

Mobile Learning (mLearning) Based on Cloud Computing: mLearning as a Service (mLaaS)

Mohssen M. Alabbadi

Computer Research Institute (CRI), King Abdulaziz City for Science & Technology (KACST)
P. O. Box 6086, Riyadh-11442, Saudi Arabia

alabbadi@kacst.edu.sa

Abstract— Despite its hype, cloud computing, with its dynamic scalability and virtualized resources usage, is being widely deployed for several applications in many organizations. It is envisioned that, in the near future, cloud computing will have a significant impact in the educational and learning environment, enabling its own users (i.e., learners, instructors, and administrators) to perform their tasks effectively with less cost. On the other hand, mobile handheld devices are being lately used in the learning arena, creating mobile learning (mLearning), due to the quality of users' experiences employing them in banking, health, and other aspects of life. However, the existing mobile devices suffer some weaknesses that may hinder the future promotion of mLearning. Some of these weaknesses can be addressed using cloud computing. In this paper, the use of cloud computing for mLearning is discussed, creating mLearning as a Service (mLaaS), with focus on its potential benefits and offerings. Furthermore, user-centric service-focused system architecture of mLaaS is proposed. The proposed architecture has the major added features: transparency; collaboration, extended into intra-organizational sharing of educational and learning resources; personalized learning; and users' motivational effects. This last feature is a user-system interactivity, aiming to establish a new kind of relation between the learners and mLaaS.

Keywords— Cloud Computing; Cloud Computing Services; Education Technologies; Information and Communication Technologies (ICT) in Education; Mobile Learning (mLearning); Personalized Learning; Web Services.

I. INTRODUCTION

These days, there are two emerging paradigms in Information and Communication Technologies (ICT). The first one is the “anytime, anywhere, on-the-move” paradigm, to be called the mobility paradigm, and the second one is the cloud computing paradigm. Both paradigms are radically transforming the way we communicate, access and utilize information resources, and connect with peers and colleagues, thus affecting all aspects of our lives — including shopping, banking, health care, etc.

The mobility paradigm evolved from the lowering cost of mobile devices and the availability of wireless infrastructures. The mobile handheld devices are turning into indispensable ubiquitous tools that would replace the desktop and laptops in the near future [4]; the mobile phones shipments, with new capabilities in terms of hardware and software, had exceeded the laptop shipments since 2006 [34] and, in the fourth quarter of 2010 (4Q10), smartphone shipments alone outpaced

Personal Computer (PC) shipments for the first time. These devices, with the ability, available only on several models now, to easily acquire and install 3rd-party applications, were first employed within gaming, movies, or other sectors of the entertainment industry, taking about 12-18 months for their adoption into mainstream industry [12]. This paradigm has established a new dimension for providing services such as mobile commerce (mCommerce), mobile business (mBusiness), mobile banking (mBanking), mobile health (mHealth), etc. Consequently, an impetus was generated to use this mobility paradigm in the learning environment, thus creating “mobile learning” (hereafter, abbreviated as m-learning or mLearning), with expected benefits to be reflected in more efficient and improved learning results.

Cloud computing is an Internet-based computing paradigm, with its built-in elasticity and scalability, for delivering on-demand computing services to its users in a pay-per-use basis, in a similar fashion as already done for other common utilities (i.e., water, electricity). It marks the reversal of a long-standing trend, where end users and organizations are now willing to surrender a large measure of control to 3rd-party service providers [14]. The emergence of cloud computing was attainable because of several existing technologies and trends. All these factors made computing more distinctively distributed, thus migrating back to huge data centers. Networks of these computing plants, called “IT factories” [8], with commercial realization, form “cloud computing” [13]. Cloud computing provides its users a power of choice among less expensive (or free) competing services that are user-friendly and more reliable with a tremendous advantages in terms of mobility, accessibility, and collaboration, allowing users, at any location, to use any device, such as a PC, or a mobile phone, etc. [8], [14]. The use of cloud computing will have a profound positive impact on the cost structure, with its dynamic re-arrangement, eliminating some of the expenditures and reducing others, to lower the total cost of ownership (TCO) of IT resources [14], on all industries using IT resources. This results in an indirect crucial impact on business creation by reducing barriers to entry and enabling quick growth, and the macroeconomic performance at national levels [10], extending to a global level.

Cloud computing is being widely deployed for several applications in many organizations, in the private as well as the public sectors, including healthcare (in particular, for providing ICT to remote or less developed areas) and several activities of government agencies. Furthermore, it is

envisioned that, in the near future, cloud computing will have a significant impact in the education, enabling more efficient cost-effective operations. The US market research firm IDC estimated the IT spending on cloud computing services to reach US\$42 billion by 2012 [23].

Despite the significant momentum and attention recently being attracted by both cloud computing and mLearning, they were both treated as separate entities, with little work has been accomplished in their synergy. Mostly, the integration of the cloud computing and mLearning was viewed in terms of accessibility and mobility features of cloud computing. On the other hand, when viewed from the mobile device perspective, cloud computing, with its dynamic scalability and virtualized resources usage, could address some of the weaknesses inherited in mobile devices (such as low computational power, small storage space, and low resolution) that may hinder the future promotion of mLearning. This creates mLearning based on cloud computing, to be called mLearning as a Service (mLaaS).

The previous work on mLaaS, though very limited, extended from proof-of-concept prototypes [5], [13] to a basic framework [20]. However, the learning-focused services that can be provided by mLaaS were hardly emphasized. In this paper, user-centric service-focused system architecture of mLaaS is proposed. This architecture has the following major features: transparency; collaboration, extended into intra-organizational sharing of educational and learning resources; personalized learning; and users' motivational effects. This last feature is a user-system interactivity, aiming to establish a new kind of relation between the learners and mLaaS.

The structure of the rest of the paper is as follows. Sections II and III describe mLearning and cloud computing, respectively, where their definitions are properly stated. In Section IV, mLaaS is introduced, where its potential benefits and offerings are highlighted. The user-centric service-focused system architecture of mLaaS is described in Section V, where the design criteria of mLaaS are first specified. Finally, the concluding remarks are given in Section VI.

II. MOBILE LEARNING

Mobile learning can be defined as any service or facility for knowledge transfer of events, content, tools, and applications to the learner [3], regardless of location and time [21], resulting in learner's alteration in behaviour [12], where mobile handheld devices, such as mobile phones, Personal Digital Assistants (PDAs), and smart phones, are being used, while the learner, but not necessarily the learning material providers, could be on the move. The behaviourist requirement, in the aforementioned definition, indicates that learning is not deemed without the learner's alteration in behaviour [12], (physical or non-physical). Furthermore, the use of mobile handheld devices, possibly on the move, emphasizes the mobility feature of mLearning, thus excluding laptops and limiting mLearning to those devices that can be used while on-the-move [18], [26].

Mobile learning is on the intersection of mobile computing and e-learning [25], [30], conveying e-learning through

mobile devices using wireless connectivity; this intersection includes the use of desktops as well as laptops. It, however, breaks the constraints of time and space, which have become a very important barrier of E-learning, thus constructing a flexible and open learning environment. This environment can provide access, context, and collaboration to learners and additionally supply facilitation measures for facilitators [12]. Furthermore, mLearning provides powerful features and functions such as mobility, reachability, localization, flexibility, and motivational effects due to self controlling and better use of spare time.

Learning is a dynamic activity that can be closely linked to mobility with respect to space, time, and topic areas [32], making a perfect match with mLearning – learning occurs at different places (e.g., learning institutes, workplaces, homes, and even places of leisure), at different times (e.g., working days, weekends, or holidays), and between different topic areas of life (e.g., education, work, self-improvement, or leisure) [32]. The diversity of space for adults daily self-learning was studied in [29], reflecting opportunities for learning during the time that learners spend on the move.

Mobile Learning actively engages learners, emphasizing learner centeredness to match all learners' styles of learning [26]. From an activity-centered perspective, the six existing learning theories (i.e., behaviourist, constructivist, situated, collaborative, informal, and lifelong learning theories) can be harnessed using mLearning. Furthermore, the ability to record information about new encountered experiences, using the enhanced features of the mobile devices, enables experiential learning [26]; according to experiential learning theory, ideas and concepts are not fixed, but are formed and modified through the present and past learners' experiences.

Generally speaking, mLearning systems can be divided into three types: push-based, application-based, and browser-based mLearning systems [22]. The push-based systems use the mobile phone email or Short Message Service (SMS), whereas the browser-based systems require an Internet-enabled mobile device, using HTML or Wireless Application Protocol (WAP). On the other hand, the application-based systems require the application to be downloaded into the learner's handheld device; this can be done either by connecting online to the website, containing the application, via the Internet, or by connecting to a PC, containing the application, via USB cables. These systems have been used, either as a single system or as a combination of two or more of them, in some k-12 schools and universities or in career development area, for class learning as well as in outdoor learning.

III. CLOUD COMPUTING

The emergence of cloud computing was attainable because of the following existing technologies and trends: the Internet technologies, in particular, World Wide Web (WWW), and Web 2.0 functionality; virtualization, for data center consolidation and providing separation and protection; grid and parallel computing; Web services and the adoption of technology standards; the catch up of telecommunications

with hardware and software, where open standards were leveraged; and the falling cost of storage and computing devices, first led by minicomputers then PCs, and, more recently, by Internet-enabled handheld mobile devices.

Despite its emergence, the term “cloud computing” could mean different things to different IT professionals. Unfortunately, there are abound of definitions for “cloud computing” in the literature, with hype and divergent viewpoints, leading to a non-standard definition of cloud computing; the Joint Information Systems Committee (JISC) confirm the confusion about the terms “cloud” and “cloud computing” [8]. In this paper, the “U.S” National Institute of Standards and Technology (NIST) definition is adopted, defining cloud computing as a “model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model promotes availability and is composed of five essential characteristics, three service models, and four deployment models” [24].

The five essential characteristics are: on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service [24]. These characteristics emphasize user's unawareness of locations of IT resources, high utilization of resources, high usability, and the ability to use heterogeneous thick or thin client platforms for accessibility such as mobile phones, laptops, and PDAs through a thin client interface such as a web browser.

There are three service models of cloud computing, where in all models the consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or applications. The three service models are Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) [24]. With IaaS, the consumer, based on demands, can provision processing, storage, networks, and other fundamental computing resources, so that the consumer can deploy and run arbitrary software, including operating systems and applications, where the consumer has control over the operating systems, storage, deployed applications, and possibly limited control of select networking components (e.g., host firewalls). However, with PaaS, the consumer can deploy onto the cloud infrastructure consumer-created or acquired applications, created using programming languages and tools supported by the cloud provider, where the consumer has control over the deployed applications and possibly the application hosting environment configurations. On the other hand, in SaaS, the provider's applications are available to the consumer, where the consumer may possibly have control over limited user-specific application configuration settings.

There are four deployment models for cloud computing: private cloud, community cloud, public cloud, and hybrid cloud [24]. When the cloud infrastructure is owned solely for an organization, providing hosted services to a limited number of people behind a firewall, it is called a private cloud; it also called an internal cloud or a corporate cloud. But when the

cloud infrastructure is shared by several organizations, supporting a specific community with some shared concerns (e.g., security requirements and compliance considerations), then it is called a community cloud. Both the private and community clouds may be managed by the organizations or a 3rd-party and may exist on premise or off premise. On the other hand, public cloud makes its cloud infrastructure available to the general public or a large group and is owned by an organization providing the cloud services; it is also called external cloud. The hybrid cloud results from combining two or more cloud deployment models (private, community, or public) such that the models remain unique but are bound together by standardized or proprietary technology. Hybrid clouds aim to enable data and applications portability.

IV. MLEARNING BASED ON CLOUD COMPUTING: MLAAS

Both cloud computing and mLearning have attracted significant momentum and attention in both academia and industry but as separate entities. Cloud computing and mLearning were both in the list of the top 10 strategic technologies and trends identified by Gartner, the US analyst firm, consecutively since 2008 and 2010, respectively [11]. Since 2009, they both have been in the Horizon reports, with different adoption Horizons [15], [16], [17]; the Horizon reports, resulted from the collaboration between the New Media Consortium (NMC) and the influential EDUCAUSE Learning Initiative (ELI), aim to provide an educational-orientated perspective on expected key emerging technologies for higher education as well as K-12 education, where the K-12 editions are published as separate reports.

A. Synergy of Cloud Computing and Mobile Computing

Bringing together thin clients and cloud computing in the front end and the back end, respectively, is a natural synergy, liberating users to choose the most suitable access machines. This was envisioned by IT futurists such as Nicholas Carr who predicted the partnership of Google and Apple in the future, foreseeing a lightweight ubiquitous mobile device crafted by Apple to tap into Google's cloud [33] and in the design criteria of the “Intelligent IT Infrastructure” [7], a form of cloud computing, underdevelopment by Hewlett-Packard (HP). The joint Google-IBM cloud prototype, a dedicated data center for students at universities and colleges to gain the skills needed to program cloud applications, used a cell phone to download data from the cloud in its demonstration on February 2008 [6], to show its power. In the fall of 2011, Apple launched the iCloud service, a comparatively limited service, focusing on downloading content to devices to allow songs, photos, and documents saved on an Apple device to appear almost instantly on any other Apple product owned by that particular person (i.e., mobile or otherwise), without using e-mail or USB. Following the same steps with more enhancements, Amazon announced to deliver its vast cloud infrastructure to its Kindle Fire tablet, for watching videos, listening to music, reading books, playing games, running apps, and accessing Amazon's vast array of digital content easily. However, the synergy of cloud computing and mobile

computing was only viewed as accessibility and mobility features of cloud computing.

B. Synergy of Cloud Computing and mLearning (mLaaS)

Mobile learning faces some challenges due to the inherited weaknesses of mobile devices. These weaknesses play an important role toward the implementation of mLearning, thus questioning the viability of mLearning. The weaknesses of mobile devices can be classified into two categories:

- *User-interface Weaknesses:* These include the small screen displays, low resolution, and restricted input capabilities of some of these devices.
- *Computational Weaknesses:* These mainly include the low processing power, small storage capacity, and limited software and applications capabilities.

The user-interface weaknesses have been addressed in the literature in terms of usability and Technology Acceptance Model (TAM) to quantify learners' adoption and acceptance for some special applications or environments [1], [2]. Fortunately, these studies reflect a great acceptance of learners and students to mLearning for different applications in different environments.

On the contrary, the computational weaknesses are mostly left unattended; indeed they were left to the manufacturers of these devices to be overcome and thus introduced as enhanced features in their future products. Unfortunately, there are hardly algorithms designed to adaptively optimize their performance with respect to the different hardware and software available in these devices. With respect to the devices, this feature-based solution is an internal solution, limited by the advances in several technologies. In addition, computational-demanding applications on mobile devices will increasingly require more and more computational power. Therefore, a solution is to be seek from outside the devices (i.e., outside the box solution).

With cloud computing, most of the computing and storage tasks are performed in the cloud, thus placing low requirement on the client devices and relieving them from performing the high intensive computation or storage. Indeed, a simple mobile device (such as a feature mobile phone) with only Internet connectivity is sufficient to utilize the cloud services. Therefore, cloud computing enhances the computational capabilities of these devices to reach the level of high powerful computers, thus empowering mobile services to provide new ideas and solutions [9], [13].

Some of the weaknesses of the mobile devices can be addressed by using cloud computing, with its dynamic scalability and virtualized resources usage. With mLearning, this creates mLearning based on cloud computing, to be called mLearning as a Service (mLaaS). The term mLaaS is not only meant to be symphonic with other cloud terms (e.g., IaaS, SaaS) but also to emphasize the service concept.

From a business perspective, the meeting of cloud computing and mLearning signifies, indeed, a marriage in heaven. Cloud computing will supply the required infrastructure in terms of hardware, software, applications, and platforms, and mLearning will supply the users in mass quantities (i.e., all the learners and students).

C. Benefits of mLaaS

The characteristics and features cloud computing and mLearning will be inherited in mLaaS, making it reliable, flexible, cost efficient (due to the on-demand, pay-per-use costing model of cloud computing), self-regulated, and QoS-guaranteed [20]. In addition, performing high computationally intensive applications (e.g., image retrieval, voice recognition, and gaming) on the cloud, called computation offloading, was shown to save energies on the mobile devices, thus extending the lifetime of their batteries [19].

With mLaaS, adaptability can be simply implemented on mLearning systems, making them tailored to the learner's ability level to establish personalized learning. Therefore, applications such as computerized adaptive testing (CAT) [31] can be easily implemented with mLaaS, which was difficult to implement with traditional mLearning systems, in particular application-based mLearning systems.

V. SYSTEM ARCHITECTURE OF MLAAS

A proof-of-concept prototype of mLaaS was implemented based on iPhones and Google's App Engine for an undergraduate computer course at the City University of New York, demonstrating high usability of learners [5]. A Hadoop-based model for mLaaS was developed in [13], where its functional modules and workflow were analyzed. A basic framework and simulation application based on 3G for mLaaS was proposed in [20].

The previous work on mLaaS, though very limited, reflects the applicability of mLaaS, at least from an implementation point of view. However, the learning-focused services that can be provided by mLearning are hardly emphasized. Therefore, learner-centric service-focused system architecture of mLaaS needs to be developed. For this, the design criteria of mLaaS are first specified.

A. Design Criteria of mLaaS

The four major design criteria for mLaaS are: transparency, personalized learning, collaboration, and users' motivational effects. The transparency criterion aims at making mLaaS device neutral, allowing the use of variety of mobile devices and thus making the user unaware of the underlying telecommunications protocols and platforms. Personalized learning aims to make learning tailored to the learner's ability level. Collaboration allows collaborative learning, extended to sharing of intra-organizational educational and learning resources. The users' motivational effects create a learner-system interactivity to establish a new kind of relation between the users and mLaaS, which reflects positively in the relation between the users and their organizations.

B. Components of mLaaS

The architecture contains three layers: the user and device layer, the services layer, and the infrastructure layer. The users of mLaaS include learners, instructors, and parents. In the following description, when a service is provided to certain users, the users will be indicated explicitly; otherwise it will be implied that the service is provided to all users.

1) The User and Device Layer

It is the convenient entrance to the different services provided to the users. It contains three main modules: the Access Control Module, the Adaptation Module, and the Personalization Module.

The Access Control Module uses a Single Sign-On (SSO) mechanism for authenticating users. The SSO allows the use of a single authentication credential (i.e., username and password) to access all the services of mLaaS. The use of SSO increases the usability of mLaaS and relieves some of the help desk operations. However, users can change their passwords, after being authenticated, through the My Setting Module in the service layer, as will be explained later. Learners and instructors are registered in the same manner as in the traditional system, whereas for parents, the registration is done using the regular postal mail.

The Adaptation Module mainly consists of device and protocol adaptations. The purpose of this module is to transparently ensure the optimal applicability of users' devices to mLaaS and to further perform the necessary protocols conversion, if needed. This module provides transparency at the device and network levels, so that users are unaware of their devices applicability or the underlying protocols.

The Personalization Module contains data about the user. The data of this module can be divided into dynamic (e.g., location, time) and static parameters (e.g., name, age, gender, address, mobile telephone numbers, native language, leisure time, and user's interests). The dynamic parameters are updated automatically by the system but the static parameters are provided manually by the users [28] during their first use of mLaaS; however, this can be delayed by the users, if they wish, with reminders every time they log into the system.

Figure 1 shows user's authentication in mLaaS. This is consistent for all users. Along with the logon information, other information is transmitted by the device to mLaaS as well. The other information is related to the device, communication protocol, and some of the dynamic parameters of the user. Furthermore, the user is allowed to reset the password, in case it is forgotten; this is accomplished by sending, after user's request, the new password as an SMS by mLaaS to the user's mobile number.



Fig. 1 Users' authentication

2) Services Layer

It provides various services for the user. Users can easily access the services by clicking on the service. This layer

consists of the following modules but other services can be easily added in the future, when needed.

- ◇ **Registry Module:** Information of the last session conducted by the users is stored in mLaaS, allowing users to return to that particular session, if desired. This service plays an important role in keeping users' motivation, especially when communication is aborted accidentally.
- ◇ **My Settings Module:** With this module, users can change their passwords. Furthermore, it allows the learners and instructors to update their static personal information.
- ◇ **My Schedule Module:** It shows the weekly schedule of the learner or instructor, with the ability to be displayed on day by day basis to show the set of activities related to a particular day. It is automatically updated by the eLearning systems to include dates for assignments, exams, reports, etc. However, the learner or instructor can update information in this module manually to include meetings and other activities such as medical appointments. This module provides a reminder service, where the learner or instructor can flag any activities to be reminded.
- ◇ **My Courses & Labs Module:** It consists of a set of variety of services, including, but not limited to, access to lecture notes, assignments, labs handouts, and instructors' announcements. If applicable, it provides access to the labs, where learners can monitor their experiments. The instructors provide information for this module to be viewed by learners. Furthermore, a discussion board is provided for each course and lab, where instructors and learners can post questions, comments, and answers.
- ◇ **My Progress Module:** This module provides information about the progress of the learner, including grades, attendance, and instructors' comments. The instructors feed information to this module that can be checked by learners and parents.
- ◇ **My Campus Module:** It consists of a set of variety of services, including, but not limited to, access to email, campus newsletters, and campus announcements. It also provides a library service to check for the availability of a resource at the library. Furthermore, it provides a public bulletin service, where learners and instructors post their ads such as the need/sale/rent of cars, houses, and rooms.
- ◇ **Recommendation Module:** This module uses the "My Schedule Module," the "Personalization Module," and the "My Courses and Lab Module," to recommend a service to the user. For example, if the user has an exam after three hours, as it is indicated in the "My Schedule Module," it will recommend to the user to review for the exam. In addition, if the "Personalization Module" of a user indicates the timing as a leisure time, then it will recommend an activity, according to the user's interests, such as reading the news. This service establishes a new kind of relation between the user and mLaaS. Acceptances or rejections of the previous recommended services are also used to select a new recommended service.

- ◇ **Outside Resources Module:** It allows other learning or educational resources at other campuses to be accessed, thus realizing the intra-organizational sharing of learning resources. Furthermore, it provides access to other resources such as news papers and magazines.

The welcome message of mLaaS, after successful authentication, of course, is depicted in Fig. 2. The welcome message typically shows some personalized parameters and reminders. For example, the figure shows the user name, time, and location. It also gives the user the ability to continue with last session or select a new service.



Fig. 2 The welcome message after successful authentication

The services provided by mLaaS to the learners are shown in Fig. 3. Similar services are provided to the instructors. For the parents, the provided services are only “My Setting” and “My Progress.” However, through “My Progress Module,” the parents can communicate with the instructors privately as in teacher-parents meetings.



Fig. 3 Services provided by mLaaS to the learners

3) Infrastructure Layer:

This layer, managed by the cloud computing provider, establishes the infrastructure for mLaaS, where virtualization technologies for hardware and software are used to ensure the stability and reliability of this infrastructure. This layer can be implemented as a private cloud or using a public cloud provider. It consists mainly of the following three sub-layers:

- ◇ **Physical Sub-layer:** It mainly supports the basic environment, including computers, storage, network interconnect devices, and database resources.
- ◇ **Virtual Resources Sub-layer:** Using virtualization technology, IT resources are combined into resource pools: the computing, data, network, storage resource pool. Thus a large number of the same type of IT resource is

configured into graph isomorphism or near graph isomorphism, providing high performance services..

- ◇ **Logic Sub-layer:** The logic sub-layer maps the services to their clusters services by simply managing the underlying resource, scheduling user's requests, and provisioning the needed resources to access the services efficiently and securely. Both the logic sub-layer and the virtual resources sub-layer provide the core management for mLaaS.

VI. CONCLUSIONS

The use of cloud computing, with its dynamic scalability and virtualized resources usage, can empower mLearning by eliminating some of weaknesses of the mobile handheld devices, creating mLearning as a Service (mLaaS), focusing on the following four features: transparency; collaboration, extended into intra-organizational sharing of educational and learning resources; personnel learning; and motivational effects. Furthermore, the system architecture for mLaaS reflects its diversity and flexibility, where new features and services can be added to enhance learning and education environment.

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