

## SURVEY ON MOBILE CLOUD COMPUTING

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**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. Mobile cloud computing is one of the technology essential in today's mobile environment run by using mobile devices in cloud environment. It combines the features of both mobile computing and cloud computing, thereby provides optimal services to the users of mobile devices. 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.*

**Keywords:** *Mobile Cloud Computing; Mobile Computing; Cloud Computing.*

### I. INTRODUCTION

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. According to the top ten strategic technology trends for 2012 [1] provided by Gartner (a famous global analytical and consulting company), cloud computing has been on the top of the list, which means cloud computing will have an increased impact on the enterprise and most organizations in 2012. One of the hottest research topics is Internet of Things (IoT). Smartphones, tablets and mobile terminals make a large part of the interconnected devices, but mobility comes with restrictions on physical dimensions, computing power, battery autonomy and power use. As the world goes mobile, the existence of these hard limits gets in direct conflict with the users' expectations and needs of a constant and predictable performance increase for all computing devices. On the mobile end, users requires more processing power and more autonomy. On the other hand, the infrastructure required to support the mobile services keeps expanding and its energy use develops with it. The small increases in energy efficiency did little to alleviate the constant growth in global power usage. The shift to mobile

was shown to be accompanied by problems such as Insufficient resources, limited battery capacity and limits in network connectivity [5]. Decreasing applications' response time, efficient batter use of battery power and available network bandwidth are the main challenges for the future of mobile applications. Mobile cloud computing is a solution for overcoming the barriers encountered by the rapid expanse of mobile use. Mobile cloud computing resides at the intersection of mobile computing and cloud computing. It is a major research topic for Information Technology and Communications (IT&C), shifting the point of use of computing resource from the end consumer to the resource reaches data centers.

### II. BACKGROUND

As a development and extension of Cloud Computing and Mobile Computing, Mobile Cloud Computing, as a new phrase, has been devised since 2009. In order to help us grasp- ing better understanding of Mobile Cloud Computing, let's start from the two previous techniques: Mobile

#### A. Computing and Cloud Computing.

Cloud Computing Cloud computing is the delivery of computing services over the Internet on the pay-per-use basis. The cloud-computing model allows access to information and resources on anytime and anywhere basis. Cloud services are very useful as it includes online file storage, social networking, webmail, and online business applications etc. By using these services, businesspersons can use software and hardware that are managed by third parties at remote locations[2]. Cloud computing provides a shared pool of resources, including data storage space, networks, specialized corporate and user applications also. Cloud computing related to computer science services and describes a type of outsourcing the computer services, without worrying about from where it is? And from how it is? One has to only pay for what they consumed. The idea behind cloud computing is similar: The user can simply use storage, computing power, or specially crafted development environments, without worrying about its internal working. Cloud computing is usually Internet-based computing which hides complex infrastructure of the internet [16]. It is a style of computing in which IT-related capabilities and services are provided "as a service", allowing users to access their needed technology or services from the Internet without gaining knowledge of it, or control over the technologies behind servers providing services. Cloud computing delivers computing resources over the Internet, instead of keeping data on your own hard drive and offers us freedom to use a service over the Internet, at another location, to store your information or for using its its applications.

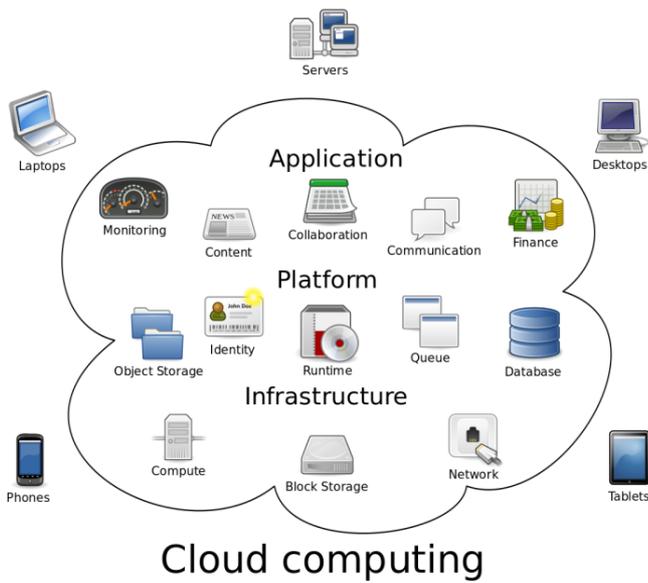


Fig 1 cloud computing

Features: the features of Cloud Computing are as follows:

- a) Virtualization: the 'Cloud' can be considered as a virtual resource pool, where all bottom layer hardware devices is virtualized. End users access desired resources through a browser and get data from cloud computing providers without maintaining their own data centers. Furthermore, some virtual machines (VMs) are often installed in a server in order to improve the efficiency to use resources; and such VMs support load migration when there is a server over-load.
  - b) Reliability, usability and extensibility: cloud computing provides a safe mode to store user's data while users do not worry about the issues such as software updating, leak patching, virus attacks and data loss. If failure happens on a server or VM, the cloud computing systems transfer and backup those data to other machines, and then delete those failure nodes from the systems automatically in order to make sure the whole system has normal operation [10]. Meanwhile, cloud can be extended from horizontal and vertical [11] in a large-scale network, to process numerous requests from thousands of nodes and hosts.
  - c) Large-scale: in order to possess the capability of supercomputing and mass storage, a cloud computing system normally consists of thousands of servers and PCs. Google Cloud Computing, for example, has already controlled 2% of all servers or about 1 million servers located in two hundred different places in the world, and will move upward to 10 million servers in the next decade [13].
  - d) Autonomy: a cloud system is an autonomic system, which automatically configures and allocates the resources of hardware, software and storage to clients on-demand, and the management is transparent to end users.
- 3) Challenges: first of all, cloud computing needs an improved mechanism to provide a safe and high efficiency service as the numerous invoked third-party software and infrastructures are implementing in computing. In addition, due to data centers of resource using a mass of electricity, efficient resource scheduling strategy and methods are required in order to save

energy. Furthermore, as a Service Level Agreement (SLA) is established between users and service providers in cloud computing, so the performance and analysis of services are necessary to be monitored. Last but not least, simple and convenient application interfaces are indispensable for service providers in cloud computing, thus a uniform standard is required eagerly.

**B. Mobile Computing** Mobility has become a very popular word and rapidly increasing part in today's computing area. An incredible growth has appeared in the development of mobile devices such as, smartphone, PDA, and laptops with a variety of mobile computing, networking and security technologies. In addition, with the development of wireless technology and internet it becomes much easier and not limited by the particular office or home or organizations [3]. Thus, more and more people have accepted those mobile devices and gives support to rise in the technology of mobile computing. Mobile computing is described as a form of human-computer interaction by which a computer is expected to be transported during normal usage [12].

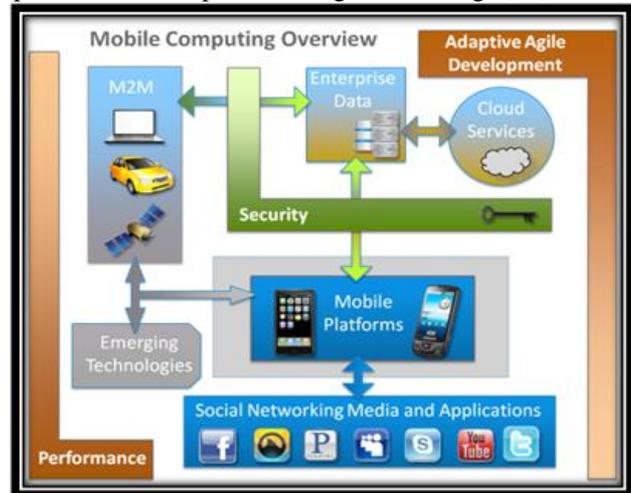


Fig 2: Mobile Computing

Mobile computing can be said as the collection of three major concepts: hardware, software and communication. The concepts of hardware are dependent on mobile devices, such as Smartphone and laptop, or their mobile components. The second concept of Software in mobile computing is the numerous mobile applications in the particular hardware devices, such as the mobile browser, anti-virus software and games stored at remote distance on some other servers. Finally, the communication issue includes the infrastructure of mobile networks, protocols and data delivery in their use, which must be transparent to end users. With the use of the cloud-computing concept, it is easier to develop mobile computation somewhat easier.

### III. MOBILE CLOUD COMPUTING

**Mobile Cloud Computing.** In the beginning, mobile cloud computing was defined as a restricted computing paradigm that considers interactions between only mobile devices and public cloud services. Later, due to the instability of mobile devices as well as wireless networks, more types of platforms and computing resources were introduced to

mobile cloud computing to achieve seamless mobile cloud services [4]. An overview of the HMC service environment is shown in Fig 3.

Based on the previous definitions and new demands, we define mobile cloud computing as follows: Mobile cloud computing is a computing paradigm that enables resource on strained mobile devices to utilize heterogeneous computing resources (e.g., public clouds, private clouds, and MANETs) over multiple types of wireless networks (e.g., cellular network, WiFi, Bluetooth, and Femtocell) to provide mobile device users with a seamless, on-demand, and scalable mobile service that has rich user experience. The term "cloud" in mobile cloud computing refers to multiple types of computing resources. A brief classification of different clouds follows.

- Infrastructure-based cloud. The infrastructure refers to public cloud services including IaaS, PaaS, and SaaS. The mobile device only outsources its computation and storage to the public cloud services via WiFi or cellular network.
- Cloudlet-based cloud. Cloudlet refers to a "trusted, resource-rich form-factor computer that is well-connected to the Internet and available for use by nearby mobile devices (Satyanarayanan et al. 2009)." Cloudlets are deployed as middle layer servers between a public cloud and mobile devices to reduce network latency.
- Mobile device cloud. This refers to a MANET, which consists of a set of mobile devices connected to each other via short-range wireless networks such as WiFi-direct and Bluetooth in dynamic topologies, with no support of networking infrastructure (Conti and Giordano 2014). A mobile device cloud can further reduce the data transmission overhead and provide augmentation services in case WLAN or public cloud services are unavailable.

*Features: the features of mobile computing are as follows:*

**mobility:** mobile nodes in mobile computing network can establish connection with others, even fixed nodes in wired network through Mobile Support Station (MSS) during their moving.

**Diversity of network conditions:** normally the networks using by mobile nodes are not unique, such networks can be a wired network with high-bandwidth, or a wireless Wide Area Network (WWAN) with low-bandwidth, or even in status of disconnected.

**Frequent disconnection and consistency:** as the limitation of battery power, charge of wireless communication, network conditions and so on, mobile nodes will not always keep the connection, but disconnect and consistent with the wireless network passively or actively.

**Dis-symmetrical network communication:** servers and access points and other MSS enable a strong send/receive ability, while such ability in mobile nodes is quite weak comparatively. Thus, the communication bandwidth and overhead between downlink and uplink are discrepancy.

**Low reliability:** due to signals is susceptible to interference and snooping, a mobile computing network system has to be considered from terminals, networks, database platforms, as well as applications development to address the security issue.

**Challenges:** Compared with the traditional wired network,

mobile computing network may face various problems and challenges in different aspects, such as signal disturbance, security, hand-off delay, limited power, low computing ability, and so on. due to the wireless environment and numerous mobile nodes. In addition, the Quality of Service (QoS) in mobile computing network is much easier to be affected by the landforms, weather and buildings.

Nowadays, both hardware and software of mobile devices get greater improvement than before, some smart phones such as iPhone 4S, Android serials, Windows Mobile serials and Blackberry, are no longer just traditional mobile phones with conversation, SMS, Email and website browser, but are daily necessities to users. Meanwhile, those smart phones include various sensing modules like navigation, optics, gravity, orientation, and so on. which brings a convenient and intelligent mobile experience to users. In 2010, Google CEO Eric Schmidt described mobile cloud computing in an interview that 'based on cloud computing service development, mobile phones will become increasingly complicated, and evolve to a portable super computer' [15]. In the face of various mobile cloud services provided by Microsoft, Apple, Google, HTC, and so on, users may be confused about what mobile cloud computing exactly is, and what its features are.

**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 smartphone, 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. 3, mobile cloud computing can be simply divided into cloud computing and mobile computing. Those mobile devices can be laptops, PDA, smartphones, 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-smartphones 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[9]. Mobile users send service requests 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.

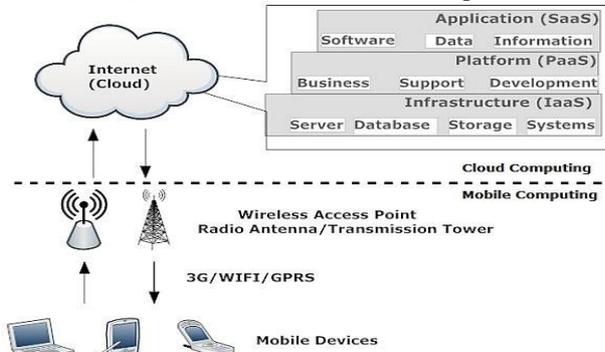


Fig. 3: Architecture of Mobile Cloud Computing

Challenges and solutions

The main objective of mobile cloud computing is to provide a convenient and rapid method for users to access and receive data from the cloud, such convenient and rapid method means accessing cloud computing resources effectively by using mobile devices. The major challenge of mobile cloud computing comes from the characters of mobile devices and wireless networks, as well as their own restriction and limitation, and such challenge makes application designing, programming and deploying on mobile and distributed devices more complicated than on the fixed cloud devices [16]. In mobile cloud computing environment, the limitations of mobile devices, quality of wireless communication, types of application, and support from cloud computing to mobile are all important factors that affect assessing from cloud computing. Table 2 gives an overview of proposed challenges and some solutions about mobile cloud computing.

*Limitations of mobile devices:* While discussing mobile devices in cloud the first thing is resource-constrain. Though smartphones have been improved obviously in various aspects such as capability of CPU and memory, storage, size of screen, wireless communication, sensing technology, and operation systems, still have serious limitations such as limited computing capability and energy resource, to deploy complicated applications[8]. By contrast with PCs and Laptops in a given condition, these smartphones like iPhone 4S, Android serials, Windows Mobile serials decrease 3 times in processing capacity, 8 times in memory, 5 to 10 times in storage capacity and 10 times in network bandwidth.

Normally, smartphone needs to be charged everyday as dialling calls, sending messages, surfing the Internet, community accessing, and other internet applications. According to past development trends, the increased mobile computing ability and rapid development of screen technology will lead to more and more complicated applications deployed in smartphones. If the battery technology cannot be improved in a short time, then how to

effectively save battery power in smartphone is a major issue we meet today.

The processing capacity, storage, battery time, and communication of those smartphones will be improved consistently with the development of mobile computing. However, such enormous variations will persist as one of major challenges in mobile cloud computing.

*Quality of communication:* In contrast with wired network uses physical connection to ensure bandwidth consistency, the data transfer rate in mobile cloud computing environment is constantly changing and the connection is discontinuous due to the existing clearance in network overlay. Furthermore, data centre in large enterprise and resource in Internet service provider normally is far away to end users, especially to mobile device users. In wireless network, the network latency delay may 200 ms in 'last mile' but only 50

- Upgrade bandwidth for wireless connection, make the web content more suitable for mobile network using regional data centres.
- Deploy the application processing node at the 'edge' of cloud in order to reduce data delivery time.
- Duplicate mobile devices to cloud using virtualization and image technologies, to process Data-Intensive Computing (DIC) and Energy-Intensive Computing, such as virus scanning in mobile devices.

Dynamically optimize application push in cloud and the division with mobile terminals

TABLE I: Challenges and Solutions of Mobile Cloud Computing

Research Paper Title	Challenges	solutions	Remarks
Mobile Cloud Computing: Review, Trend and Perspectives[1]	Quality of communication	Bandwidth upgrading, Data delivery, time reducing	RESEARCH ARTICLE
	Limitations of mobile devices	Virtualization and Image, Task migration	
Mobile Cloud Computing: Its Challenges and Solutions	Division of applications	Elastic application division mechanism	RESEARCH-2015
	Lack of Resource of Mobile Devices: Comparing mobile device with older desktop PC shows that how the cost features of mobility is being achieved. As there is lack of resources makes it hard for the adoption of mobile cloud computing in general conditions.	For overcoming this limitation of mobile devices and there resources, they are added to the cloud infrastructure so that they can be used on anytime on anywhere basis makes it easy for most of advanced applications. As the mobile device performances, and the resource constraints of mobile devices going on increasing and fixed devices will remain and must be accounted for the types of application selected for mobile cloud computing.	
	computation power problem	Mobile cloud convergence is the technique that provides performance improvement and solution to the computation power problem. For this there is a partition of application takes place such that parts that need more computation run on the cloud and run on the mobile device. Wireless technologies, advanced electronics and internet are important to achieve pervasive and ubiquitous computing	
A Novel Approach for Reduce Energy Consumption in Mobile Cloud Computing [6]	Interoperability issue becomes a major challenge in pulling pushing data across multiple devices.	Applications that are run on mobile cloud infrastructure should be supported by certain mobile cloud infrastructure that can easily be judged possibly on the basis of its requirements against the cloud infrastructure characteristics. Along with the device, network bandwidth and latency vectors should perform computation intensity, network bandwidth, and network latency properly.	Research October 2015
	The low confidence due to consider hypothetical situations	Reducing accuracy requirements in positioning 2. Determine exact time and place in order to turn on GPS	
Energy Efficient Task Scheduling in Mobile Cloud Computing [7]	The task scheduler is limited in some cases and requires selecting profile	Using compression techniques in order to reduce data volume	IFIP International Federation for Information Processing 2013

#### IV. APPLICATIONS

With the rise in sales of mobile devices and increasing development in the field of mobile cloud computing, mobile applications have gained a growing share in the global mobile market. Some of the applications of mobile computing are as follows:

A. Mobile commerce M-Commerce is a business model for commerce through mobile devices. It was developed to provide the capabilities of commerce by means of wireless technology. The commerce applications are divided into three categories finance, purchase and advertising. With the help of m-commerce, banks and other financial institutions allow their users to access their account information and carry out transactions like buying of stocks, paying money etc. Stock market services allow people to respond to the stock market changes at any time irrespective of their location. Mobile vouchers, coupons, tickets etc. can be sent to the users via their mobile phones. The users are then able to use these vouchers or tickets by showing their mobile phone at the ticket counter thus making the whole process a lot quicker and simpler. Mobile advertising is the advertisements that are sent to mobile phones. Companies have reported that a better response is received through mobile marketing campaigns than traditional campaigns. Thus, this promises to be a big area of advertising in the future.

B. Mobile gaming Mobile gaming (m-game) is a burgeoning market that is generating revenues for service providers. M-game can completely free game engines requiring large computing resources (e.g., graphic rendering) to the server in the cloud allowing gamers to only interact with the screen interface on their mobile devices[14]. Techniques are being developed to reduce the energy consumption of the mobile devices and thus to increase the gaming time on the mobile devices along with the performance of the mobile application. The main goal is to maximize the user experience.

C. Mobile healthcare In healthcare environments, mobile computing devices help in faster and simpler access of data, thus resulting in better care of the patients. Mobile healthcare (m-healthcare) enables patients to be monitored at any time, any place through wireless technology. Also, health-aware mobile devices can detect pulse rate, blood pressure to alert the emergency system. Furthermore, m-healthcare allows patients or other health-care organizations to access the current and past medical data at the tip of their fingers. Mobile computing devices create more free space, less clutter and lower costs, while delivering more services more efficiently, with a lower error rate through linking with electronic health systems.

D. Other Uses Mobile cloud computing also helps mobile users to share photos and videos with people on popular social networking websites like Facebook and twitter. Mobile users are also provided with cloud services such as map and other applications that provide location-based services like finding the local whether, road traffic or nearby restaurants.

#### V. 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., thereby providing optimal services for mobile users. According to a recent study, more than 240 million businesses will use cloud services through mobile devices by 2015. That traction will push the revenue of mobile cloud computing to \$5.2 billion. With this importance, this article has provided an overview of mobile cloud computing in which its definitions, architecture, and advantages have been presented. The applications supported by mobile cloud computing including mobile commerce, mobile learning, and mobile healthcare have been discussed which clearly show the applicability of the mobile cloud computing to a wide range of mobile services. Then, the issues and related approaches for mobile cloud computing (i.e., from communication and computing sides) have been discussed. Finally, the future research directions have been outlined.

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