Mobile Cloud Computing: Introduction, Issues and Challenges

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Abstract-*Mobile Cloud Computing is evolving as a key computing platform for sharing resources that include infrastructures, softwares, applications, and business processes using mobile phones. Mobile Cloud Computing combines the advantages of cloud computing and mobile computing, and also it suffers from the challenges of mobile computing and cloud computing. In mobile cloud computing the internet based data, applications and other related services are accessed through smart phones, laptops, computers, tablets and other portable devices. Or in other words we can say that mobile cloud computing is a method or model where different apps which run on mobile are built, powered and hosted by cloud computing technology. Mobile devices need not have powerful configuration because all computations can be performed outside the mobile devices. In this paper we provide a detailed survey on mobile cloud computing research including issues and challenges, architecture, some existing approaches and future research direction.*

Keywords: *Cloud computing, Mobile Computing, Mobile Cloud computing, issues and challenges, Computation offload.*

1. INTRODUCTION

In recent years mobile devices such as smartphones, tablets, laptops, etc. are becoming an important and essential part of human life. These are the most effective and convenient communication tools which are not bounded by time and place. There are a lot of mobile applications, experienced by the mobile users, which run on the devices like laptops, tablets, etc or on remote servers via wireless networks. The rapid progress of mobile computing (MC) [1] has become a powerful trend in the development of IT technology as well as commerce and industry. Today's mobile applications are used in many fields like games, entertainment, health, business, social networking, travel, and news and so on. However, with a lot of facilities mobile devices are facing many problems and challenges also such as resources (like battery life, storage and bandwidth), and communication (like security and mobility) [2]. There are many real time applications such as location based social networking, GPS reading, speech synthesis, image processing for video games, augmented reality, natural language processing, warehouse computing, etc which demand high computational capacities and intensive computation resources. So it restricts the developers to develop and implement these applications into mobile phones, as these applications make mobile phones more bulky and consume more battery power.

In recent years these issues have been addressed by many researchers through cloud computing using computational offloading. In simple terms Cloud computing, which is also called 'on demand computing', 'utility computing' or 'pay- as- you- go computing', is defined as accessing third party software and services on web and paying as per usage. It facilitates scalability and virtualized resources over internet as a service providing cost effective and scalable solutions to customers. Cloud
Computing uses the concept of computation offloading where all the computations are done on the remote servers rather than on the mobile phone. The services provided by cloud computing are: software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS) [3].

Mobile Cloud Computing is defined as the integration of cloud computing into mobile computing. It includes the features of mobile computing and cloud computing and brings new types of services and facilities for the mobile users to take full advantages of cloud computing.

2. CLOUD COMPUTING

Cloud computing is an internet-based computing, through which shared resources, software and information are provided to computers and other devices on-demand basis, like the electricity grid [4]. For example, Amazon's Elastic cloud, Microsoft's Azure platform, Google's App Engine and Salesforce are some public clouds that are available today. Cloud computing is the advancement of traditional computing technology and network technology like grid computing, distributed computing, parallel computing and so on. The main objective of cloud

computing is to develop a perfect and powerful system through a large number of relatively low-cost computing entities, and using the advanced business models like SaaS (Software as a Service), PaaS (Platform as a Service), IaaS (Infrastructure as a Service) to distribute the powerful computing capacity to end users. It has many advantages like flexibility, disaster recovery, automatic software updation, increased collaboration, work from anywhere, document control. etc. Its deployment model includes public cloud, private cloud, hybrid cloud and community cloud.

3. MOBILE CLOUD COMPUTING

The Mobile Cloud Computing Forum defines MCC as follows [5]: "Mobile Cloud Computing refers to an infrastructure where both the data storage and the data processing happen outside of the mobile device. Mobile cloud computing uses the concept of computation offloading where all the computations are done at clouds and not in the mobile devices. Mobile users can save their data on mobile cloud and also retrieve those data from the cloud after completion of all processing at cloud. In this way we need not worry about the storage space and heavy configuration about the mobile device. Following figure defines the architecture diagram of mobile cloud computing:

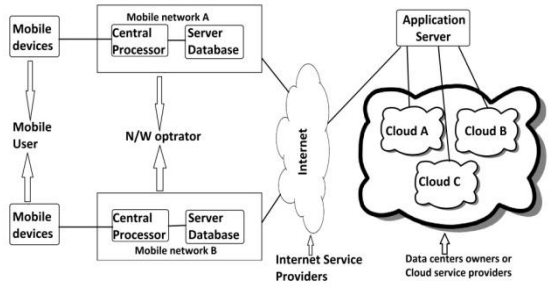

Fig 1. Architecture of Mobile Cloud Computing

Here mobile devices are connected via base station and functional interfaces between the networks and mobile devices. Mobile users request some information like id and location, and these information are transmitted to the central processor. The central processors are connected to servers which provide mobile network services. When mobile user's requests are authenticated and authorised, they are transferred to the cloud storage. In the cloud, cloud controllers process the requests to provide mobile users with the corresponding cloud services. Conceptually there are four layers in cloud computing architecture which are as follows:

1. SAAS (Software as a service)
2. PAAS (Platform as a service)
3. IAAS (Infrastructure as a service)
4. Data Centre layer

In SAAS layer, the users can access an application and information remotely via the internet and pay only for what they use. PaaS offers an advanced integrated environment for building, testing and deploying custom applications. IaaS enables the provision of storage, hardware, servers and networking components. Infrastructure can be expanded or shrunk dynamically as needed. And at the last the Data Center layer provides the hardware facility and infrastructure for clouds. In data centre layer, a number of servers are linked with high-speed networks to provide service for customers. Typically, data centres are built in less populated places, with high power supply stability and a low risk of disaster.

4. BENEFITS OF USING MOBILE CLOUD COMPUTING

1. Battery lifetime of a mobile device can be extended by using mobile cloud computing techniques. Some of the methods for extending battery lifetime are explained in [6], [7], [8], [9], [10] and [11]. Specially using computation offloading [10] and [11] power consumption can be reduced because this technique avoids taking a long application execution time on mobile devices which results in large amount of power consumption.

2. Another big constraint of mobile devices is storage capacity. With the help of mobile cloud computing the mobile device users can store or access their data or information on the mobile cloud through wireless networks. For example Facebook, Amazon simple storage service (S3), google+, etc. are the applications where mobile user can upload or access their photos and data.

3. The compute-intensive applications take long time and large amount of energy when performed on the limited-resource devices. Mobile cloud computing can be used to reduce the running cost for these types of applications because Cloud computing can efficiently support various tasks for data warehousing, managing and synchronizing multiple documents online.

4. Storing data or running applications on clouds is an effective way to improve the reliability since the data and application are stored and backed up on a number of computers. This reduces the chance data and application lost on mobile devices.

5. The nature of cloud computing is dynamic on-demand provisioning of resources on a fine grained, self service basis. And this is a flexible way for service providers and mobile users to run their applications without advance reservation of resources.

6. Service providers can easily add and expand an application and service without or with a little constraint on the resource usage. And also the deployment of mobile application can be scaled to

meet the unpredictable user demand due to flexible resource provisioning.

7. Service providers (e.g., network operator and data centre owner) can share the resources and costs to support a variety of applications and a large number of users.

8. Multiple services from different service providers can be integrated easily through the cloud and the internet to meet the users' demands.

5. Application of Mobile Cloud Computing

1. 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.

2. Multimedia sharing is another application which provides secure viewing and sharing of multimedia information stored on smart phones while providing administrative controls to manage user privileges and access rights necessary to ensure security.

3. Cloud based mobile learning allows a thin terminal to access learning materials on the cloud any time and any place. This learning solves the problem or limitations in terms of high cost of devices and network, low network transmission rate, and limited educational resources associated with traditional m-learning application without cloud storage.[12], [13] and [14]. For example, utilizing a cloud with a large storage capacity and powerful processing ability, the applications provide learners with much richer services in terms of data (information) size, faster processing speed, and longer battery life. In addition, a contextual m-learning system based on IMERA platform [15] shows that a cloud-based m-learning system helps learners access learning resources remotely. In [16], an education tool is developed based on cloud computing to create a course about image/video processing. Through mobile phones, learners can understand and compare different algorithms used in mobile applications (e.g., de-blurring, de-noising, face detection, and image enhancement).

4. Mobile cloud computing can be implemented in medical applications to reduce the limitations of traditional medical treatment like small physical storage, security and privacy and medical errors. [17], [18]. For example U. Varshney proposes five main mobile healthcare applications in the pervasive environment [19]. Similarly C. Doukas, T. Pliakas, and I. Maglogiannis proposes a prototype (HealthCloud) implementation of m-healthcare information management system which is based on cloud computing and a mobile client running Android operating system [20]. Another practical system (a telemedicine homecare management system), which is implemented in Taiwan, to monitor participants, especially for those patients with hypertension and diabetes [21].

5. There is a big market of mobile games (M-game) and it is a better way for service provider to generate revenues. M-Game can completely offload game engine which requires a large amount of computing resources to the cloud server. Here mobile game players only interact with the screen interface on their device. Z. Li, C. Wang, and R. Xu demonstrate that offloading can save energy for mobile devices, thereby increasing game playing time on mobile devices [22]. Also a new cloud-based m-game presented by S. Wang and S. Dey using a rendering adaptation technique. In this technique the game rendering parameters are dynamically adjusted according to communication constraints and gamer's demands [23].

6. A Cloud becomes a very useful tool for mobile users which helps to share their photos and video clips in popular social networks. There is a very popular MCC application "MeLog" that enables mobile users to share real time experiences over cloud through automatic blogging [24].

7. A cloud becomes most effective tool when mobile users require searching services for example, searching location, information, images, voices, videos and so on. Some searching mechanisms for this purpose are Keyword-base Searching [25], Voice-based Searching [26] and Tag-based Searching [27].

8. P. Angin, B. Bhargava, and S. Helal, have designed a very nice MCC application for the blind to detect traffic light [28] and Y-C. Li, I-J. Liao, H-P. Cheng and W-T. Lee, has proposed a cloud computing framework to monitor different corners in a house through a mobile device [29].

5. ISSUES AND CHALLENGES IN MOBILE CLOUD COMPUTING

Mobile cloud computing is a combination of mobile communication and cloud computing, so it has several advanced features than mobile computing and cloud computing but this technology also suffers from some technical issues. Some issues **are** identified by N. Fernando et al. [30] such as Operational level issues, End user level issues, Service and application level issues, Privacy, security and trust, Context-awareness and Data management.

1. Under operational issues technological matters such as offloading computations, cost benefit analysis that are used in taking decision to offload or not, mobility management: how the mobility of devices is managed or supported and connection protocols used such as Bluetooth, WiFi, 3G .and so on are analysed. Current research discusses offloading in three main directions: client-server communication methods,

Virtualization and Mobile Agents. Client server communication is stable and well supported APIs but it needs prior installation. It is very prone to network congestion and also not suited for disconnected operation. There is a need to do more work in these fields. In virtualization no code rewriting is needed so it reduces the burden on the programmer. However, VM migration is time consuming and the workload could prove to be heavy for mobile devices. There is also a compatibility issue between different VM overlays. The mobile agent is dynamically implemented and is much suitable for mobile and disconnected operations but it also suffers from some security issues and more work is required in security and fault tolerance with mobile agent.

Cost benefits analysis is also important to analyze the costs of offloading on to the cloud such as time, energy and monetary. Existing cost models in current mobile cloud computing systems mainly fall into three categories: history based profiling, parametric, and stochastic. Also the cost of cost-benefit analysis should also be considered along with analysing cost of offloading for optimal performance.

The design of intelligent mobility management techniques which support user mobility while providing a seamless service is also an important issue in mobile cloud computing. Majority of research has been done in this area including location management in wireless networks [31]. Work on localization primarily falls into either infrastructure based technique that uses GSM, WiFi, GPS, RFID and IR and so on, or peer based techniques for determining the position of a mobile device. A lot of models have been proposed in peer based technique but these do not work for more than two nodes. The infrastructure based techniques need additional infrastructure and dense deployment of access points for accurate results. Furthermore, these methods are energy consuming and hardly suit the conservative needs of mobile cloud devices. Also a number of research has been done in the area of mobility management via fault tolerance methods and via component and proxy migration but it is not a viable mechanism in the following cases; where mobile devices are resource providers themselves and are moving in ad-hoc manner, and where the mobile device offloads tasks to a local resource provider such as a cloudlet [32].

Current cloud computing research uses a variety of connection protocols for communication including WiFi, Bluetooth and 3G. The WiFi suffers from interoperability issue, security issue and limited connection issue. 3G consumes high energy, its bandwidth is limited and its performance is poor. And the main problem with Bluetooth is its limited range which is about 10 meters.

2. There is less research in the area of user interface because mobile devices span a large number of different platforms. It is very difficult and highly inconvenient to design and develop a separate user interface for each and every type of mobile device [33]. The display area of mobile devices is very small as compared to PCs in which the information and the way to present it for the user is problem. In addition, users of mobile cloud computing frameworks would also need some user level controls in the interface specific mobile clouds.

3. Service and application level issues relate to the factors concerned with performance measurements of the system and the quality of the service of the system. In this area how the data availability is ensured by the mobile cloud computing, what type of fault tolerance mechanisms are employed to ensure smooth execution and uninterrupted service and what type of libraries provided by the cloud APIs to support cloud application development for mobile devices are analyzed and discussed. Several approaches are discussed such as redundancy, proxy migration and resource tracking for meeting availability requirements.

4. There are so many security and privacy issues exists regarding mobile cloud computing. Many users keep their essential information like contacts, photos and calendar appointment on the mobile cloud due to limited storage capacity of mobile phones. These cloud services are stated to be vulnerable due to security breaches. And also security concerns that are specific to the mobile devices such as battery exhaustion attacks [34], Mobile BotNets and targeted attacks [35] should also be considered. The mobile devices equipped with GPS system suffer from privacy issues. Also some data related issues like integrity, authentication and digital rights management in mobile cloud computing are also considered.

5. It is important for the service provider to fulfill mobile users' satisfaction by monitoring their preferences and providing appropriate services to each of the users. A lot of research work **try** to utilize the local contexts (e.g., data types, network status, device environments, and user preferences) to improve the quality of service (QoS) such as Mobile service cloud (MSC) [36] and VOLARE [37].

6. It is very complex and difficult to manage data on the clouds for the cloud users and cloud providers. There are several issues regarding data management on the mobile cloud such as storing personal files, photos, contacts and also accessing those data to their mobile devices, data portability and interoperability. In the context of the mobile cloud, mobile databases need to be lightweight, and require the ability to download data from a remote repository and execute on this

data even in a disconnected state, and also should be able to synchronize the modified data during the downtime with the enterprise whenever the network becomes available again. Furthermore, databases for mobile clouds need to have a quick start up time since faults in mobile devices can be more frequent than for a fixed host. Security constraints regarding access and real time processing are also important.

With the above discussion some challenges are to be explored: How the mobile users support continuous mobility when they are connected to cloud? What type of fault tolerance methods can be implemented to reduce the possible failures? Many security and privacy techniques are proposed to ensure security and privacy in Mobile Cloud Computing but only some of them are implemented. So more attention is required in this area. When a user collaborates and shares his resources with other then how they are motivated. How they will be benefited with incentives? How will the credit be represented in mobile cloud? What will be the prices of resources and how will these be decided? How will monetary transactions proceed in a secure method?

6. CONCLUSION

Mobile cloud computing provides rich functionality to the mobile users as it combines the functionalities of mobile communication and cloud computing. In this paper we define the cloud computing, mobile cloud computing in detail. We also define benefits of MCC, some application area of mobile cloud computing such as mobile commerce, mobile learning, and mobile healthcare and so on. Apart from these some issues and challenges are also discussed such as security and privacy, data management, cost benefit analysis mobility management and so on. Besides this we have also discussed some research questions on which some attention is required.

7. REFERENCES

[1] M. Satyanarayanan, "Mobile computing: the next decade," in Proceedings of the 1st ACM Workshop on Mobile Cloud Computing & Services: Social Networks and Beyond (MCS), June 2010.
[2] M. Satyanarayanan, Fundamental challenges in mobile computing, in: Proceedings of the Fifteenth Annual ACM Symposium on Principles of Distributed Computing, PODC'96, ACM, New York, NY, USA, 1996, pp. 1–7.
[3] J. Carolan, S. Gaede, J. Baty, G. Brunette, A. Licht, J. Remmell, L. Tucker, J. Weise, "Introduction to cloud computing architecture—white paper", 2009.
[4] http://en.wikipedia.org/wiki/Cloud_computing.
[5] http://www.mobilecloudcomputingforum.com
[6] R. Kakerow, "Low power design methodologies for mobile communication," in Proceedings of IEEE International Conference on Computer Design: VLSI in Computers and Processors, pp. 8, January 2003.
[7] L. D. Paulson, "Low-Power Chips for High-Powered Handhelds," IEEE Computer Society Magazine, vol. 36, no. 1, pp. 21, January 2003.
[8] J. W. Davis, "Power benchmark strategy for systems employing power management," in Proceedings of the IEEE International Symposium on Electronics and the Environment, pp. 117, August 2002.
[9] R. N. Mayo and P. Ranganathan, "Energy Consumption in Mobile Devices: Why Future Systems Need RequirementsAware Energy Scale-Down," in Proceedings of the Workshop on Power-Aware Computing Systems, October 2003.
[10] A. Rudenko, P. Reiher, G. J. Popek, and G. H. Kuenning, "Saving portable computer battery power through remote process execution," Journal of ACM SIGMOBILE on Mobile Computing and Communications Review, vol. 2, no. 1, January 1998.
[11] A. Smailagic and M. Ettus, "System Design and Power Optimization for Mobile Computers," in Proceedings of IEEE Computer Society Annual Symposium on VLSI, pp. 10, August 2002.
[12] X. Chen, J. Liu*, J. Han, and H. Xu, " Primary Exploration of Mobile Learning Mode under a Cloud Computing Environment," in Proceedings of the International Conference on E-Health Networking, Digital Ecosystems and Technologies (EDT), vol. 2, pp. 484 - 487, June 2010.
[13] H. Gao and Y. Zhai, "System Design of Cloud Computing Based on Mobile Learning," in Proceedings of the 3rd International Symposium on Knowledge Acquisition and Modelling (KAM), pp. 293 - 242, November 2010.
[14] Jian Li, "Study on the Development of Mobile Learning Promoted by Cloud Computing," in Proceedings of the 2nd International Conference on Information Engineering and Computer Science (ICIECS), pp. 1, December 2010.
[15] C. Yin, B. David, and R. Chalon, "Use your mobile computing devices to learn - Contextual mobile learning system design and case studies," in Proceedings of the 2nd IEEE International Conference on Computer Science and Information Technology (ICCSIT), pp. 440, September 2009.
[16] R. Ferzli and I. Khalife, "Mobile cloud computing educational tool for image/video processing algorithms," in Digital Signal Processing Workshop and IEEE Signal Processing Education Workshop (DSP/SPE), pp. 529, March 2011.
[17] L. T. Kohn, J. M. Corrigan, and S. Donaldson, "To Err Is Human: Building a Safer Health System," NATIONAL ACADEMY PRESS Washington, 1999.
[18] D. Kopec, M. H. Kabir, D. Reinharth, O. Rothschild, and J. A. Castiglione, "Human Errors in Medical Practice: Systematic Classification and Reduction with Automated Information Systems," Journal of Medical Systems, vol. 27, no. 4, pp. 297 - 313, August 2003.
[19] U. Varshney, "Pervasive healthcare and wireless health monitoring," Journal on Mobile Networks and Applications, vol. 12, no. 2-3, pp. 113 - 127, March 2007.
[20] C. Doukas, T. Pliakas, and I. Maglogiannis, " Mobile Healthcare Information Management unitizing Cloud Computing and Android OS," in Annual International Conference of the IEEE on Engineering in Medicine and Biology Society (EMBC), pp. 1037 - 1040, October 2010.
[21] W-T. Tang, C-M. Hu, and C-Y. Hsu, "A mobile phone based homecare management system on the cloud," in Proceedings of the 3rd International Conference on Biomedical and Informatics (BMEI), vol. 6, pp. 2442, November 2010.
[22] Z. Li, C. Wang, and R. Xu, "Computation offloading to save energy on handheld devices: a partition scheme," in Proceedings of the 2001 international conference on Compilers, architecture, and synthesis for embedded systems (CASES), pp. 238 - 246, November 2001.
[23] S. Wang and S. Dey, "Rendering Adaptation to Address Communication and Computation Constraints in Cloud Mobile Gaming," in IEEE Global Telecommunications Conference (GLOBECOM), pp. 1-6, January 2011.
[24] H. Li and X-S. Hua, "Melog: mobile experience sharing through automatic multimedia blogging," in Proceedings of the

2010 ACM multimedia workshop on Mobile cloud media computing (MCMC), pp. 19-24, 2010.
[25] V. S. Pendyala and J. Holliday, "Performing Intelligent Mobile Searches in the Cloud Using Semantic Technologies," in IEEE International Conference on Granular Computing, pp. 381, September 2010.
[26] G. D. Fabbrizio, T. Okken, and J. G. Wilpon, "A speech mashup framework for multimodal mobile services," in Proceedings of the 2009 international conference on Multimodal interfaces (ICMI-MLMI), pp. 71-78, November 2009.
[27] Cai-Dong Gu, Kan Lu, Jian-Ping Wu, Ying-li Fu, Jing-xiang Li, Chang-shui Xiao, Mao-xin Si, and Zhao-bin Liu, "The Investigation of Cloud-Computing-based Image Mining Mechanism in Mobile Communication WEB on Android," in Proceedings of the 9th International Conference on Grid and Cooperative Computing (GCC), pp. 408, January 2011.
[28] P. Angin, B. Bhargava, and S. Helal, "A Mobile-Cloud Collaborative Traffic Lights Detector for Blind Navigation," in Proceedings of the 2010 Eleventh International Conference on Mobile Data Management (MDM), pp. 396-401, 2010.
[29] Y-C. Li, I-J. Liao, H-P. Cheng, and W-T. Lee, "A cloud computing framework of free view point real-time monitor system working on mobile devices," in International Symposium on Intelligent Signal Processing and Communication Systems (ISPACS), pp. 1, January 2011.
[30] N. Fernando, S. Loke, and W. Rahayu, "Mobile cloud computing: A survey," *Future Generation Computer Systems*, vol. 29, no. 1, pp. 84–106, 2012.
[31] I. Akyildiz, J. McNair, J. Ho, H. Uzunalioglu, W. Wang, Mobility management n next-generation wireless systems, Proceedings of the IEEE 87 (1999) 1347–1384.
[32] M. Satyanarayanan, P. Bahl, R. Caceres, N. Davies, The case for VM-based cloudlets in mobile computing, IEEE Pervasive Computing 8 (2009) 14–23.
[33] J.-H. Ye, J. Herbert, Interface tailoring for mobile computing devices, in: C. Stary, C. Stephanidis (Eds.), User-Centered Interaction Paradigms for Universal Access in the Information Society, in: Lecture Notes in Computer Science, vol. 3196, Springer, Berlin, Heidelberg, 2004, pp. 175–182. http://dx.doi.org/10.1007/978-3-540-30111-0_15.
[34] B. Moyers, J. Dunning, R. Marchany, J. Tront, Effects of Wi-Fi and Bluetooth battery exhaustion attacks on mobile devices, in: Proceedings of the 43rd Hawaii International Conference on System Sciences, HICSS, IEEE, 2010, pp. 1–9
[35] J. Oberheide, F. Jahanian, When mobile is harder than fixed (and vice versa): demystifying security challenges in mobile environments, in: Proceedings of the Eleventh Workshop on Mobile Computing Systems & Applications, HotMobile'10, ACM, New York, NY, USA, 2010, pp. 43–48.
[36] F. A. Samimi, P. K. Mckinley, and S. M. Sadjadi, "Mobile Service Clouds: A Self-Managing Infrastructure for Autonomic Mobile Computing Services," in Proceedings of the 2nd International Workshop on Self-Managed Networks, Systems & Services (SelfMan), vol. 3996, pp. 130-141, 2006.
[37] P. Papakos, L. Capra, and D. S. Rosenblum, "VOLARE: context-aware adaptive cloud service discovery for mobile systems," in Proceedings of the 9th International Workshop on Adaptive and Reflective Middleware (ARM), pp. 32-38, November 2010.