

Mobile Cloud Computing: Implications and Challenges

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Abstract

During the last few years, there is a revolutionary development in the field of mobile computing, multimedia communication and wireless technology. Together with an explosive growth of the mobile computing and excellent promising technology of cloud computing concept, Mobile Cloud Computing (MCC) has been introduced to be a potential technology for mobile services. MCC integrates the cloud computing into the mobile environment and overcomes opportunities and its issues related to this environment (e.g., heterogeneity, scalability, and availability), performance (e.g., storage, battery life, and bandwidth), and security (e.g., reliability and privacy). This paper will explain how cloud computing and mobile devices can be combined for future opportunities, implications and legal issues for developing countries.

Keywords: Cloud computing, SaaS, PaaS, IaaS, MCC.

1. Introduction

Cloud computing will economically moderate the requirement of advanced handsets for running mobile applications. Conferring to the up-to-date study from Juniper Research [1], the market for cloud based mobile applications will breed 88% from 2009 to 2014. The market was just over $400 million this past recent year, Juniper web domain showing by 2014 it will touch $9.5 billion. Most of us utilize our mobile phones as mini-computers that travel and being with us and retain us connected round the clock. Mobiles are now essential part in this modern age of education, business world and significance of mobile database is unavoidable. According to a novel study from ABI Research [2] cloud computing will entirely renovate future of mobile applications development and their utilization. Cloud computing offers a range of new opportunities and its issues for developing countries to do what they could not do earlier with computers and the Internet. Cloud computing infrastructure and applications are able to interact with users who have mobile phones, Tablet PCs, OLPC [One-Laptop-per-Child] [3] and other mobile devices. In this study, we explore how cloud computing will surpass the Internet in adoption and usage as this technology's users are on the other side of the digital divide. Mobile phones and other devices have penetrated and saturated developing countries where the Internet has failed. This paper looks at the diffusion of mobile phones and devices in developing countries and its continuous dramatic rise of mobile phone users in developing countries $15 Mobile Phones and $20 Tablet PCs are now in the hands of that technology connectivity deprived billions.

This paper will explain how cloud computing and mobile devices combine present and future new imperatives and challenges for developing countries. Because the mobile phone and devices user market is too big to be ignored, cloud service providers, in collaboration, with mobile service providers have deployed hundreds of cloud-enabled applications and are continuing in their cloud venture to provide an endless range of products. The popular mobile applications that are helping development efforts, such as m-Commerce, m-Learning, m-Health, m-Banking, m-Game, m-Agriculture, and others that already exists within developing countries. Each technology has its own excellent (imperatives), good (challenges), and poor (issues) side by side. There is an attempt to address the issues and challenges in deploying mobile applications via cloud computing in developing countries when compared to be developed countries. For example, issues such as connectivity to remote regions and the challenges faced by service providers and ruling governments to subsidize and provide mobile infrastructure.

1.1 Cloud Computing

Cloud computing can be defined as a new style of computing in which dynamically scalable and often virtualized resources are provided as a services over the Internet. Cloud computing has become a significant technology emerging trend, and many experts, researchers and academicians expect that cloud computing will reshape information technology (IT) sector and the IT marketplace in world. With the cloud computing technology, users use a wide variety of devices, including PCs, Laptops,

Smart Phones, and PDAs to access different kinds of utility programs, storage, and application development platforms over the Internet, via services offered by cloud computing providers. An advantage of the cloud computing technology includes cost savings, high availability, and easy scalability. The below figure.1 adapted from [4], shows six phases of computing paradigms, from dummy terminals/mainframes, to PCs, Networking Computing, Internet Computing to Grid and Cloud Computing.

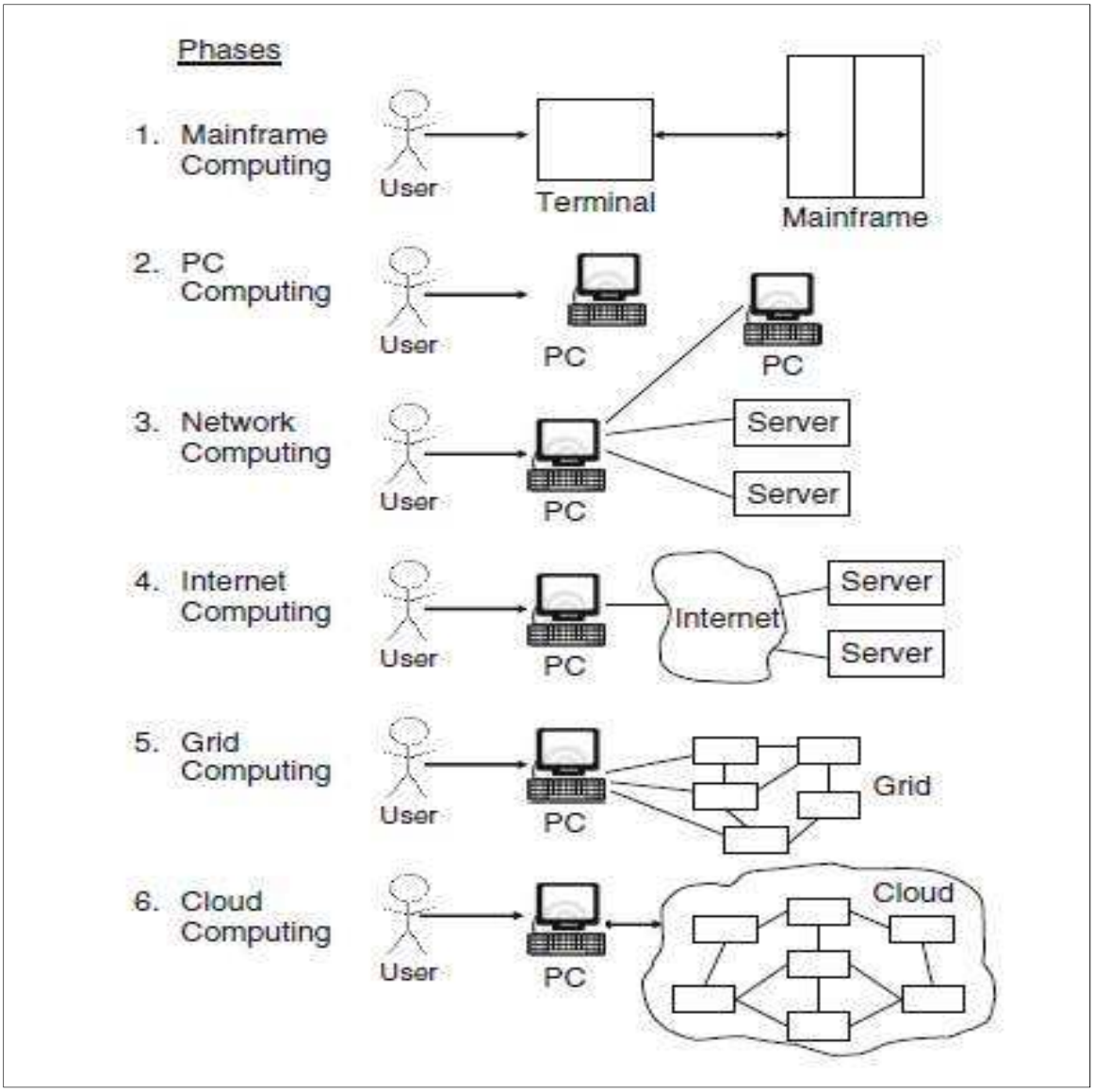

Figure.1 Six computing paradigms – from mainframe computing to Internet computing, to grid computing and cloud computing (Adapted from Voas and Zhang (2009))

1.1.1 Service Layers of Cloud Computing

Cloud computing can be viewed as a collection of services, which can be represented as a layered cloud computing architecture, as shown in Fig.2

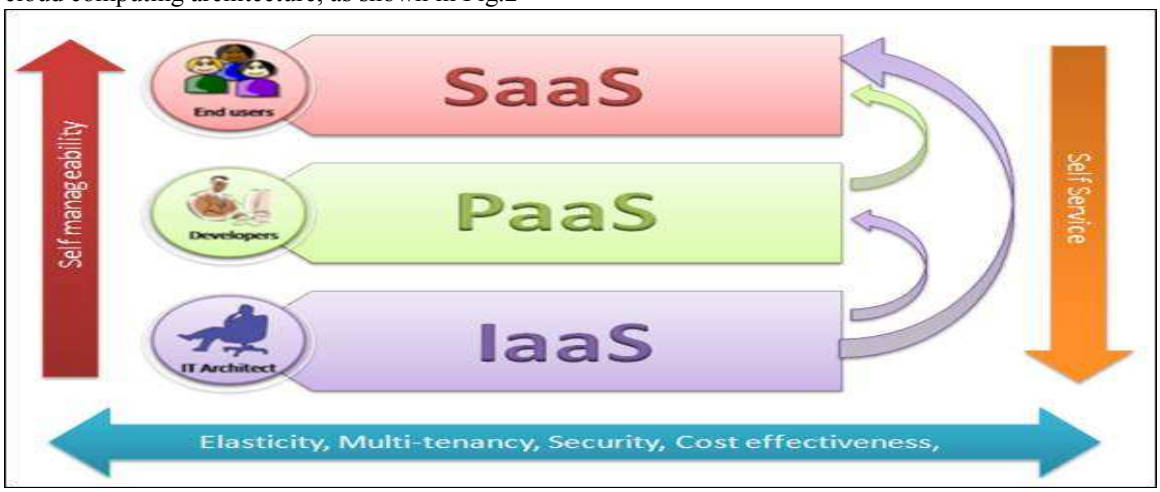

Figure.2 Layered architecture of Cloud Computing

- **Software as a Service (SaaS)** - It is a model of software deployment whereby the provider licenses an application to the customers for use as a service on demand. The capability provided to the End users is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through a thin client interface such as a web browser (e.g., web enabled e-mail). The end users does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user specific application configuration settings. Today SaaS is offered by companies such as Google, Salesforce, Microsoft, Zoho, etc.
- **Platform as a Service (PaaS)** - It is the delivery of computing platform and solution stack as a service. The capability provided to the end users is to deploy onto the cloud infrastructure user created or acquired applications created using programming languages and tools supported by the provider. The end user does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage. PaaS providers offer a predefined combination of OS and application servers, such as WAMP platform [5] (Windows, Apache, MySql and PHP), LAMP platform (Linux, Apache, MySql and PHP), and XAMP(X-cross platform) limited to J2EE, and Ruby etc. Google App Engine, Salesforce.com, etc are some of the popular PaaS examples.
- **Infrastructure as a Service (IaaS)** - It is the delivery of computer infrastructure (typically a platform virtualization environment) as a service. The capability provided to the end users is to provision processing, storage, networks, and other fundamental computing resources where the end user is able to deploy and run arbitrary software, which can include operating systems and applications. The user does not manage or control the underlying cloud infrastructure but it has control over operating systems, storage, deployed applications, and possibly limited control of select networking components. Some of the common examples are Amazon, GoGrid, 3tera, etc.
- **Monitoring-as-a-Service (MaaS)** – It is the outsourced provisioning of security, primarily on business platforms that leverages the Internet to conduct business. [21] MaaS has become increasingly popular over the last decade. Since the advent of cloud computing, its popularity has grown even more. Security monitoring involves protecting an enterprise or government client from cyber threats. A security team plays a crucial role in securing and maintaining the confidentiality, integrity, and availability of IT assets. The major functionality of MaaS is to monitor the working of all the three layers SaaS, PaaS and IaaS.

1.1.2 Types of Cloud Computing Deployment Models

There are three types of cloud computing deployment models [6] are: (a) Private Cloud (b) Public Cloud and (c) Hybrid Cloud as shown in Fig. 3.

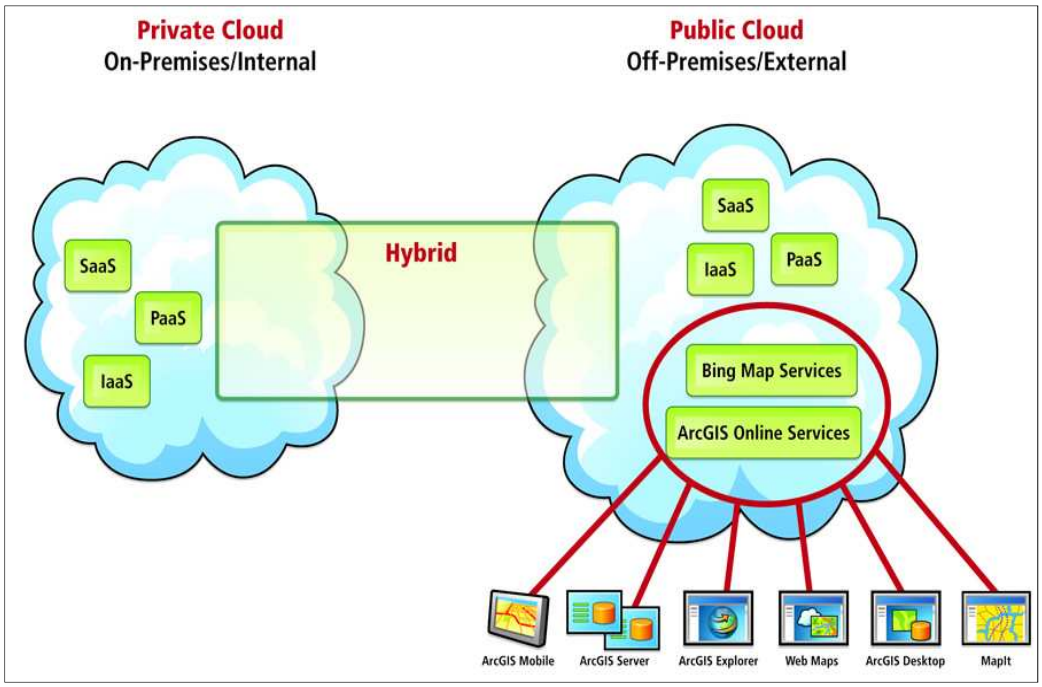

Figure.3 Three types of Cloud Computing Deployment Models

a. **Private Cloud (or Internal Cloud)** – It refers to cloud computing on private networks. Private clouds are built for the exclusive use of one client, providing full control over data, security, and quality of service. Private clouds can be built and managed by a company's own IT organization or by a cloud provider.
b. **Public Cloud (or External Cloud)** – In this model, computing resources are dynamically provisioned over the Internet via Web applications or Web services from an off-site third party provider. Public clouds are run by third parties, and applications from different customers are likely to be mixed together on the cloud's servers, storage systems, and networks.
c. **Hybrid Cloud (or Mixed Cloud)** – This environment intersects and combines multiple public and private cloud models. Hybrid clouds introduce the complexity of determining how to distribute applications across both a public and private cloud.

1.1.3 Cloud Computing Features

Cloud computing brings an array of new features compared to any other computing paradigms. There are briefly described in this section.

- **Scalability and On-Demand Services** - Cloud computing provides resources and services for users on demand. The resources are scalable over several data centers.
- **Quality of Service (QoS)** - Cloud computing can guarantee QoS for users in terms of hardware or CPU performance, bandwidth, and memory capacity.
- **User-Centric Interface** - Cloud interfaces are location independent and they can be accessed by well established interfaces such as Web services and Web browsers.
- **Autonomous System** - Cloud computing systems are autonomous systems managed transparently to users. However, software and data inside clouds can be automatically reconfigured and consolidated to a simple platform depending on user's needs.
- **Pricing** - Cloud computing does not require up front investment. No capital expenditure is required. Users may pay and use or pay for services and capacity as they need them.

1.1.4 Cloud Computing Challenges

The new paradigm of cloud computing provides an array of benefits and advantages over the previous computing paradigms and many organizations are migrating and adopting it. However, there are still a number of challenges, which are currently addressed by researchers, academicians and practitioners in the field.

a. Performance
   The major issue in performance can be for some intensive transaction-oriented and other data intensive applications, in which cloud computing may lack adequate performance. Also, users who are at a long distance from cloud providers may experience high latency and delays.
b. Security and Privacy
   Companies are still concerned about security when using cloud computing. Users are worried about the vulnerability to attacks, when information and critical IT resources are outside the firewall.
c. Control
   A quantity of IT wings or departments are concerned because cloud computing providers have a full control of the platforms. Cloud computing providers typically do not design platforms for specific companies and their business practices.
d. Bandwidth Costs
   Cloud computing, companies can save money on hardware and software; however they could incur higher network bandwidth charges. Bandwidth cost may be low for smaller Internet-based applications, which are not data intensive, but could significantly grow for data-intensive applications.
e. Reliability
   Cloud computing still does not always offer round the clock reliability. There were cases where cloud computing services suffered few hours' outages. In the present and future days to expect more cloud computing providers, richer services, established standards and best practices.

2. Mobile Cloud Computing

Mobile Cloud Computing is a new paradigm for mobile applications whereby most of the processing and data storage associated with the applications is moved off the mobile device to powerful, centralized computing platforms located in the Cloud. These centralized applications are then accessed over the mobile Internet, using either a thin native client or web browser on the device. However, this model for Mobile Cloud Computing still does not fully leverage the powerful communications, context and commercialization capabilities of the mobile network itself. Mobile Cloud Computing builds on the principles of cloud computing, bringing attributes such as on demand access, no on premise software and "XaaS" (Everything as a Service) to the mobile domain, adding Network as a Service (NaaS) and Payment as a Service to the maximum of on demand capabilities and allowing applications to leverage the full power of mobile networking and billing without the need for specialist application servers. The phrase "Mobile Cloud Computing" was introduced after the concept of "Cloud Computing" was launched in mid 2007. It has been attracting the attention of entrepreneurs as a profitable business option that reduces the development and running cost of mobile applications and mobile users as a new technology to achieve rich experience of a variety of mobile services at low cost, and of researchers as a promising solution for green core IT [7].

The Mobile Cloud Computing Forum [8] defines MCC as *"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 smart phone users but a much broader range of mobile subscribers".*

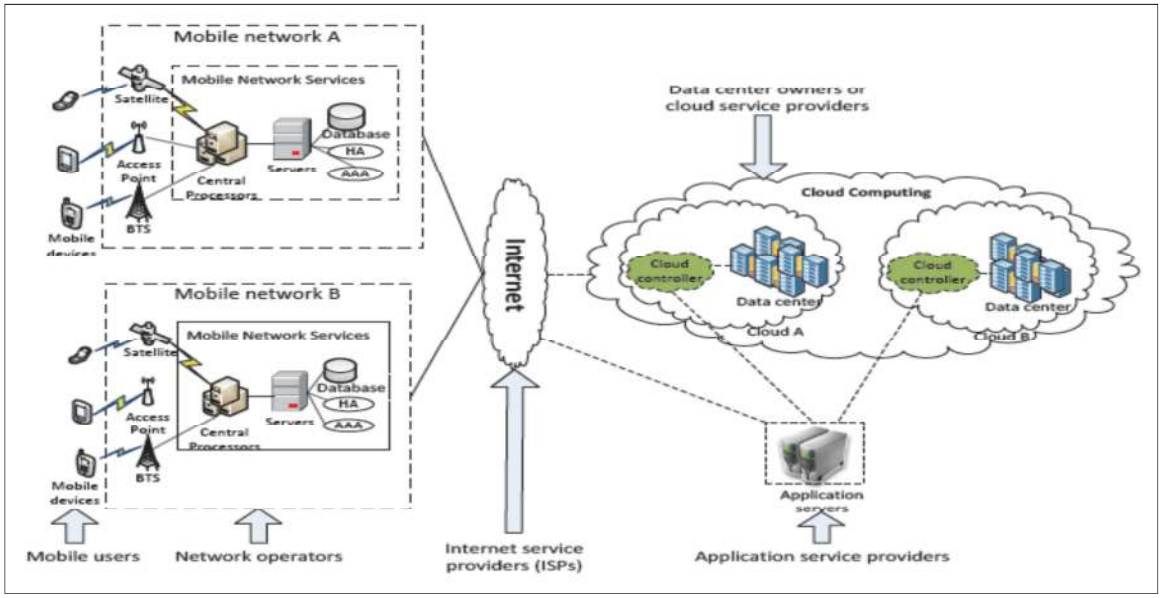

Figure.4 Mobile Cloud Computing (MCC) Architecture

The general architecture of MCC proposed by [20] can be shown in Fig.4 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 user's 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 (Authentication, Authorization, and Accounting) based on the home agent (HA) and subscriber's data stored in databases. After that, the subscriber's requests are delivered to a cloud through the Internet. In cloud, the 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 (eg.web application, and database servers).

3. Key Requirements for Mobile Cloud Computing

There are some key features of Mobile Cloud Computing that make it possible to implement seamless service delivery in across the network environment. From the perspective of the enterprise solution provider or web/mobile application developer, the objectives of the Mobile Cloud Computing platform are:

- Simple APIs offering transparent access to mobile services, and requiring no specific knowledge of underlying network technologies.
- The ability to deploy applications across multiple carrier networks, under a single commercial agreement.
- Seamless handling of each carrier's specific network policy, such as chosen mobile subscriber confirmed opt-in / confirmed opt-out and privacy management principles.

4. Importance of Mobile Cloud Applications

Mobile cloud computing is one of the mobile technology trends in the future since it combines the advantages of the integration of both mobile computing and cloud computing, thereby providing optimal services for mobile users. The applications supported by mobile cloud computing including mobile commerce, mobile learning, and mobile healthcare and other areas. The below issues and related approaches for mobile cloud computing (i.e., from communication and computing areas) have been identified. The future work has been explored for the existing problems and its solutions. Mobile applications gained considerable share in a global mobile market. Various mobile applications have taken the advantages of Mobile Cloud Computing. The following are the few implications:

4.1. m-Commerce

Mobile commerce (m-commerce) is a business model for commerce using mobile devices. The m-commerce applications generally fulfill some tasks that require mobility (e.g., mobile transactions and payments, mobile messaging, and mobile ticketing). The m-commerce applications have to face various challenges (e.g., low network bandwidth, high complexity of mobile device configurations, and

security). Therefore, m-commerce applications are integrated into cloud computing environment to address these issues [9]. Proposes a 3G e-Commerce platform based on cloud computing.

4.2. m-Learning

Mobile learning (m-learning) is designed based on electronic learning (e-learning) and mobility. However, traditional m-learning applications have limitations in terms of high cost of devices and network, low network transmission rate, and limited educational resources [10, 11, 12]. Cloud based m-learning applications are introduced to solve these limitations, for example utilizing a cloud with the large storage capacity and powerful processing ability, the applications provide learners with much richer services in terms of data (information) size, faster processing speed, and longer battery life.

4.3. m-Health Care

The purpose of applying MCC in medical applications is to minimize the limitations of traditional medical treatment (e.g., small physical storage, security and privacy, and medical errors [13]). Mobile healthcare (m-healthcare) provides mobile users with convenient helps to access resources (e.g., patient health records) easily and quickly. Besides, m-healthcare offers hospitals and healthcare organizations a variety of on-demand services on clouds rather than owning standalone applications on local servers.

4.4. m-Banking

Mobile banking (also known as m-Banking, SMS Banking, etc.) is a term used for performing balance checks, account transactions, payments etc., via a mobile device such as a mobile phone or Personal Digital Assistant (PDA). Mobile banking today is most often performed via SMS or the mobile Internet but can also use special programs, called clients, downloaded to the mobile device.

4.5. m-Game

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 [14] demonstrates that offloading (multimedia code) can save energy for mobile devices, thereby increasing game playing time on mobile devices.

5. Key Benefits of Mobile Cloud Computing Applications

MCC provides the software engine that fuels the convergence of open mobile networks, mobile cloud computing, on demand enterprise solutions, and web and mobile applications, opening up new low friction commercial channels between multiple diverse industries and vertical market segments. Our solution, when deployed either by Mobile Operators or cross-network Mobile Cloud Providers, makes it easy for enterprise solution providers and web or mobile application developers to turbo-charge a wide variety of applications and services, enriching them with powerful mobile network features and intelligence available on demand via the mobile cloud. The solutions deliver significant benefits to a range of organizations, including Mobile Cloud Providers, Network Operators, Enterprise Solution Providers, and Web or Mobile Application developers. These benefits are summarized in the following sections.

- **Mobile Cloud Providers** - It enables Mobile Cloud Providers to develop new industry-targeted B2B solutions by adding mobile network enablers and intelligent commerce to their range of on demand cloud based services.
- **Network Operators** - It enables operators to monetize their mobile network and billing assets by providing a full commercial solution for Network as a Service.
- **Enterprise Solution Providers** - The solution allows enterprises and organizations to improve customer service, increase employee collaboration, enhance business processes and drive productivity gains.
- **Web and Mobile Application Developers** - It empowers Web and Mobile application developers to differentiate their applications with mobile network features and allows them to reach and bill their maximum potential customer base.

The solution makes it easy for developers to enrich their applications with valuable mobile network capabilities and intelligence and provides a new direct-to-billing channel for their applications.

6. Legal Issues in Cloud Computing

In the same way that the electricity one uses may have been generated in another country where costs are lower, the computer processing power or storage one buys via a Cloud service may be based in another country, or indeed may be divided between multiple countries. But as well as the cost and efficiency advantages brought in this arrangement, this also raises vexing legal issues in the case of Cloud Computing arising out of exporting customers data abroad; also, the Cloud Services Provider has to contend with the Legal Systems under different Jurisdictions with not so much of visibility as to

where the Data resides and how it is routed to the End User while passing through different Legal Jurisdictions. Again, vexing Legal Issues relating to ownership of data and liability for its loss or misuse have to be dealt with by the Cloud Service Providers. The legal issues differ from those arising from conventional outsourcing or hosting.

A traditional data hosting or server hire contract may have involved use of someone else's storage or computer. But it would normally have been clear who you were dealing with and where your rented resources were located. Such arrangements were also unlikely to have been established on a casual or informal basis. With Cloud computing, however, the location(s) of your data may be unclear, possibly even unidentifiable and it is also much easier to set up such an arrangement. The ease with which Mobile Cloud resources can be allocated and reallocated makes it more likely that it will be done without an appropriate review of the relevant legal issues.

7. Conclusion

The emergence of Cloud Computing, and its extension into the mobile domain, has brought a new dimension to Network as a Service: the vision of a global, interconnected "Mobile Cloud" where application providers and enterprises will be able to access valuable network and billing capabilities across multiple networks, making it easy for them to enrich their services whether these applications run on a mobile device, in the web, in a SaaS Cloud, on the desktop or an enterprise server. Mobile Cloud Computing will provide a full commercial environment for applications, providing an easy way for smaller developers to monetize their services as well as new routes to market. Crucially, Mobile Cloud Computing will eliminate the commercial and technical fragmentation that has thus far proven to be a barrier to successful collaboration between application providers and operators on a global scale.

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