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With the advances in mobile technologies it is already possible to support learners and teachers activities on the move. Nevertheless the interoperation between a Learning Information Systems and mobile technology is still weakly explored. We analyzed the functionalities that should be provided by e-learning and m-learning and present them in a general mobile learning platform. It is extension to traditional LMS and thus able to provide all possible e-learning services and additional specific services to the mobile users. Such a system should have three main functionalities – "Context Discovery", "Mobile Content Management and Presentation Adaptation" and "Packaging and Synchronization".

1 Introduction

E-learning is growing very fast and many Universities and companies are already supporting in some way an e-learning solution. The rush in the field of wireless and mobile technologies creates opportunity for new field of research - so called 'mobile learning'. The domain of mobile learning can include a wide variety of applications and new teaching and learning techniques. In their tries of finding the best way to apply mobile devices in education people are experimenting with different fields. Courses modules were created throughout different projects for people with numeracy and literacy problems, for kids and university students, for teachers, for studying computer science, psychology or languages (for a review see [5]).

In this paper, we present and analyze different ways to apply mobile devices in education. We consider university e-learning system and the possibilities to extend it to provide services for mobile devices. This led us to classify services that are specific and should be provided by a general m-learning platform.

The paper is arranged as follows: Section 2 gives a description of what e-learning is and what services are generally offered by different e-learning platforms; Section 3 describes m-learning and analyze what are the problems in the transition from e- to m-learning. Section 4 is dedicated to the proposed architecture, followed by related work (Section 5), conclusions (6) and references.

2 E-learning

E-learning in general can be seen as technology-delivered or technology-enhanced learning. In one scenario of usage the learners and the instructors can be physically separated (can never or rarely meet for face-to-face lectures, discussions, etc.) and thus all the process of studying and teaching is technology-mediated. In another scenario the traditional learning approaches can be supported with complementary services, like online delivery of the learning materials, syllabus, schedules and etc. The goals of the different e-learning systems can differ and so the functionalities offered by them: the educational needs and goals of an industrial company are different from those of a university institution. These functionalities can be grouped in four categories: resources (data), specific e-learning services, common services and presentation. We will list the main services and later shall discuss how these services get modified with the introduction of mobility and small devices.

- Resources
  - Support of learning objects (LO) – any written digital material, applet, link to other sources, simulations, etc. Breaking the educational content into small pieces allows modularity and reusability of the content. These chunks of digital resources are usually described with additional metadata attached to them and later arranged in more meaningful modules – lectures, courses and programs.
  - Tests and quizzes – the lecturers can a priori define questions and the corresponding answers for automatic formal examination or self-assessment of the students.
  - Learning Metadata repositories – specific data can be kept to additionally describe the learning content elements, which can be used to catalog learning objects, to facilitate searching and reusing.

- E-learning specific services
  - Content management services - For grown people studying by default is arranged in courses, lectures, classes, etc. thus an e-learning system must have the notion of Course and Lecture. The course can be composed by series of resources: syllabus, one/many lectures, structure for describing lecture sequence, forum, board, etc. A lecture is usually composed by many resources: presentation section, exercise section, additional material section. All these components should be organized and accessed through a proper engine. There could be searchable directories of courses, programs, etc.
  - Self-assessment - one of the main advantages of computer-supported learning is the automation of some important processes. The self-assessment is one example. The a priori defined questions and corresponding answers allow automatic generation of different versions of tests and quizzes but also automatic checking of the results, evaluation of performance and comparison with others' results.
  - Knowledge management – today most e-learning system do not support knowledge management services. It's a new tendency in the e-learning platforms which aims at extraction, summarization and organization of explicit or tacit knowledge from data sources (e.g. Web, e-mails, chats, etc.). Knowledge management is mostly explored in companies, where it is essential, while in university context it can be a useful add-on, but is less relevant.
  - Tools to support learners and tutors in managing their learning resources - some systems can allow different users to have their own workspace and to upload personal resources (links, documents, notes, etc.). The access to must be controlled by permissions (checked against user authentication)
- Common services
  - Support of different actors (User management) - students, teachers, tutors, administrator and sometimes guests. Different registered users can have different levels of permissions. Guests are unregistered users and their access to the platform is typically very limited.
  - Collaboration - synchronous (whiteboards, chat rooms, web-cast), asynchronous (discussions, forums, message/news boards, e-mail, mailing lists),cooperative work (shared electronic whiteboards, video/audio conferencing, multi-party game simulations). Usually few different services are offered for communication between users of the system (learners, lecturers, tutors, mentors). Some activities group the users for cooperative work, other are for posting important or topical information.
  - Events management - usually calendars and schedulers are provided for all the users. They can take into account the single student/lecturer events and also group events.
- Presentation
  - Presentation of content - The common requirement is that e-learning system must be accessible from a single point (e.g. a portal) by using a normal browser, but also special applications can be used.
  - User/activity tracking and monitoring - history of the interaction of the actors and the system and statistics on the performance are often important sources of information and basis for adaptation of the system. This process is often hidden from the actors.

3 M-Learning

M-learning is often defined as e-learning through mobile computational devices. In general by mobile device we mean PDAs and digital cell phone, but more generally we might think of any device that is small, autonomous and unobtrusive enough to accompany us in every moment in our every-day life, and that can be used for some form of learning. These small tools can be seen as instruments for accessing content, either stored locally on the device or reachable through interconnection. They can also be a tool for interacting with people, via voice and through the exchange of written messages, still and moving images.

There are many properties that differ when comparing a mobile device from a desktop PC (the usual medium to deliver e-learning) and they have impact on what is reasonable, useful and even pleasant to do on such devices. Some of them are the output (i.e. the screen size and resolution capabilities, etc.); input (i.e. keypad, touch-screen, voice input); processing power and memory; supported applications and media types. When we try to transfer services provided by an e-learning platform into services in an m-learning platform we can see that some of them should change to fulfill the limitations of the small devices, some are impossible to be delivered in a certain context, but also new services appear, provoked by the mobility.

The Connectivity - Contrary to e-learning, which supposes always-on connection, m-learning could be delivered in three different ways. We can schematically call them "pure connection", "pure mobility" and mixture of the previous two (intermitted connection). "Pure connection" is when the mobile device is always connected to internet. Now there are quite a lot of technological ways of having the WWW and other services available for the small devices, i.e. through WAP, GPRS, UMTS, Bluetooth, etc. On the other hand "pure mobility" is when no connection is available and so all the data the applications need should be uploaded on the device and used offline. In this case nowadays mobile phones, which still have very limited memory, can not be used. But the situation quickly changes and the new generation cell phones have more processing power, memory and embedded software. The PDA's could be used now but they also have memory limitations that should be considered though they can be evaded by using extension packs with extra memory. If so delivering also sound/video-lectures offline could be possible.

The Devices' hardware/software characteristics - Access to the web through personal electronic devices, with their small screen size, has been an interesting problem for lots of researchers. Unfortunately, today most web pages are designed to be displayed on desktop computers with color monitors having at least 800x600 resolution. This leads to at least 2-to-1 (often greater) ratio of designed vs. available screen area, making direct presentation of most pages on the small devices aesthetically unpleasant, un-navigable, and in the worst case, completely illegible. Depending on the devices used the delivery format and the needed transformations on it could defer. In some cases if we think about WAP devices some transcoding techniques could be used to transform from one presentation language to another (WAP-HTML-WAP). Although it is possible to deliver content to WAP phones the reading is rarely easy enough and the interaction is quite a difficult task. One can also think of delivering the content in alternative ways (e.g. voice, video). When we consider PDAs instead of WAP devices the possibilities are wider, but still all problems linked with conversion/adaptation/transcodification of general purpose content remain.

The New Context (Location-awareness) - The mobility of the devices used in m-learning scenarios involves a new context data to be considered – location. Services involving location-discovery are for example a student/teacher receiving directions how to get to a certain room or alerts for seminars/lectures that can be triggered while taking into consideration the current place and the time to get to the needed aula, location-aware printing of the learning content, etc.

4 A General Architecture for M-Learning

Earlier we enumerated the major functionalities offered by e-learning platforms as services. This approach gives an extra level of abstraction so the e-learning platform can interoperate with the new functionalities that must be offered by m-learning platform (mobile specific services). The services approach also provides support in the interoperability between different e-learning platforms (not only e- to m-learning) that can run on variety of platforms and are language independent [2].

The coupling of advanced technologies, like the ones involved in mobile computing, with learning and assessment models represents an advanced point of research. In order to support the experimentation of any tool or technique of m-learning a rather complex information system is necessary. Its role should include distributing didactic material, user identification and authorization, gathering of data relative to the user-system interaction, provisioning of mobile services etc. The idea of interoperation between a Learning Information Systems (LIS) and mobile technology is still weakly explored. In this sense we think that the provided m-learning architecture should: (1) sit on the top of e-learning platform, i.e. be an extension to traditional LMS and should provide adapted and additional services for the mobile users; (2) be general, i.e. the system should be able to carry out all the services of the e-learning and all the services for m-learning; (3) be generic, i.e. it should be easily extensible for different nowadays devices and also for the new generation mobile phones and PDAs thus not excluding their usage in the future.

In first place it is best if a mobile device is able to access all the available system's functionalities through either a specific application or through a web/wap browser. This means that the system should be able to automatically detect the devices' capabilities and limitations (software and hardware) and to check what services can be provided. We called this functionality "Context Discovery" service. As discussed

earlier the infrastructure is only one of the possible contexts that should be considered. “Context Detection” adds additional abstraction that can hide the details about the different physical methods of context discovery. For example for finding location different positioning systems can be used – in one case the user will be outside and can use a GPS system and in another will be inside the building and will use the local network signal for that. A possible solution is the introduction of a semantic server, which translates data from the format used by the device (GPS, WLAN, etc.) into format, proper for the service that requests the context information. It is also not necessary that the system detects all possible context data at the first user request for service. Some context data might be detected and provided when needed (on demand).

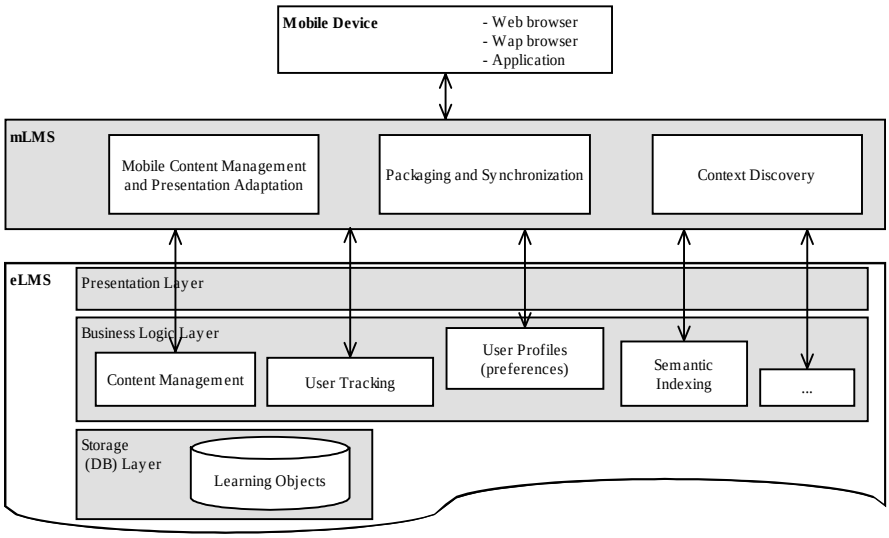

Figure 1: General and Generic m-learning Architecture

The second step should be to select the services proper for the device and adapt them the best way. Nowadays the main service in e-learning is the presentation of content. Adapting e-learning material for a mobile scenario might imply something more than a simple reshaping of material or translating from one presentation language into another. It should be more precise and could involve different presentation logic than in e-learning (Mobile Content Management). The presentation adaptation can include adaptation of the structure, adaptation of the media format, quality or even type, etc. This module should be also used to adapt the presentation for auxiliary services, not only presentation of content.

For allowing offline usage we need a mechanism for selecting what is needed by the user and also for taking care of content’s coherence and synchronization with the system. During the offline usage it is better to continue the tracking of the user activities and feedback the statistics to the LMS.

Up to now we can identify some as functionalities that should be supported by an m-learning system:

- The first is discovery of context. By context we mean here identity, spatial information (i.e. location), temporal information, environmental information (i.e. noise level), availability of resources (i.e. battery, display, network, and bandwidth), and etc. The context information could be used for specific m-learning services, but also for adapting the services offered by the eLMS for the mobile device.
- Second is the content management and specific adaptations for presenting content to mobile devices.
- The third is support for disconnected operation.

On Fig. 1 above the architecture shows only some of the services that should be provided by eLMS. In the business logic layer these services might not be so clearly separated. In the mLMS the different modules also interact to provide the full range of functions. For example to display the content of a lecture to a user that uses PDA the “Context Discovery” detects the characteristics of the device, then the needed content is retrieved from the eLMS and is redesigned by the “Mobile Content Management” to best fit the device. Meanwhile the reshaped content might be packaged and seamlessly uploaded for offline usage.

5 Related Work

A work closely related to ours is on defining the requirements for a mobile e-learning platform [3]. The authors discuss the possible m-learning scenarios in respect of e-learning platforms and the functionalities an m-learning platform is best suitable for. Also the characteristics of the mobile devices are discussed and their impact on foreseeable learning scenarios. What differs drastically in this work from our point of view is that the mobile platform functionalities are direct mapping of the functionalities of an e-learning platform and only those that are impossible to deliver are excluded. In our opinion is important to foresee the support also of new services that are proper only in the mobile case, like location-dependent services.

A lot of work has been done in the area of content adaptation for mobile devices and of device independent representation of web content. In this context different approaches are proposed for describing device capabilities (HTTP Request Header, CC/PP, UAPROF, etc.). Also different architectural approaches are developed for using the information of devices' capabilities and adapting the content accordingly. The adaptation could be server-based (XML/XSLT,Cocoon,Axkit), proxy-based (AvantGo,Palm Web Clipping) and client-based (XHTML/CSS). A comprehensive review of the current device-independence technologies and activities could be found in [1]. Adapting the content through transcoding servers or proxies is one of the often used techniques (see e.g. [4]). The web content is retrieved by the server, the client preferences and constraints are collected, and a negotiation is done between the client and the server about the needed adaptations and finally the converted content is delivered. Different transcoding techniques can be used for translating from one presentation language to another (e.g. WAP-HTML-WAP), for reducing the contents size, for satisfying bandwidth or screen capabilities, for adapting the structure of the content etc.

What is missing in all these architectures is that they consider only online access to the content. Only some of the transcoding proxies take care also for caching web pages for offline usage (e.g. AvantGo). Another point to consider is that in the learning scenario the content that is to be delivered could be sometimes quite large. We think that delivering content for offline usage is an important issue as still mobile devices are often disconnected because of the lack of access in certain places but also because of the high prices in most of the cases, thus our intention is to support both online and offline access to data.

A similar to our problem (off-line access to data) is treated in the offline browsing of web content. The typical pre-fetching solutions offered by offline browser utilities cannot be cast to the mobile domain without taking into account the (severe) memory limitations of such devices.

6 Conclusions

In this paper we analyzed the functionalities that a general m-learning architecture should cover and how it should be connected to the underlying eLMS to satisfy the needs of mobile users. We discussed the need of three main modules, namely "Context Discovery", "Mobile Content Management and Presentation Adaptation" and "Packaging and Synchronization". We argue that the system should automatically detect the devices' capabilities and limitations (software and hardware) and on that basis to select and propose the services proper for the device and adapt them the best way. For allowing offline usage, a mechanism is needed for selecting what is necessary for the user and for taking care of content's coherence and synchronization with the system. During the offline usage it is better to track the user's activities and feedback the statistics to the LMS.

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