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# Multimedia augmented m-learning: Issues, trends and open challenges

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ABSTRACT

The advancement in mobile technology and the introduction of cloud computing systems enable the use of educational materials on mobile devices for a location- and time-agnostic learning process. These educational materials are delivered in the form of data and compute-intensive multimedia-enabled learning objects. Given these constraints, the desired objective of mobile learning (m-learning) may not be achieved. Accordingly, a number of m-learning systems are being developed by the industry and academia to transform society into a pervasive educational institute. However, no guideline on the technical issues concerning the m-learning environment is available. In this study, we present a taxonomy of such technical issues that can impede the life cycle of multimedia-enabled m-learning applications. The taxonomy is devised based on the issues related to mobile device heterogeneity, network performance, content heterogeneity, content delivery, and user expectation. These issues are discussed, along with their causes and measures, to achieve solutions. Furthermore, we identify several trending areas through which the adaptability and acceptability of multimedia-enabled m-learning platforms can be increased. Finally, we discuss open challenges, such as low complexity encoding, data dependency, measurement and modeling, interoperability, and security as future research directions.



## 1. Introduction

The enhancement of new technologies in wireless communication systems as well as smartphone hardware and software (operating system) enabled the deployment of sophisticated communication and computation infrastructures to deliver various multimedia-oriented mobile services. In these multimedia services, their generated multimedia contents/data have common continuous-, data-, and compute-intensive qualities. In general, multimedia contents are bounded by strict timing relationships. These timing relationships must be obeyed when processing and rendering such data (e.g., transmitted video, displayed video, rendered 3D graphics, or played out audio).

The intensive penetration of smart mobile devices and mobile applications has fueled a new wave of demand for mobile services, such as mobile learning (m-learning), which introduces the wireless and ubiquitous system of learning. With the assistance of such systems, smartphone users can use the educational material on their device to learn. Such educational materials can be in the form of multimedia content or learning objects, which are more interactive, highly visual, engaging, and effective for learner quality of learning (QoL). Indeed, these learning objects can be easily used by the students whenever necessary and wherever they are by maximizing this “always there, always on” technology (Ally, 2009). Consequently, the subscribers to the learning system not only expect ubiquitous network connections but further demand to seek a rich media experience wherever they go and whenever necessary. In fact, this overwhelming thriving of mobile media gives rise to multifold technical challenges. These problems include (i) the difficulty in sustaining the satisfactory quality of experience (QoE)/QoL over inherently unreliable wireless links and (ii) the tendency of large simultaneous delivery of media contents tends to swamp existing mobile network infrastructure. Moreover, a fundamental gap exists between the resource demands of computationally expensive processing of multimedia contents and the capabilities of battery-constrained mobile devices. In this context, the current development in mobile cloud computing (MCC) seems

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to bridge this gap in terms of providing mobile applications the capabilities of cloud servers and storage together with connectivity.

Cloud computing offers on-demand and elastic delivery of software and hardware infrastructures via the Internet using a service-oriented model (AFox et al., 2010). Cloud computing emerges because of advantages, such as reduction of the capital cost, decoupling technological fabric from service delivery, and providing mobility and flexibility of stored data. MCC is actually the amalgamation of the mobile environment with the cloud computing systems. MCC is conceived to mitigate the issues related to mobile device performance (battery life, processing time, and storage), mobile environment (heterogeneity, availability, and scalability), and security (privacy and reliability). By resorting to the cloud as a reservoir for additional computation and storage, mobile media services can scale better with user demand because of their flexibility and dynamism at relatively low costs.

Furthermore, MCC can provide an infrastructure for scalable delivery of various mobile multimedia applications, such as m-learning, mobile gaming, and interactive video streaming (Chang, Walters, & Wills, 2015). In addition, MCC technologies can enhance the desktop-based web-facilitated or traditional classroom-based educational experiences by offloading the personalized translating and transformation of the learning material to the cloud from the subscribers' devices. Furthermore, in the large-scale location and time-agnostic m-learning environment, a distributed cloud environment in conjunction with the mobile cloud can provide various multimedia services to the subscriber of the m-learning environment. These services may include pre-composed multimedia lectures, videos, animations, and images. However, the retrieval and communication of pre-orchestrated and real-time multimedia data impose challenges of heterogeneous networks, quality of service (QoS) requirements, and heterogeneous multimedia data on the design of the MCC architecture (Felemban, Basalamah, & Ghafoor, 2013).

In recent times, the smartphones capabilities have significantly improved; however, when compared with the tradition desktop computers they are still far behind. Furthermore, the introduction of cloud-based mobile media has further posed various limitations due to heterogeneious mobile devices and dynamics of other technologies on the applications in which they are being utilized. Consequently, providing a generic solution for these limitations for all types of mobile environments; therefore, special attention is required when developing such mobile multimedia learning applications. To mitigate the heterogeneity problem for a wide range of mobile devices, the multimedia content objects should be agnostic of mobile device software and hardware (Ahmad & Gabbouj, 2008). Furthermore, recent years witnessed a significant growth in the total of multimedia coding standards and the number of delivery protocols for multimedia contents (Deursen et al., 2009). In fact, the diverse mobile phone architectures and characteristics, multimedia coding standards, delivery protocols, intrinsic characteristics of the wireless networks and cloud-based multimedia service delivery create several issues. These concerns may include cloud resource provisioning and scheduling, media content management and delivery, QoS, user mobility, and security. Furthermore, the service providers may pool the statistics of mobile devices in the same region and leverage such knowledge to improve their media transport and caching strategies. Apart from this attempt, mobile applications may offload computationally expensive tasks to the cloud.

This paper aims to outline the mobile multimedia cloud computing issues in the m-learning environment and provide insights on these issues, which will be useful when designing the m-learning system. The remainder of the article is organized into the following five sections: Section II presents the background on m-learning system and education as a service (EaaS) with its characteristics and advantages. Section III presents the taxonomy of issues related to m-learning environments. Section IV presents several trending areas, which can increase the adaptability and acceptability of multimedia-enabled m-learning systems. Section V discusses several open research challenges, which should be addressed to stabilize and improve the m-learning environments. Finally, Section VI concludes the article.

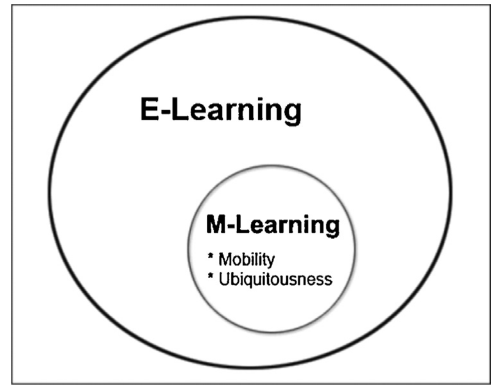


**Fig. 1.** Schematic of mobile learning.

## 2. Background

In this section, we describe the m-learning environments by exploring how the cloud can benefit m-learning using EaaS.

### 2.1. Mobile learning

The ever-increasing functional capabilities transformed the smart mobile devices into ubiquitous computing devices. This development probably led to the incubation of new m-services into the spectrum of the mobile environment, services offers, provisioning and consumption of audiovisual formats, context, and localization-based information dissemination, and user preference-based personalized assistance (Chang, 2016; Herrington, Herrington, & Mantei, 2009; Sharples & Roschelle, 2010). These type services consumed by end user mobile devices can be utilized for learning purposes to improve desktop/web-facilitated or conventional classroom based educational process. This possibility has led to research on educational initiatives to investigate the potential and effect of the learning contents delivered via ubiquitous mobile devices. Generally, "m-learning" is the process of development, delivery, and consumption of learning material via a learning system subscriber using mobile devices. Fig. 1 shows the schematics of m-learning in conjunction with distance and e-learning.

In fact, m-learning is a form of distance education system delivered on a mobile device. However, m-learning is distinctive in its application through its emphasis on the learning across contexts (location, time and other environmental factors), differentiated through mobile devices. One can simply define m-learning as a learning process in which the learner does not remains at a fix location and benefits the learning prospects accessible via smart mobile devices (Alabbadi, 2011; Chen, Liu, Han, & Xu, 2010; Gao & Zhai, 2010; Kitanov & Davcev, 2012; Masud & Huang, 2013). Consequently, m-learning reduces the constraints of location bounded learning, given the flexibility and mobility of smart mobile devices. A generic m-learning environment is presented in Fig. 2.

The suitability of m-learning lies in its nearly complete accessibility from practically anywhere in the globe, provided the presence of network connectivity. M-learning (e.g., e-learning) is also collaborative, resulting in the availability of immediate feed-