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Mobile Cloud Computing: World's Leading Technology for Mobile Devices

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Abstract— Mobile cloud computing (MCC) has been introduced as a new paradigm for mobile applications and it is a universal term for anything that involves delivering hosted any kind of services which includes cloud computing as a middleware, like as mobile-healthcare, mobile learning, mobile-entertainment, etc. over the Internet. Mobile cloud computing is the usage of cloud computing in combination with mobile devices or mobility hardware. This paper gives a survey of MCC, which helps general readers to have a brief account of MCC: from mobile computing to cloud computing and then followed by MCC definition, architecture, advantages and applications.

Keywords— Cloud Computing, Mobile Computing, Mobile Cloud Computing (MCC).

I. INTRODUCTION

At the present, mobile devices are increasing rapidly, since they are the easiest and the most effective communication tools. In addition, their crucial role in human life, when and where to use them are not restricted (called ETEW1) [1]. Mobile users can use different applications on their devices or receive even different kinds of services through wireless networks distantly. With increasing propagation of mobile devices technology, the popularity of this device has also increased. Some features such as mobility, optimized and easy to use are of the benefits of mobile devices. Nevertheless, the challenges of the resources of mobile devices (such as short battery life, small memory capacity and low bandwidth) and also of communication (such as mobility and data security) are the reasons for the decrease of service quality.

Mobile devices allow users to run powerful applications that take advantage of the growing availability of built-in sensing and better data exchange capabilities of mobile devices. As a result, mobile applications seamlessly integrate with real time data streams and Web 2.0 applications, such as mashups, open collaboration, social networking and mobile commerce. The mobile execution platform is being used for more and more tasks, e.g., for playing games; capturing, editing, annotating and uploading video; handling finances; managing personal health, micro payments, ticket purchase, interacting with ubiquitous computing infrastructures. Even mobile device hardware and mobile networks continue to evolve and to improve, mobile devices will always be resource-poor, less secure, with unstable connectivity, and with less energy since they are powered by battery. Resource poverty is major obstacle for many applications. Therefore, computation on mobile devices will always involve a compromise. Mobile devices can be seen as entry points and interface of cloud online services. Recently, it has been discussed what cloud computing really means. The cloud computing paradigm is often confused about its capabilities, described as general term that includes almost any kind of outsourcing of hosting and computing resources. According to NIST [2] cloud computing is a model for enabling convenient, on-demand network access to computing resources that can be rapidly provisioned and released with minimal management effort. The combination of cloud computing, wireless communication infrastructure, portable computing devices, location-based services, mobile Web, etc., has laid the foundation for a novel computing model, called mobile cloud computing, which allows users an online access to unlimited computing power and storage space.

II. MOBILE COMPUTING

What is Mobile computing exactly? In Wikipedia, it is described as a form of human-computer interaction by which a computer is expected to be transported during normal usage. Mobile computing is based on a collection of three major concepts: hardware, software and communication. The concepts of hardware can be considered as mobile devices, such as smartphone and laptop, or their mobile components. Software of mobile computing is the numerous mobile applications in the devices, such as the mobile browser, anti-virus software and games. The communication issue includes the infrastructure of mobile networks, protocols and data delivery in their use. They must be transparent to end users.

A. Features

1) Mobility: In mobile computing network, mobile nodes can establish connection with others, even fixed nodes in wired network through Mobile Support Station (MSS) during their movement.

2) Diversity of Network Conditions: Normally the networks used 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.

3) Frequent Consistency and Disconnection: 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.

4) Dis-symmetrical Network Communication: Access point's servers and other MSS enable a strong receive/send ability, while such ability in mobile nodes is quite weak

comparatively. Thus, the communication bandwidth and overhead between downlink and uplink are discrepancy.

5) 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.

B. 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.

III. CLOUD COMPUTING

Cloud computing is a term for technologies that providing computation power, software, data access, and storage services that do not require end-users knowledge of the physical locations and configurations of the system that delivers the services. Cloud Services refers to software functions exposed as WS on the Internet, also called Web API. For e.g., some services that provides information about the closest city based on geo co-ordinates. In this paper we have shown "Mobile Cloud Computing" architecture which uses Cloud-hosted middleware to support mobile clients consuming Web Services (Cloud Services). The architecture enhances the interaction between mobile clients and Web Services and provides a personal service mash up platform for mobile clients.

A. Framework:

Cloud computing systems actually can be considered as a collection of different services, thus the framework of cloud computing is divided into three layers, which are infrastructure layer, platform layer, and application layer (see Fig. 1).

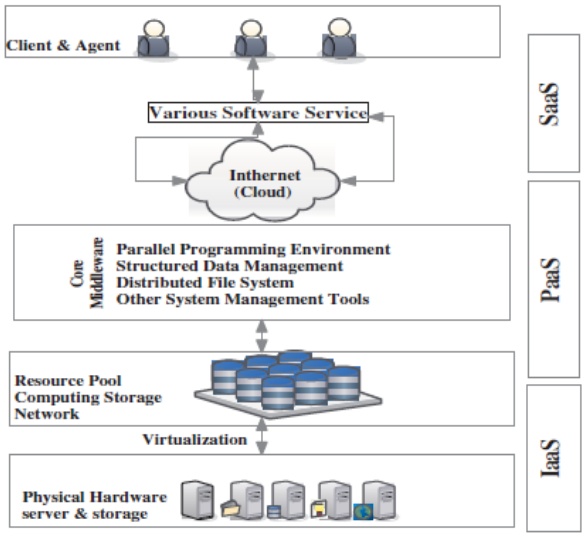

Fig. 1 Framework of Cloud Computing

1) Infrastructure Layer: It includes resources of computing and storage. In the bottom layer of the framework, physical devices and hardware, such as servers and storages are virtualized as a resource pool to provide computing storage and network services users, in order to install operation system (OS) and operate software application. Thus it is denoted as Infrastructure as a Service (IaaS). Typically services in this layer such as Elastic Computing Cloud of Amazon [3].

2) Platform Layer: This layer is considered as a core layer in the cloud computing system, which includes the environment of parallel programming design, distributed storage and management system for structured mass data, distributed file system for mass data, and other system management tools for cloud computing. Program developers are the major clients of the platform layer. All platform resources such as program testing, running and maintaining are provided by the platform directly but not to end users. Thus, this type of services in a platform layer is called Platform as a Service (PaaS). The typical services are Google App Engine [4] and Azure from Microsoft [5].

3) Application Layer: It provides some simple software and applications, as well as costumer interfaces to end users. This type of services in the application layer is named as Software as a Service (SaaS). Users use client software or a browser to call services from providers through the Internet, and pay costs according to the utility business model (like water or electricity) [6]. The earliest SaaS is the Customer Relationship Management (CRM) [7] from Sales force, which was developed based on the force.com (a PaaS in Sales force). Some other services provided by Google on-line office such as presentations, documents, spread sheets are all SaaS.

Although the cloud computing architecture can be divided into three layers, it does not mean that the top layer must be built on the layer directly below it. For example, the SaaS application can be deployed directly on IaaS, instead of PaaS. Also, some services can be considered as a part of more than one layer. For example, data storage service can be viewed as either in IaaS or PaaS. Given this architectural model, the users can use the services flexibly and efficiently.

B. Essential Characteristics

1) On-demand self-service: A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service's provider.

2) Resource Pooling: The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. There is a sense of location independence in that the customer generally has no control or knowledge over the exact location of the provided resources but may be able to specify location at a higher level of virtuality (e.g., country, state, or data center). Examples of resources include storage, processing, memory, network bandwidth, and virtual machines.

3) Broad Network Access: Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, laptops, and PDAs).

4) Rapid Elasticity: Capabilities can be rapidly and elastically provisioned, in some cases automatically, to quickly scale out, and rapidly released to quickly scale in. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be purchased in any quantity at any time.

5) Measured Service: Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported, providing transparency for both the provider and consumer of the utilized service. [8]

C. Figures and Tables

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.

mobile cloud computing

The Mobile Cloud Computing Forum defines MCC as follows [9]: "Mobile Cloud Computing at its simplest refers to an infrastructure where both the data storage and the data processing happen outside of the mobile device. Mobile cloud applications move the computing power and data storage away from mobile phones and into the cloud, bringing applications and mobile computing to not just smartphone users but a much broader range of mobile subscribers". Aepona [10] describes MCC as a new paradigm for mobile applications whereby the data processing and storage are moved from the mobile device to powerful and centralized computing platforms located in clouds. These centralized applications are then accessed over the wireless connection based on a thin native client or web browser on the mobile devices.

Alternatively, MCC can be defined as a combination of mobile web and cloud computing, which is the most popular tool for mobile users to access applications and services on the Internet. Briefly, MCC provides mobile users with the data processing and storage services in clouds. The mobile devices do not need a powerful configuration (e.g., CPU speed and memory capacity) since all the complicated computing modules can be processed in the clouds.

A. Architecture of Mobile Cloud Computing

From the concept of MCC, the general architecture of MCC can be shown in Fig.2. In Fig. 2, mobile devices are connected to the mobile networks via base stations (e.g., base transceiver station (BTS), access point, or satellite) that establish and control the connections (air links) and functional interfaces between the networks and mobile devices. Mobile users' requests and information (e.g., ID and location) are transmitted to the central processors that are connected to servers providing mobile network services. Here, mobile network operators can provide services to mobile users as AAA (for authentication, authorization, and accounting) based on the home agent (HA) and subscribers' data stored in databases. After that, the subscribers' requests are delivered to a cloud through the Internet. In the cloud, cloud controllers process the requests to provide mobile users with the corresponding cloud services.

These services are developed with the concepts of utility computing, virtualization, and service-oriented architecture (e.g., web, application, and database servers). The details of cloud architecture could be different in different contexts. For example, four-layer architecture is explained in [11] to compare cloud computing with grid computing.

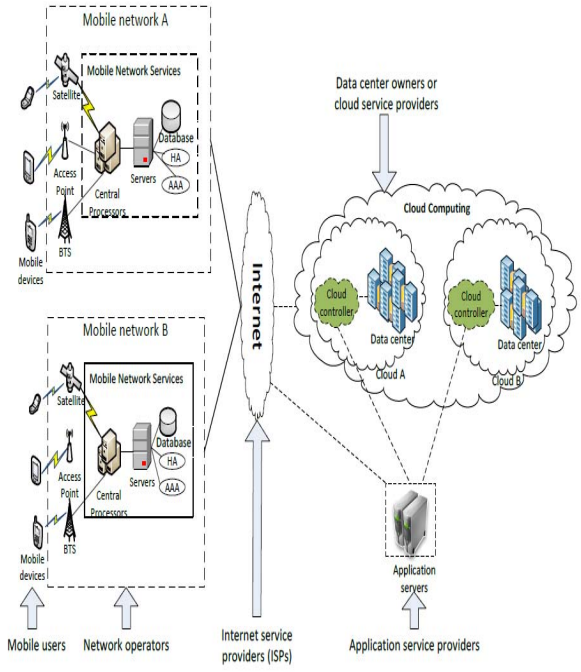

Figure.2: Mobile Cloud Computing (MCC) Architecture

Alternatively, service oriented architecture, called Aneka, and is introduced to enable developers to build .NET applications with the supports of application programming interfaces (APIs) and multiple programming models [12]. [13] Presents architecture for creating market-oriented clouds, and [14] proposes architecture for web delivered business services.

IV. CHALLENGES AND SOLUTIONS

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. 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 1 gives an overview of challenges and some solutions about mobile cloud computing.

TABLE 1: CHALLENGES & SOLUTIONS OF MCC

Challenges	*Solutions*
Limitations of mobile devices	Virtualization and Image, Task migration
Quality of communication	Bandwidth upgrading, Data delivery time reducing
Division of applications services	Elastic application division mechanism

V. ADVANTAGES

A. Improving Processing Power and Data Storage Capacity

One of the main constraints for mobile devices is also storage capacity; MCC is developed to enable mobile clients to store or access the large amount of data on the cloud through wire-less networks. First example is the Amazon S3 (Simple Storage Service) [15] which supports file storage service. Another example is Image Exchange which utilizes the large storage space in clouds for mobile clients [16]. This mobile photo sharing service enables mobile clients to upload images to the clouds immediately after capturing. Mobile users may access all images from any devices. With the cloud, the clients can save considerable amount of energy and storage space on their mobile devices because all images are sent and processed on the cloud side. Flicker [17] and ShoZu [18] is also the successful mobile photo sharing applications based on MCC. Facebook [19] is the most successful social network application today, and it is also a typical example of using cloud in sharing images.

Mobile cloud computing also helps in reducing the running cost for compute-intensive applications that take long time and large amount of energy when performed on the limited-resource devices. Cloud computing can efficiently support various tasks for data ware housing, managing and synchronizing multiple documents online. For example, clouds can be used for transcoding, playing chess, or broadcasting multimedia services to mobile devices. In these things, all the complex calculations for transcoding or offering an optimal chess move that take a long time when perform on mobile devices will be processed efficiently on the cloud. Mobile applications also are not constrained by storage capacity on the devices because their data now is stored on the cloud.

B. Improved Reliability

Storing data/information or running applications on clouds is an effective way to improve the reliability because the data and application are stored and back-up on a number of computer systems. This one reduces the chance of data and application lost on the mobility devices. In addition, M.C.C. can be designed as a comprehensive data security model for both service providers and mobile clients. For example, the cloud can be used to protect copyrighted digital contents (e.g., video-clip, and music) from being abused and unauthorized distribution. Also, the cloud can remotely provide to mobile clients with security services such as virus scanning, authentication and malicious code detection. Also, such cloud-based security services can make efficient use of the collected record from different users to improve the effectiveness of the services.

C. Extending Battery Lifetime

Mobile devices battery is one of the main concerns for mobile devices. Numerous solutions have been proposed to enhance the CPU performance and to manage the disk and screen in an intelligent manner to reduce power consumption. However, these solutions require changes in the structure of mobile devices, or they require a new h/w that results in an increase of cost and may not be feasible for all mobile devices. Computation off-loading technique is proposed with the objective to migrate the large computations and complex processing from resource-limited devices (i.e., mobile devices) to resourceful machines (i.e., servers in clouds). This avoids taking a long application execution time on mobile devices which results in large amount of power consumption. Rudenkoet al. [21] and Smailagic and Ettus[22] evaluate the effectiveness of offloading techniques through several experiments. The results demonstrate that the remote application execution can save energy significantly. Especially, Rudenkoet al. [21] evaluates large-scale numerical computations and shows that up to 45% of energy consumption can be reduced for large matrix calculation. In addition, many mobile applications take advantages from task migration and remote processing. For example, offloading a compiler optimization for image processing can reduce 41% for energy consumption of a mobile device. Also, using memory arithmetic unit and interface (MAUI) to migrate mobile game components to servers in the cloud can save 27% of energy consumption for computer games and 45% for the chess game.

D. Ensures Security

Mobile cloud computing enhances security for your data and other related devices. Since the data is stored virtually, there are no cases of attacks from other companies that can access your personal hardware. Cloud computing provides a safe way in which one can send data without exposing the data to other people. Additionally, the data is safely stored in the hands of the mobile cloud computation technologies. The fact that all the data uploaded is encrypted and stored

within the cloud makes the information safe. Mobile cloud computing ensures that the businesses continue even in cases of disaster since the data is not lost.

E. Dynamic Provisioning

Dynamic on-demand provisioning of resources on a fine-grained, self-service basis is a flexible way for service providers and mobile users to run their applications without advanced reservation of resources.

F. Scalability

The deployment of mobile applications can be performed and scaled to meet the unpredictable user demands due to flexible resource provisioning. Service-providers can easily add and expand an application and service without or with little constraint on the resource usage.

G. Multi-tenancy

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

H. Easy Integration

Multiple services from different service providers can be integrated easily through the cloud and Internet to meet the user demand

VI. ADVANTAGES

Mobile applications usages are a rapidly emerging division of the globally mobile markets. They consist of Software's that running on mobile devices and performs a certain tasks for the users of the mobile phone/device. As reported by World Mobile Applications Market, about 7 billion (free and paid) application downloads were made globally in 2009 alone from both native and 3rd-party application stores, generating revenues of $3.9 billion in the equal year. The global mobile application market is, expected to be worth $24.4 billion in 2015, growing at a CAGR of 64% from 2009-to-2015. Apple is a typical example for the flare-up of mobile applications. Apple with an enormous more than 4 billion downloads to date commanded more than 90% of the application market share in 2009 year. The success of Apple's App Store has not only established the scalability of mobile application's, but has also shown that the best of these offer the potential to generating vast profits.

A. Mobile Learning

Mobile learning, now-a-days is becomes more popular as there are many peoples using mobile devices to Enhance their learning through the use of mobility. Mobile learning (m-learning) is not only electronic learning (e-learning) but e-learning with plus point as mobility. It is vibrant idea that learning via mobile brings many benefits for mobile users. It brings the accessibility for them since they can learn anywhere they want in any convenient time from a portable/mobile device. However, there are some researches pointed out restrictions of traditional mobile learning such as: high cost of network access, expensive mobile devices, poor network transmission rates, and limited educational resources. As a result of that, it is tough for mobile learning to take its own advantages and to be popular as well.

B. Mobile Commerce

The bang in the use of electronic commerce (e-commerce) by the business sector has been incredible since its commencement only a few years ago. E-commerce is known as: buying and selling of products or services over electronic systems such as other computer networks and the Internet. From, governments to multi-national companies to 1-person start-ups, e-commerce is increasingly viewed as a key business modality of the future aspect. Wide markets (across the countries as well), Ease of transaction, and de-creased overheads are some aspects that make e-commerce solutions much more attractive, as apparent with the growing of on-line sales.

C. Mobile Healthcare

The growth of telecommunication technology in the medical field helped diagnosis and treatment become easier for various peoples. This can helps patients regularly monitor their health and have timely treatment as well. Also, it leads to increase accessibility to health-care providers, more and more efficient tasks and processes, company need a whole team of experts to installation, configuration, testing, and running, secured, and update them as well. When you are going to multiply this effort across hundreds or dozens of applications, it's easy to realize why the giant companies with the best Information Technology departments aren't getting the applications or services they necessity. Small scale and mid-sized businesses do not stand a chance. Mobile-Cloud-Computing, A better way: With MCC, you eradicate those worries because you aren't managing h/w and s/w, that's the responsibility of cloud vendors like sales force, amazon. The sharing basis infra-structure means it working like as service: You only pay for what you use, need, and updates are automatic and mounting up or down is easy.

D. Mobile Gaming

Mobile game (m-game) is a potential market generating revenues for service providers. M-game can completely offload game engine requiring large computing resource (e.g., graphic rendering) to the server in the cloud, and gamers only interact with the screen interface on their devices. [22] demonstrates that offloading (multimedia code) can save energy for mobile devices, thereby increasing game playing time on mobile devices. [24] proposes MAUI (memory arithmetic unit and interface), a system that enables fine-grained energy-aware offloading of mobile codes to a cloud. Also, a number of experiments are conducted to evaluate the energy used for game applications with 3G network and WiFi network. It is found that instead of offloading all codes to the cloud for processing, MAUI partitions the application codes at a runtime based on the costs of network communication and CPU on the mobile device to maximize energy savings given network connectivity. The results demonstrate that MAUI not only helps energy reduction significantly for mobile devices (i.e., MAUI saves 27% of energy usage for

the video game and 45% for chess), but also improves the performance of mobile applications (i.e., the game's refresh rate increases from 6 to 13 frames per second). [24] Presents a new cloud-based m-game using a rendering adaptation technique to dynamically adjust the game rendering parameters according to communication constraints and gamers' demands. The rendering adaptation technique mainly bases on the idea to reduce the number of objects in the display list since not all objects in the display list created by game engine are necessary for playing the game and scale the complexity of rendering operations. The objective is to maximize the user experience given the communications and computing costs.

VII. CONCLUSION

Mobile cloud computing refers to the combination of mobile networks and cloud computing with an aim of benefiting the network operators, mobile users, and cloud providers. Usually it's a technology that leverages the elastic resources of network technologies and varied clouds toward unrestricted mobility and functionality. This enables mobile devices to be used anywhere without worrying about their location. 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.

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