A Review on Trends & Perspectives of Mobile Cloud Computing

Meenakshi Bhat, V.V Ravi Teja, Padmja B.

Abstract— Mobile Cloud Computing (MCC) which combines mobile computing and cloud computing, has become one of the industry buzz words and a major discussion thread in the IT world since 2009. As MCC is still at the early stage of development, it is necessary to grasp a thorough understanding of the technology in order to point out the direction of future research. With the latter aim, this paper presents a review on the background and principle of MCC, characteristics, recent research work, and future research trends. A brief account on the background of MCC: from mobile computing to cloud computing is presented and then followed with a discussion on characteristics and recent research work. It then analyses the features and infrastructure of mobile cloud computing. The rest of the paper analyses the challenges of mobile cloud computing, summary of some research projects related to this area, and points out promising future research directions.

Index Terms— Mobile Computing, Cloud Computing, Mobile Cloud Computing, Mobile Cloud Architecture, Quality of Service

1 INTRODUCTION

Nowadays, cellular systems are faced with drastic changes and great challenges. The rapid penetration of smart phones and tablets has triggered an exponential growth of mobile data traffic in the past few years. In response, both academia and industry have been devoted to enhancing the capacity of existing cellular systems with dense small
cells, high-frequency bands, and novel transmission technologies such as massive multiple-input multiple-output (MIMO). It is anticipated that through these enhancements,
the next-generation (5G) cellular system can have
1000× capacity and 100× transmission rate compared to 4G (Release 8) systems.We have hardly managed to accommodate billions of mobile devices before an even greater number of machines are already waiting to communicate with each other. Over the past few years, advances in the field of network based computing and applications on demand have led to an explosive growth of application models such as cloud computing, software as a service, community network, web store, and so on. As a major application model in the era of the Internet, Cloud Computing has become a significant research topic of the scientific and industrial communities since 2007. Commonly, cloud computing is described as a range of services which are provided by an Internet-based cluster system.
Such cluster systems consist of a group of low-cost servers or Personal Computers (PCs), organizing the various resources of the computers according to a certain management strategy, and offering safe, reliable, fast, convenient and transparent services such as data storage, accessing and computing to clients. The core technology of cloud computing is centralizing computing, services, and specific applications as a utility to be sold like water, gas or electricity to users. Thus, the combination of a ubiquities mobile network and cloud computing generates a new computing mode, namely
Mobile Cloud Computing.

- *Meenakshi Bhat is currently working as an assistant professor in school of electronics and electrical engineering in Lingaya's University, India, E-mail: menakshibhat@yahoo.co.in*
- *V.V Ravi Teja is currently pursuing B.tech desgree program in electronics & Communication engineering in Lingaya's University, India. E-mail: tejaravi957@gmail.com*
- *Padmja B. is currently pursuing B.tech desgree program in electronics & Communication engineering in Lingaya's University, India. E-mail:*

2 MOBILE COMPUTING

Mobile Computing is a technology that allows transmission of data, voice and video via a computer or any other wireless enabled device without having to be connected to a fixed physical link. The main concept involves −

- Mobile communication
- Mobile hardware
- Mobile software.

Mobile computing is human–computer interaction by which a computer is expected to be transported during normal usage, which allows for transmission of data, voice and video. Mobile computing involves mobile communication, mobile hardware, and mobile software. Communication issues include ad hoc networks and infrastructure networks as well as communication properties, protocols, data formats and concrete technologies. Hardware includes mobile devices or device components. Mobile software deals with the characteristics and requirements of mobile applications.

Principles of Mobile Computing

- Portability: Facilitates movement of device(s) within the mobile computing environment.
- Connectivity: Ability to continuously stay connected with minimal amount of lag/downtime, without being affected by movements of the connected nodes
- Social Interactivity: Maintaining the connectivity to collaborate with other users, at least within the same environment.
- Individuality: Adapting the technology to suit individual needs.
- Portability: Devices/nodes connected within the mobile computing system should facilitate mobility. These devices may have limited device capabilities and limited power supply, but should have a sufficient processing capability and physical portability to operate in a movable environment.
- Connectivity: This defines the quality of service (QoS) of the network connectivity. In a mobile computing system, the network availability is expected to be maintained at a high level with the minimal amount of lag/downtime without being affected by the mobility of the connected nodes.
- Interactivity: The nodes belonging to a mobile computing system are connected with one another to communicate and collaborate through active transactions of data.
- Individuality: A portable device or a mobile node connected to a mobile network often denote an individual; a mobile computing system should be able to adopt the technology to cater the individual needs and also to obtain contextual information of each node.

3 CLOUD COMPUTING

Cloud computing is a type of *Internet-based computing* that provides shared computer processing resources and data to computers and other devices on demand. It is a model for enabling ubiquitous, on-demand access to a shared pool of configurable computing resources (e.g., computer networks, servers, storage, applications and services), which can be rapidly provisioned and released with minimal management effort. Cloud computing and storage solutions provide users and enterprises with various capabilities to store and process their data in either privately owned, or third-party data centres that may be located far from the user–ranging in distance from across a city to across the world. Cloud computing relies on sharing of resources to achieve coherence and economy of scale, similar to a utility (like the electricity grid) over an electricity network. Advocates claim that cloud computing allows companies to avoid up-front infrastructure costs (e.g., purchasing servers). As well, it enables organizations to focus on their core businesses instead of spending time and money on computer infrastructure.

The word "cloud" is commonly used in science to describe a large agglomeration of objects that visually appear from a distance as a cloud and describes any set of things whose details are not further inspected in a given context. Another explanation is that the old programs that drew network schematics surrounded the icons for servers with a circle, and a cluster of servers in a network diagram had several overlapping circles, which resembled a cloud. In analogy to the above usage, the word *cloud* was used as a metaphor for the Internet and a standardized cloud-like shape was used to denote a network on telephony schematics. Later it was used to depict the Internet in computer network diagrams.

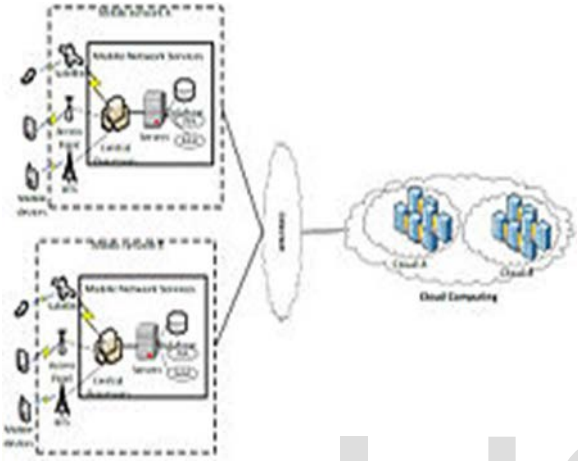
4 MOBILE CLOUD COMPUTING

Concept and principle

Similar with Cloud Computing, there are a lot but no consensual definitions on what mobile cloud computing is. In this paper, we consider it is a novel computing mode
consisting of mobile computing and cloud computing, which provide cloud based services to users through the Internet and mobile devices. On one hand, the mobile cloud computing is a development of mobile computing, and an extension to cloud computing. In mobile cloud computing, the previous mobile device-based intensive computing, data storage and mass information processing have been transferred to 'cloud' and thus the requirements of mobile devices in computing capability and resources have been reduced, so the developing, running, deploying and using mode of mobile applications have been totally changed. On the other hand, the terminals which people used to access and acquire cloud services are
suitable for mobile devices like smart phone, PDA, Tablet, and iPad but not restricted to fixed devices (such as PC), which reflects the advantages and original intention of cloud computing. Therefore, from both aspects of mobile computing and cloud computing, the mobile cloud computing is a combination of the two technologies, a development of distributed, grid and centralized algorithms, and have broad prospects for application. As shown is the Fig, mobile cloud computing can be simply divided into cloud computing and mobile computing. Those mobile devices can be laptops, PDA, smart phones, and so on. which connects with a hotspot or base station by 3G, WIFI, or GPRS. As the computing and major data processing phases have been migrated to 'cloud', the capability requirement of mobile devices is limited, some low-cost mobile devices or even non-smart phones can also achieve mobile cloud computing by using a cross-platform mid-ware. Although the client in mobile cloud computing is changed from PCs or fixed machines to mobile devices, the main concept is still cloud computing. Mobile users send service re-

quests to the cloud through a web browser or desktop application, then the management component of cloud allocates resources
to the request to establish connection, while the monitoring and calculating functions of mobile cloud computing will be implemented to ensure the QoS until the connection is completed.

5 ARCHITECTURE



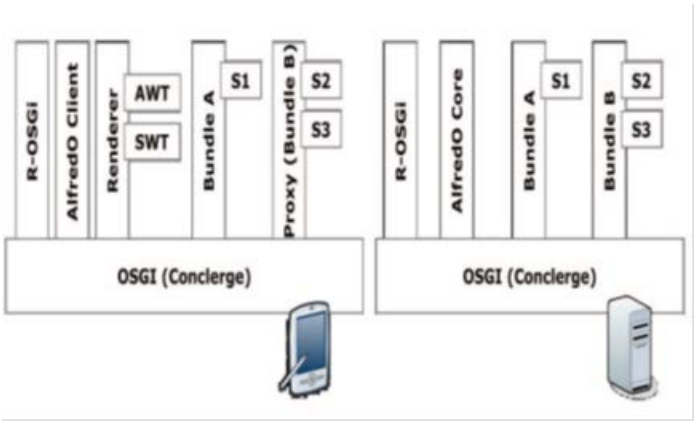
MOBILE CLOUD ARCHITECTURE

MCC uses computational augmentation approaches (computations are executed remotely instead of on the device) by which resource-constraint mobile devices can utilize computational resources of varied cloud-based resources. In MCC, there are four types of cloud-based resources, namely distant immobile clouds, proximate immobile computing entities, proximate mobile computing entities, and hybrid (combination of the other three model). Giant clouds such as Amazon EC2 are in the distant immobile groups whereas cloudlet or surrogates are member of proximate immobile computing entities. Smart phones, tablets, handheld devices, and wearable computing devices are part of the third group of cloud-based resources which is proximate mobile computing entities.

Vodafone, Orange and Verizon have started to offer cloud computing services for companies. to bring rich computational resources to mobile users, network operators, as well as cloud computing providers. The ultimate goal of MCC is to enable execution of rich mobile applications on a plethora of mobile devices, with a rich user experience. MCC provides business opportunities for mobile network operators as well as cloud providers. More comprehensively, MCC can be defined as "a rich mobile computing technology that leverages unified elastic resources of varied clouds and network technologies toward unrestricted functionality, storage, and mobility to serve a multitude of mobile devices anywhere, anytime through the channel of Ethernet or Internet regardless of heterogeneous environments and platforms based on the pay-as-you-use principle."

6 RELATED WORK

So far, industrial and scientific communities have been doing various researches for responding to the above challenges.
Some typical research projects and cases are presented in the following.
1) Augmented Execution: So far, industrial and scientific communities have been doing various researches for responding to the above challenges. Some typical research projects and cases are presented in the following. Clone Cloud is introduced by B. Chun in 2011. The core method is using virtual machine migration technology to
offload execution blocks of applications from mobile devices to Clone Cloud seamlessly and partly, in order to fully or
semi-automatically extend or modify the Smartphone-based execution to a distributed environment (smart phone computing
plus cloud computing.
2) *Elastic Applications:* In order to provide a more effectively mobile cloud application, researchers have developed and extended Clone Cloud-based algorithms using dynamically migrating partition of applications to the remote server in cloud. Alfred is a middleware platform to automatically distribute different layers of application in smart phones and cloud, respectively, by modeling applications as a consumption graph, and finding the optimal modules. The test result shows that such platform improves the performance of applications in cloud computing effectively. AlfredO system consists of three bundles (the interface encapsulation on Java classes and services): AlfredOClient and Renderer on the client and AlfredOCore on the server.



3) Migration Optimization: As the mobility feature in mobile devices, provide a seamless migration environment for data transmission or service guarantee has becoming another hot issue in mobile cloud computing research. An optimal migration mechanism can reduce interaction delay,
enhance processing capability, and improve user's experience effectively.

7 CHALLENGES

In the MCC landscape, an amalgam of mobile computing, cloud computing, and communication networks (to augment smart phones) creates several complex challenges such as Mobile Computation Offloading, Seamless Connectivity, Long WAN Latency, Mobility Management, Context-Processing, Energy Constraint, Vendor/data Lock-in, Security and Privacy, Elasticity that hinder MCC success and adoption.

OPEN RESEARCH ISSUES

Although some projects of mobile cloud computing have already been deployed around the world, there is still a long way for business implementation, and some research aspects should be considered in further work.

A. Data delivery

Due to the feature of resource-constrains, mobile devices have potential challenges in cloud accessing, consistent accessing, data transmission, and so on. Such challenges can be solved using: special application (service) and middle-ware (provide a platform for all mobile cloud computing systems).

B. Task division

Researchers divide tasks (applications) from mobile devices into multiple sub-tasks and deliver some of them to run in cloud, which is a good solution to the resource limited mobile devices. However, we do not have an optimal strategy or
algorithm on how to divide these tasks, which one should be processed by cloud and which one by devices.

C. Better service

The original purpose of mobile cloud computing is providing PC-liked services to mobile terminals. However, as the existing different features between mobile devices and PCs, we cannot directly transplant the services from PCs' platform
to mobile devices. Therefore, further research should try to identify the method on how to provide suitable and friendly interactive services for mobile devices.

8 CONCLUSION

With the high increasing of data computation in commerce and science, the capacity of data processing has been considered as a strategic resource in many countries. Mobile cloud computing (MCC), as a development and extension of mobile
computing (MC) and cloud computing (CC), has inherited the high mobility and scalability, and become a hot research topic in recent years. We conclude that there are three main optimization approaches in MCC, which are focusing on the limitations of mobile devices, quality of communication, and division of applications services. Firstly, using virtualization and image technology can address it effectively, and immigrate task from terminal to cloud is also a good way to achieve better results. Secondly, as we know the quality of communication in wired network is better than in wireless network, so reducing the proportion of data delivery in wireless environment is an effective way to improve the quality.

9 REFERENCES

[1] Cisco, "Cisco Visual Networking Index: Forecast and Methodology, 2013–2018," June10,2014; http://www.cisco.com/c/en/us/solutions/collateral/service provider/ip-ngn-ip-next-generation-network/white_paper_c11-481360.html

[2] S. Lien, K. Chen, and Y. Lin, "Toward Ubiquitous Massive Accesses in 3GPP Machine-to-Machine Communications," *IEEE Commun. Mag.*, vol. 49, no. 4, 2011, pp. 66–74.

[3]. S. Sun *et al.*, "Interference Management through CoMP in 3GPP LTE-Advanced Networks," *IEEE Wireless Commun.*, vol. 20, no. 1, 2013, pp. 59–66.

[4] S. Zhou *et al.*, "CHORUS: A Framework for Scalable Collaboration in Heterogeneous Networks with Cognitive Synergy," *IEEE Wireless Commun.*, vol. 20, no. 4, 2013,
pp. 133–39.

[5] C. I *et al.*, "Toward Green and Soft: A 5G Perspective," *IEEE Commun. Mag.*, vol. 52, no. 2, 2014, pp. 66–73.

[6] China Mobile Research Inst., "C-RAN: The Road Towards Green RAN (v. 3.0)," June 13, 2014; http://labs.chinamobile.com/cran/wp-content/uploads/2014/06/20140613-C-RAN-WP-3.0.pdf

[7] Y. Lin *et al.*, "Wireless Network Cloud: Architecture and System Requirements," *IBM J. Research and Development*, vol. 54, no. 1, 2010, pp. 4:1–4:12.

[8] Z. Zhu *et al.*, "Virtual Base Station Pool: Towards a Wireless Network Cloud for Radio Access Networks," *Proc. 8th ACM Int'l. Conf. Computing Frontiers*, Ischia,

Italy, 2011.
[9]. G. Zhai *et al.*, "Load Diversity Based Optimal Processing Resource Allocation for Super Base Stations in Centralized Radio Access Networks," *SCIENCE CHINA Info. Sciences*, vol. 57, no. 4, 2014, pp. 1–12.
[10]. J. Liu, *et al.*, "On the Statistical Multiplexing Gain of Virtual Base Station Pools," *Proc. IEEE GLOBECOM '14*, to be published.
[11] ETSI, "Network Functions Virtualization: An Introduction, Benefits, Enabler, Challenges & Call for Action," Oct.22-24,2012; http://portal.etsi.org/NFV/NFV_White_Paper.pdf [12] Z. Niu *et al.*, "Energy Efficiency and Resource Optimized Hyper-Cellular Mobile Communication System Architecture and Its Technical Challenges," *SCIENCE CHINA Info. Sciences*, vol. 42, no. 10, 2012, pp. 1191–1203.
[13] T. Zhao *et al.*, "Software Defined Radio Implementation of Signaling Splitting in Hyper-Cellular Network," *Proc. 2nd Wksp. Software Radio Implementation Forum*, in conjunction with ACM SIGCOMM '13, Hong Kong, China, 2013, pp. 81–84.
[14] H. Ishii, Y. Kishiyama, and H. Takahashi, "A Novel Architecture for LTE-B :C-Plane/U-Plane Split and Phantom
Cell Concept," *Proc. Int'l. Wksp. Emerging Technologies or LTE-Advanced and Beyond-4G*, in conjunction with IEEE GLOBECOM '12, CA, 2012.
[15] M. Felemban *et al.*, "A Distributed Cloud Architecture for Mobile Multimedia Services," *IEEE Network*, vol. 27, no. 5, 2013, pp. 20–27.
[16] S. Chetan, G. Kumar, K. Dinesh, K. Mathew, and M. Abhimanyu, "Cloud computing for mobile world," *available at chetan. ueuo. com*.
[17] B. Chun, S. Ihm, P. Maniatis, M. Naik, and A. Patti, "Clonecloud: Elastic
execution between mobile device and cloud," in *Proceedings of the sixth
conference on Computer systems*. ACM, 2011, pp. 301–314.
[18] X. Zhang, A. Kunjithapatham, S. Jeong, and S. Gibbs, "Towards an elastic application model for augmenting the computing capabilities of mobile devices with cloud computing," *Mobile Networks and Applications*, vol. 16, no. 3, pp. 270–284, 2011.
[19] Y. Lu, S. Li, and H. Shen, "Virtualized screen: A third element for cloud-mobile convergence," *Multimedia, IEEE*, vol. 18, no. 2, pp. 4–11, 2011.
[20] I. Giurgiu, O. Riva, D. Juric, I. Krivulev, and G. Alonso, "Calling the cloud: Enabling mobile phones as interfaces to cloud applications," in *Proceedings of the ACM/IFIP/USENIX 10th international conference on Middleware*. Springer-Verlag, 2009, pp. 83–102.
[21] G. Alonso, J. Rellermeyer, and T. Roscoe, "R-osgi: Distributed applications
through software modularization," *IFIP Lecture Notes in Computer Science (LNCS)*, vol. 4834, no. 4834, pp. 1–20, 2011.
[22] S. Jeong, X. Zhang, A. Kunjithapatham, and S. Gibbs, "Towards an elastic application model for augmenting computing capabilities of mobile platforms," *Mobile Wireless Middleware, Operating Systems, and Applications*, pp. 161–174, 2010.
[23] M. Satyanarayanan, P. Bahl, R. Caceres, and N. Davies, "The case for vm-based cloudlets in mobile computing," *Pervasive Computing, IEEE*,
vol. 8, no. 4, pp. 14–23, 2009.
[24] E. Marinelli, "Hyrax: cloud computing on mobile devices using mapreduce,"
DTIC Document, Tech. Rep., 2009.