Mobile Cloud Computing: A reverberation in the field of Giant Computational Ubiquitous Network

Wani Irfan Ul Haq, Shailendra Narayan Singh

Abstract— **Mobile Cloud Computing (MCC) has revolutionized the way in which mobile subscribers across the globe leverage services on the go. The mobile cloud computing (MCC) has been introduced to be a potential technology for mobile services with an explosive growth of the mobile applications and emerging of cloud computing concept. In terms of storage ability, computation, enhanced feature support, mobile devices have been improving very quickly. Notwithstanding, these versatile applications are still naturally restricted by a relative absence of transmission capacity, processing force, and vitality contrasted with their fastened partners. This paper gives an overview of Mobile Cloud Computing, which helps users to have an outline of the MCC including the definition, architecture, and characteristics. The issues, existing solutions and approaches are presented. In addition, the future research directions of MCC are discussed.**

***Index Terms*— Cloud Computing, Mobile Computing, Mobile Cloud Computing, Issues in MCC, Research Directions.**

I. INTRODUCTION

There has been a significant development in various application models. Cloud computing is one of the emerging research topic through which various IT services and functionalities are delivered to the users as a utility to be sold "as a service". Cloud computing can be thought as the cluster of Personal computers providing the safe, reliable and convenient services to its client. The services offered by the cloud computing is provided on-demand in a self service fashion. According to the Gartner (a famous global analytical and consulting company), in the next 3-5 years cloud computing will be globally accepted by all the organizations and will have a high impact on the working of the various organization and enterprises [2]. According to the Sean Martson [1] one of the greatest achievement in the history of the computing is the evolution of the cloud computing in which the various hardware and software services are delivered on demand to the customers over the network. The end users simply log on to the network without installing the software and access the products and the services from the remote location.

The market of the mobile phones is rapidly increasing. According to the Cisco IBSG [3] mobile phones have revolutionized our lives and more than 80% of the world use mobile phones. Mobile phones are the effective means of communication connected to the internet through the rapidly growing wireless networks. Mobile users use the smart phones such as iPhone, palmtops & tablets and utilize the services from mobile application (e.g. iPhone apps, Google apps, etc.) irrespective of their location i.e. not bounded by time and space. The capability of mobile devices has also been largely increased through the use of sensing technology and better data exchange capabilities.

The combination of Cloud computing, wireless network technology & portable computing devices generates a new computational model namely Mobile Cloud computing which allows the user to access the unlimited storage space and have high computation power. Thus Mobile cloud computing (Fig 1) can be defined as:

"Mobile cloud computing is an infrastructure where both data processing and data storage takes place outside of the mobile devices."

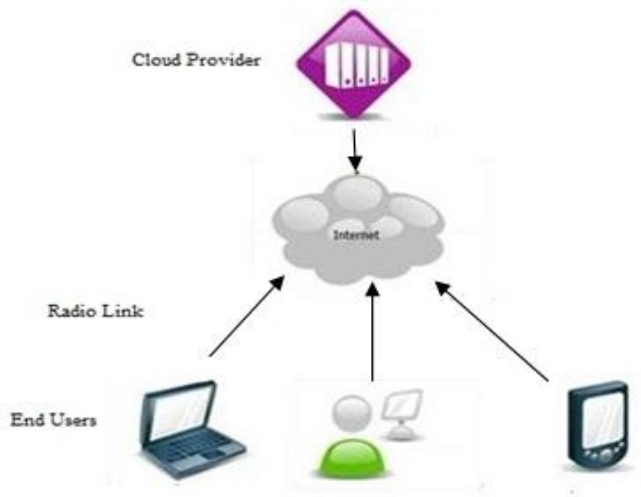

Fig 1: Mobile Cloud Computing

Thus MCC enriches the mobile user with the higher capabilities to utilize the services of the cloud computing to the fullest. Various applications have already been developed and served to the user. These applications include Googles Gmail, some Android applications, Live Mesh, MobileMe etc.

Inspite of the various benefits that a Mobile Cloud Computing has there are numerous challenges and problems. Although there are various developments in the field of Mobile hardware and networks, they are still less secure, resource poor and limited by battery life. The primary concern in Mobile Cloud Computing is to secure users privacy and integrity of applications and data. Since mobile cloud computing is a combination of mobile computing and cloud computing therefore we need to consider security issues of both mobile network user's and mobile cloud.

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II. OVERVIEW OF MOBILE CLOUD COMPUTING

The term MCC was introduced in 2009. The cost incurred in the development and running the mobile applications is highly reduced and thus has attracted the attentions of entrepreneurs. The mobile users achieve rich experience of mobile services at a low cost. The mobile users can leverage the services of the cloud computing even when they are on the go not bounded by time and space. Mobile users access the services on the cloud using a web browser. When the mobile user requests to the cloud the cloud management responds to the request by allocating the resource to the user and establish a connection. The other sections of the cloud ensure that the Quality of service is maintained until the connection is terminated.

A. Architecture

Fig 1 explained a general architecture. Fig 2 presents a more detailed architecture of Mobile Cloud Computing [4].

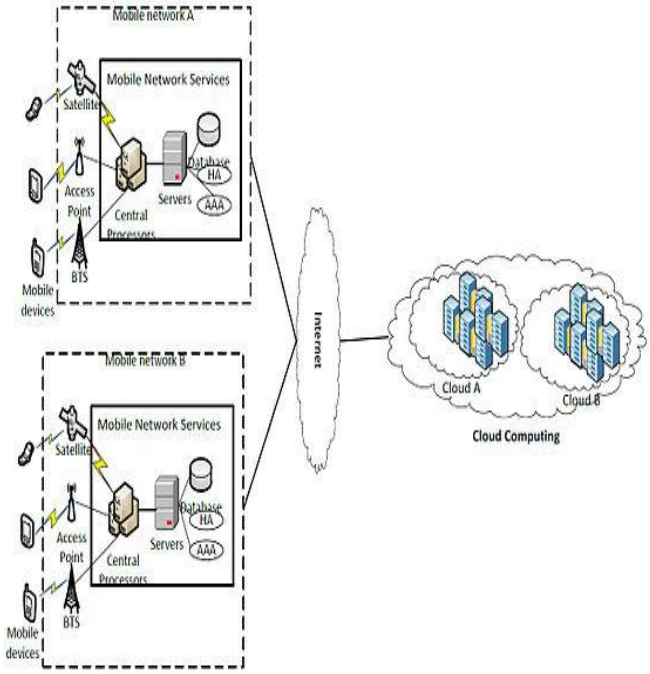

Fig 2: Mobile Cloud Computing architecture

As depicted in the Fig 2 base stations are used to connect the mobile nodes to the mobile network. The base stations may include BTS, access point, or satellite. These base stations are responsible for establishing and maintaining the connection between the mobile devices and the mobile network. It acts as an interface between the mobile nodes and mobile networks. Whenever a mobile user requests a service its request is transmitted to the central processor which in turn is connected to the servers. The users request is then sent to the cloud through the internet where the users request is processed and is allotted with the desired service. However depending on the type of context, the cloud architecture can be different for different context. In order to compare the cloud computing with the grid computing a four layer architecture is explained in [5]. Aneka (service oriented architecture) was introduces so that the developers can use APIs and multiple programming models to build .Net applications [6]. Alternately architectures for creating market-oriented clouds and web business services architecture is explained in [7] & [8] respectively.

The layered architecture of Mobile Cloud Computing is given below in Fig 3.

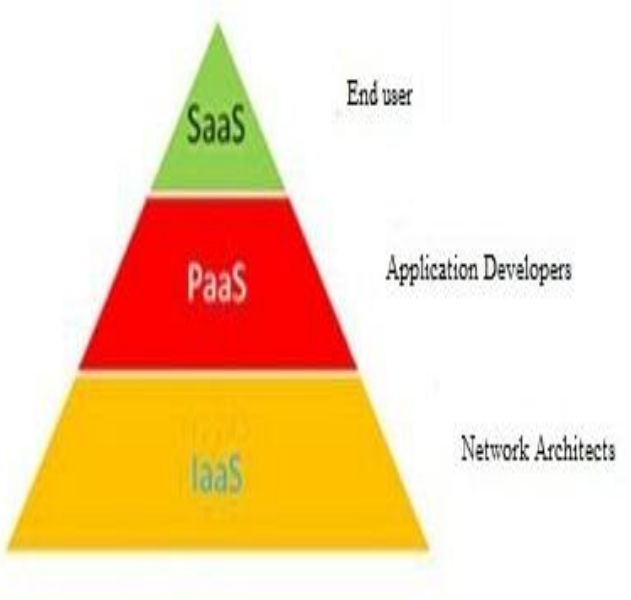

Fig 3: Layered Architecture.

1) *Software as a Service (SaaS):* The cloud infrastructure in software as a service (SaaS) is such that the applications running on a cloud is used by the consumer. A web browser is used to access the applications from various client devices and pay only for that they use. The mobile user that requests to the cloud does not manage or have any control on the cloud infrastructure. Salesforce, Microsoft's Live Mesh provides this service model.

2) *Platform as a Service (PaaS):* Platform as a service (PaaS) is a category of cloud computing services that provides a computing platform for building, testing and deploying applications. The cloud infrastructure in PaaS is not in the control of the consumer but can deploy on the cloud infrastructure using some programming language. The developers here need only to concentrate on developing their applications as the management is done by the service provider. PaaS is cost-effective, simple and robust but is complex of the three.

3) *Infrastructure as a Service (IaaS):* In Infrastructure as a service the deployment is done by the consumer. IaaS is also known as Hardware as a service (HaaS). The consumer here is also responsible for running arbitrary software. Here the consumer has control on the operating system and deployed application but has no control over the cloud infrastructure. In IaaS the organization outsources the equipment required to support the operations in delivering the service.

B. Characteristics

1) *Resource Pooling*: A cloud is a resource pool [9] where the consumer consumes large number of resources on demand. A model known as multi-tenant model enables the consumer to assigns and reassigns the resources depending on the demand and is used to serve multiple consumers. A web browser is used to access the data available on the cloud and the consumer has no knowledge about the location of the data.

2) *Reliability and usability:* The user need not to worry about their data present on the cloud as the data on the cloud is

safe from the virus, attacks and data loss. The cloud also provides the backup to the data in case of any failure on the cloud. It may also transfer the data to other machines in case it senses any failure. The cloud then performs a checkup to find the failure nodes to remove them from the cloud and resume the halted operation to its normal state. The cloud also has the capability to process the numerous requests coming from thousands of nodes. Thus in a large network cloud can be assumed to be available in the both axis i.e. horizontally and vertically.

3) *Autonomy:* Cloud system is an automated system. Here the resources on demand are automatically allocated to the consumer on pay per use basis. The computing capabilities are independent of the human involvement and are automatically assigned to the consumer depending on its need.

4) *Mobility:* In Mobile Cloud Computing environment MSS is used to establish the connection with both mobile nodes and fixed nodes even when they are not stationary.

5) *Multiple networks:* Depending on the bandwidth the mobile networks can either be wired or wireless.
The mobile networks with high bandwidth are wired while as the mobile networks with the low bandwidth are wireless.

6) *Low reliability:* MCC are not reliable as the signals involved are prone to snooping and interference. Therefore it is must to consider the mobile network system to address the security issue.

7) *Disconnection:* Mobile phones usually suffer from frequent disconnections due to the limitations incorporated in it. The poor battery life, low bandwidth etc. prevent the mobile phones from keeping the connection always.

III. ISSUES AND APPROACHES IN MCC

Effective utilization of the cloud resources is the primary goal of the mobile cloud computing. There are various factors that prevent from accessing the effective service from the cloud that include the limitation of both mobile devices and cloud infrastructure as well as the means of accessing the cloud services. Mobile cloud computing faces many technical challenges because of the integration of cloud computing and mobile networks.

A. Low Bandwidth

One of the main issue in the mobile cloud computing is that the resources in wireless networks is limited as compared to the wired networks.

A solution to this problem is to allow the mobile users who are in a certain area and interested in the same content [12] to share the same limited bandwidth. Each user is then allowed to transmit/exchange a portion of the video to the other consumer and there exist no transmission policy.

Another solution involves the allocation of available bandwidth among the shared users in a distributed manner i.e. as per the user's requirement [13]. It employs the use of MDP algorithm to create a decision table so as to collect the user profiles periodically.

B. Availability

One of the main issue in the MCC is the availability of the service. Problems such as network failures, traffic congestion or out of service may prevent a mobile phone to avail the services of the cloud.

A solution is to find the nodes who have failed and cannot establish a connection to the cloud. The target application is then changed and the mobile users can use its neighbouring nodes to connect to the cloud instead connecting directly to the cloud [14].

C. Heterogeneity

MCC is useful in a heterogeneous networks where mobile nodes use the cloud through radio access technologies such as WCDMA, GRPS, CDMA2000 and WLAN. Now here the problem in wireless connectivity occurs.

A solution is to provide architecture which delays effectively the heterogeneity of access networks using intelligent radio network access [15].

D. Resource Poverty

The battery limitations of mobile nodes is one of the major concern in the development of the mobile applications because with the development of the mobile devices (faster processors, sharper screens, inbuilt sensors) the capability of the smart phones in terms of battery life is reduced effectively. The users demand for applications that consume much of the battery life is increasing.

The solution is to enhance the CPU performance and to reduce the power consumption by managing the resources availability. Computation offloading avoids the mobile devices to take large execution time by migrating the large and complex processing from the mobile devices to the cloud infrastructure. According to Alenxey Rudenko [16] 50% of the power consumption can be reduced by the remote execution of large tasks. Also about 29% of the power consumption for computers can be saved if we transfer mobile components to the cloud(Eduardo Cuervo [17]).

E. Data Storage and Processing

Mobile phones suffer from the problem of having limited storage. This problem has been solved to major extent by MCC which permits the user to store the large amount of the data on the cloud. A few examples include Facebook which provides an unlimited storage to the users for sharing the images. Thus the mobile devices does not suffer from the limitation of storage capacity as the data is now available on the cloud.

F. Security

Just like standard computers, mobile devices also pose security threats. The threat detection services involve the intensive usage of resources in mobile devices. To prevent this we can move these detection services to the cloud and thus enrich with the benefits of better malicious software detection and reduced on-device resource consumption.
Security, availability and performance are the top three issues in the cloud computing that one must account for. Security holds the first position and is depicted in the Fig 4.

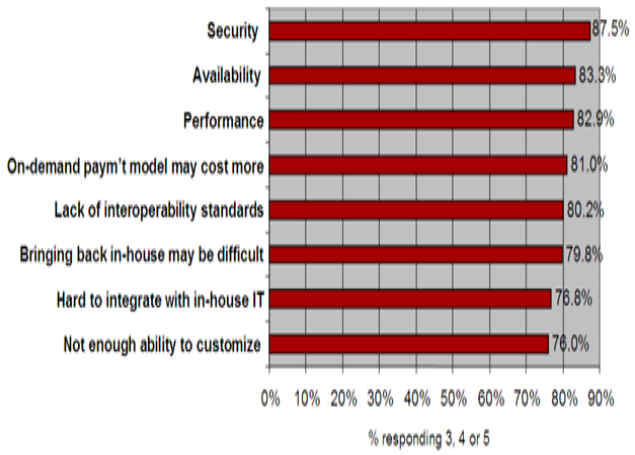

Fig 4: - Results of IDC survey ranking security challenges

IV. Open Research Issues

Various projects of Mobile cloud Computing have been already been deployed and there is still far away to go. Here are some of the research aspects that must be considered in future work.

A. Low Bandwidth

The bandwidth limitation is a big hurdle in Mobile Cloud Computing because the number of mobile and cloud users are rapidly increasing. To overcome this limitation we consider two emerging technologies i.e. 4G network and Femtocell.

1) *4G Network:* 4G network [18] significantly increases the bandwidth for the mobile subscribers and is capable of providing up to 100 Mbits/s. Widening mobile coverage area, smoothening quicker handoff, etc are some other advantages of 4G network.

2) *Femtocell:* Femtocell [19] is designed for use in a small area, consisting of small cellular base station. Cloud computing and Femtocells are combined to deliver a secure and economical network for mobile operators. It allows the resources to expand or contract depending on the users demand. Thus the additional resource is automatically added and the surplus resource is automatically removed. Femtocells connect to the cloud via the internet and the Mobile operators connect with the cloud via standards-based A and Gb interface
connections, providing access to their network when using a femtocell connected to cloud.

B. Task Division

Efforts are being made by researchers to find the optimal strategies and algorithms to offload computation tasks from mobile devices to cloud. Mobile device tasks are divided into multiple sub-tasks and some of them are made to run in cloud. Since the market is flooded with the variety of handsets and different application require different computational requirements an optimal strategy is this area is to be explored which could decide which one should be processed by cloud and which one by devices.

C. Better Service

The core objective of mobile cloud computing is to provide PC-like services to mobile terminals, but due to the differences in features between mobile devices and PCs, the transformation of the services from PCs' platform to mobile devices cannot be direct. Thus further effort should be made to find suitable interactive services for mobile devices.

D. Security

Security and privacy of data involved in Mobile Cloud Computing poses a serious issue because of the absence of the standards. Mobile Cloud Computing must have standard protocol, signaling, and interface for interaction between mobile users and cloud to ensure seamless services.

E. Quality of service

While requesting services and resources in the cloud, Mobile Cloud Computing may face some problems such as network disconnection, congestion due to the low bandwidths and the signal attenuation caused by mobile user's mobility and thus QoS is reduced significantly when users want to communicate with the cloud. To solve this problem two research directions are CloneCloud and Cloudlets.

1) *CloneCloud:* The power of cloud computing in your smart phones is highly increased by CloneCloud [20]. CloneCloud uses nearby computers or data centers to increase the speed of running mobile phone applications by cloning the entire set of data and applications from the smartphone onto the cloud. Smartphone can have multiple clones and clones pretend to be more powerful smartphones.

2) *Cloudlets:* A cloudlet is a cluster of computers which is connected to the internet and used by nearby mobile devices. Thus, a nearby cloudlet can be used when mobile devices do not want to offload to the cloud. The result is that the mobile users meet the one-hop, high-bandwidth wireless access to the cloudlet. A virtual machine is exploited on a nearby cloudlet to initiate customized service software and then use that service over a wireless LAN [21]. Thus cloud computing limitations such as WAN latency and low bandwidth can be overcomed with the help of this technology. But there are some considerations that need to be addressed before this idea is implemented such as how policies for the cloudlet can be managed? How trust and security for cloudlet can be attained?

F. Pricing

Mobile Cloud Computing services involve the usage of both cloud service provider (CSP) and mobile service provider (MSP). Due to the varying services management, methods of payment and prices of both MSP and CSP many issues such as step by step instructions to set cost, how the cost will be separated among distinctive entities, and how the customers pay may arise. For example the price paid by the game player playing the game on the cloud has to be divided among the three entities i.e. mobile service provider, game service provider (providing a game license), and cloud service provider.

V. CONCLUSION

Mobile Cloud Computing has become the hot research topic in the recent years. It is the fast growing technology as Mobile Cloud Computing is the extension and the development of Mobile Computing and Cloud Computing. According to the ABI Research, a New York-based firm, the revenue of mobile cloud computing will be pushed to $5.2 billion and more than 240 million business will use cloud services through mobile devices by 2015. This paper covers several representatives of mobile cloud approaches. The purpose of this paper is to give an overview of mobile cloud computing. It covers an

overview in which the definitions, architecture, and characteristics of mobile cloud computing have been presented. Various issues and approaches of Mobile Cloud Computing have also been discussed which clearly outlines the capabilities of Mobile Cloud Computing. Finally, open research issues and future research direction have been presented.

REFEENCES

[1] Sean Marston, Zhi Li, Subhajyoti Bandyopadhyay, Juheng Zhang, Anand Ghalsasi, "Cloud Computing – The business perspective", Decision Support Systems, Volume 51, Issue 1, Pages 176-189, 2011
[2] M. Cooney. (2011, Oct) Gartner: The top 10 strategic technology trends for 2012. [Online]. Available: http://www.networkworld.com/news/2011/101811-gartner-technology-trends-252100.html
[3] IBSG Cisco, "Mobile Consumers reach to the Cloud"
[4] Hoang T. Dinh, Chonho Lee, Dusit Niyato, and Ping Wang, "A survey of Mobile Cloud Computing: Architecture, Applications and Approaches", Wireless Communications and Mobile Computing, 2011
[5] I. Foster, Y. Zhao, I. Raicu, and S. Lu, "Cloud Computing and Grid Computing 360-Degree Compared," in Proceedings of Workshop on Grid Computing Environments (GCE), pp. 1, January 2009.
[6] C. Vecchiola, X. Chu, and R. Buyya, "Aneka: A Software Platform for .NET-Based Cloud Computing," Journal on Computing Research Repository (CORR), pp. 267 - 295, July 2009.
[7] R. Buyya, C. S. Yeo, S. Venugopal, J. Broberg, and I. Brandic, "Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility," Journal on Future Generation Computer Systems, vol. 25, no. 6, pp. 599 - 616, June 2009.
[8] Y. Huang, H. Su, W. Sun, J. M. Zhang, C. J. Guo, M. J. Xu, B. Z. Jiang, S. X. Yang, and J. Zhu, "Framework for building a low-cost, scalable, and secured platform for Web-delivered business services," IBM Journal of Research and Development, vol. 54, no. 6, pp. 535-548, November 2010.
[9] B. Rochwerger, D. Breitgand, E. Levy, A. Galis, K. Nagin, I. Llorente, R. Montero, Y. Wolfsthal, E. Elmroth, J. C´aceres *et al.*, "The reservoir model and architecture for open federated cloud computing," *IBM Journal of Research and Development*, vol. 53, no. 4, pp. 1–11, 2009.
[10] G. Boss, P. Malladi, D. Quan, L. Legregni, and H. Hall, "Cloud computing," *IBM white paper, Version*, vol. 1, 2007.
[11] L. Mei, W. Chan, and T. Tse, "A tale of clouds: paradigm comparisons and some thoughts on research issues," in *Asia-Pacific Services Computing Conference, 2008. APSCC'08. IEEE*. IEEE, 2008, pp. 464–469.
[12] X. Jin and Y. K. Kwok, "Cloud Assisted P2P Media Streaming for Bandwidth Constrained Mobile Subscribers," in Proceedings of the 16th IEEE International Conference on Parallel and Distributed Systems (ICPADS), pp. 800, January 2011.
[13] E. Jung, Y. Wang, I. Prilepov, F. Maker, X. Liu, and V. Akella, "User-profile-driven collaborative bandwidth sharing on mobile phones," in Proceedings of the 1st ACM Workshop on Mobile Cloud Computing & Services: Social Networks and Beyond (MCS), no. 2, 2010.
[14] G. Huerta-Canepa and D. Lee, "A virtual cloud computing provider for mobile devices," in Proceedings of the 1st ACM Workshop on Mobile Cloud Computing & Services: Social Networks and Beyond (MCS), no. 6, 2010.
[15] A. Klein, C. Mannweiler, and H. D. Schotten, "A Framework for Intelligent Radio Network Access Based on Context Models," in Proceedings of the 22nd WWRF meeting 2009, May 2009.
[16] 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, 2003
[17] E. Cuervo, A. Balasubramanian, Dae-ki Cho, A. Wolman, S. Saroiu, R. Chandra, and P. Bahl, "MAUI: Making Smartphones Last Longer with Code offload," in Proceedings of the 8th International Conference on Mobile systems, applications, and services, Pages: 49-62, 2010
[18] M. Rahman and F. A. M. Mir, "Fourth Generation (4G) Mobile Networks - Features, Technologies & Issues," in Proceedings of the 6th IEEE International Conference on 3G and Beyond, pp. 1, June 2007.
[19] J. Boccuzzi and M. Ruggiero, "Femtocells: design & application," McGraw-Hill, 2011.
[20] B. G. Chun, S. Ihm, P. Maniatis,M. Naik, and A. Patti, "CloneCloud: elastic execution between mobile device and cloud," in Proceedings of the 6th conference on Computer systems (EuroSys), pp. 301-314, April 2011.
[21] M. Satyanarayanan, P. Bahl, R. Caceres, and N. Davies, "The Case for VM-Based Cloudlets in Mobile Computing," IEEE Pervasive Computing, vol. 8, no. 4, pp. 14-23, October 2009.

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