**International Graduate School in Information and Communication Technologies**

# HOARDING CONTENT IN M-LEARNING CONTEXT

Thesis Proposal

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# Hoarding Content in M-Learning Context

**Abstract:** With the advances in mobile technologies it is already possible to support learners and teachers activities on the move. We analyzed the functionalities that should be provided by a general mobile learning platform and identified a problem that is weakly studied by previous research, namely offline usage of learning material (hoarding of content). Hoarding can use some of the techniques that are used by different caching and prefetching schemas, but in most cases the goal of the last two is to reduce latency time, bandwidth consumption and/or servers workload, while in hoarding the aim is to improve the accuracy of set selection. Caching and prefetching content are problems that are considered widely since the introduction of Internet for mass usage, still hoarding is not so well explored. We want to study the parameters that could help a hoarding algorithm improvement in order to cover the peculiarity in m-learning scenario. Our goal is to provide an efficient strategy, taking into account additional parameters, extracted automatically by the system.

## 1. Introduction

E-learning is growing very fast and many Universities and companies are already supporting in some way an e-learning solution. There is now little doubt that the World Wide Web is a very successful educational medium. On the other hand 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 subjects, psychology or language learning.

We analyzed different ways to apply mobile devices for educational purposes. We considered a university e-learning system and the possibilities to extend it to provide services for mobile devices. This led us to classifying services that are specific and should be provided by a general m-learning platform and later we concentrate on one of these services as a concrete problem to solve. Namely this is the hoarding of content for offline usage.

Hoarding is a technique for selecting a set of documents to be uploaded and used when disconnected. Related terms are caching and prefetching, though they are more often used when considering online conditions and Web performance. Caching is a technique for keeping content that has been requested by one user available on the nearest server for a certain amount of time so other requestors can access it faster. Prefetching on the other hand is a technique which tries to guess what will be needed to the client in the near future, cache it and this way improve the clients’ experience. Different schemes of caching and prefetching are proposed and the goal is to reducing network traffic, minimizing access latency, bottlenecks, servers’ workload and etc. in the WWW world. Although the goal of hoarding content for offline usage is little shifted from the one of Web caching, some of the techniques can be reused. However while in the online case one can balance between the accuracy of the cached set and the added traffic, in the situation we consider very higher accuracy is required and the added limitation is the memory availability. The learning scenario has characteristics that expose some additional information to be considered and thereby possibility to improve the existing solutions.

The rest of the proposal 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 how mobile devices can be used in educational scenarios; in Section 4 we analyze what are the problems in the transition from e- to m-learning. Section 5 is dedicated to defining the actual problem for the PhD thesis, followed by the related work in 6. Section 7 gives short explanation of the projects that motivated us. Section 8 explains the work done so far, which led to the definition of the problem. List of publications (Section9), acknowledgments (10) and references (11) follow.

# 2. E-Learning

## 2.1. Definition

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 (e.g. university education) 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 – an industrial company can have as a goal to support the continuous delivery of up-to-date knowledge to its employees while the goal of a university institution is to deliver guided education in particular area and develop the students thinking. We will list the main services provided by e-learning platforms and later shall discuss how these services get modified with the introduction of mobility and small devices.

## 2.2. Services provided by e-learning platforms:

The functionalities offered by different e-learning platforms can vary, but generally can be grouped in four categories: resources (data), specific e-learning services, common services and presentation. The content is the data that should be used by the instructors to present the learning materials to the students. It could be any written digital material, applet, link to other sources, simulations, etc. Usually few different services are offered for communication between the users of the system (learners, lecturers, tutors, mentors). Some activities involve groups of people for cooperative work while other are just for posting important and topical information. Different communication methods have their advantages and disadvantages and are preferred in different scenarios (e.g. asynchronous approach allows the users to communicate effectively even if they are on different continents). And certainly all computer-assisted activities need to be managed.

- Resources
  - Support of learning objects – the educational content could be broken in small pieces and the main goal of this is to have modularity and reusability of the content. These chunks of digital resources are usually described with additional metadata information 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. In some sense they could be also seen as small chunks of data (single question/answer), stored in the system, and the rules that couple them together to form a uniform unit. These rules are part of the management.
  - 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 them.
- E-learning specific services
  - Content management services - For grown people studying a subject is by default arranged in courses, lectures, classes, etc. thus an e-learning system must have the notion of Course and Lecture. The course is composed by a series of resources: syllabus, one or 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 of the examples. The a priori defined questions and corresponding answers (that we earlier described in the content section as tests and quizzes) 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. The automation is not possible in all situations, thus sometimes additional interactions between the system and the lecturers are necessary.
  - 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, to upload personal resources (links, documents, notes, etc.). The access to these various resources must be controlled by permissions that are checked against user authentication, and against groups to which the user belongs. The teachers must be also able to define/modify the syllabus of their courses.

- Common services
  - Support of different actors (User management) - students, teachers, tutors, administrator and sometimes guests. Guests are unregistered users and their access to the platform is very limited. All other users are registered, and have different levels of permissions. The registration is a "once only process", which involves security issues at least for the sensible data.
  - 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)
  - 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. Recent version of major browser must work correctly with the system (like Netscape, Mozilla, Explorer, in the versions of at least the last two years) on Windows and Linux platforms.
  - 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

## 3.1. Definition

There is a common agreement that m-learning is 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.

## 3.2. Services that should be provided by m-learning platforms:

We shall begin by enumerating the different ways such a device can help us.

- In first place, they can be seen as tools for accessing content, which can be stored locally on the device or can be reached through interconnection.
- A second possibility is to consider them as tools for interaction with people, via voice and through the exchange of written messages, still and moving images.

The different interface that such instruments have (small screen, small or no keyboard) has an impact on what is reasonable, useful and even pleasant to do on such devices.

## 3.3. Example scenarios for mobile learning

In this section I will try to go through some possible scenarios, involving mobile devices in learning. These scenarios are showing by example how mobile devices can be used in the educational process and how they shift the needs of the user from services provided by eLMS.

*Scenario 1:* A student with a PDA, away from the University (for example traveling in a train) wants to access a lecture from the course he/she is attending. The lecture can contain different media types, like text (for the definitions and explanations), animations or applets for the examples and so on. In order to do that the student needs a preliminary preparation. He/she has to synchronize the PDA to the m-learning system and to download the needed modules. The course's module should be designed (converted from the University's mLMS) especially for these kinds of small devices, having in mind the lack of memory and the small screen. After going through the lecture's content the student may want to test his/her knowledge improvements. Depending on the system the results can be displayed at the same moment (if the correct answers are recorded in the module) or right after the student connects to the mobile learning platform for synchronization.

*Scenario 2:* Imagine the same situation (as explained in Scenario 1), but the student has a WAP phone instead of PDA. In order to read the course content the student needs to connect to a WAP portal and than access the course, again especially designed (manually or automatically) with WML, to fit the mobile equipment. The course content will not be the same, as some media types are not appropriate for the device, thus changing the whole structure of the lecture.

*Scenario 4:* After taking the online test on his desktop PC a cell phone equipped student can receive his results by SMS and could be recommended to go to a seminar on the same subject that is taking place nearby.

*Scenario 5:* A teacher that is away from the university can also take the advantage of having a PDA or mobile phone. Mobile devices (especially PDAs) are great tools for keeping track of and organizing information. He/she can for example access the university system and update the next lecture's content. Or even more, if there is a proper tool the teacher can put together his/her notes and assemble a module (course content or test questions), which could be uploaded to the University's system when synchronizing the PDA.

*Scenario 6:* We can imagine a scenario that involves 3G devices. 3G phones are already well known and used in Japan and Korea, but soon they are going to become common equipment in Europe too. A teacher that has a 3G phone, because of having a permanent internet connection, can receive all mails from the students anytime, wherever he/she is at the moment. A tutor can have a live video conference via the 3G phone with a student or a colleague.

Online course content delivering (to mobile devices) is perhaps in principle the best solution. However, it requires higher speed and lower prices. In the offline access scenario we have to think about problems with updates. Imagine a situation, in which the student has downloaded some modules. If for some reason the teacher updates the modules content the student has to be informed. If and when elements of a module are revised, the student and others concerned could, for example, receive a message on e-mail and changed elements or the entire revised course may be downloaded anew. This scenario supposes that the system is keeping track on what modules are being downloaded and by whom.

Communication is one really important part of the educational process. Students may need to discuss a subject with other students, to ask the teacher something about the course content or to send his/her assignment to the tutor. Student to student communication can be by e-mails, bulletin boards, discussion forums or chat rooms in which students can communicate with other students in their class or institution mainly by typed interactions. Student to tutor communication can be also by e-mail, tutors can intervene in mailing lists or react to student assignments, quizzes and other forms of summative or formative evaluation. Another possibility is that the tutor receives SMS messages via his mobile phone and answers back to the students again by SMS.

## 4. From E-Learning to M-Learning

There are many properties that differ when comparing a mobile device and a desktop PC (the usual medium to deliver e-learning). 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 different then text media type (e.g. voice, video). In the case when we consider a PDA as a mobile tool the possibilities are wider. Still all the problems that exist in converting/adapting/transcoding general purpose content for mobile devices are valid for learning content.

*The New Context (Location-awareness)*

The mobility of the devices used in m-learning scenarios involves a new context data to be considered – location. One possible service, which involves location context and thus differs from the services offered in e-learning case, is a location-aware printing of the learning content. Other 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.

In the implementation of a location-aware system different techniques for determining position can be considered. Usually they have different parameters, properties and accuracy (from few meters to few centimeters). Some of them are suitable only for finding the position of the device outdoors (Global Positioning System GPS), while other only work indoors. Additional infrastructure and/or equipment is necessary for some of the location-determining systems (special tags and basis/stations or additional hardware on the client machine), while in other the only requirement is to add an additional software layer (e.g. system that uses IEEE 811b network for determining location). We also note that information about the locations might be "raw" (e.g. expressed in latitude/longitude/height co-ordinates), or converted to a semantically more meaningful expression such as "Science Faculty Building, Office D11, 2nd floor".

Up to now we can already identify the specifications that should be supported by an m-learning system (A possible architecture for mobile learning is discussed in more details in section 8.2.):

- 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.

- The second is the content management and specific adaptations needed for presenting content to mobile devices.

- The third is support for disconnected operation.

We made experiments in these three areas (see section 8) and finally decided to concentrate on the last one – disconnected operation of mobile devices in learning domain.

## 5. Goals of the thesis

As we discussed earlier one of the things that drastically differs m-learning from e-learning is the offline usage of such system. Operation in a disconnected or intermittent connection situation is a common problem in mobile computing. This issues, called caching, perfetching or hoarding, are often considered in the Internet world. For the disconnected m-learning case the content should be specially packaged (hoard and uploaded) after being adapted to the device characteristics. The problem which appears is how to automatically select the content to be uploaded so that the student has all the materials he/she needs. In the case of study materials the decision should be more precise then in the general hoarding case and we need more efficient solution, but in the case of mobile learning we also have some advantages:

- the search space is much more limited that in the whole web case
- semantic information might be available through the metadata
- behavior of generic users can be analyzed so as to extract most likely paths to be followed
- behavior of the particular users (preference, learning style etc.) could also contribute finding an optimal strategy.

Our goal is:

- To define a strategy for efficient hoarding taking advantage of the peculiarity of the problem in the m-learning scenario.
- To provide a prototype hoarding system
- To test the prototype on two different e-learning platforms

In order to do this we intend to implement a basic hoarding system that will considers the memory amount of the targeted device and the "semantic distance" of the files to be uploaded.

We will consistently experiment with the different parameters, which can affect the algorithm for determining the hoarding set of files for particular user. Some of these parameters are: user preferences, the tracking of particular user's behavior during online usage, analysis on the general user behavior during online usage, semantic information about the learning materials kept inside the LMS, recently or rarely accessed file (access patterns), etc. These experiments should help us determine weights to these different parameters for calculating the final "semantic distance" between the materials, which can be different for different e-learning platforms.

An important issue that should be considered is that the system should be able to keep track of the user activities during off-line usage of the learning materials and later feedback the gathered statistics for keeping the tracking information of the LMS up to date and for improving the work of the hoarding algorithm. We intend to insert this functionality as a second step.

## 6. Related work

A work that is closely related to our is on defining the requirements for a mobile e-learning platform [9]. The authors are discussing the possible m-learning scenarios in respect of e-learning platforms and what functionalities an m-learning platform is best suitable for. Also the characteristics of the mobile devices are discussed and how they impact the 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 it is important to foresee the support also of new services that are proper only in the mobile case, like location dependent services.

There is a lot of work that is been going on in the area of content adaptation for mobile devices and 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 technologies of device independence and device independence activities could be found in [2]. Adapting the content through transcoding servers or proxies is one of the often used techniques. An example is [10]. 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 in suitable for the device form content is delivered. Different transcoding techniques can be used: for simply translating from one presentation language to another (e.g. WAP-HTML-WAP), for reducing the contents size, for satisfying bandwidth or screen capabilities of the devices, to adapt the structure of the content in more appropriate way and 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. A quick review of the available offline browser utilities (like www.avantgo.com, www.httrack.com, www.webstripper.net, etc.) shows that generally during the online periods the user selects sites that should be uploaded for later off-line usage and entire sites are dumped to the local storage or the user specifies the depth of the links to be cached. In situation where mobile devices are considered the memory limitations should be taken into account.

The caching problem has been studied in the general case for the internet. In [6] a survey of the state-of-the-art techniques and elements of Web caching systems is presented. These techniques include Prediction-by-Partial-Matching, analyses of users' access patterns, provided by the servers, prediction of the user's future Web accesses by analyzing his or her past Web accesses, etc. Although some of these techniques are useful for predicting the content needed also in m-learning domain still they aim different goal – reduction of bandwidth consumption, of access latency, server workload and etc. They explore the case of the Web where the search space is much bigger, the users are numerous and have different interests thus the prediction accuracy is quite low comparing to what is needed in our scenario, but could be compensated by the fact that the internet connection is permanent. An interesting problem that is pointed is the lack of techniques for caching dynamic or personalized content (web pages). In the recent years the percentage of dynamically generated web pages is growing drastically and in our scenario it is almost impossible to imagine an m-learning solution without supporting personalization.

The idea of hoarding for disconnected devices in distributed file systems has been first described in [5] (although they do not consider mobile devices). They propose the Coda File System to explore the usage of caching of data not for improving performance but for increasing the availability. They propose architecture for hoarding and for keeping the coherence of the utilized files. The initial system was based on client-server architecture which tracks the local file modifications and saves a 'Client Modification Log'. The project has lately evolved into UbiData project [1, 7] and the direction it took is in double-middleware architecture for ubiquitous data (file) access. They introduce incremental hoarding, where the idea is to use a version control system to maintain object differences and also study the automatic data selection problem. A metadata server is included to store the 'users' mobile profile' which keeps a list of user files that are considered 'interesting'. They define a "hybrid priority" metric for choosing the hoarding set of files. The "hybrid priority" is calculated by taking into account the recency of use, the frequency of access and the active periods of the file usage and the algorithm also considers upper space limit of memory. The reported effectiveness of their filtering algorithm is more than 84% [7].

Facing the hoarding problem for mobile computing disconnected operation an interesting solution has been proposed in SEER [3]. The authors were also inspired by the work on Coda system but go in different direction. They defined a new measure, "semantic distance", between individual files by observing the user activities and propose an algorithm for automatic hoarding of projects for mobile computers. With "semantic distance" the author tries to quantify the user's intuition about the relationship between files in the same project. For this different measuring criteria are used – "temporal semantic distance", "sequence-based semantic distance", "lifetime semantic distance", directory membership, filename conventions and hot links, and are combined to assign weights to documents and take decisions for hoarding them in an automatic way (automatic periodic hoarding). The approach met some unpredictable behavior in the real-world system, which appeared because of the way the operating systems and some often used programs work (like the "find" operation under Unix). Recent experimentations with the same system [4] showed surprising finding – the complex clustering methods that are used in the system work in most of the cases worse then a LRU (least recently used) algorithm enhanced with some heuristics. This shows us that the research field is still open for work.

We believe that we can define a strategy for efficient hoarding taking advantage of the peculiarity of the m-learning scenario and the semantic data that is kept in the LMS.

# 7. Motivating projects

Our work is motivated by two different e-learning systems.

The first one is the new e-learning platform of the University of Trento, called E-Leaf. It offers a modular infrastructure with a clean separation between data, business logic, presentation logic and actual presentation. It is built by using J2EE tools, and in particular it has an Enterprise Java Bean layer that abstracts the data from their actual database implementation and contains the business logic. On top of that, a layer based on the Struts framework contains the presentation logic, and exposes a set of JSP custom tags. Web designers are therefore offered something that might be thought as a conceptual extension of HTML, i.e. a set of tags that can be used and composed to build the actual presentation. The goal of such architecture is to allow "external" customization and maintenance of the system without knowing about programming, but maintaining a high level of freedom in the presentation choices. On the opposite side, it is possible to adapt the system to different data architectures without breaking the upper levels. An interface to data and services is provided through Web Service technology, so that a vendor-neutral door is opened to additional systems that may offer other functionalities.

The second is the ELDIT system at the European Academy of Bolzano. The Electronic Learners Dictionary for German and Italian system is specially designed to satisfy the specifics of South Tyrol region – an Italian-German bilingual region. ELDIT is an innovative web-based language learning educational system, on which the team makes research on dynamic content adaptation (adaptation of the learning material, according to students' personal preferences, to their knowledge level and speed of studying and etc.) and also on collaborative learning in a web-based system. A large group of linguists is carrying out the linguist/pedagogical part of the project. ELDIT is an adaptive language learning platform which consists of learner's dictionary, text corpus, exercises, tandem system and a tutor module. The system works online and the adaptation of the content is done dynamically according the interactions with the learner.

As these two systems are very innovative it will be nice to have a mobile version of them. They also offer us a good space for experimentation and testing how our strategy for hoarding works. The reason is that the two systems have very different learning materials logical structure. While E-Leaf has the commonly supported by e-learning systems structure of Classes, Lectures, Courses and etc. (which can be presented more-or-less as tree structure), ELDIT has highly interlinked between each other data instances (graph). Our prediction is that this will lead to stronger influence of different parameters in the hoarding set choosing method and we intend to experiment on different techniques for tuning the strategy in different underlying systems.

# 8. What has been done so far

The above proposed thesis topic is a logical consequence of the work that has been done so far. My work started from the study of the current activities and the things that have been done so far in the mobile learning domain. The outcome is a review of the state-of-the-art, shortly explained in Section 8.1. Later we defined three directions that are interesting from research point of view and are weakly concerned in existing m-learning projects – 1) integration of m-learning with e-learning; 2) adaptation to context (infrastructure, location, time, user behavior, etc.); and 3) tools for mobile devices that support e-learning. We experimented with these trends, trying to find the best path to follow next. Facing the first direction led us to analyzing the functionalities offered by e-learning platforms and defining a general and generic architecture for m-learning (8.2). The second and third directions pushed us in experimentations, explained in 8.3 and 8.4.

## 8.1. M-learning state-of-the-art

Part of the work done so far is in studying the state of the existing research work in the m-learning and classifying the research directions in the domain. In fact, as m-learning is quite a new domain, there is a lot of work and research that is presently going on. People are trying to understand:

- Which learning models can help obtaining better learning processes when communication is mediated by mobile devices, and how the student mobility affects her/his learning process.

- How it is possible to evaluate efficiency and effectiveness of learning processes based upon mobile technologies, given the physical limitation of mobile devices.
- Which services are useful for mobile devices, and which is the enabling technology that can affect the wide diffusion of mobile learning.

In a paper accepted at E-Learn 2003 Conference we aim at helping answering the question of *how* m-learning will help reaching the goals of a better learning, and *how* it will be different from the rest of e-learning. We also try to foresee some directions for successful m-learning research.

## 8.2. Analyzing the functionalities offered by e-learning platforms and defining a general and generic architecture for m-learning

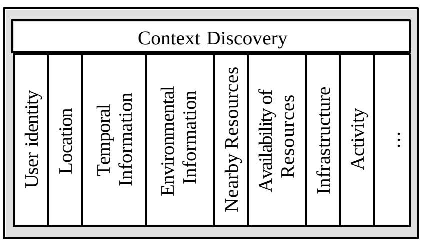
Earlier we tried to represent the functionalities offered by the e-learning platforms as services. This approach gives an extra level of abstraction so the e-learning platform can interoperate with the new functionalities that have to be offered by m-learning platform (mobile specific services). The 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.

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 unexplored. In this sense our goal was:

- To investigate the ways services provided by e-learning platforms change when moving into mobile context and to capture the requirements for a general m-learning architecture
- To provide an architecture for m-learning which:
    - sits on the top of e-learning platform - the proposed architecture should be an extension to traditional Learning Management System and should provide adapted and additional services for the mobile users.
    - is general – the system should be able to carry out all the services of the e-learning and all the services for m-learning
    - is generic - as we wanted to develop an architecture that supports rich multimedia content and explore the interactions of the user with the system the intention was to use iPaq. The usage of mobile phones was out of the range of the current work as nowadays cell phones have very poor capabilities for using multimedia data. Still the adaptation process would involve detection of mobile device capabilities with CC/PP (or other approach) that is being standardized and is being adopted in the new generation mobile phones thus not excluding their usage in the future.

We followed and analyzed the scenarios given earlier to identify the components that are required for the m-learning platform. I will shortly discuss their functionality.

On the first place it is best if a mobile device is able to access all possible for this device functionalities of the system 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. I called this functionality "Context Discovery" service. As discussed earlier the infrastructure is only one of the possible contexts that should be considered.




In the system where more than one context data should be collected "Context Detection" (showed on the left) adds an 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, Bluetooth) 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).

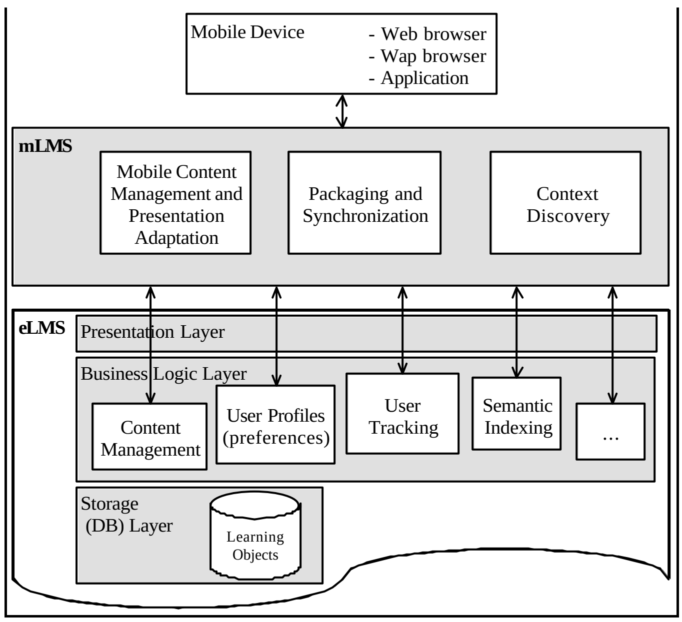



**Figure 1:** General and Generic m-learning Architecture

The second step should be to select the services proper for the device and adapt them the best way. 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. As we discussed earlier during the offline usage it is better to continue the tracking of the user activities and feedback the statistics to the LMS.

In the figure above the architecture shows only some of the services that should be provided by the 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.

### 8.3. Analyses and experiments with the current technologies for device independence and multi-channel content delivery for e-learning

I have also started to experiment with the usage of some new technologies for device independence and with the effect of their utilization in a future m-learning application. I've setup and tried an exemplary multi-channel e-learning service, in which the same content is adjusted to different devices. The data is provided in different media types (such as text, sound, picture, and video) depending on the device capabilities [8]. The idea is to use the capabilities of the device (i.e. CC/PP) and user preferences for transforming the content into the most appropriate format both for the devis e and for the user.

The data (the content of the courses) should be kept on the server separated from the presentation, so XML was used. Moreover some redundancy in the data is needed i.e. the same data is kept in two or more different forms, like picture, sound and text with more or less identical meaning, so for a device that doesn't supports images the corresponding text/sound replaces them or when the user is in a noisy environment the sound is automatically replaced by text. For this the learning theories are applied to define matching media types. This system is realized by the use of Cocoon and Deli technologies developed by Apache group and available free of charge (some more details about these systems will be given in a later section).

### 8.4. Prototype of an example mobile service

Printing is a common task, necessary in most of computer-supported activities. Learning and studying are very often connected with reading printed materials and in this context location-aware printing system is a good example extension to any m-learning application. I started experimenting with a simple at first glance task – printing, but when applied in a mobile environment. I considered few different architectural approaches to the location-aware printing problem and after that I developed a prototype for one of them. We argue that the printing problem can be mapped on a more general one, where the focus is on providing some context-dependent service, while using basic services provided by the infrastructure (e.g. by the OS, or by a Learning Management System). The idea is to insert a software layer between the service requestor and the service provider. We discuss that such software layer should in general refer to an external server for at least two reasons: the mobile component cannot be aware of all possible settings that are available in different places, and the optimal choice might depend by factors that could be dynamic, and therefore unknown by the mobile component. The external server must obtain context data from the requestor. At this point two choices are possible: either the server fully provides the customized service, or it provides a "meta-service", i.e. it only identifies the best option and then passes this information back to the requestor. The requestor then performs the actual customized service. In some cases (like in the printing problem) this last solution might be highly unpractical; in other cases however it might be a viable solution, and might even be preferable since it diminishes the workload on the server. Implementing this middleware in a seamless way can require digging into technical details of the infrastructure (e.g. of the OS). In the particular case of the printing, it required writing (or at least modifying) a device driver, that is not a trivial task. In other cases, like for instance in the case of a service provided by a Learning Management System, it might mean entering in the (possibly proprietary) code of the infrastructure providing the service: a possibly prohibitive task. In such cases, a less convenient, two step process can reconduct (through the notion of a stub) to a conventional, local use of the needed service (i.e. one might have an actor on the server that asks for a local service on behalf of a remote, mobile user).

Figure 2 shows the processes of the chosen architecture. The system consists of few modules, which I'll describe here briefly.

For finding the user/device location there should be a location discovery module that works on the client device (this part is developed as part of WILMA project). It uses the IEEE 811b network that is already in place and therefore it requires only adding a software layer. The module connects sequentially to three or more access points in the wireless local network and measures the signal strength (the wireless network card acts as a sensor). The results of the measurements are used to determine the position. There are different ways of doing this. With one of the methods called regression the position could be returned in physical coordinates (x, y, [z]) and in another (classification) as a more semantically meaningful (symbolic) expression, like floor and room number or "The Open Space, ICT area". Accuracy varies depending on the chosen method. The research shows that the average error percentage in this second method is lower, thus it is more reliable. For the "printing" problem it is also the better option, as it explicitly takes into account of the local topology of the building.

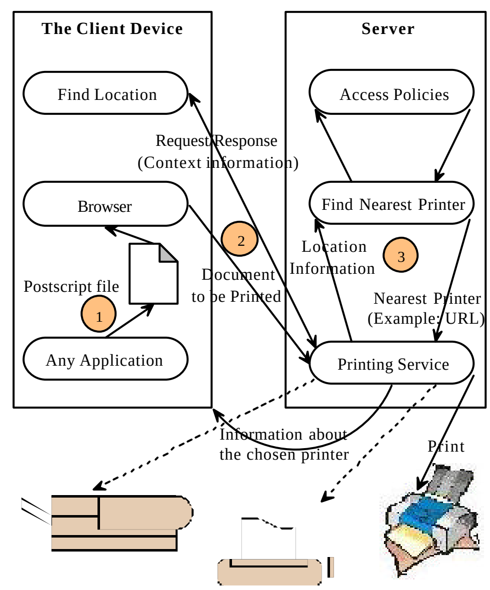



**Figure 2:** The printing process

For the architecture we chose the location-discovery module is the only think that should be additionally installed on the client's device. There are various reasons to try to keep as little as possible on the device – the limited device's memory could be endangered (if we consider a big area that the application will cover the data about the correlation between the current position of the device and the position of the printers could become quite big); it is hard to keep the data on the device up-to-time as it may be changing dynamically (we might think of having the system aware of printers' queues and taking the optimal decision also on that base) and finally the device can not always be aware of all possibilities (in order to print on a certain printer a driver is needed but it is difficult to have on the device all possible drivers).

For these reasons the rest of the system is on the server. In the current version of the system the client should have the file he/she wants to print in a device-independent format (i.e. postscript). This could be done by printing to a file on any postscript printer driver. A better (probably even the best) for the client solution of this problem would be if there was a pseudo printer driver, so the client could print from any application to it and in this way activating the rest of the "location-aware printing" process described here. The practical realization of this though is device dependent and needs digging in the OS, which is not a trivial work and is still to be done. After having the file in the proper format the client explicitly asks the server to print the file through HTTP, uploading the needed file. The server provides a form for this, which is accessed with any web-browser client. On the server side an active component (a servlet) takes care of collecting the location information from the mobile device. This could be done either by connecting to the location-determining module through socket or for example by HTTP. Finding the optimal solution (the closest printer) is the next step done on the server. At the end the server prints the received document to that printer and notifies the client, again trough a web page in a browser, where it was printed. It is possible to print postscript documents to non-postscript printers by using the GhostScript on the server side software, which is available for various OS.

A more detailed discussion on this problem is available as a technical report (DIT Technical Report DIT-03-010). The first report to the printing problem, as a supporting service to m-learning is accepted at the IADIS International e-Society 2003 Conference.

## 9. List of publications

1. Marco Ronchetti, Anna Trifonova: "Context Dependent Services in an M-Learning Environment: the Printing Case": IADIS International Conference e-Society 2003, Lisbon, Portugal
2. Anna Trifonova, Marco Ronchetti: Where is mobile learning going?: E-Learn 2003 Conference, Phoenix, Arizona, USA
3. Luigi Colazzo, Andrea Molinari, Marco Ronchetti, Anna Trifonova: Towards a multi-vendor Mobile Learning Management System: E-Learn 2003 Conference, Phoenix, Arizona, USA

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