Mobile Experimentation: Closing an Educational Gap for New Student Generations?

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30th March 2006

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Abstract

The M-learning concept is a consequence of mobile technology evolution, i.e. the appearance of devices like Personal Digital Assistants, smart phones and mobile phones with improved features, namely Java support. It is in the same line of E-learning versus Personal Computers and therefore the counterpart of one E-learning subset, named Remote Experimentation, within M-learning, could be designed as Mobile Experimentation. Remote Experimentation is traditionally regarded as the remote access to real-world experiments through a simple web browser running on a PC connected to the Internet, while Mobile Experimentation may be seen as the access to those same (or others) experiments, through mobile devices, used in M-learning contexts. The emergence of two distinct client types (PCs versus mobile devices) creates new requirements for the remote lab infrastructure, namely the ability to tune the experiment interface according to the characteristics (e.g. display size) of the accessing device. This paper proposes a new architecture for the remote lab infrastructure, namely for the software layer to be based in Java and XML, able to accommodate both Remote and Mobile Experimentation scenarios, this last one being especially important for new student generations keen on mobile technology.

Keywords: *Mobile Experimentation, mobile devices, M-learning.*

1 Introduction

The permanent technological evolution has been changing habits and attitudes. Technology has become a major change factor of global economics, allowing an easy exchange of information among different places and countries. The increasing pace at which information circulates has been improving people's lives, giving them flexibility to access knowledge. However, and at the same time, it promotes new changes, imposing more requirements for people to meet the demand of information and culture, in order to avoid being out of up-to-date knowledge.

While in the early transistor days (20th century) the radio, in the 20's, and the TV, at the end of the 50's, gave access to information, later, during the 60's, computers appeared. These started to be machines to process data in situations where man work was hard and difficult, namely in repeated tasks like calculations. Later on, in the 80's, the appearance of Personal Computers (PCs) with enhanced features, namely the possibility to display images, video, interactive contents, and others, triggered the feeling in the educational community that these devices could change the learning/teaching process.

As time went by, the Data Processing Era (1960 to 1980) gave place to the MicroComputer Era, (1980 until 1990), where PCs took an important role in many sectors of our society. It was during this last era, in the mid 80's, that PC features were seen as a benefit to education, namely as a complementary resource to improve the quality of the teaching/learning process. A new concept named Computer Based Learning (CBL) and defined as the local access to educational resources like demonstrations, video and audio, graphics and others, through a PC [1], emerged. However, and since 1995, a new era called Network Era has been growing, where information circulates among different places using PCs and other network technologies. The appearance of the Internet and associated services, e.g. the World Wide Web (WWW), facilitated an easy circulation of information using software applications called Virtual Learning Environments (VLE). These brought more freedom and flexibility to students and teachers to access courseware contents, with almost the same requirements encountered in a traditional class [2]. The expression E-learning gained worldwide acceptance. Although VLEs provided a great support to education, they did not allow the realization of experiments (in a remote access context), which was seen as essential for engineering and science students. Consequently, and together with network improvements, with faster data rates and a better Quality-of-Service (QoS), emerged a new concept called Remote Experimentation (RE), which allowed students to perform remote experiments by interacting with real equipments using a PC connected to the Internet. This area has been explored in recent years, with several projects like MARVEL [3], PEARL [4] or RexNet [5] seeking for models to reduce costs, promote the exchange of knowledge between students and institutions, increase the flexibility to access expensive instruments anytime, from anyplace, and easy the access for people (students/teachers) with special needs [6].

If until 1991 the only available network was wired, after then, Wireless Application Protocols (WAP) emerged, further facilitating the exchange of information. It was in the beginning of 2000 that mobile devices took also an important role in the teaching/learning process, again contributing to a change on human society. If the actual working people grew up with PCs, which nowadays contribute to their presence in all areas of knowledge, in future, mobile devices (mobile phones, PDAs and smart phones) will tend to play the same role, namely in education and particularly because of its wide acceptance by young students. If we regard this usage as beneficial and if we follow the idea that new generations require new methods, then it is fundamental to feed the habits of those students by using mobile technology as a resource to access pedagogical contents, which could give them further motivation for education [7].

Mobile devices brought a new concept for the teaching/learning process, named M-learning [8, 9]. Although some recent projects have been exploring this concept, like the MOBILearn project described in [10], none has yet considered the extension to the already referred RE scenario. Accessing a remote lab in a M-learning context is better described by the expression Mobile Experimentation (ME) to distinguish the two scenarios (notice that E-learning and M-learning are also two different expressions focusing the same learning/teaching process). Fig. 1 presents the evolution of both concepts and technologies from the 20th century to the first years of the 21st century included the three last mentioned eras.

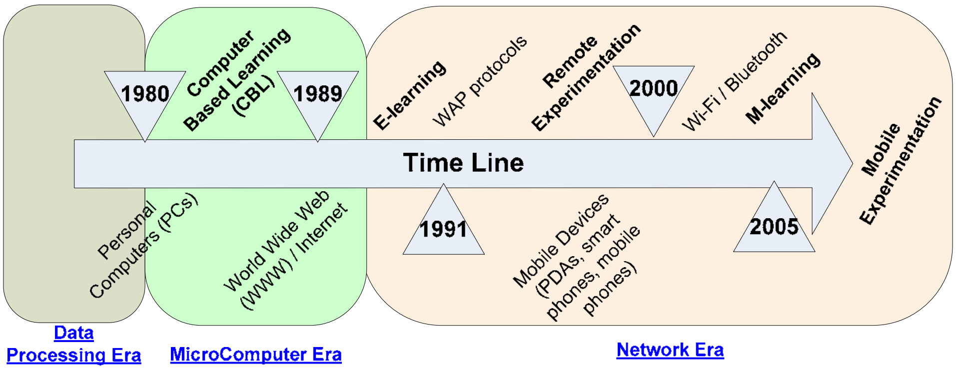

Figure 1: Technology versus concept evolution

Following the facts described in this introduction, the remaining of the paper concentrates on a deeper understanding of the devices used to access a remote lab in a ME scenario, and the enabling network technologies (section 2), plus the impact of this dual access type on the remote lab infrastructure (section 3). Before concluding (section 4), we also provide a simple example of a ME scenario, based on a digital multimeter being controlled from an emulator of a mobile phone supporting Java.

2 Characterizing mobile devices and wireless networks

There is a relation between M-learning and E-learning, as well as between ME and RE. The differences among them are based in the enabling technologies as represented in fig. 2.

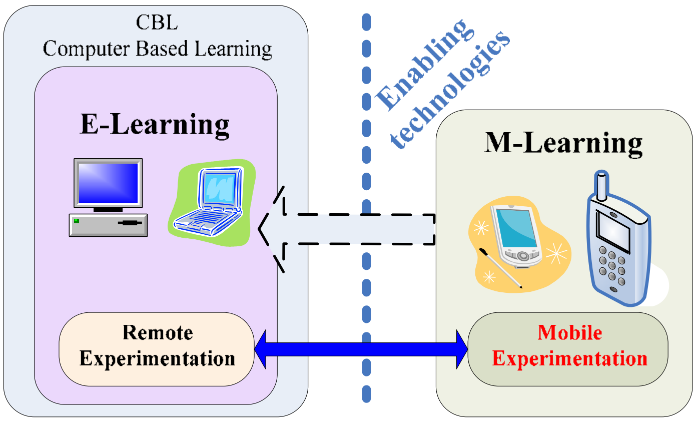

Figure 2: E-learning x M-learning and RE x ME

Adopting a distance learning solution that includes mobile experiments requires a model similar to the scenario encountered in RE, as illustrated in fig. 3. The similarities are confined to the lab infrastructure that consists on:

a) the Instrumentation Server, responsible for controlling/monitoring the instruments and robots that together with the apparatus under experiment form the 'remote experiment';

b) the Lab Server, which provides the remote interfaces for user control, and a database that keeps all the required information to support mobile experiments, namely guides, reports, log files with user's interactions and other persistent information.

Before describing in more detail the additional layers (client devices and media access) that form the ME scenario, we will present a general mapping of both the mobile devices and the wireless networks. This mapping will lay the ground for the higher complexity of ME in comparison to RE scenarios.

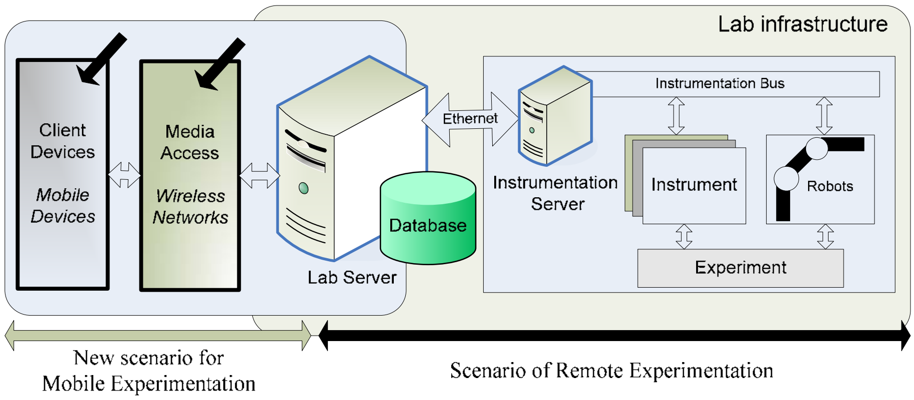

Figure 3: Conceptual architecture for a ME scenario

2.1 Mapping mobile devices

Given the general use of PCs in education, a first approach to characterize mobile devices would be a comparison between these two equipment types according to the following criteria (in mobile devices we will also distinguish mobile phones from PDAs and smart phones):

- Resources/Processing Power: PCs still have more processing power and memory capacities, and faster computing speeds and larger displays than PDAs, smart phones and mobile phones. These facts impose some restrictions when developing software solutions for mobile devices. However, certain features associated with mobile devices (see following paragraphs) and new software platforms place them as resources to considerate for education support.
- Mobility: the light and small sizes of mobile phones, smart phones and PDAs enable their use anywhere, anytime and by anyone. PCs, and even laptops, are still heavier and bigger than mobile devices and thus have less mobility.
- Price: mobile phones are a very attractive solution because of their lower prices comparing to PDAs, smart phones and PCs. This is the most important and supportive characteristic of ME over RE. Reduced costs support the idea that education should be for all, independently of a person's social condition.
- Number of users: Recent studies show that mobile phones are largely the most used devices [9, 11], which supports the assumption that M-learning (and ME) will contribute to a better and more inclusive education (in the sense of e-inclusion). Although smart phones are more expensive than mobile phones, the added characteristics will eventually make them a first choice in the light of new services, such as ME.

Fig. 4 resumes this comparison and illustrates future tendencies, denoted by a (red) dashed arrow.

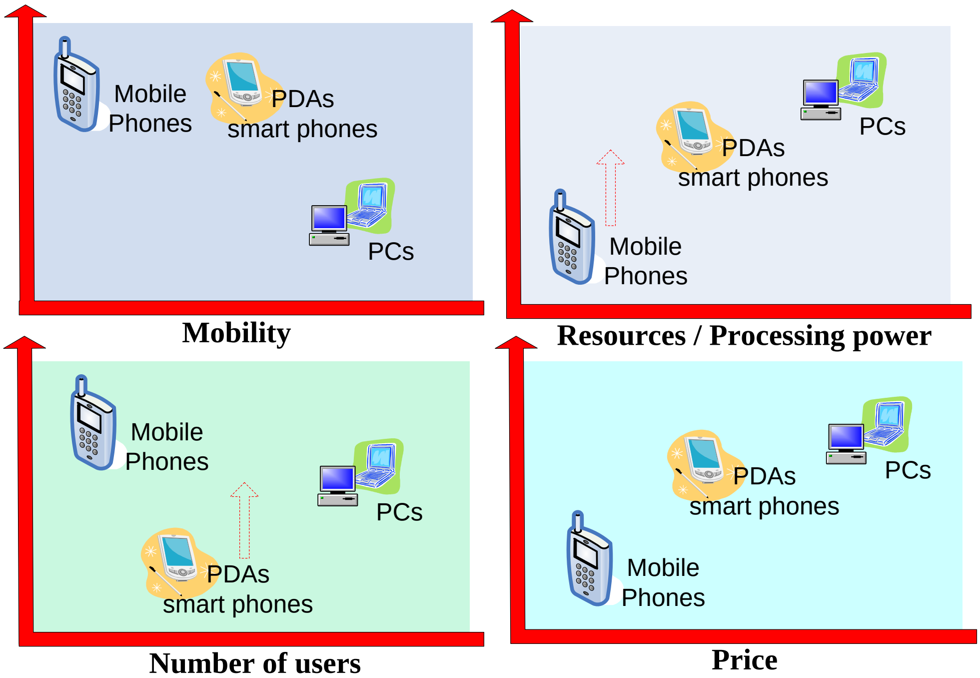

Figure 4: Mapping resources/processing power, mobility, price and number of users

2.2 Mapping wireless networks

Accessing a remote lab through a mobile device requires a network with high data rates and a good QoS to provide a real time interaction with remote instruments and to allow communications between users to perform collaborative tasks, like in a real lab. Therefore, it is essential to understand the communication infrastructure, i.e. the wireless networks that allow transferring data, voice and video. Fig. 5 illustrates the network technologies that presently support those wireless communications, namely between the remote infrastructure (server, instrumentation and database) and the mobile devices/PCs, as in [12].

Wireless networks aim to provide mobility and flexibility to users, preferentially at low costs. The ones that fulfill the enumerated requirements (high data rates and a good QoS) are Cellular networks, Bluetooth and Wi-Fi (based on the IEEE 802.11 std.), each one having specific features that influence a possible choice.

- Cellular networks: presently divided in 3 generations (the 4th is expected soon) that can cover tenths of kilometres, with distinct data rates and enabling technologies. Fig. 6 gives an overview of these networks (protocols and data rates) plus a reference to the future 4G and 5G networks [13, 14], which will bring better QoS and faster data rates than the actual 3G [15, 16], which is already a good choice for accessing ME scenarios.
- Bluetooth: enables connecting and exchanging information between devices via a secure, low-power, and free cost communication channel. The specification is based on a master-slave architecture for Private Area Networks (PANs). Already supported by a wide range of mobile devices, the data rate does not exceed 2 Mbps and covers ranges up to 100 metres [17, 18].
- Wi-Fi: represents a set of product compatibility specifications based in the IEEE 802.11 standard, for Wireless Local Area Networks (WLANs). As described in table 1, these networks are the fastest (the new 802.11n has up to 200 Mbps [19]), covers distances of hundred of metres and are the most used in PCs, laptops, and even PDAs [20].

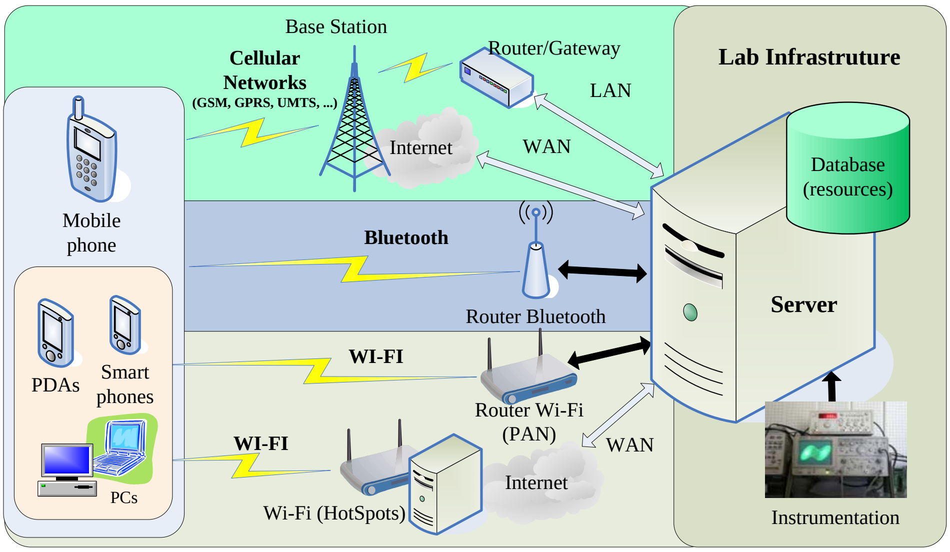

Figure 5: Network components in ME

Today, Wi-Fi networks have several regions covered by access points called hotspots[1] that make them useful for ME. However, the area coverage of both Wi-Fi

[1] The reader interested in a list of currently available Wi-Fi hotspots may consult a directory in [21].

and Bluetooth networks (limited to hundred of metres) is inferior, by several orders of magnitude, to the area coverage of cellular networks (limited to tenths of kilometres) thus providing less user mobility. Considering that moving from an area covered by one hotspot to an area covered by a different hotspot is not transparent to a Wi-Fi compatible device[2], suggests cellular networks to be a preferable scenario for accessing remote experiments in Wireless Wide Area Networks (WWAN) contexts. In other words, cellular networks provide a better scheme for roaming and authentication processes when compared to Wi-Fi networks. Despite this, Wi-Fi and Bluetooth networks are also valid choices for ME scenarios, since they are very useful in PANs or WLANs contexts (e.g. in a campus school) and they present lower utilization costs than cellular networks.

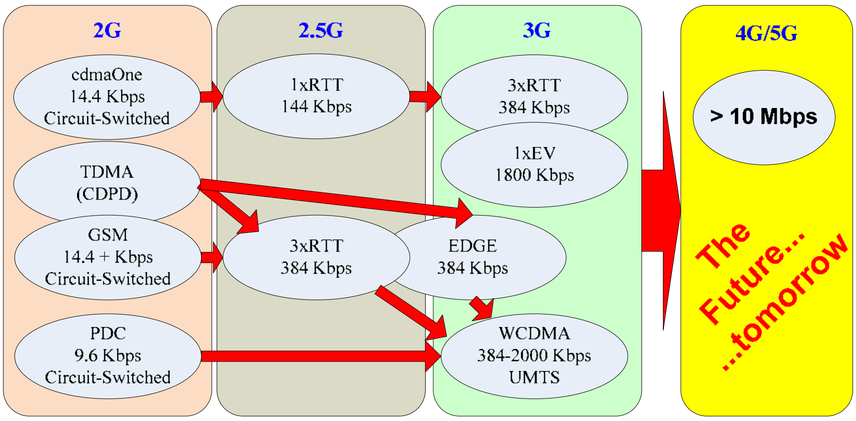

Figure 6: Cellular networks

Table 1 Wi-Fi specifications

Specification	Data rate	Frequency Band	Compatible with
802.11b	11 Mbps	2.4 GHz	b
802.11a	54 Mbps	5 GHz	a
802.11g	54 Mbps	2.4 GHz	b,g
802.11n	+200 Mbps	2.4 GHz	b,g,n

[2] In opposition to the situation of moving from an area covered by a base station (providing access to a cellular network) to an area covered by a different base station.

Summing up, it is difficult to select a particular wireless network as the preferable one for accessing a remote lab. This conclusion presents an important requirement to the remote lab infrastructure, in ME contexts, namely the need to accommodate several types of access media. This and other requirements will be further analysed in following section, just after table 2, which briefly resumes the characteristics of the three considered wireless networks, in terms of: price; need for an operator; data rate; physical architecture; and the context usage.

Table 2 Comparing wireless networks

	Price	Operator	Data rate	Architecture	Context
Cellular	*Always paid* Requires an operator card and is charged based in the quantity of transmitted information	Yes	Up to 2 Mbps Future: 10 Mbps with 4G/5G	Client-Server	WWAN
Wi-Fi	*Not always paid* Requires an Internet Server Provider with free connec-tions	No	Up to 100 Mbps Future: +200 Mbps with IEEE802.11n	Client-Server	WLAN
Bluetooth	*Always Free*	No	Up to 2 Mbps (V2.0)	Master-Slave	PAN

3 Mobile Experimentation

3.1 Remote lab infrastructure requirements

A ME scenario comprehends three components: (i) a remote lab infrastructure; (ii) mobile devices able to access the remote experiment(s); and (iii) one or more communication channels, i.e. the wireless networks that establish the connection between the first two components. To control a remote experiment the client must have an application installed in his device, able to communicate with a second application (located in the remote lab), using for instance the Hyper Text Transfer Protocol (HTTP) [22]. As already mentioned, the existence of several devices in the market requires the second application to adapt the remote experiment interface in accordance to the characteristics of the accessing device (a mobile phone, a PDA, a smart phone, or a PC), namely its memory capacity, processing power, and display size, among other features. In other words, the remote lab infrastructure should be based on a logical architecture similar to the one proposed in fig. 7, capable of accommodating all the available devices in the market.

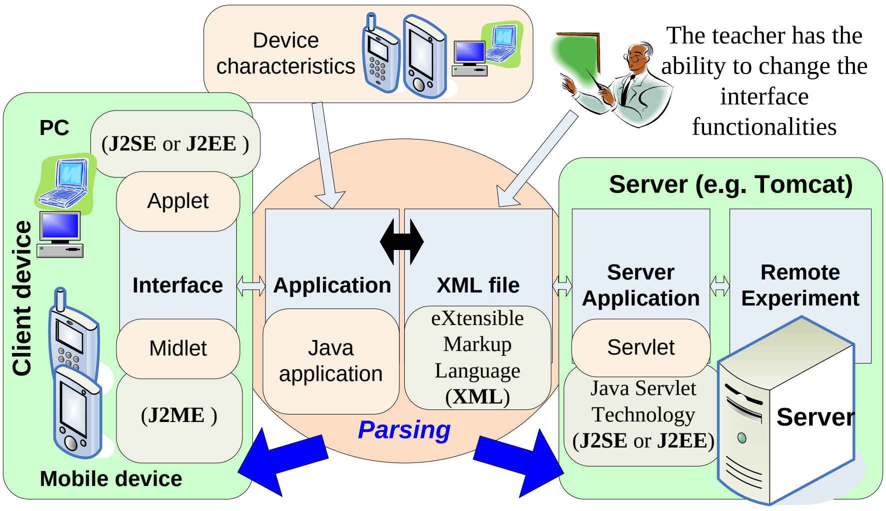

Figure 7: Proposed architecture to implement a ME scenario

Fig. 7 illustrates the client-server architecture that implements the two previously referred applications, using the Java software language. At this point, it is possible to identify a requirement for mobile devices able to access the remote lab: the support of the Java Virtual Machine J2ME [23]. The applications installed on the mobile device, also called Midlets, are the interfaces that enable users to control the remote experiment(s). These Midlets communicate with the second application located in a Java Web server (e.g. TomCat [24]), which in its turn is named Servlet and is developed in Java under a different platform (J2SE or J2EE) [23]. If instead of mobile devices, a PC is used to access the very same lab infrastructure the first application will be an Applet (in opposition to a Midlet) running on the top of a J2SE or J2EE. The two scenarios have in common the Java software language and therefore a solution based on this architecture supports both remote and mobile experiments. The capacity to distinguish the client type and to adapt the user interface according to that distinction is provided by the layer described in XML [25]. Versatility is therefore provided by the XML file that contains a description of all the functionalities and interfaces characteristics (access ports, display size, functionalities of the buttons and controls, among others) in order to adapt the application to all client devices. A simple modification in the XML file allows a quick and easy change of the interface functionalities. The teacher may use this simple customization process to tune the interface characteristics according to the level of understanding of the target audience, i.e. the previous knowledge of the students that are going to perform the remote experiment. A simple interface would be presented to students with a basic understanding, while students on an advanced level would be presented with an interface showing the full features set of the device(s) under control. Another advantage of this process is the possibility to create partial views of general measuring devices used on a RE scenario. For instance, the interface to a simple multimeter could only present a button for the scale selection and a reading display for the electrical current flowing through a temperature sensor on a remote experiment dealing with a heating process. Although a multimeter is also capable of reading electrical voltages, resistances, and frequencies, the teacher would cut off the buttons controlling these measures in order to help the student focusing on the heating process and not on the multimeter paraphernalia.

Also shown in the architecture illustrated in fig. 7, is a Java application that parses the XML file and creates the interface to control the remote experiment(s) (a Midlet for mobile devices, or an Applet for PCs). Although individualized as a single application, the parser functionality could also be provided by a simple function integrated into either the Servlet or the Java application running at the client side (Midlet or Applet). The first option consists of parsing the XML file and creating the Midlet or the Applet at the server side, and then transferring it to the client devices, through the network infrastructure, upon a remote access to the lab server. The second option requires transferring the XML file from the server to the client device, where the Java application parses it and creates the Applet or the Midlet. In mobile devices the parsing process is done using small parsers [26] while in PCs other parsers should be adopted [27]. Both options have advantages and disadvantages, therefore the decision process should consider items such as: the size of each file and application; the processing power and memory capacities of the client devices; the data rate supported by the network infrastructure; and the communications costs, among others.

In order to provide some practical insight, the following subsection describes an implementation example of the first option, in our case on the use of a mobile remote phone to remotely control a digital multimeter.

3.2 Implementing a simple mobile experiment

To validate the proposed architecture for a remote lab infrastructure we implemented a proof-of-concept experiment at our site. Fig. 8 illustrates the developed Java applications that allow controlling a digital multimeter either through a PC or through a mobile phone emulator, named Java Wireless Toolkit [28]. Two notes at this point: i) PC access implies an Applet while mobile phone access implies a Midlet; ii) we used an emulator instead of a real device, because we had no budget to acquire a real mobile phone with the required characteristics (J2ME implemented) and the emulator supplier guarantees the match in terms of functional results.

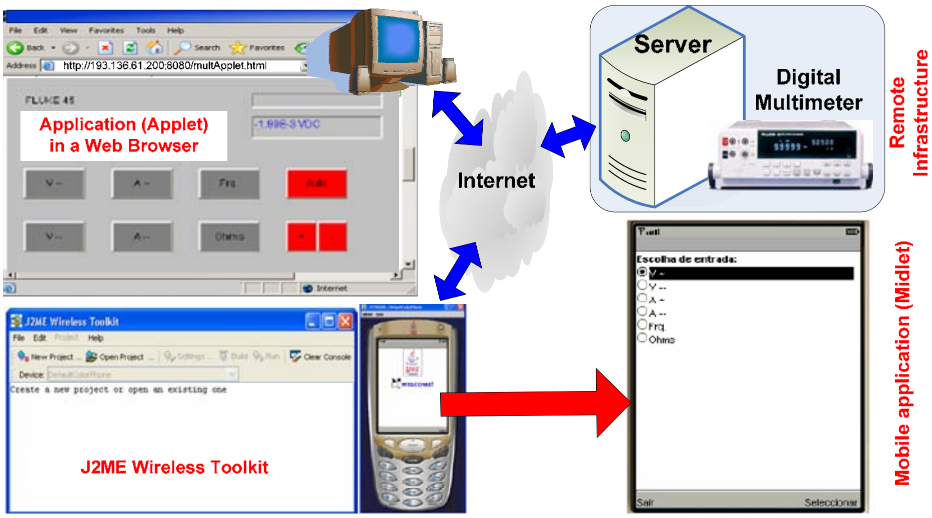

Figure 8: Architecture to control the digital multimeter

As stated before, versatility is provided by a XML file that follows a structure described in *Schema* [29]. This file contains the interface specifications (position, length, color and functionality of buttons, size and color of the display, and others) and is parsed at the server side by a Java Application that creates both the Midlet and the Applet, which enable controlling the digital multimeter. The solution of creating both the Midlet and the Applet (instead of one at each time, depending on the access device) implies more processing time and memory space (as both are stored at the server) but it had the advantage of simplicity, i.e. it eased the code development. After being created, the interface (in fact, a file) is transferred to the user device, using the HTTP protocol. For transferring and establishing the client-server communication we used the TomCat Web server which also has the responsibility of interpreting and running a Servlet that establishes the actual link between the user and the physical device under experiment, namely by receiving/sending all the commands and data to/from the multimeter.

Although we have used the Internet and a mobile phone emulator to control the multimeter through a Midlet, if Wi-Fi or Cellular networks were to be used the software layer would require no changes. Bluetooth networks would be the exception requiring software modifications, because this network specification is based on a master-slave architecture, which requires specific libraries [30].

4 Conclusions

ME guarantees the benefit given by RE to engineering and sciences e-courses, in M-learning contexts, namely the flexibility, mobility and motivation given to students. Nowadays, QoS of wireless networks are improving and every person has, at least, one mobile device, which guarantees the acceptance of new developed applications based in the ME concept.

Further to the benefit that ME gives to the learning/teaching process, the proposed architecture based in a XML layer contributes to the development of versatile software applications. This layer enables adapting the RE interface both according to the characteristics of the client devices and to the teacher view on which interface layout is more appropriated to the student(s) in question. To conclude, we stress out the fact that versatility is a key aspect, not only of the proposed architecture but also, of any particular education style.

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