M2Learn: Towards a homogeneous vision of advanced mobile learning development

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***Abstract*—The vertiginous penetration and advance of mobile devices in all levels of our society leads towards new technological challenges. This paper is focused on the application of mobile devices in the learning environment, since the current mobile learning development is finding several problems and lacks, such as use of the new features (e.g. location and motion sensors) and the desigh without having including the existing e-learning services. This paper introduces a framework created as a need to interconnect the mobile learning environment with context aware systems and existing e-learning resources. The paper describes the requirements that a framework like this must support, to finally give an overview of the author's solution.**

Keywords-middleware; mobile learning; service-oriented learning; ubiquitous learning.

I. INTRODUCTION

Nowadays, mobile computing is one of the fastest growing areas within the technology industry worldwide. Rates of use of mobile devices in western countries are around 90%, having the youngest generations as main users [1]. One of the reasons of this success is the improvement in the devices' technical features and the low prices. New generations of mobile devices have wider and touchable screens, built-in digital cameras, and connectivity through Wi-Fi or 3G. In many cases it is even possible to find Global Positioning System (GPS) receivers, RFID, NFC readers or smartcards integrated.

All these new technologies inside a small and portable device are giving rise to a new generation of applications in all kind of environments. These are applications more aware of the user's context that enable connectivity and communication every time and everywhere. One of the environments where these devices can suppose an inflection point is education. Here, mobile computing acquires some specific features to support the enhancement of the learning process.

On the other hand, proliferation of mobile devices causes the increase of the demand of mobile learning development. As a result, it creates the need of some kind of software that could help in the development tasks. For that reason, many systems have been created to decrease the inherent complexity of the technologies implied in the mobile learning development.

This paper arises as a response to current research on mobile learning projects, which are geared mostly to implement the e-learning and traditional teaching methodologies on mobile devices. It means that many of the existing mobile learning applications are based on concepts such as study and assessment of digital material via mobile phones. Mobile devices are not the ideal technology to carry out these tasks due to the small size of its interface (display and keyboard).

The paper might be of interest for those involved in the development of mobile learning applications, since the introduced framework could become a powerful and useful tool for them; for those also designing supportive tools to simplify the development of mobile learning applications; and in general for those involved in the development of any kind of e-learning or m-learning application, since the paper introduces a service-oriented methodology for the development of applications.

The paper is structured as follows: Chapter II offers an overview of the main goals of the system. Chapter IV introduces the most relevant requirements to have in consideration to design a framework for supporting mobile context-aware applications. Chapter V relates the reasons why e-learning platforms and applications should not be left aside of mobile learning design. Chapter VI introduces the design of the proposed middleware. Chapter IX offers an overview of the evaluation to be carried out in the following months; and Chapter X some conclusions.

II. OBJECTIVES

Mobile devices are a very familiar tool for learners. Their experiences are closer to the use of videogames; watch videos; communication via mobile devices; and use of collaborative technologies (e.g. blogs, wikis, mash-ups and social networks) than to be a mere listener in a master class given by a teacher. Therefore, thanks to the use of these devices, students will take an active role in the learning process in a more interactive and according way to what they are accustomed to use. Learners will feel more motivated and engagement with learning. This idea was remarked by Elliot Soloway, an expert in mobile learning from the University of Michigan: "The kids these days are not digital kids. The digital kids were in the '90s. The kids today are mobile, and there's a difference. Digital is the old way of thinking, mobile is the new way."

M2Learn project is intended to give a step further in the state of the art of design of mobile learning applications. It supports the development of innovative mobile learning applications that really complement and enrich the learning experience. This is a learner-centred paradigm that really encourage the “anywhere, anytime”, improving the social interactions, providing a personalized educative experience to each learner, and reaching to places where traditional or on-line learning cannot reach. M2Learn Middleware is devoted to help mobile learning to find its place in education, as a complement to traditional and on-line learning instead of replace them and promoting blended approaches.

The main objective of the M2Learn project is to implement a middleware devoted to simplify the development of mobile learning applications based on the following characteristics:

- Middleware that simplifies the integration of:
  - Context-aware systems
  - Location-based technologies (GPS, RFID, Wi-Fi, ...)
  - E-learning resources (digital content, chat, forums, on-line labs, evaluation, ...)
- Offering collaboration capabilities (synchronous and synchronous communication; Web 2.0, ...)
- Open and flexible architecture with a service-based infrastructure (Through Web services and SOAP)

Through this development, educational organizations will achieve successful m-learning projects, because it encapsulates the inner complexity of the location techniques, learning services, context-awareness systems and management of e-learning resources.

III. Existing systems to support mobile learning development

Lately, many frameworks and middlewares have been created to decrease the complexity and simplify the design and development of mobile applications. Although few of them are devoted specially for mobile learning, we have focused our research in all the scope, i.e. learning-focused or general purpose. The reason is because any middleware for general mobile applications development can be also used for mobile learning purposes, although it will lack in some specific learning requirements, such as integration with e-learning platforms, protocols, applications and standards.

One of the first environments created to support ubiquitous computing is the Context Toolkit [2]. It is a context-aware framework developed at Georgia Institute of Technology. Its main strength is the use of Widgets to encapsulate the complexity of the lowest levels, as the sensor management. They also provide callbacks to notify applications of changes, and offer attributes that may be polled by applications [2].

Other related example is the SOCAM (Service-oriented Context-Aware Middleware) project [3], which uses a central server (context interpreter) and several context providers. The central server retrieves context data from the context providers, which have previously processed it. At the top level layer are the context-aware applications in the mobile device that make use of the context data provided by the central server.

A similar architecture is introduced in the CASS project (Context-awareness sub-structure) by Fahy and Clarke in [4]. This architecture is not designed for mobile devices with sensors embedded, but for context-aware environments with spread sensors that communicate with a mobile device.

A different approach is developed by Hansen in [5] within the HyCon Framework, which is devoted mainly to hypermedia services, although it also supports J2ME applications. The architectural design is similar to other hypermedia architectures, such as the Dexter architecture [6], the Open Hypermedia System Working Group’s Open Hypermedia Model [7] and Construct [8]. The difference is the sensor layer that encapsulates the sensing management. Other interesting feature of this framework is the integration of external services, such as a Weather Server and a Location Mapper, which use the information retrieved from sensors (Context Interpreter) to obtain a more sophisticated one.

Within the MOBIlearn project is developed the Open Mobile Access Abstract Framework (OMAF) [9] based on layers of infrastructure and application profiles. It is interesting from a design point of view because it is based on the IMS Abstract Framework.

IV. Technical Requirements involved in Development of Mobile Learning Applications

A. Architectures for Development of Mobile Learning Applications

This section describes the most common architectures used in the existing middlewares for the development of mobile applications. The objective is to establish the basis for the posterior definition of the M2Learn architecture.

According with Biegel, the main features that a programming model to develop mobile context-aware applications must address are [10]:

- Capture of context data
- Uncertainty of context data
- Representation of context data
- Privacy
- Scalability
- Synchrony
- Extensibility and reusability
- Centralized/Distributed resources

In relation with the first featured cited by Biegel, there are different approaches to acquire contextual information according with the work of Chen [11]:

- **Direct sensor access.** Used in devices with embedded sensors. The application gathers the desired information directly from these sensors. In this approach there is no additional layer in charge of retrieving or processing sensor data.
- **Drivers for the sensors are hardwired into the application**. This tightly coupled method is usable

only in rare cases and not suitable for mobile applications.

- **Middleware infrastructure**. Modern software design uses methods of encapsulation to separate the different layers involved in the design. The middleware-based approach introduces a layered architecture with the intention of hiding low-level sensing details. Compared to direct sensor access this technique simplifies extensibility and promotes reusability [12].

Other fundamental factor in the architecture design is the use of centralized or distributed resources. If the system is autonomous and does not require any connection with other systems, the architecture is considerably simplified. On the other hand, the distributed approach must affront the communication challenge, which can be carried out using different techniques [13]:

- **Widgets**. A widget is a component that offers a public interface for a hardware sensor [14]. Widgets hide low-level details of sensing and simplify application development due to their reusability. Thanks to the encapsulation in widgets it is possible to exchange widgets that provide the same kind of context data
- **Networked services.** This approach is based on a more distributed architecture. It requires a service discovery server that will manage the services offered in the network [15].
- **Blackboard model**. The blackboard model is an asymmetric approach that requires a server where the clients are subscribed to be notified when some specific event occurs. In this system, there are some components (e.g. sensors) that provide information to the blackboard. This information is used by other components to provide more information. When the existing information in the blackboard matches with the needs of some client (higher level components), it is notified.

The most common design approach for distributed context-aware frameworks is a classical hierarchical infrastructure with one or many centralized components using a layered architecture. This approach is useful to overcome memory and processor constraints of small mobile devices but provides one single point of failure and thereby lacks robustness.

And finally, the last relevant feature regarding to architectural design is the way to represent the contextual information. According to Stephanidis in [15] it can be structured as follows:

- key-value model
- markup scheme model
- graphical model
- object-oriented model
- logic-based model
- ontology-based model

This last one is considered the most promising for context-aware systems, due to the fact it offers reasoning features. However, for mobile systems the object-oriented model can be more effective and flexible as the Hydrogen project demonstrates in [16]. That is because some of them are able to manage their own context data without connecting with an external central server. Object-oriented models are usually supported by middleware architectures providing distributed context handling. Whilst ontology-based models usually make use of centralized context management components [15].

B. Interoperability through the service-oriented paradigm

Nowadays, technological interoperability is a fundamental component within complex systems, because of the need of interconnection among different environments and systems. It takes special relevance in the mobile field, due to the fact there are different kind of devices, with different Operating Systems and hardware features. Thus, usually new systems developed for these devices are not isolated programs, but they must connect to other services and resources to retrieve and send information. This connection is one of the key issues within the mobile computing paradigm.

According to the literacy there are no defined standards for interoperability in mobile learning that specify e.g. the interface between a mobile learning application and a LMS or a location service.

On the other hand, there are specifications, such as the "IMS Abstract Framework: Applications, Services & Components" (IAF), which is a mechanism to define the set of interfaces for which interoperability specifications will be needed by some application domain [17]. This specification can be followed as a guide for development of mobile learning frameworks. It offers a structured architecture that allows interoperability between different components, using mainly SOAP. It can be used specially in the interconnection with external services, e.g. services from a LMS, contextual services, etc.

The main principles of this framework [17] are:

- Interoperability – the specifications are focused on the exchange of information between systems.
- Service-oriented – the exchange between the systems is defined in terms of the services being supplied by the collaboration of the systems.
- Component-based – the set of services will be supplied as a 'sea of components' that can be mixed and matched to form a particular service.
- Layering – the total set of services required to make an eLearning system will be modeled as a set of layers.
- Behaviors and Data Models – a service will be defined in terms of its behaviors and data model, and can be supported through multiple bindings e.g. Java, XML, web services, etc.

IAF is a layered model, consisting of four layers [18] as it is shown in figure 1:

- Application layer.
- Application Services layer.
- Common Services layer – a set of services that are available to the application services.
- Infrastructure layer – this provides the end-to-end transaction and communications services for the application and common services.

The interface between layers is the Service Access Point (SAP), which is provided by the services. It means that each service will offer one or more SAPs, which will be the communication interface with other layers. This concept can be implemented for example through an API.

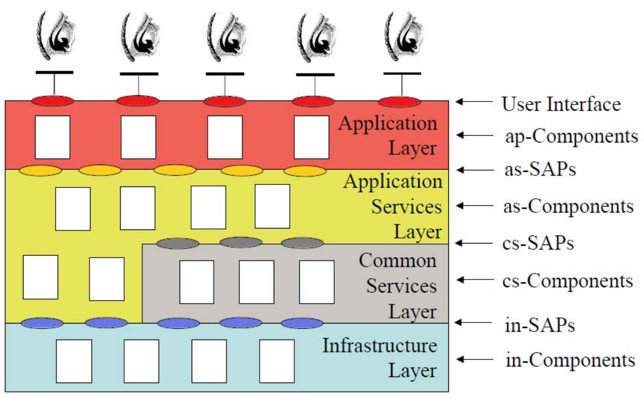

Figure 1. IAF Layers [17] includes, from bottom to top, the following layers: Infrastructure, Common Services, Application Services and Application.

V. Enabling Innovations on Mobile and Ubiquitous Learning

According with several authors, such as Shuiler [18], the successful implantation of mobile learning applications within the educational environment involves some changes in the mentality of both technicians and trainers. In first place, the development of new pedagogy theories that fulfil the mobility opportunities that new technologies are offering.

Secondly, the design and implantation of innovative learning applications that provide an added-value to the educational experience, complementing both traditional and electronic learning. Third, the support to fill the gaps between differentiated access and technologies. A wide range of technologies and their inner complexity are a challenge to overcome by teachers and learners. And finally, move these new innovations into the real educational environment by training teachers.

As a result, authors have developed a system to support the development of these innovative mobile learning applications within the new learning approaches. The M2Learn project arises as a response to current research on mobile learning development, which is usually geared to implement the same methodology used in the e-learning and traditional teaching on mobile devices. It means that many of the existing mobile learning applications are based on concepts such as study and assessment of digital material via cell phones. Mobile devices are not the ideal technology to carry out these tasks due to the small size of its interfaces (display and keyboard).

Therefore, new trends must exploit the potential offered by these devices changing the methodology and thinking on new scenarios. There, new mobility features must offer a complement to traditional education, as for example:

- Learning outside the classroom (botanical garden, archaeology, etc.);
- Learning on the move (transportation, running, etc.);
- Informal and lifelong learning (museums, aircraft, zoos, etc.);
- Collaborative learning (performance review in class, voting, resolving queries, etc.).

The other focus of the project is the fact that most mobile learning applications have left behind what has been established as the main repository of learning resources during the last years: the e-learning platforms, e.g. Web-CT, dotLRN, Moodle or Sakai.

Lately, much effort has been undertaken to develop e-learning platforms able to offer the services and resources that students need within the learning process. But most of these new mobile applications leave them aside, created ad-hoc, with almost none interoperability with other systems.

Finally, reviewing the technical literature related to the mobile learning field, we find that there are no tools to facilitate the development of mobile applications that comply with the new paradigm of mobility: integration of resources and services from e-learning platforms with context-aware systems and collaborative environments.

VI. M2Learn: A Service-oriented Middleware for the Development of Mobile and Ubiquitous Learning Applications

Achievement of a successful implantation of mobile devices in education requires the development of applications able to provide the needed support to the mobile learning experience. Thus, authors have committed to create a middleware devoted to support the development of new generation mobile learning applications.

Based on the analyzed features, the following technical requirements are part of the final design:

- Context-awareness through location technologies, e.g. GPS, Wi-Fi, RFID, etc.
- Internal context representation using an object-oriented model.
- Capture of contextual information through a middleware infrastructure. It hides low-level sensing details to higher level layers.
- Communication between components (both internal and external) through the use of Widgets and Web Services using SAPs (IAF based). Together with the middleware infrastructure it provides reusability and simplifies the application development.

These factors are common for the development of any kind of mobile application. However, focusing on mobile learning, other key factors have been kept in mind in the design are:

- Integration with existing e-learning resources
- Support for social collaboration

The reason is that e-learning platforms are currently the centre of the on-line and blended education. These platforms are a repository of both content and services. That is why mobile applications should not be designed independently of the already developed e-learning standards and platforms, without taking advantage of all the existing resources. Within the mobile environment, existing e-learning resources can be very useful to better personalize the services provided to learners. For example, using the credentials (login and password) it is possible to retrieve information about learner's educational environment such as student's degree or subjects. This information will be provided to higher level applications to personalize the services offered to the student. In fact, there is a lot of contextual information about the learner that can be used to improve the learning experience: for example, personalized information services or search results in the library.

M2Learn middleware interacts with the university LMS through a set of Web Services, providing an interface to implement some functionalities in a mobile device, e.g. access to forum rooms, content or FAQs. In addition, there are other advantages related to the re-use of services instead of creating them again: authentication, tracking activities, evaluation, content, etc. LMSs can provide also very useful contextual information. On the other hand, social interaction and collaboration is one of the key issues for modern learning. It has been widely implanted in the e-learning environment and must be moved into the mobile one.

M2Learn project offers several additional advantages that mean an advance in the state of the art of mobile learning development:

- Interrelation between hitherto isolated location technologies (e.g. GPS, RFID, Wi-Fi, etc).
- Interoperability between existing services in e-learning platforms and mobile devices.
- Encapsulation and homogenization of student's contextual information (based on geo-location technologies and other profile data).
- Encapsulation and standardization of services, such as those from e-learning platforms, which provide an added value to the mobile application, e.g. intelligent auto-response, information services, etc.
- Reduction in development time.

This middleware manages several location sensors to provide contextual information about the user. For that reason several sensor controllers (Widgets) have been developed to understand the information provided by sensors (Figure 2).

The system has been designed using open interfaces in order to make easy to add other services (e.g. new location methods such as cell towers or Bluetooth [19]).

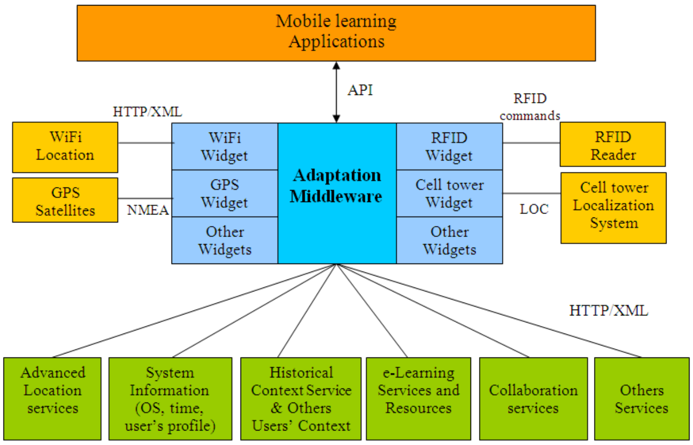

Figure 2. M2Learn Architecture includes location technologiesWidgets to manage e.g. Wi-Fi, GPS or RFID. The Adaptation Middleware integrates several services, some of them from e-learning platforms.

Adaptation layer processes the contextual information provided by widgets to access to other services, e.g. information in a LMS, e-mail, etc [20], to get more contextual information. This is the most important layer in the architecture because offers an interface to top level applications. Mobile applications will not have to interact with sensors or services, and even they will not know from which sensor or service the information comes from. This interface provides all the contextual information and educational services in a transparent way, ensuring the applications will not have to worry about the implementation of lower layers [21].

This architecture considerably simplifies the development of mobile learning applications. For example, users will be able to create a mash-up system using the location information instead of learning how the NMEA protocol of the GPS works; or communicating through a serial port with an RFID controller to read the information from an RFID tag, without understanding the RFID commands or the data organization inside the tag. Or they will create a mobile blog using the services provided by an e-learning platform, but they will not need to create any web service in the language of the platform or understand how its database is structured. They just use the simple interface with information and services provided by the M2Learn Middleware.

At this stage, most of the M2Learn framework has been already developed, although evaluation has not been carried out yet.

VII. Evaluation

Evaluation will be conducted through a pilot using students of a "Professional Expert Course on Mobile Programming". They will develop several applications using the framework. Later, students will complete a questionnaire on user satisfaction and the simplification degree obtained through the framework's use. Evaluation will also include other instruments such as interviews, and development time required.

VIII. CONCLUSIONS

M2Learn project gives a solution to the development problems within the mobile learning field. At the same time, this project promotes the creation of innovative applications and provides the guide for the development of new applications based on the new key factors of mobility in learning: context-awareness, social interaction and integration of e-learning resources.

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