,40]	Multidimensional heterogeneity, Service-based arbitrated multi-tier
Mobility management	[41-43]	M^2C^2, Mobility-Aware Optimal Service Allocation, OpenFlow
Service selection	[44,45]	MACSS, network-centric

Barbera *et al*. [35] suggested architecture for MCC where each real device is connected with a software clone of the cloud environment. They considered 2 types of clones, one is an off-clone that supports computational offloading and the other is a back-clone used to restore the data of the mobile device. The architecture was evaluated based on the bandwidth and energy consumption of the mobile devices. Ravi Teja *et al*. [36] proposed a congestion network model for M2M devices by managing the network traffic using the 2 level mapping. The first level mapping is carried in between cluster head to the sink nodes and second level of mapping is carried in between sink nodes to the cloud gateway. The mapping is done based on the social choice mechanism.

Shiraj *et al*. [37] extensively reviewed distributed application processing frameworks for mobile devices in MCC. They made the contribution towards the study of current offloading frameworks and analysed the critical aspects and implications. Zhang *et al.* [38] presented the research challenges in cloud computing. The clone-cloud is addressed for the efficient availability of the network bandwidth to the devices which are connected to the cloud services. They reviewed different challenges and important research issues in the direction of cloud computing.

Sanaei *et al*. [39] discussed heterogeneity and different challenges in MCC. Heterogeneity in terms of hardware, software, platform and network were analysed. The impacts of heterogeneity in various environments were discussed and they also presented the handling approaches like middleware, virtualization and service oriented architecture for heterogeneity. Sanaei *et al*. [40] proposed a Service-based Arbitrated Multitier Infrastructure (SAMI) for a service oriented platform. This architecture deals with 3 layers: cloud, Mobile Network Operators and MNO's for dealers. This architecture concentrates on the arbitrator layer which has the functionality to classify the services and assign them to the available resources based on the latency, service resource requirement and security.

Mitra *et al.* [41] concentrated on heterogeneous access of networks over MCC. They proposed an M^2C^2 model for supporting the multihoming, cloud and network probing, and cloud and network selection. The experimental results of the model support the efficiency of the M^2C^2 model. In the future, the usability of the mobile devices will increase rapidly. It is important to manage the mobility of the devices and handover processes. Ryu *et al*. [42] proposed fast handovers for MIPv6 (FMIPv6). FMIPv6 provided an efficient handover process and prevented the packet losses and handover latency through buffering and tunnelling. Kempf *et al.* [43] described the Software Defined Networks (SDN) with the help of mobile Evolved Packet Core (EPC). They proposed OpenFlow 1.2 for 2 vendors. One is for encapsulation and de-capsulation of virtual points and another is flow routing through GTP Tunnel Endpoint Identifier (TEID).

To address the service selection, Liu *et al*. [44] proposed a mobile-aware framework to Mobile Cloud Streaming Services (MACSS) for optimizing mobility management by using server selection. The MACSS significantly improved the user mobility management and channel selection and variation. Ejaz *et al*. [45] concentrated on the limitations of mobile devices, overcoming these limitations by integrating with cloud services. They analysed the task offloading process through the network centric mechanism. The proposed model was analysed with an application migration process with the impact of various parameters such as file size, the number of users in the LAN, the traffic load on the Wi-Fi network, the number of nodes in the network, message length and mobility speed. The proposed model was tested with migration time and packet delivery ratio. The main drawback of the proposed model was that it did not consider the energy consumption of the network.

Operational issues in MCC

The operational issues of MCC refer to technological matters such as computational offloading, cost benefit models and connection protocols used.

Computational offloading

The main operation of MCC is offloading of tasks from the mobile device to the cloud. Due the distance between the mobile and cloud a heterogeneous communication is needed for the underlying system. Different research has been carried out in heterogeneous communication in many ways. In this section, the review concentrates on the client server model, VM migration model and mobile agents.

Client-server model: The communication with the network is carried with a client server model. The client server model is a traditional technique where the communication is taken care of by remote procedure calls and remote method invocations. These methods are well-supported APIs for developers to offload the task. But, these 2 methods have to be pre-installed on the mobile devices. It is a drawback of this model when it is participating in Ad-hoc networks. In [46,47], they used the RPC for communication in the offloading process. The RPC are pre-installed into the device which invokes the functionality in the cloud and mobile SPECTA servers. The servers have the RPC pre-installed methods. The spectra clients consult the database server for information regarding the CPU, memory, availability etc., when the task is to be offloaded. Developers will partition the application manually and take the decision on which part of the application has to be offloaded and which part has to be executed locally.

Marinelli [48], has proposed a model called Hyrax for applications of smartphones. They used the Hadoop framework for both data and computation in android. Hyrax investigates the likelihood of utilizing a group of mobile phones as resource providers and demonstrates the possibility of such a portable cloud. They introduce a ‘HyraxTube’ application; which is a search and sharing multimedia mobile application. The goal of HyraxTube is to permit clients to look through multimedia applications in relation to quality, location and time.

Huerta-Canepa and Lee [49] presented another Hadoop framework for mobile devices considering the set of mobile devices as cloud resource providers. This method argues that the location of the user plays a major role in deciding the task offloading. The manager in the offloading process manages the sending and receiving of the task from the other devices and creates VMs on the other mobile devices. They tested this environment in a Korean OCR application. The results for the application are not satisfactory in terms of speedup. But, it showed noticeable results in energy saving.

The Mobile Message Passing Interface (MMPI) framework is proposed for mobile devices, it uses Bluetooth as the communication medium for creating a connection with other mobile devices [50]. This model follows the mesh network procedure so that each mobile device can communicate with other mobile devices. They implemented the model using the BlueCove [51].

Kemp *et al*. [52], the Cuckoo framework was proposed for the offloading of tasks to the cloud using the Java model. The server which runs Java instances is eligible for executing the offloading tasks. The Amazon EC2, commercial cloud provider is selected to evaluate the framework.

Virtual machine migration: As per Clark *et al*. [53], virtual machine migration is defined as the process of transferring source server memory images to the destination server. This process duplicates the memory pages without the involvement of the operating system and other installed software. This technique guarantees the secure execution and no code changes are essential when tasks are offloaded, since the VM limit protects the surrounding mobile devices. VM migration is tedious to a particular level and the workload could end up being substantial for mobile devices.

The CloneCloud is presented and it utilizes the virtual machine migration policy to offload the task to the cloud server through Wi-Fi or 3G network [33]. Since they utilize mobile device clones, the applications are unmodified and there is no need for decision making for example, as followed in MAUI [18]. The CloneCloud proposed the cost model for examining the cost of VM migration and execution in the cloud. The android platform mobile devices were selected to manage the clones.

Sathyanarayanan *et al*. [54] proposed cloudlets as a solution for connecting distant clouds. The cloudlet is like a small data center which is present nearer to the devices and connected to the cloud through the internet. The mobile devices have the flexibility to connect the cloudlets for offloading of tasks. The computation power of the cloudlets is minimal when compared to the cloud. The major drawback of this process is reliability and energy consumption.

MobiCloud [55] is a mechanism for integrating the cloud computing with Mobile Ad-hoc Networks (MANET). In this model, the general architecture of the MANET is considered as the service oriented architecture and each node in the architecture is considered to be a service node. The serve broker in the architecture takes care of incorporating the service nodes in to the cloud. Extended Semi-Shadow Images (ESSIs) are used to clone the environment in to the cloud.

Mobile agents: Kristensen and Scavenger [56], Scavenger suggested the framework for cyber foraging which utilizes Wi-Fi as a communication medium. It uses the mobile agent approach for partitioning and execution of tasks. It also introduced the cost assessment policy with the help of a scheduler. It is possible to offload the tasks and execute at multiple servers using the framework. Apart from the advantages, the limitation of the model is that it does not consider fault tolerance.

Table 2 Analysis of offloading approaches.

Computational offloading	Frameworks	Advantages	Disadvantages
Client-Server Model	Spectra [46] Chroma [47] Cuckoo [52] Hyrax [48]	Stable and supported by APIs	Require pre-installation, network congestion
VM Migration	CloneCloud [33] MAUI [18] Cloudlets [54] MobiCloud [55]	No code modification is required	VM migration takes time and compatibility issues
Mobile Agents	Scavenger [56]	Dynamic execution and suitable for mobile devices which are not connected.	Security and agent management

The analysis of offloading frameworks is given in **Table 2**. In spite of the fact that a comparison of results have been given in some papers, looking at them against one another is difficult since the energy consumption and performance rely upon the application too. Actually, while utilizing the same framework, execution differs for distinctive applications. The communication medium (whether 3G, LTE or Wi-Fi) and size of the task plays a crucial role.

Cost benefit model

The cost is a major issue in MCC, the offloading of the task in to the cloud considers different issues like time, energy, and economical execution. To calculate the cloud cost, Li *et al.* proposed a model with a set of rules [57]. They considered utilization cost and the Total Cost of Ownership (TCO) as the deciding factors for cost analysis. Utilization cost is calculated in terms of resource utilization with respect to particular users according to the dynamic demand; resources are VMs, power, computational resources and software. The TCO is the cost estimation for installing the IT infrastructure. In terms of the cloud, the TCO is the infrastructure cost, software cost, network cost, maintenance cost and much more.

Walker *et al.* [58] presented an analysis of electrical cost, the memory utilization cost and infrastructure maintenance cost of the commercial cloud service provider Amazon EC2. They made a decision model whether to buy the services or to lease. The decision model calculates the Net Present Value (NPV) of the services. The value of the NPV ≥ 0 represents to buy the service otherwise to lease the service. Eq. (1) represents the calculation of NPV.

$$NPV = \sum_{Y=0}^{n} \frac{C_Y - E_Y + L_Y}{(1+R_F)^Y} + \frac{S}{(1+R_F)^n} - C \quad (1)$$

where C_Y, E_Y and S represent the disc controller unit cost, operating cost per year and disc lifetime salvage value. L_Y represents the expected lease payment per year and R_F represents the interest rate per year.

Kim *et al*. [59] proposed a Luyapunov drift-plus-penalty technique for dual side control algorithms in mobile device and cloud services. They suggested an NC-UC (Non-Cooperation) algorithm for the mobile device by concentrating on the delay factor and NC-CC algorithm for the cloud.

In MCC, due to the dynamic nature of mobile devices, the resources may change at any movement. Therefore, the cost analysis model is required to get benefit from the offloading process. **Figure 3** illustrates the user specific requirements of cost analysis.

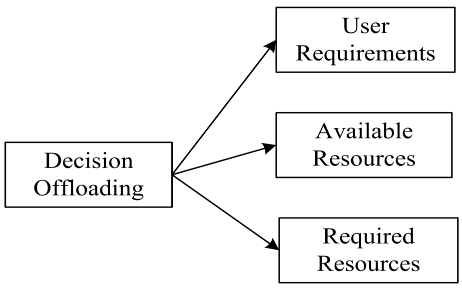

Figure 3 Cost analysis for MCC.

Connection protocols

The MCC research has been carried with many communication protocols like 3G, LTE, Wi-Fi and Bluetooth, but the majority of users have utilized Wi-Fi as a communication medium. An overview of the communication protocols used in MCC frameworks is shown in **Table 3**.

3G: Third Generation mobile telecommunication is the mobile technology which is used for communication in MCC [60]. The data rate of 3G is much slower when compared to LTE and Wi-Fi.

LTE: Long Term Evolution is the technology for the communication that increases bandwidth for mobile users. The capacity of the LTE is up to 100 Mbps. Moreover, LTE provides additional advantages such as quicker handoff, wide coverage area and varied services [61]. However, it has some drawbacks related to the access of protocols, QoS, network architecture [62].

Wi-Fi: Wireless Fidelity (802.11b) is operated on unlicensed 2.4 GHz bandwidth. Initially, Wi-Fi was introduced to replace the wired network for sharing of data among the computers; later on it was used by mobile devices for data. The range of Wi-Fi is 100 m and the typical data rate is 11 Mbps [63,64].

Bluetooth: Bluetooth was introduced for wireless devices like mobile phones, laptops, tablets and is designed with low cost transceiver chips. The transmission range of Bluetooth is 10 m and data rate is up to 24 Mbps [65]. The analysis of communication protocols in MCC is given in **Table 3**.

Table 3 Comparison between Communication Protocols.

Communication protocols	**MCC models**	**Advantages**	**Disadvantages**
3G	[18,33,52,60]	Near pervasive coverage	Bandwidth is limited, higher round trip time, high energy consumption
LTE	[18,61,62]	Higher data rate	Higher energy consumption
Wi-Fi	[46-48,52,63,64]	Better performance, less energy consumption when compared to 3G and LTE	Security threats, limited operational issues
Bluetooth	[50,52,65]	Low energy consumption, availability [66],compared to the other protocols [67]	Limited range

Security issues

The computational offloading of tasks from mobile devices poses some questions regarding privacy and security. The data and the user programs are sent to the servers that are not under the control of the user. Hence it raises a privacy issue. The third party is introduced to store the user's data so there is no security. Major research has been carried out in the area of protecting outsourced data [68-70] the solutions include hardware based execution [71], homomorphic encryption [72-74] and steganography [76,77]. These techniques have their own limitations due to the size of the encryption key and the approaches the researches followed for encryption.

Context awareness

Context awareness is a mechanism in MCC that identifies the state of the mobile user and surroundings of the device and infers the context information. This is important for MCC for offloading decisions because the performance of the offloading may vary based on the users location and context; the advancement of the research is carried out in the area of adaptive mechanism based on context awareness [78-81].

Applications of MCC

MCC has gained popularity in the global mobile market. Different applications in the android platform support MCC. In this section MCC applications are presented briefly.

M-learning

Mobile learning is developed with the help of E-learning and with the combination of mobility. The conventional M-learning process has some restrictions, for instance, low network transmission rate, limited educational resources, and the high cost of the device [82,83]. To overcome those issues the cloud based m-learning has been introduced. Utilization of services like networks, data, and storage from the cloud is much cheaper when compared to conventional M-learning [84]. Yu-Shan *et al*. [85] made a study on cloud based m-learning and designed a model called a non-equivalent pretest-posttest. The research showed positive results on creative performance of the students in engineering. The proposed model also improves the overall performance of the designed products. Aftab *et al*. [86] studied whether the design of E-learning is suitable for the MCC environment. They made several comparisons regarding the MCC architectures and estimated the performance of the MCC.

M-commerce

In a recent trend, M-Commerce is one of the developing areas concerned with the business market. M-commerce generally has some task with requirement for mobility. For example, online purchasing, mobile messaging, mobile banking, mobile ticketing etc. M-commerce faces some issues regarding the low bandwidth, security, high complexity, and mobile device configuration. These issues can be resolved by integrating m-commerce with the cloud. Yang and Lin [87], the authors proposed a mobile payment mechanism with the anonymity of cloud computing. The model concentrated on reducing the computational cost and non-repudiation requirement at the mobile device. The results of the model showed better results in terms of security. **Figure 4** explains the payment gateway model in MCC.

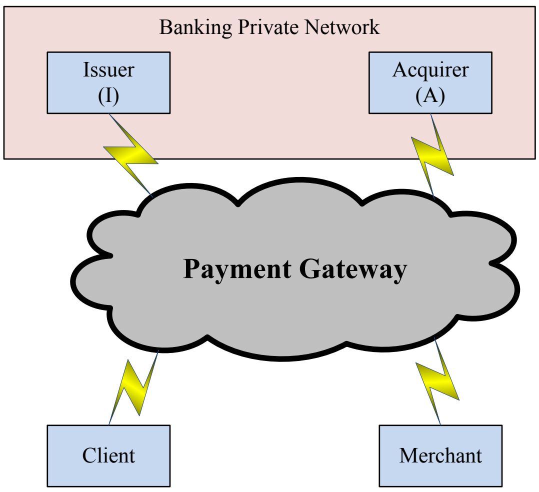

Figure 4 Payment gateway for M-commerce adapted from [87].

Turban *et al*. [88] have explained the infrastructure that supports m-commerce, applications of m-commerce in banking and financial services, and value added attributes of the m-commerce.

M-health

To overcome the limitations of the traditional health care, mobile health (M-health) using MCC has been introduced. The limitations are physical storage, medical errors, privacy and security [89,90]. M-health provides convenient access to the health records of patients without any complications. Besides this, M-health offers multiple on demand services to the hospitals with the help of the cloud [91-94]. For instance, 4 modules in [90] to deal with M-health.

Emergency management: It can manage emergency situations by responding to calls from accidents and incidents.

Daily heath monitoring: This will be used for continuous health monitoring of patients and can be useful for the doctors to observe the patients daily activities.

Context aware mobile devices: This will monitor the blood pressure, pulse rate, heart rate and alerts the health system.

Ubiquitous access: It allows the patient to check their health status daily and past data will be accessed from the data base.

Mobile gaming

The application of MCC in the field of gaming has made a drastic change to the gaming market. The computation needed for gaming is completely offloaded to the cloud and it will ultimately reduce the computational cost at the mobile device. Wang and Dey [95], the authors proposed an adaptive mechanism for a gaming platform that considers the users parameters and communication parameters and dynamically adjusts to the environment. They concentrated on the rendering an adaptive mechanism which minimizes the objects in the display screen of the mobile device and gives the user a fair play mode. The objective of this model is to increase the user experience and reduce the communication and computational cost.

Other practical applications

The MCC is used for evaluating multimedia [96-98], text editors [99-101], vision and voice recognition [102]. Text editors consume less data i.e., computations like spell check. Multimedia, vision and voice recognition consumes large amounts of data in the form of videos and images [102].

Open challenges for research

The research which has been carried out up to now in the field of MCC is discussed in the earlier sections. Though there are several open challenges which have to be discussed. In this section, some research directions related to the MCC are presented.

Network management

The network management plays a crucial role in the performance of task execution over MCC. The better network manages to improve the link performance and bandwidth usage. Cognitive radio networks improve the spectrum utilization of mobile users. When the cognitive radio networks are integrated with the MCC, it saves thousands of dollars to the network providers.

Low bandwidth

Already a lot of research is going on in the field of improving bandwidth efficiency. But, it is continuous because of the drastic increase in the number of mobile and cloud users. LTE can be suggested as a solution as it is a promising technology to overcoming limitations and for improving bandwidth efficiently. Moreover, LTE also has some operational issues like network architecture, QoS, protocols, and much more.

Quality of service

The QoS improvement is the major research area in the field of MCC. Mobile users can access the services from the cloud service providers. Moreover, mobile users face some challenges regarding the access of the services from the cloud such as network congestion at the time of mobility, time delay at the time of establishing the connection with the cloud. So, better QoS mechanisms need to be developed to overcome the research gaps.

Compatibility

Compatibility plays a major role while the mobile user is connected with the cloud interface. The present interface between mobile users and cloud platform is web services. The web services are not particularly designed for mobile devices. Hence, the web interface becomes overhead. There is a need for an efficient programming interface to address the compatibility issues in MCC.

Cost

In MCC, the mobile services as well as cloud service providers are converged to provide the services. Therefore, cloud service providers have different cost policies for utilization of resources. So, cost is a major issue in MCC i.e., how to decrease the cost of cloud computing and how the resources will be utilized efficiently is a major research area.

Conclusions

MCC aims to enable mobile users by giving them consistent and rich functionality, apart from the limitations of the mobile devices. MCC provides versatile support for mobile applications in the future. This paper surveys and classifies large bodies of research regarding communication issues and applications of mobile cloud computing. Various types of architectures for computational offloading and virtualization are examined. Classification of different types of applications that are used by the MCC is also presented. Finally the open issues and research directions in the field of MCC are presented.

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