M-learning in review: Technology, standard and evaluation*

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Abstract: Nowadays E-learning as a form of learning depending on networks and computer devices has been expanding by leaps and bounds. As a special kind of E-learning, M-learning (mobile learning) aims at the use of mobile devices anywhere at anytime by anybody. In this paper, the technologies to develop a M-learning system are deeply analyzed according to the layer model at first. Then, from the view of application, the standardization in M-learning is researched in order to accelerate the development and popularization of M-learning. Finally, quality estimation of M-learning system is discussed from the view of QoE (quality of experiences). The experience form end-user is the sole effective norm to judge the result of M-learning technology. It is no doubt that technologies, standardization and evaluation will play very important parts in the course of M-learning development.

Key words: M-learning; technology; standard; evaluation

1. Introduction

E-learning is a learning environment supported by continuously evolving, collaborative processes focused on increasing individual and organizational performance[1]. E-learning is the acquisition and use of knowledge distributed and facilitated primarily by electronic means. This form of learning currently depends on networks and computers but will likely evolve into systems consisting of a variety of channels (e.g., wireless, satellite), and technologies (e.g., cellular phones, PDA's) as they are developed and adopted. E-learning can take the form of courses as well as modules and smaller learning objects. E-learning may incorporate synchronous or asynchronous access and may be distributed geographically with varied limits of time[2]. In short, E-learning is the learning facilitated and supported through the use of information and communication technology[3].

At the initial stage, E-learning was mostly targeted toward PC users using fixed line access to Internet (e.g., KBS 2000, CBR 2002, SQL 2002, Blackboard 2002, VEDA 2002, Prentzas 2002). With the availability of high bandwidth wireless channels such as 3G-telecommunication infrastructure and wireless LAN, M-learning is becoming more feasible now[4].

With respect to technologies, 'mobile' generally means portable and personal[5], like a mobile phone. M-learning (mobile learning) is a kind of E-learning which based on the use of mobile devices (PDAs, mobile phones, notebooks or Tablet PCs) anywhere at anytime[6]. These devices must support wireless communicational technologies (GPRS, GSM, IEEE 802.11, Bluetooth, IrDA) and have a possibility to present teaching materials, and to realize an asynchronous/synchronous communication between learners and teachers[7].

In this paper, we focus on the technologies, standardization and evaluation of M-learning by the literatures review in mobile technologies and E-learning. Firstly, M-learning system overview and its layer model are given in this paper. The technologies and characteristics in M-learning are deeply analyzed. M-learning is a special E-learning supporting mobility

* **Acknowledgement:** This work was supported by Joint European Project ICT Learning Pentagram (No. CD_JEP-32162-2004).

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and needs existing E-learning application improved from media content to transmission technology. Secondly, the line map and practical method of developing M-learning standards are researched. As a kind of network application based on mobile communication platform, M-learning is related to equipment provider, network provider, content provider, technology provider and service provider. In the process of disseminating and applying M-learning technology, the standardization of M-learning will play a leading role. Finally, the investigation of usability and user-based methods in quality estimation of M-learning system are discussed from the view of QoE (quality of experience). End-user's QoE is undoubtedly the sole effective norm to judge the success or failure of M-learning technology.

2. M-learning technologies

2.1 M-learning system

Several technologies are available to implement a dynamic and adaptive M-learning system. Sever side techniques using Java servlet, JSP, ASP, PHP and other proprietary authoring tool such as macromedia flash with action script can be used. Other enhanced severs such as CoCoon or Xalan are capable of implementing device adaptable system. Fig. 1 shows an overview of M-learning system, where XML files are used to store the content (questions), directions for multimedia representation of revision material for the students, and the user model. These involve the content and user dimensions[4]. M-learning systems can support different types of mobile devices, such as wireless laptops, iPods, cell phones, PDAs, Tablet PCs, and smart phones.

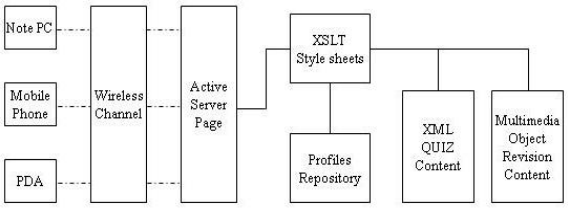

Fig. 1 M-learning system overview

M-learning is a special E-learning supporting mobility. M-learning takes wireless communication instead of wire communication in E-learning to build the network platform. Since both M-learning and E-learning are the systems on Internet network environment, we can reference TCP/IP layer model [8-9]. From the viewpoint of layer model, M-learning system is composed of learning application layer, transport layer, network layer, and data link layer (physical communication platform). Fig. 2 shows the layer model of M-learning system. At the bottom layer of M-learning layer mode, optional wireless communication technologies include GPRS (General Packet Radio Service), 3G, IrDA (Infrared Data Association), Bluetooth, IEEE 802.11 (Wireless LAN), IEEE 802.16, WiFi, WiMAX (Worldwide Interoperability for Microwave Access), etc.

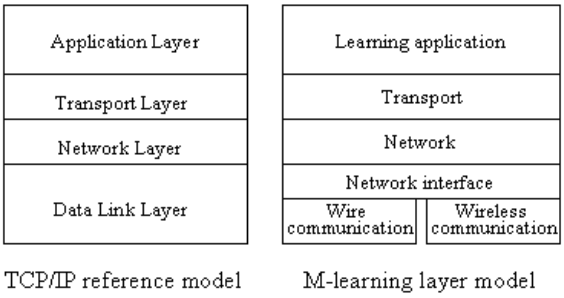

Fig. 2 M-learning layer model

Nowadays vast majority of mobile equipments are able to support IP networking with NOS. Optional OS platform includes Windows CE, Pocket PC, Symbian OS, Palm OS, J2ME (Java 2 micro Edition), and Pogo Linux. Moreover, optional development languages include Flash, C, WML, VoiceXML, HTML, XHTML. Multimedia application information, including video, audio files, Phone calls, voice recognition, still Images, mobile Web, interactive media, can be delivery between server and client through many kinds of transport protocols such as WAP (Wireless Application Protocol), E-mail, SMS (Short Message Service), MMS (Multimedia Messaging Services), and HTTP.

From the viewpoint of communication service character, M-learning is the integration of data service

and mobile service. WAP is the standard for mobile data service support by many equipment providers, and has been widely applied in wireless Internet. WAP protocol stack is compared with Internet protocol stack, as seen in Fig. 3. In order to understand their difference, lower layer protocol is also given in Fig. 3. Now WAP has developed from initial V1.0 (WSP/WTP/WTLS/ WDP) to V2.0 (WP-TCP).

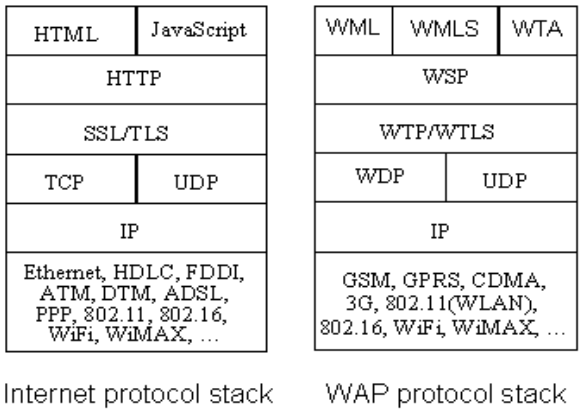

Fig. 3 Protocol stack comparison between WAP and Internet

Above analysis shows that five broad categories of information and communication technologies (ICT)[10], namely transport, platform, delivery, media technologies, and development languages, should be considered in considering the implementation of M-learning.

Further investigation on M-learning system shows that Different Delivery Platforms and Removable Storage Memory Formats should be considered in Client Platforms; in the respect of Mobile Content Development, Different media (audio, video, Web, images, document, Flash Lite) and their relevant questions, such as Resolution, Compression, Codecs, Local Playback, and Wireless/Streaming Access, should be separately examined in its entirety; in the respect of Mobile Content Support, a comprehensive programmer should be made for accessibility, content packaging and metadata; in the respect of Mobile Content Delivery, we should focus on mobile Web services, wireless data connectivity (IrDA, Bluetooth, WiFi, GPRS, et al) and proximal learning technologies (GPS, RFID, 2D Barcodes) .

2.2 M-learning characteristics

M-learning is the integration of E-learning and mobile communication technologies. Above analysis shows apparently that existing E-learning system also needs to be improved from the learning application at upper layer to transmission technology at lower layer in order to support user's mobility.

An essential distinction between M-learning and general E-learning is that the former has mobility. In other words, E-learning system is able to support mobile data service. From the viewpoint of information and communication technologies (ICT), Mobility of M-learning lies in the following main indicators:

(1) support of mobile devices;

(2) support of wireless communication technologies.

Since M-learning is a kind of special E-learning, it has also the same characters as general E-learning. From the viewpoint of educational technologies, common characters of E-learning lie in the following main indicators:

(1) Support of synchronous and/or asynchronous education;

(2) Support of on-line and/or off-line mobile learning;

(3) Support of user's location (on-campus, off-campus);

(4) Access to learning materials and/or administrative services.

3. M-learning standards

From the viewpoint of application, M-learning is a kind of network application based on mobile communication platform. Like the other applications, it is also related to equipment provider, network provider, content provider (specialized website), technology provider, and service provider. In the process of disseminating and applying M-learning technology, all

above roles have their own duty, location, and function. For example, portable terminal equipment should not only possess abundant interface to support some mainstream wireless communication technologies, but also possess appropriate OS and application software to support mobile learning environment including different kinds of media content and interactive mode. Wireless network should possess better signal coverage and connection performance, and provide more bandwidth and higher rate. It is also necessary to provide better interflow of service, especially M-learning service, between different networks or different ISPs. The trend of learning materials (content) is the integration of text, photograph, audio, video, et al. The content design should take into account the limit of mobile learning environment including transport protocol and terminal ability.

It is very important to coordinate all above roles to promote M-learning application, and M-learning standardization would play an important part in this course. History shows that revolutionary changes do not take off without widespread adoption of common standards. For Internet, this was the common standards of TCP/IP, HTTP, and HTML. Common standards for metadata, learning objects, and learning architecture are mandatory for similar success of the knowledge economy.

Unfortunately, there are no unified international specifications and standards for M-learning at present. Since M-learning is the subset of E-learning, it is reasonable for M-learning to refer to E-learning specifications and standards at first. Fortunately, the work to create such standards for learning objects and related standards has been going on around the world for the past few years. This includes the creation of accredited standards from the IEEE Learning Technology Standards Committee (LTSC) for Learning Object Metadata, Computer Managed Instruction, Course Sequencing, Learner Profiles and much more[11].

Currently, E-learning standards are being developed by four main organizations: IEEE LTSC, AICC (Aviation Industry CBT (Computer-Based Training) Committee), IMS (Instructional Management System), and ADL (Advanced Distributed Learning). Based on accepted technology standards, including XML and JavaScript, SCORM (Sharable Content Object Reference Model) is fast becoming the de-facto E-learning technology standard widely embraced and supported today by world-leading corporations, universities, system providers, and content vendors. The SCORM standard comprises of four major elements: an overview, Content Aggregation Model, IMS guidelines, and the run-time environment. The SCORM standard is focused on enabling the plug-and-play interoperability, accessibility, and reusability of Web-based learning content[12].

However, M-learning posses itself characteristics which needs appropriate standards. The need for standards in M-learning has been well established by educators and education support professionals over the last few years[13]. To define appropriate standards and best practices for M-learning, a practical method is to utilize the activity-based model as following[14]:

Step 1. By identifying the learning activities associated with the practice of M-learning, a learner-centric standards model may be developed to support the known activities of teachers and learners.

Step 2. By utilizing this activity-based model of M-learning, a literature review was conducted that accumulated a body of knowledge of best practice, and then standards and best practice in M-learning might be informed.

Step 3. It is the peer consultation phase to present the findings of the literature review and accompanying research to M-learning practitioners, mobility and mobile content experts, and associated support professionals, so as to complement with anecdotes and recommendations drawn from practical experience.

The development of M-learning standards and best practices must address issues affecting the creation, delivery, interoperability, and discovery of mobile

learning resources. In the investigation of these issues, equity and accessibility issues should also be given due consideration, to reduce barriers to accessing M-learning content.

The development and popularization of M-learning should be step by step, accompanying by the development and popularization of common mobile communication technology (such as 3G, 4G), and it should also be compatible with some new technologies, such as Ad Hoc, universal computing, and grid. Undoubtedly, the standardization of M-learning will play a leading role.

4. M-learning evaluation

Technical standards for M-learning are used in guiding its system design and technical implementation in order to get better application results, but how to determine the value of a realized M-learning system? Usability is the basic parameter for the evaluation of M-learning technologies and systems. Usability means quality and puts the users and their real needs in the center. Therefore investigation of usability and its integration or contribution to the learning process is worthwhile.

It is known that the major dimensions of usability defined by ISO (1993) are effectiveness, efficiency, and satisfaction. As to their refined meanings in the M-learning context, we may refer to the definition for the instructional interface design process[15].

(1) Effectiveness: Learner interprets instructional interface function correctly; instructional interface function performs according to the learner's expectations.

(2) Efficiency: Learner experiences minimal frustration interpreting instructional interface function; learner experiences minimal obstacles in using instructional interface element.

(3) Satisfaction: Learner seems comfortable in the environment overall.

For evaluating the usability of interactive systems, user-based methods and inspection methods are the most commonly adopted. User-based methods[16] mainly consist of user testing, in which usability properties are assessed by observing how the system is actually used by some representatives of real users. Meanwhile, usability inspection methods[17] involve expert evaluators only, who inspect the application and provide judgments based on their knowledge and experience.

Here we focus on user-based usability in evaluation techniques of M-learning, so that we can do our best to realize and implement the learner-centered design paradigm, reflect upon learners' needs, and understand their attitudes. It is suggested that such a method incorporate the following basic characteristics[18]: (1) It must be built upon the creative integration of the usability and instructional design; (2) It must take into account the learners' perceptions themselves; (3) It must be short, easy to deploy so that M-learning economics can afford its use.

We can adopt the three-step approach to learner-centered usability testing[19]. First, designers and usability experts do a quick run through of the instructional interface to see if it is addressing some of the most basic types of learner questions. Second, a check sheet matrix is employed to guide the usability testing. The matrix consists of two sections: a. user actions that evaluators can observe, and b. questions that evaluators can ask the users. Observation and interviews are the main methods proposed. Third, thinking aloud protocol is employed in usability tests with users' involvement.

In fact, Quality of Experience (QoE) from end users is the best criterion to evaluate M-learning, because practice is the sole criterion for testing truth. Nowadays Service accessibility, retainability, availability and integrity define the QoE performance and competitive advantage across packet-based communications networks. A very well known and widely used approach to measuring QoE is service level performance measurement using statistical samples[20].

This methodology relies on a statistical sample of the overall network users to measure the QoE for all the users in the network. This process involves the determination of key service weights (in the case different metrics are combined to form an overall user satisfaction index); the identification of QoE key performance indicators (KPIs); definition of a proper statistical sample (time of day, traffic mix, geographic areas, etc.); collecting measurements utilizing mobile QoS agents in handsets; and giving an overall QoE score (index) from KPI values for each separate service and service mix.

5. Conclusions

Technology is the foundation of realizing M-learning, standardization is the guarantee of a good M-learning system, and evaluation is the approach to examine the effect of an M-learning system. In this paper, technologies, standard and evaluation in the reconstruction of M-learning systems have been analyzed in detail. For the better comprehension and practical use of above concepts, related model, methods and detail realization steps were also provided.

Learning is eternal theme in both M-learning and E-learning. Learning is a deeply personal act that is facilitated when learning experiences are relevant, reliable, and engaging. Different kinds of learning demand appropriate strategies, tools, and resources. Therefore technology in and of itself may not guarantee better learning. Successful M-learning should emphasize user's experience, encourage contacts between students and faculty, develop reciprocity and cooperation among students, and give prompt feedback in order to improve itself ceaselessly.

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(Edited by Flyer, Marx)