16th IMEKO TC4 Symposium
Exploring New Frontiers of Instrumentation and Methods for Electrical and Electronic Measurements
Sept. 22-24, 2008, Florence, Italy

Mobile Measurement Support for Remote Laboratories and E-learning Systems

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Abstract- Practical work in the laboratory using real instruments is a strong emphasis for theoretical knowledge but also a powerful drawback for distance learning in universities. The paper describes development of a remote laboratory for mobile devices. Given the detailed analysis of potential benefits coming from the deployment of such a system, the author analyzed the technologies suitable for its realization. Multi-tier platform has been developed to support Mobile learning and experimentation. For visualization and control of experiments a thin-client paradigm based on DHTML has been developed. It allows users to visualize and control experiments remotely on handheld devices, using mobile browser only. Application tier is based on deployment of ProperJavaRDP client with custom web server written in Java. Experiment tier runs experiment written in whichever language, thus enabling high reusability of the system. Data tier is based on deployment of customized Moodle LMS with layout adapted to fit the screen and other limitations of handheld devices. It takes care of user authentication and opening session towards Mobile Laboratory Server. This Mobile learning system can enhance user learning process by providing support for discursive learning approach according to the behavioral, cognitive and constructivist theories of learning.

I. Introduction

In the last two decades the Internet infiltrated all areas of human activity, especially the ones connected to information exchange. Millions of people across the globe started to use the Internet as a communication channel and its potentials have been growing on daily basis. Economic and society changes following this growth are occurring at an accelerating rate in our information society making lifelong learning for most people an unavoidable requirement. Through e-learning, Internet technologies are changing education paradigm by enabling implementation of different pedagogical principles on the level that was not possible before.

Fink's approach to course design carries out three crucial phases in learning process: *Information and Ideas*, *Reflecting* and *Experience* [1].While information and ideas (as a part of a learning process) are spread quickly through Internet, lectures and communication with others; what we miss today is opportunity to experience their influence on real life situations. Without practice knowledge will in time parish, if even believed it existed in the first place. It is known that in the electrical engineering education this kind of experience is gained through experimentation and measurement in the laboratory. However, electric and electronic measurement laboratories, due mainly to their costs and maintenance problems, are difficult to set up.

A number of solutions, based on simulations, have been proposed to solve these problems. A virtual laboratory offers a simulation of real measurements but the data is artificial, and even though they are useful in deepening the students' conceptual understanding they are a poor replacement for practical work in real laboratories [2; 3]. Student engineers need to be exposed to practical experiences and the uncertainties of real life environment, which can be achieved only in real hands-on laboratories, even though they take up badly needed space and consume student's time in menial set-up and tear-down procedures. The Internet enabled learners to get in touch with the measurement resources worldwide by requiring a minimal connection cost and allows realization of numerous flexible and customized measurement solutions. Today, the best solutions modern technologies can offer are remote laboratories. They offer a student remote control over the real experiments taking place at a distant location. With this aim geographically distributed remote laboratory LA.DI.RE. " G. Savastano" was realized at the University of Sannio [3]. It includes complete Learning Management System (LMS) with a wide range of experiments in the field of electrical engineering. LA.DI.RE. „G. Savastano" made experiment available to the students using their PC, requiring internet connection and a browser only. Still, there are situations where even higher availability of the measurement processes is required.

The need for „mobile measurements" is justified straightforward (especially for time consuming measurements and processes), but why should learning ever go „mobile"? Learning is considered to be a process which primarily requires time and concentration, stagnancy. Even though, learner is the one who moves, and he/she moves a lot, especially in the last few decades. While doing so, he/she learns. He/she learns by reading newspapers, communicating with other people or trying to solve a certain problem. Often he/she will take the literature to the park, friend's house, or jus to read it in the train. This is a part of an informal learning process and most of our knowledge has been adopted in similar fashion. Learning has always been mobile and this everyday reality provides a framework for use of mobile devices for discursive learning. To make information mobile is a requirement that goes beyond the scope of merely data. We want information of reality - measurement results or control over a process taking place remotely [4; 5].

M-Learning is directly tied to possibilities of mobile technology and researchers and practitioners must be familiar with this technology to use it properly. Koole et al. [5] explains how the main difference between e-learning and m-learning is in the technologies used for educational content supply. But, it was shown that the differences go far beyond technology used. In fact, m-learning acts as a partner to e-learning providing learners the opportunity to maintain involvement in their learning environment while the same is not accessible via static technological devices such as desktop computers. M-Learning is a dedicated, special-purpose component of the e-learning world that provides different opportunities and abilities to the learners [5; 6; 7]

This paper describes realization of Mobile learning support for remote laboratory LA.DI.RE "G. Savastano", including LMS adaptation and development of multitier platform for support of Mobile Measurements. It enhances traditional e-learning systems.

First section of the paper addresses the critical issues in development of such a system, like hardware and software limitations and design recommendations. Second part will describe how these issues were solved through realization of proposed multitier platform for m-learning.

II. Constrains of Mobile Technology

Given the potential benefits coming from deployment of m-learning system, it is necessary to look into constrained space of possibilities that mobile technology can offer. Without proper knowledge of limitations of handheld devices, it is impossible to produce system that would exploit its benefits in proper way. After presenting the three groups of limitation factors, specific constrains derived from requirement of LA.DI.RE. framework are presented.

A. Hardware limitations

Biggest limits of handheld devices are small displays and control-navigation problems for mobile devices without touch-screen [5]. Reduced display size which highly differs from device to device requires adaptive environment, and produces special requirements on the Graphical User Interface (GUI) creation. Testing of m-learning systems [5] showed that graphics used on handheld devices must have reduced number of details to the highest degree possible. In the case of remote experiments, it forces creation of experiments with basic functionality. Experiments of higher complexity, which require more than one screen, will require vertical scrolling or multi-page approach. Adaptive GUI is presents problem, because software for creating virtual instruments (like LabVIEW) usually uses non scalable GUI components. Even when it is possible to create such a GUI, use of it is questionable due to the request of *reusability*. Teachers who should be creator of such experiments would have programming knowledge far beyond their interest or possibility.

To ease solving of mentioned problems, author proposes differentiation of two groups of ubiquitous handheld devices [7]. First one is group of browser enabled mobile phones (e.g. smart phone), while typical representative of other group is a Personal Digital Assistant (PDA). While mobile phones today, according to the author's investigation, have screens with resolution not more than Q-VGA 240×320 pixels, the PDA screens have up to 480x640 pixels. Smart phones usually don't have touch screen or any pointing devices, while the PDAs does, which is an important issue for navigation. It forced the development to flow in two different directions. For mobile devices navigation problems require particular solutions for experiments control, like simplest tabbed browsing up to advanced simulations of mouse pointer. PDA devices do not have these problems. Modern phones like iPhone or other devices with touch screen also go in the group of PDA due to the similar hardware characteristics. This way an experiment creator should only take care which devices group he is creating experiment for.

Limited processor power of these devices is also a strong drawback because applications must be very "light", consuming memory as less as possible. It reduces application's response time. PDA's in general have bigger memory resources and processor power. While smart phones usually have processor clock speed about 100MHhz and typically 2MB of RAM, nowadays average PDA devices have processor power of 600 MHz and around 128 MB of RAM. Similar devices groups are used for Java Mobile Edition (J2ME) configuration specifications [8].

B. Software Limitations

Mobile devices have wide variety of software versions and producers which are sources of huge problems for developer trying to produce product for widest group of users possible. Author was trying to create Thin Client application or dynamic web page which would remain open, capable of working on all the devices that could be used for the purpose of m-learning. That is of course, impossible, but even coverage of majority of handheld devices reduces number of possible solutions drastically. Starting from operating system, which has strict requirements for creating applications and others for Web based solutions, the supported programming languages differ greatly. The most popular, Microsoft Windows Mobile throughout its versions changes level of supporting languages, especially when speaking about possibilities of Internet Explorer Mobile (IE Mobile). Almost every successive edition of IE Mobile supports different set of JavaScript, Document Object Model (DOM) and XML support. Situation is a bit better with Symbian and Palm Operating Systems.

Java 2 Micro Edition (J2ME) is one of the most ubiquitous application platforms for mobile devices. Because of its nature of openness it would be ideal solution for creation of dynamical m-learning content. But unfortunately, J2ME varies greatly in versions and built-in packages from device to device. J2ME currently defines two configurations: *Connected Limited Device Configuration (CLDC)* and *Connected Device Configuration (CDC).* They were invented to support idea of *„Write once, run everywhere"* but currently they, with combination of different profiles (additional classes for added functionality), made J2ME code more suitable for definition *„Write once, test everywhere"*.

C# is well suited for development of applications for PDA based on Microsoft operating systems. After abandoning J2ME as possible programming language, author considered possibility to write the client for remote control of experiments in C#. This idea was abandoned due to the portability reasons (it would run only on Microsoft platforms) and general not much advantages when comparing to possibilities of DHTML (regarding special requirements of the system). Possible benefits could come from partial updates of GUI bitmap or caching algorithms. Unfortunately, on PDA processor power is insufficient to perform this kind of calculations in real time. Even size of the image of 240x320 pixels saved as Portable Network Graphics (.png) varies from 2 to 20 kB, which makes it small enough to be transferred as it is.

C. Connection Limitations

Wireless LAN, although ideal for our purpose, is not always available to the potential user, and mainly does not fulfill "anytime and anywhere" requirement, so the system should be able to work over HSPDA, UMTS, EDGE or GPRS connections. The latter has high latency and restricted bandwidth which is a big drawback for applications or services using it. Not to forget, price should also be taken into account in these cases. Students are usually not willing to pay for learning additionally. But decreasing price and increasing connection speed allow us to count on these solutions in the near future.

D. Particular Constrains Derived from LA.DI.RE. "G. Savastano" Platform

The Remote Laboratory design unites knowledge of information engineering and ICT with adeptness of metrologists to create didactically efficient solutions. Widespread of Learning Management Systems (LMS) has solved the problems in the management of user accounts, tracking of the students, management of the activities and the courses, security issues and others. But still, LMSs by default do not allow user to work on the real measurement equipment but only on the simulations of laboratory experiments. Control over experiment or measurement application requires dedicated applications or use of Web services, which are complicated for deployment for non programmers. Even for programmers, they do not provide sufficient required reusability.

To overcome this problem, LA.DI.RE. „G. Savastano" platform was created [3; 2]. Block diagram of remote laboratory system structure is shown on the Figure1. It is a multitier platform that provides off the shelf solution for deployment of experiments (applications), written in whichever language, inside LMS. Presentation tier is based on the *LaboratoryApplet* – a optimized version of ProperJavaRDP client written in Java. LaboratoryApplet allows experiments to became integral part of any open LMS, providing *reusable* solution for remote laboratory. It actually retrieves user inputs (mouse and keyboard events) and transfers them to the server, while sending to the user parts of bitmap representing application window. Experiments are executed on Measurement server – a PC connected to the measurement equipment, which runs Windows 2003 server with Terminal services which allow remote control of specified application (experiment). LaboratoryApplet was specially designed and tested in comparison with other possible solutions. It includes advanced caching algorithms, variable cache dimension and higher compression than usual RDP so it gives the best results in bandwidth occupation measurement. Java ensured system portability and usability while optimization enabled reduction of the bandwidth occupation and improved the user interaction with experiment.

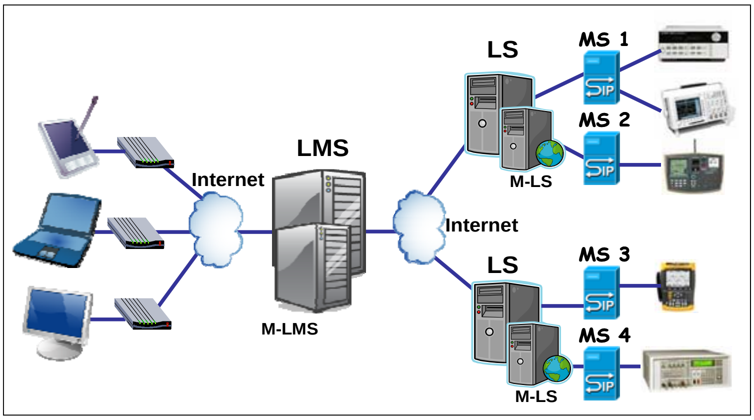

Figure 1. Platform of LA.DI.RE. "G. Savastano" extended with M-LMS and M-LS to support mobile learning.

The server-side logic, composing the middle-tier, is distributed on the following servers: (i) a LMS, executed on a central server, called Laboratory Portal. It is based on deployment of MOODLE, customized to fit particular needs of the system; (ii) The Laboratory Server (LS), used to interface each laboratory with the rest of the system. It delivers the access to the laboratory equipment, and (iii) The Measurement Server (MS), a server located in a laboratory that enables the interactions with one or more instruments. Each MS is physically connected to a set of instruments through GPIB, USB, PCI card or other ports. The server-side software component used to control the electronic instruments is LabVIEW™, developed by National Instruments.

III. Realized System

Request for m-learning system to be compatible with LA.DI.RE."G. Savastano", although limiting, brings numerous benefits to developer. It allows users and developers to inherently benefit from the RL multilevel scalability and reusability. Compatibility makes possible use of existing hardware (most expensive part of RL) and setup and structure of RL including measurement and laboratory servers with their functionality.

Solution developed by the author relies on the structure shown on the Figure 1. The servers which are added to the platform for desktop computers are Mobile Learning Management Server (M-LMS) and Mobile Laboratory Server (M-LS) (see Figure 1). Both of the servers can be installed on the same physical servers, making extension of the RL functionality much easier and cheaper. As can be seen in the Figure 2, currently employed system prototype is based on a multi-tier approach. The multitier architecture is based following tiers: Presentation, Application, Data and Experiment Tier.

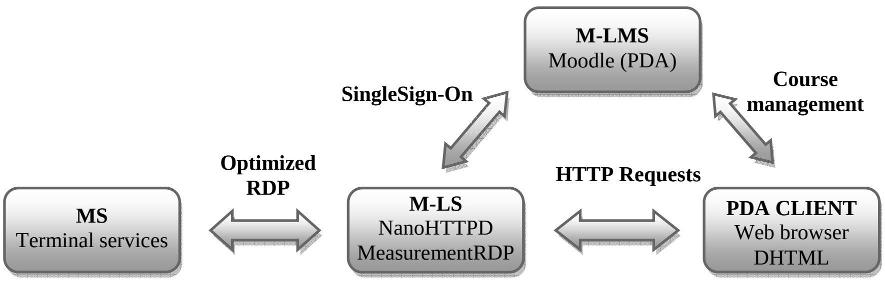

Figure 2. Mobile experiment visualization software architecture.

Data tier is actually a Moodle LMS (M-LMS) installed on LS deployed by the system to manage user accounts and complete learning and tutoring activity. The LMS is modified for the use with handheld devices. In short, width specific code is removed and all the data is placed in one row. Information are formatted in a way to not distract user attention, and page layout is simplified as much as possible. Big logos or images are omitted, and high clarity of the content is achieved. Moodle has the role of creation and keeping the session for connection with M-LS. When a user logins to the Moodle, his/hers list of courses is displayed to him/her. He/she can choose to conduct different learning activities like reading materials, chat inside online community or forum, perform quizzes and test or he/she can execute experiment. The user can choose between: *a)* Experiment visualization (monitoring) - it allows student to monitor certain measurement processes on his handheld device whilst away from the laboratory and *b)* Experiment control – allows student to control experiment remotely from any handheld device with JavaScript and HTML DOM enabled browser.

Experiment Tier also uses the same hardware used by Remote laboratory for desktop PCs. Experiment for which mobile version is needed consists in the standard, desktop size form, and reduced size for hand held devices. Experiment for handheld devices should be used only when it is considered useful from the curriculum perspective, or when it is convenient to control and monitor time consuming experiments. If the teacher finds it useful he should only create experiment in whichever programming language, with the window matching the screen size of the target devices. Actually, full size experiment can be relatively easily transformed in size fitting the handheld devices screen. When realized, the experiment is compiled in executable file and placed in dedicated directory to be published on demand by Terminal Services. After that, experiment name and location (IP of MS controlling it) should be entered in the database of the system, in the table of available m-learning experiments. Unique `expId` should be assigned to each experiment, and that `expID` is passed as a `$_POST` variable from the Moodle together with the `sesskey` string to M-LS wich opens connection towards MS.

Application tier is based on M-LS is installed on the LS of RL. This server is the central part of the system. M-LS interface the geographically distributed laboratories to the rest of the system. Each laboratory has its own M-LS (same as LA.DI.RE."G.Savastano"). M-LS consist of two separate Open source programs which were reprogrammed from the bottom to act together as successful application for particular bridging service.

To interface the laboratory to the WAN a solution based on ProperJavaRDP has been used. It had to be changed from scratch to fit our purpose. Firstly, ProperJavaRDP is actually a Java Applet, and it cannot be used as a bridge. It was transformed into application named MeasurementRDP. MeasurementRDP was created in the way that all the GUI specific code was removed, and the rest was optimized for synchronization with NanoHTTPD, who was embedded into application with extended functionality. On initialization `NanoHTTPD` creates a new instatnce of `RdpMain` classes which takes the arguments (IP address, username and password, screen height and width) which open a socket towards MS and opens a new thread to handle response. `NanoHTTPD` takes parameter `uri` from `GET` request and `parms` from Moodle's `POST` and firstly checks if the user session is valid. If so, the `new rdpMain` object is created with arguments passed from Moodle (experiment ID `expId`, `username` and session key `sesskey`). `RdpMain` was modified to output GUI of MS in Portable Network Graphics (`.png`) format, which is mostly spread image format on handheld devices. Method then transforms it on the fly to the stream which is written to the socket of HTTP protocol. This way image is not stored on the disk, and response time of server is much lower. HTML and JavaScript code is also written dynamically from the memory directly to the socket. Another parallel way of communication is happening between client and the TerminalServices (MS). JavaScript catches the mouse clicks (or screen clicks actually) on the client side. They are passed through `onclick()` event as the arguments of the GET method. `rdpMain` object is used again to pass these values to the `input` object with `getCommLayer()` method. This way TS receive the control data over the experiment.

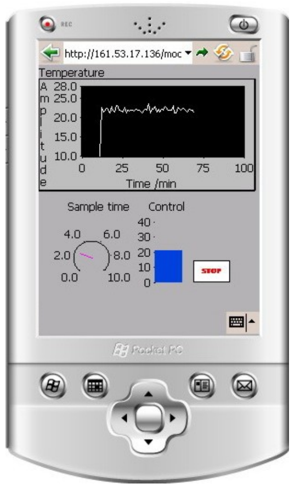

Figure 3.Temperature Control Experiment

Presentation tier is based on deployment of dynamic Web pages to enable visualization and control over the experiment. Figure 3 depicts Temperature Control Experiment designed for demonstration of possibilities of the Mobile Remote Laboratory. As described, several programming languages were tested or planed to be used but due to the specific system requirements, DHTML and the AJAX gave the best results. Presentation tier handles two level communication with M-LS as shown on Figure 2. Thin-client paradigm splits the presentation layer between client and server. The presentation logic runs on the M-LS, while the thin client has only two tasks. First task is visualization of the GUI of the particular experiment - window of the application running on the Measurement Server (MS). It can be done automatically or on demand. Second task is to act as an event handler – catching users input and control data and recalculate it and transfer it to the Mobile Laboratory Server (M-LS) running modified ProperJavaRDP client. *Visualization* of the experiment based on the JavaScript that allows user to choose refresh rate for retrieval of the image. If the user chooses refresh rate of one second, after the each second XMLHttpRequest is sent to NanoHTTPD to send next image of the process. *Control* of the experiment is based on the JavaScript which "catches" mouse coordinates and transfers it to the originating experiment (Terminal Services) allowing control as explained earlier. Web pages are also dynamically loading on demand or after changing certain parameter of the experiment. Heavy JavaScripts, which handle this transmission, can be loaded dynamically with the body, or on demand – same like image, which would reduce start-up time of the web page. For this purpose AJAX is used. To enable experiment to be visible on the most of handheld devices it should not exceed 176x208 pixels for smartphones and 240x320 for PDAs. XMLHttpRequest object is very convenient because it allows control over displaying the data – it enables making of loaded XML data to be visualized when loading reaches the final phase (`readyState` property is set to 4). But, if only image is to be visualized (which is enough in most cases) than asynchronous loading can be accomplished by dynamical changing of the `src` attribute of `<img>` tag (by using DOM `getElementByID` method) holding the required image. This solution, although limited, has advantage over XMLHttpRequest in following. XMLHttpRequest object can only load hypertext files to the certain object of originating document. This means that images must be loaded by separate HTTP request by the browser, after the loading of textual contents. One GET request is usually meaningless for the desktop browsers, but for handheld device it represents noticeable increase in response time.

II. Conclusion

The paper describes realization of Mobile Learning System supporting Mobile Measurements in electrical engineering education. This approach gives the possibility of providing remote access to any application, written in whichever language, running locally on the server and requiring only mobile browser on the client side. This way it can be used for uneducational purposes also. The presented solution rises accessability of worldwide information, multimedia, simulated and remote laboratories and creates learning environment where students are encouraged to collaborate, explore and learn in more effective manner.

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