

# Exploring the Convergence of Mobile Computing with Cloud Computing

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## Abstract

The advancements in computing have resulted in a boom of cheap, ubiquitous, connected mobile devices as well as seemingly unlimited, utility style, pay as one go computing resources, commonly referred to as cloud computing. It is desirable to have ubiquitous access to emails and information through mobile computing. More and more individuals are carrying smartphones and utilizing tablet PCs for business and personal use. The 2010 IBM Tech Trends survey predicted that cloud computing will overtake on-premise computing and mobile software application development will emerge as the most in-demand software application development through 2015. Accordingly, it is reasonable to predict that mobile cloud computing, the niche where these two areas merge, will also transpire as a dominant force in both the development and research arenas through 2015 with the convergence of smartphones, tablets, and cloud computing. This paper introduces and explores the convergence of mobile computing with cloud computing and cloudlets and discusses the challenges and growth prospects of this dynamic field.

**Keywords:** cloud computing, mobile cloud computing, cloudlets

## 1. Introduction

A definition of mobile cloud computing in (Open Gardens, 2010) is expressed as “the availability of cloud computing services in a mobile ecosystem” and refers to an infrastructure where both the data storage and the data processing happen outside of the mobile device from which an application is launched. Having immediate access to email and data and the power to analyze, manipulate it and store it on the fly has become not only possible, but extremely sought after. More and more businesses and individuals are utilizing smartphones and tablet PCs, and mobile service providers are constantly striving to offer faster service, greater mobile abilities and longer battery-life. In order to accomplish this, mobile cloud computing is an essential ingredient.

Energy efficiency is a fundamental consideration for mobile devices. Cloud computing has the potential to save mobile client energy but the savings from offloading the computation need to exceed the energy cost of the additional communication. While the most energy-efficient setup for many current mobile applications is local computing, there clearly are workloads that can benefit from moving to remote infrastructures because these workloads demand higher resources (Miettinen & Nurminen, 2010). An obvious solution to the resource poverty of mobile devices is offloading of processing to the cloud. Mobile cloud computing is the art of or delicate balance of offloading various data, processing capabilities, and even Operating System (OS) tasks into the cloud.

To the typical consumer, a cloud-based mobile application (app) looks and feels just like any app purchased or downloaded from a mobile application store like iTunes. However, the app is driven from the cloud and not the mobile device itself. Cloud-based mobile apps are perfectly capable of being packaged in a way that allows them to be sold alongside traditional mobile apps in mobile application stores, with no one but the developers any wiser. As an example, when such an app is launched via an iPhone shortcut, the app performs just like any other app on the iPhone, but all of its processing power comes from the cloud. According to ABI Research, over the next five years, the number of mobile cloud computing subscribers worldwide are expected to grow rapidly, rising from 42.8 million subscribers in 2008, (approximately 1.1% of all mobile subscribers) to about 1 billion in 2014 (nearly 19%) (ABI Research, 2009). The number of potential mobile cloud users is much higher if we include cloud-ready devices. IBM predicts that by 2015, there will be 1 trillion cloud-ready devices (Cox, 2011). Indeed, there seems to be no dearth of opportunities for exploiting the information those devices will be able to generate.

Currently, mobile applications are tied to a carrier. As an example, to run an iPhone or Blackberry app, the user has to first have a relationship with the mobile operator who carries that mobile device. But with mobile clouding computing applications, as long as the user has web access, the user can access the mobile application (ABI Research, 2010). Cloud computing will dramatically reduce the requirement of advanced handsets for running mobile applications. Applications can run on servers instead of locally, so handset requirements can be greatly reduced and developers can create just one version of an application (ABI Research, 2010). According to ABI Research analyst Mark Beccue, "This trend is in its infancy today, but this has the potential of becoming the prevailing model for mobile applications" (Gohring, 2010).

Driving all this growth will be the adoption of the new web standard HTML5, increased mobile broadband coverage and the need for always-on collaborative services for the enterprise. The full roll-out of 4G technology will also help with issues of latency and bandwidth.

## **2. The Current State of Mobile Cloud Computing**

This section discusses mobile platforms such as smartphones, tablets, existing mobile applications and users, as well as enabling trends for mobile cloud computing.

### *2.1 Mobile Platforms: Smartphones*

Smartphones no longer offer just the ability to communicate via voice, like a standard phone, or by way of data, such as email. Rather, these have evolved into small personal computing platforms as well. The International Telecommunication Union (ITU) stated in 2009 that the number of mobile phone subscriptions worldwide had exceeded 5 billion in 2010. According to the ITU, in 2007, 85 countries worldwide had launched 3G networks, with over 335 million mobile broadband subscribers in 2008. Since then 4G has been introduced with a large footprint expected in 2012 (Adolph, 2009). As Pieter Simoens et al noted in (Simoens & Turck, 2011), mobile cloud computing allows mobile devices, such as smartphones, to act "as a remote display, capturing user input and rendering the display updates received from the distant server" (Simoens & Turck, 2011). This allows for logic or data intensive applications to be utilized on-the-go.

### *2.2 Mobile Platforms: Tablet PCs*

iPads and other tablet PCs are larger versions of their smartphone counterparts, and in some cases, aim to market at a much broader and sophisticated audience, such as educational institutions and the healthcare industry. The iPad essentially is a larger version of the iPhone, which provides longer battery-life and greater processing capabilities. It utilizes the iOS operating system. Another leading mobile operating system is Google's Android OS which, according to some, can be considered to more open and customizable than the iOS.

### *2.3 Existing Mobile Applications*

According to [9], the Apple App Store has exceeded 10 billion downloads and features more than 325,000 apps. The Google Android OS claims it has more than 30,000 applications available for its end-user. These two platforms are not the only two platforms, and as more companies create products to compete with Apple and Google, the number of applications and platforms will increase.

### *2.4 Existing Users/Consumers*

More than 8 million iPads were sold this year (Ankeny, 2011) and more than 10 million Samsung Galaxy S phones were sold in just 7 months (Schroeder, 2011). Across all makers in all markets, the number of mobile devices such as smartphones and iPads is exponential of that noted above. People are buying smartphones and iPads or Tablet PCs for both business and personal use. Many people like the idea of having technology at their fingertips, the ability not to have to lug around a laptop to and from school or a book or textbook everywhere with them. Instead, they can have it all in one small device which provides a nearly full-sized keyboard. Others like instant access to emails or the ability to tweet on Twitter or submit a new Facebook status on something small like a smartphone. Regardless of the reason, the trend is still increasing, and it is predicted that the iPad will dominate the tablet market through 2015 (Whitney, 2011). Android designs from Samsung, Acer, and the budget-friendly Amazon Kindle Fire are close competitors of the iPad.

### *2.5 Enabling Trends for Mobile Cloud Computing*

There are several enabling trends for mobile cloud computing. Besides the sheer increase in cloud-ready devices, customers are expecting smartphone and tablet applications so they can access companies' key applications. Employees are demanding access from their mobile devices. According to a survey conducted by the Pew Research Project, by 2020, most people using the Internet will work primarily through apps on remote servers accessed through networked devices.

### 3. Mobile Cloud Computing vs. Standard Cloud Computing

In traditional cloud computing data is stored in the "cloud" of the internet where web-based applications are utilized to access the data and perform various tasks. There are various categories of Cloud Computing systems offered. These include software-as-a-service (SaaS), platform-as-a-service (PaaS), and infrastructure-as-a-service (IaaS), and database-as-a-service (DBaaS).

With SaaS, clients can purchase a piece of software that is accessed online, or possibly data that will be stored online. While SaaS can almost generally be applied to all types of software, in the context of cloud computing we take it to represent software that is accessed from a machine residing on the Internet as opposed to software that is downloaded and installed locally. Salesforce.com is a major SaaS provider.

The PaaS type systems are especially useful for Web servers. Instead of having to purchase their own infrastructure and hosting that hardware somewhere, users can purchase the rights to host their web site in the cloud on somebody else's infrastructure. Google App Engine is a popular example of a PaaS provider.

IaaS providers deliver computer infrastructure, typically at the level of a virtualized environment, as a service including storage and networking. Clients can buy these resources as a fully outsourced service. The amount of services consumed by the client determines the cost. Amazon's EC2 is major provider of IaaS services.

There is a relatively new concept to the cloud computing community being termed as Database-as-a-Service (DBaaS). Microsoft recently released a beta version of SQL Server called SQL Server Data Services (SSDS). They intend this to be used in cloud environments so that customers of a specific cloud provider can still use the mainstream database they have come to depend upon without having to purchase full licenses that would have to be installed by the cloud provider.

These services are charged by the hour, like the electric company charges their clients per kilowatts an hour of usage. The multitude of service platforms offered allow consumers to tailor their service subscriptions meet their specific needs and ultimately provide both operational and financial benefits to their company.

In mobile cloud computing, cloud services converge with Mobile Multimedia Broadcasting (MMB). Mobile cloud computing more-or-less requires an everything-as-a service concept where software, platform, and database services are really all required to be in the cloud to provide small devices with reasonable battery-life quick access to information and the ability to manipulate large quantities of data. Additionally, the concept of offering Networking-as-a Service (NaaS) is added too.

### 4. Mobile Cloud Computing in Diverse Industries

Mobile cloud computing has applicability in fields as diverse as healthcare, education, and business. This is discussed further in this section.

#### 4.1 Healthcare

The healthcare industry is a prominent user of mobile cloud computing. The industry had developed applications which allow patients and doctors access to information anywhere at any time, the ability to monitor patients remotely and enhance emergency response. Due to the sensitive nature of health information, mobile cloud computing for the healthcare industry faces many challenges such as data storage, heterogeneous resources, and last but not least, security.

Nevertheless, according to Hashim et al. in (Adnan & Hashim, 2009), mobile cloud computing is being identified as one of the "key factors contributing to better health care for the society." Mobile cloud computing utilized in fields like the healthcare industry offer improved efficiency and improved quality (Whitney, 2011).

#### 4.2 Education

The use of technology in the classroom has continuously offered benefits. Various studies have been completed supporting the use of Tablet PCs in education. It has been established that students are more easily able to take notes efficiently with a Tablet PC and they are able to take more of them than they are using a pen and paper (Ando & Ueno, 2010). One of the many benefits of technology in the classroom is that it actively involves students in the learning process. According to Tront in (Tront, 2007), "Mobile computing and communication devices like the Tablet PC, along with a high-bandwidth communication infrastructure, help increase the quantity and quality of teaching/learning interactivity with the expectation of improving student learning" (Tront, 2007).

### 4.3 Business

Cloud Computing has proven to reduce costs for businesses, while mobile devices are rapidly becoming an important part of daily business life. However, as Liu et al note in (Liu, Moulic, & Shea, 2010), “Unlike mobile devices that are used by end consumers, those enterprise mobile devices need to be managed and serviced to ensure security, productivity and business integrity” (Liu, Moulic, & Shea, 2010).

Cloud computing differs from the traditional way that data and resources are stored and Mobile Cloud Computing adds another layer to the security issues. In case security is breached, the question arises on who is the responsible party. Businesses don't want to assume responsibility, but if they aren't to be held accountable, then who is? Although the US National Institute of Standards and Technology (NIST) has decided to create a section that is responsible for outlining security standards, it is clear that this is an area in which businesses also need to address as their business models begin to take advantage of mobile cloud computing technology.

## 5. Technical Challenges and Limitations

Presently, MMB services have non-aware production and consumption synchrony, and heterogeneity. MMB services currently use push technology and the desired end result is always to meet the personalized demand of users as quickly as possible. However, when many users are trying to access the same information at the same time and/or a large amount of users need fast access to network storage, or processing capabilities, the ability to provide this information quickly and efficiently becomes a challenge due to the ignorant MMB (Li, Li, Youxia, & Wen, 2010).

The battery-life of mobile devices is a constant struggle. Mobile cloud computing has significantly improved the battery-life of mobile devices; however it can be argued that the perfect balance of what is performed and stored in the cloud versus what is performed and stored on the mobile device to offer the most reasonable battery-life is still to be found. Research in this area is underway but more will need to occur.

Latency and bandwidth affect the mobile cloud, as well. Wi-Fi improves latency but may decrease bandwidth when many mobile devices are present. The rollout of 4G networks and HTML5 is expected to help with latency and bandwidth as mentioned earlier.

With respect to international businesses, there is the issue of lack of international and implementation standards.

Devices such as the iPad or a smartphone are resource constrained and therefore a remote display protocol must be able to deliver complex multimedia graphics over wireless links and render the graphics.

Data security is a long standing issue and cloud computing is no stranger to its scrutiny. The goal is to ensure that only authorized people have access to data. Traditionally, data governance models have called for individual companies to maintain information and records. With cloud computing, companies must rely on their vendors to ensure the safety of their data and trust that they are following all the applicable IT governance and rule sets as well as their governing laws (Nkosi & Mekuria, 2010).

Cloud computing differs from the traditional computing in the way that data and resources are stored. Even when outsourcing a server to somebody else's data center, the user knows exactly where the data is stored and what resources may be shared. However, cloud computing obscures such low-level details by decoupling the actual data from the physical infrastructure. It is possible that the data could be spread across multiple physical servers that also happen to be storing data for other clients on the same machine.

Mobile cloud computing adds another layer to the security issues. The issue arises about who is to be held responsible in the event of a security breach. In order to identify proper security methods for cloud computing vendors, the US National Institute of Standards and Technology (NIST) has decided to create a section that is responsible for outlining security standards. Their goal is to ensure that vendors are properly implementing their security guidelines in order to protect both the vendor and their clients.

## 7. Cloudlets as an Enabler of Mobile Cloud Computing

Cloudlets promise to help, along with 4G and HTML5, with the latency issue in mobile cloud computers. A *cloudlet* is a small, simple device that resides nearby-maybe in a coffee shop or other Wifi hotspot. Cloudlets are located within proximity of handheld devices that use them, thereby decreasing latency by using a single-hop network and potentially lowering battery consumption by using WiFi instead of broadband wireless. When needed, the device downloads user data from a centralized location, permitting local access by the user and thereby reducing latency. When finished, the user data can be returned to the centralized location, if necessary. This process occurs invisibly to the user, except that the user is pleased with faster response. From a security

perspective, cloudlets use WiFi networks, thus taking advantage of existing security policies, including access from only specific handheld devices and encryption techniques.

## 8. Conclusions

Technological advances have made it not only possible, but desirable to have ubiquitous access to emails and information. More and more individuals are carrying smartphones and utilizing tablet PCs for business and personal use. Mobile cloud computing is predicted to see significant growth through 2015. The iPhone and the iPad platform are likely to accelerate the rate of growth of application development. This trend is applicable to other mobile application platforms such as the Android platform. Research is continually underway to offer greater mobile abilities such as greater processing speed, longer battery-life, greater storage capacity, better display size, and quality. This, along with standards and cloud services that support remote data access, storage, and security, is the key to the success of mobile cloud computing. Mobile Network Operators are likely to enter the market with carrier-cloud services that are expected to compete with established public cloud offerings. This will be yet another driver for mobile cloud computing since customers can expect better service guarantees. Mobile cloud computing is an extremely dynamic area of technology experiencing rapid expansion and has a bright future.

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