A Survey of Mobile Cloud Computing Applications: Perspectives and Challenges

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ABSTRACT

As mobile computing has been developed for decades, a new model for mobile computing, namely, mobile cloud computing, emerges resulting from the marriage of powerful yet affordable mobile devices and cloud computing. MCC integrates the cloud computing into the mobile environment and overcomes obstacles related to the performance.
This paper gives a survey of MCC application including the definition, architecture, as well as speculate future generation mobile cloud computing applications. The challenges and existing solutions and approaches are presented

KeyWords: Mobile computing, cloud computing, mobile cloud computing, mobile cloud applications.

1.0 Introduction

The NIST defines cloud computing as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction [14]. It has three layers of services, namely, Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). The cloud provides a powerful processing core and a massive storage space with configurable computing resources for users to do computation on it. Cloud service is characterized as on-demand, elastic, quality of service guaranteed, and pay-per-use. Cloud computing propels a new class of applications which called MCC applications.
The term "mobile cloud computing" was introduced not long after the concept of "cloud computing" launched in mid-2007. It has been attracting the attentions of entrepreneurs as a profitable business option that reduces the development and running cost of mobile applications, of mobile users as a new technology to achieve rich experience of a variety of mobile services at low cost, and of researchers as a promising solution for green IT [14].
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. Alternatively, MCC can be defined as a combination of mobile web and cloud computing [1] which is the most popular tool for mobile users to access applications and services on the Internet.

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 brings new types of services and facilities for mobile users to take full advantages of cloud computing. MCC provides mobile users with the data processing and storage services in clouds. The mobile devices do not need a powerful configuration (e.g., CPU speed and memory capacity) since all the complicated computing modules can be processed in the clouds.

1.1 Why Mobile Cloud Computing?

- Mobile devices face many resource challenges (battery life, storage, bandwidth etc.)
- 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 etc), as all resource-intensive computing can be performed in the cloud.

2.0 MCC Architecture

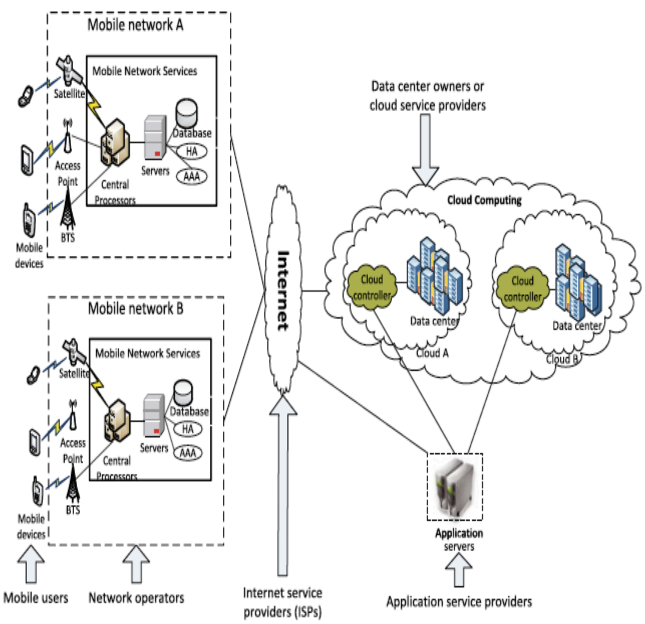

Fig. 1. Mobile Cloud Computing (MCC) architecture.
In Fig. 1, mobile devices are connected to the mobile networks via base stations (e.g., base transceiver station (BTS), access point, or satellite) that establish and control the connections (air links) and functional interfaces between the networks and mobile devices. Mobile users' requests and information (e.g., ID and location) are transmitted to the central processors that are connected to servers providing mobile network services.

Here, mobile network operators can provide services to mobile users as AAA (for authentication, authorization, and accounting) based on the home agent (HA) and subscribers' data stored in databases. After that, the subscribers' requests are delivered to a cloud through the Internet. In the cloud, cloud controllers process the requests to provide mobile users with the corresponding cloud services. These services are developed with the concepts of utility computing, virtualization, and service-oriented architecture (e.g., web, application, and database servers).

2.1 Advantages of MCC

- 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). Many mobile applications take advantages from task migration and remote processing, thereby allowing remote application execution to save energy significantly.

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- Improving data storage capacity and processing power: MCC enables mobile users to store/access large data on the cloud. It helps reduce the running cost for computation intensive applications by not been constrained by storage capacity on the devices because their data now is stored on the cloud therefore improving reliability and availability: with data and services in the clouds, then are always (almost) available even when the users are moving.
- Dynamic provisioning: Dynamic on-demand provisioning of resources on a fine-grained, self-service basis therefore there is no need for advanced reservation
- Scalability: Mobile applications can be performed and scaled to meet the unpredictable user demands and Service providers can easily add and expand a service
- Multi-tenancy: Service providers can share the resources and costs to support a variety of applications and large no. of users.
- Ease of Integration: Multiple services from different providers can be integrated easily through the cloud and the Internet to meet the users' demands.

2.2 MCC Applications

Mobile applications gain increasing share in a global mobile market. Various mobile applications have taken the advantages of MCC. We have witnessed a number of MCC applications in recent years, including mobile commerce, multimedia sharing, mobile learning, mobile sensing, mobile healthcare, mobile gaming, mobile social networking, location-based mobile service, and augmented reality. Mobile commerce, such as e-banking, e-advertising and e-shopping, uses scalable processing power and security measures to accommodate a high volume of traffic due to simultaneous user access and data transaction processing multimedia sharing provides secure viewing and sharing of multimedia information stored on smartphones while providing administrative controls to manage user privileges and access rights necessary to ensure security. Mobile learning allows a thin terminal to access learning materials on the cloud any time and any place. Mobile sensing utilizing sensor-equipped smartphones to collect data will revolutionize many MCC applications including healthcare, social networking, and environment/health monitoring. Mobile healthcare allows an enormous amount of patient data to be stored on the cloud instantaneously. A doctor can conveniently look at the patient records on his/her mobile device for remote diagnosis or monitor a patient's status for preventive actions. Mobile gaming achieves scalability by leveraging scalable computation and instantaneous data update on the cloud side and screen refresh at the mobile device side. Mobile social networking allows a group of mobile users to upload audio/video/multimedia data for real-time sharing, with cloud computing providing not only storage for data, but also security to protect secrecy and integrity of data.

2.3 MCC Issues

- 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
- 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

3.0 Related Works

Weiguang Song et. al. [1] summarize the core concepts of Mobile Cloud Computing [MCC] by developing a basic idea model of Mobile Cloud Computing. Major problems faced by MCC are discussed such as stability of wireless connectivity, tackling the unnecessary battery usage etc. Also, few possible solutions are suggested. Qureshi et. al. [2] discusses about the mobile cloud computing technology and proposes the implementation methods for Mobile Cloud Computing solutions such as General Purpose Mobile Cloud Computing (GPMCC) and Application Specific Mobile Cloud Computing (ASMCC). Certain barriers such as network availability and bandwidth are focused. Two aspects of security issues such as mobile device security and cloud security are addressed. Le Guan et. al. [3] addresses the challenges in Mobile Cloud Computing design such as network latency, limited bandwidth and availability. In order to analyze Mobile Cloud Computing technology, a concept model is proposed which includes context management, resource scheduling, client and transmission channel. A Cloud architecture of Mobile Cloud Computing is described for organization of Mobile Cloud Computing systems. Application partition and offloading and various context aware services are explained briefly. Dejan et. al. [4] addresses several mobile cloud approaches. An overview of various possibilities of Mobile Cloud Computing is given. Native and web applications are too extremes of mobile applications. The cost model of elastic mobile cloud applications is described.

Han Qi et. al. [10] discuss Mobile cloud computing (MCC) as a development and extension of mobile computing (MC) and cloud computing (CC) which has inherited high mobility and scalability. The proposed system in the paper explains the principle of MCC, characteristics, recent research work, and future research trends. Proposed system analyzes the features and infrastructure of mobile cloud computing and also analyzes the challenges of mobile cloud computing. Vinod et. al. [12] discuss about the cloud computing which enables the work anywhere anytime by allowing application execution and data storage on remote servers. This is useful for mobile computing and communication devices that are constrained in terms of computation power and storage. The goal of the paper is to characterize under what scenarios cloud-based applications would be relatively more energy-efficient for users of mobile devices.

Hung et. al. [7] analyzes the performance of many mobile applications which are weak due to lack of computation resources, storage, and bandwidth and battery capacity. To overcome this, application is rebuilt using the cloud services. The proposed system explains a framework to execute the mobile application in cloud based virtualized environment with encryption, and isolation to protect against unauthenticated cloud providers. Results show the execution of mobile application by offloading the workload with efficient application level migration method via mobile networks. The migration of application form one device to another is easy and quick in the proposed system. Ricky et. al. [13] discuss that mobile cloud computing allows mobile applications to use the large resources in the clouds. In order to utilize the resources, migration of the computation among mobile nodes and cloud nodes is necessary. Therefore, a highly portable and transparent migration approach is needed. The paper uses a Java byte code transformation technique for task migration without effecting normal execution. Asynchronous migration technique is used to allow migrations to take place virtually anywhere in the user codes. The proposed Twin Method Hierarchy minimizes the overhead from state-restoration codes in normal execution. Milos et. al. [5] discusses the Biometric applications such as fingerprint identification, face, or iris scanning. These applications actually work in a laboratory setting where the client computer has unlimited access to the throughput and computational resources of the network. The problem focused here is on the battery power of the device and the throughput of the communication channel of the client node to the cloud. The paper explains the mobile cloud computing technique for biometric applications such as fingerprint identification, face recognition and iris recognition. Debessay et. al. [6] analyzes and studies the impact of cloudlets in interactive mobile cloud applications. In order to study the impact, cloudlet network and service architecture is proposed. This architecture focuses on file editing, video streaming, and collaborative chatting. The performance gains with the usage of clouds are shown by simulation results. NKosi et. al. [8] discusses mobile devices which are used in Health information delivery access and communication challenges like power, bandwidth, and security. The proposed system explains how cloud computing can be used in mobile devices to provide sensor signals processing and security. The system described in the proposed system uses an NGN/IMS system with cloud computing to reduce the burden of organizing and also for improving the functions of existing mobile health monitoring systems. The interaction between health service provider, IMS network operator and cloud computing service providers should be regulated so that identity management and security verification is performed.

Yan Gu et. al. [9] focuses on the fundamental issue in the mobile application platform which is the deployment decision for individual tasks when the battery life of the mobile device is a major concern for the mobile user's experience. The proposed system explains the deployment scheme to offload expensive computational tasks from thin, mobile devices to powered, powerful devices on the cloud. The proposed system is implemented and various experiments on the Android devices for individual components. Chun et. al. [11] discuss about the mobile applications which are providing functionality on mobile devices. Also, mobile devices provide strong connectivity with more powerful machines ranging from laptops and desktops to commercial clouds. The proposed system in the paper presents the design and implementation of CloneCloud. CloneCloud is a system that automatically transforms mobile applications to get benefit from the cloud. CloneCloud uses a combination of static analysis and dynamic profiling to automatically partition an application.

4.0 Emerging and Future MCC Applications

Future MCC applications must leverage unique characteristics of MCC. Due to limitation of power, intensive data processing on mobile devices is always costly. With the technology advancement, however, mobile devices are equipped with more functional units, such as high-resolution camera, barometer, light sensor, etc. Emerging and Future MCC Applications includes:

- Application Category References
- Crowdsourcing (crowd computing) [15] [16] [17]
- Collective sensing [18] [19] [20] [21]
- - Traffic/Environment monitoring [22, 23, 24] [25]
- - Mobile cloud social networking [26] [27] [28]
- - Mobile cloud healthcare [29] [30] [31]
- Location-based mobile cloud service [32] [33]
- Augmented reality and mobile gaming [34] [35]

Future MCC applications must leverage deep sensing capability of smartphones for data collection. Data can be uploaded to the cloud and the cloud can integrate pieces of observations from mobile devices and utilize data analytics techniques to mine and visualize trends or patterns embedded in massive data collected in parallel at runtime from millions of mobile devices. For instance, given a severe natural disaster, people nearby can send photos taken from the cameras in their smartphones to the cloud, and the cloud server can process these data, analyze possible crucial points, and plot a detailed map, covering not only visible objects but also invisible physical phenomena, such as the presence of poisonous air to help facilitating the rescue mission. With potentially unlimited storage and processing power, MCC brings out potential killer applications.

Crowdsourcing (crowd computing) is one of the emerging MCC applications [15]. It utilizes sensing functions of pervasive mobile devices and high processing capability of the cloud. Two future crowdsourcing applications discussed in [16] can potentially benefit from MCC. One is for finding a lost child; one is for disaster relief. In the first application, smartphones upload pictures taken within an hour to a website in response to an amber alert via texting, and a policeman searches for the lost child by doing data analytics on thousands of photos uploaded using an application in his smartphone.

In the second case, after a disaster the infrastructure around the disaster site is broken and there is no way to assess the damage using the existing infrastructure. By using cameras on smartphones, citizens take pictures of the disaster site and transmit them via wireless communication, helping a detailed map of the disaster site to be reconstructed, such that rescue work can be effectively and efficiently performed. Defining scalable architectures, creating efficient algorithms for crowdsourcing, stimulating crowd participation, and preserving user privacy are major issues. Yang et al. [17] devised two incentive mechanisms for user-centric and platform-centric computing.

On the user side, users contribute data through a bidding process to maximize their profits. On the cloud side, a game theoretical approach based on auctioning is used to maximize the system utility.

Another emerging and future mobile cloud application is collective sensing [18]. Cheng et al. designed SenseOrchestra [19] for node location tracking via collective sensing. Lu et al. [20] designed SoundSense to run in Apple iPhones to recognize events by collectively sound sensing. Lastly, Sensorly [21] provides a map of free wireless coverage through collective sensing by its mobile cloud members. Emerging collective sensing applications include composing a realtime traffic map from collective traffic data sensing [22, 23, 24], monitoring environmental pollution [25], mobile cloud social networking [26] [27] [28], and mobile cloud based healthcare [29, 30, 31].

Location-based mobile service is also an emerging MCC application. Tamai et al. [32] designed a platform for location-based services leveraging scalable computation and large storage space to answer a large number of location-based queries efficiently. Location-based mobile service is often context-aware. In addition to taking account of location information, location-based mobile services also consider the environment and application context, such as people, other devices and time between changes. The environment information can be feasibly obtained. Social networking can connect several people around sharing common interests. For example, the application can recommend an online game to play or a chat session connecting people with common interests. La et al. [33] developed a framework for location-based mobile service with user mobile devices monitoring the context information to send to the cloud and with the cloud analyzing and adapting the context information to suggest location-based mobile services to users sharing common interests.

Lastly, augmented reality and mobile gaming is emerging as a MCC killer application. While traditionally augmented reality is made possible only with special equipment with huge processing power, it is now made possible with mobile cloud computing with scalable computation and big data storage.

Kangas et al. [34] developed mobile code to be processed by the cloud to realize augmented reality. Luo [35] proposed an augmented reality application to enhance user experiences.

4.0 CONCLUSIONS

This paper surveys the challenges, scope, approaches and solutions in the area of Mobile Cloud Computing. The paper focusses on Energy conservation in mobile devices, migration issues, application development platforms and the various mobile cloud computing applications.

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