

# J2ME-Based Mobile Virtual Laboratory for Engineering Education

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**Abstract**—A mobile virtual laboratory is developed to help students perform virtual experiments using mobile devices to make it possible for teaching to be conducted anytime anywhere. In addition, resources and equipment can be integrated and shared efficiently where an environment is created to promote learning interests and efficiency by using mobile devices via the Internet and the GPRS telecommunication networks. Java wireless communication technologies were used in the design which implements a multi-tier architecture in order to integrate different fields of technology. The ultimate objective is to improve the scalability of the system and to allow for the use of Scalable Vector Graphics which makes it possible for developers to create interactive graphical content, with the ability to zoom and resize on displays with different resolutions and aspect ratios.

**Index Terms**—Mobile Learning, Virtual Laboratory, J2ME.

## I. INTRODUCTION

Over the past decade, mobile learning has grown from a minor topic into a significant research field with a focus on how can mobile technology offer new opportunities for learning that extend within and beyond the traditional teacher-led classroom [1-4]. Yet, the diversity of the field makes it difficult to capture the essence of mobile learning or to show how it contributes to the theory and practice of education. The situation becomes pronounced further by the availability of small personal computerized devices as an essential tool in modern everyday life. Furthermore, the ongoing penetration of computers into society leads to ubiquitous environments where networking capabilities are used everywhere. In fact, the rapid development of wireless networks has transformed cell phones, Pocket PCs, iPods and other PDAs into learning devices where data is transferred over the General Packet Radio Service (GPRS) network. As long as the users' cell phones are situated on a signal location, they can enjoy various network resources and services via GPRS [5-6]. As a consequence, teaching will no longer be limited by time or confined by location, and there is strong evidence that traditional education may easily leap through eLearning into to mobile learning or simply mLearning [7].

Mobile learning is particularly important in science and engineering education which requires for the students to learn theoretical foundations in classrooms and experiment in laboratory sessions. However, teaching of measurement science requires a vast practical experience in order to assure a good knowledge transfer from the

teacher to the students [8]. The students should achieve such experience by working in actual conditions and on the actual instruments. Usually, the sophisticated and expensive measurement instrumentation involved makes it difficult to keep the technical staff up to date [8]. Moreover, there is the necessity for repeating the same experience many times in order to make all students able to operate the measuring instrumentation which makes the technician shortage even more severe. Online laboratories, virtual and remote, have therefore become a very useful support for practical aspects of teaching methods world wide. Teaching is thus conducted anytime anywhere and resources and equipment can be integrated and shared efficiently where an environment is created to promote learning interests and efficiency by using mobile devices via the Internet and the GPRS telecommunication networks.

In addition, it is very rare to combine both lectures and laboratory sessions at the same time due to the fact that in many occasions, laboratory equipment cannot be brought into a classroom due to its size and characteristics or it is simply not available in campus [9-12]. Thus, it becomes necessary to utilize mobile technology to implement a virtual laboratories network to allow remote interaction with laboratory equipment so experiments can be controlled as they occur [13-16].

In this paper, a mobile virtual laboratory is developed to help students perform virtual experiments using mobile devices and to remotely control real hardware and perform measurements wirelessly. The remote lab was designed and implemented using a cellular phone or a PDA because they are widely used amongst students. The experiments run on a server which is directly connected to the circuit under test via data acquisition card terminals. The user should be able to perform different experiments in the field of logic design, apply different gates, combinational and sequential circuits. The system is aimed to eventually provide an environment to train students to handle factory automation, data acquisition, data management, and manufacturing process using the various types of mobile devices. Java wireless communication technologies were used in the design which implements a multi-tier architecture in order to integrate different fields of technology and the data generation and acquisition were controlled by J2ME. The ultimate objective is to improve the scalability of the system and to allow for the use of Scalable Vector Graphics which makes it possible to create and develop interactive graphical content, with the ability to zoom and resize on displays with different resolutions and aspect ratios.

## II. ONLINE LABORATORIES

Digital electronics education may be easily converted to a simulation-based learning environment to help students in acquiring the theoretical foundations of digital design, together with analysis and problem-solving capabilities and practical synthesis and design skills. Different formats of instruction, including lectures, exercises and lab assignments can be adapted and delivered at different student levels. The system may be based on a set of tools that teachers can combine together and personalize to suit appropriate pedagogical needs by contributing to the lecture space their own learning materials. The system covers the following areas of digital electronics: combinational logic networks, sequential logic networks [17].

The logic design laboratory may be taken as an example to illustrate the proposed system. In the real lab, students use breadboards to mount chips, such as AND and OR gates, and they connect the chips with wires. Then, the students connect the board to the power supply and verify by observation whether the circuit is functional. During their physical presence in the lab, students are merely rewiring the breadboard, staging certain inputs, and observing the resulting output. If these three actions are performed remotely, the online Remote Lab is born. The first and third actions are simply the I/O part of the experiment, which could be replaced by a standard computer interface with the proper instrumentation device. Any computer on the Internet can perform these I/O operations, once handled by a local computer with software interface. The second action of wiring and rewiring offers the true challenge. Standard breadboards are replaced by special interactive breadboards whose pins are connected to a programmable interconnect network controlled by a local computer with a proper software interface. A connection between any pin to any pin is accomplished by a click of a mouse on the software interface. If all necessary components, gates and chips are placed on the interactive breadboard, then a full experiment is conducted through the computer software interface without touching the breadboard. Again, action that can be performed on a local computer could also be taken on any computer or mobile device on the Internet. This method liberates students from the physical labs; hence, real engineering experiments can take place through distance learning [18].

The use of a host computer in these instances should not be confused with software simulation because students are still manipulating physically working electronic parts and still have the freedom to make any connections they choose. The computer simply acts as a front-end interface to lay out the connection on-screen and for downloading it to the board [18].

## III. SYSTEM ARCHITECTURE

A remote laboratory is defined as a computer-controlled laboratory that can be accessed and controlled externally over a communication medium. It may be considered as an experiment, demonstration, or process running locally on a software platform but with the ability to be monitored and controlled over the Internet from within a Web browser. The remote lab server can be an experiment connected to a computer through a standard interface such as a DAQ, GPIB or serial, parallel, and with the host

computer connected to the Internet. The client can be any computer connected the Internet running a simple browser or mobile device. Once connected, the client will see the same front panel as the local host and also have the same program functionality [19].

A remote lab is designed to enable users to control a system via a mobile device, such as a cellular phone or a PDA, and to monitor its outputs anytime and anywhere as shown in Fig. (1). The hardware infrastructure includes a server and a client ends. On the server side, the equipment may include any equipment that can be connected and controlled by a computer. In addition, there is usually a camera on the server end which videos activities of the outputs on the control server interface.

Java language was selected for the development of the model of remote labs because it is well suited for interactive web applications and offers the feature of multithreading to enable many students to work on the same laboratory setup simultaneously. It is a very innovative language which allows one to write programs that can be embedded in Internet web pages. Java is a good candidate since the entire system of building remote laboratories relies on the Internet. The student in this environment could logon from any system. As Java is a machine also an independent language, which creates programs that run on a wide variety of computers using a range of operating systems. The Java program does not execute directly on the computer and hence it will not interfere with the operating system or users data. Instead, as it runs on a standard hypothetical computer called 'Java virtual machine'. This solves the problems of security and unauthorized access. In addition, Java is an Object Oriented programming language unlike others like CGI and HTML. Therefore, Java programs can be easily maintained, as reusability of code is possible.

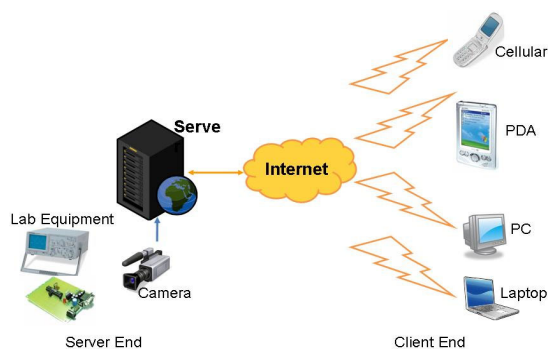


Figure 1. Mobile Remote Lab Architecture.

Students at the client side can access and control the equipment in the lab remotely using a PC, a laptop, a cellular phone or PDA or any similar device. The design was based on transmit standards, including RS232, IrDA, and Wireless Local Area Network (WLAN), thus, students can use mobile devices operation in the remote sites [16].

## IV. SYSTEM SOFTWARE

Java Micro Edition (J2ME) was selected as the platform to implement the mobile virtual lab (MVL) because of its great connectivity and portability. What J2ME can do for mobile devices is just the same as what Java 2 Standard Edition (J2SE) and Java 2 Enterprise Edition (J2EE) did

for desktop and server systems [20]. In J2ME the Connected Limited Device Configuration (CLDC) defines a generic "configuration" for a broad range of handheld devices through implementing a set of CLDC libraries on top of K Virtual Machine as shown in Fig. (2). The main benefits of CLDC devices involved are cross-platform where work is transferred between CLDC and other devices, dynamic content where content is determined by user experience, and information transfer between CLDC and other devices, security, and developer community where the developer talent needed for these devices already exists and is readily available for CLDC devices. A Java virtual machine (KVM) implementation and a configuration specification CLDC are very closely aligned. Together they are designed to capture just the essential capabilities of each category of device [21]. On top of the CLDC, the Mobile Information Device Profile (MIDP) is defined specifically for wireless devices such as cell phones and PDAs [22] as shown in Fig. (2). Wireless device manufacturers need to implement MIDP in order to support Java applications on their devices. A J2ME profile MIDP is layered on top of (and thus extends) a configuration CLDC. A profile addresses the specific demands of a certain "vertical" market segment or device family. The main goal of a profile is to guarantee interoperability within a certain vertical device family or domain by defining a standard Java platform for that market. Profiles typically include class libraries that are far more domain-specific than the class libraries provided in a configuration CLDC [21].

The KVM is a compact, portable Java virtual machine specifically designed from the ground up for small, resource-constrained devices. The high-level design goal for the KVM was to create the smallest possible "complete" Java virtual machine that would maintain all the central aspects of the Java programming language, but would run in a resource-constrained device with only a few hundred kilobytes total memory budget. More specifically, the KVM was designed to be:

- Small, with a static memory footprint of the virtual machine core in the range of 40 kilobytes to 80 kilobytes depending on compilation options and the target platform;
- Clean, well-commented, and highly portable,
- Modular and customizable,
- As "complete" and "fast" as possible without sacrificing the other design goals [21].

A user friendly client-side interface with circuit- and instrument like images to allow the experimental configuration and parameters to be controlled interactively by the user was developed. This interface was realized by means of the Scalable Vector Graphics (SVG) file format. SVG is a new vector-based, open-standard file format developed by the World Wide Web Consortium, which represents a new generation of dynamic, data-driven and interactive graphics. An interactive web page can be created with SVG and JavaScript, where the client may configure the measurement to be performed. Several setups may be prepared for direct selection, and the corresponding circuit diagram pops up by clicking on the various elements in the circuit diagram. A given setup may be further customized and the external wiring of the test chip is displayed. The experimental settings are entered and the external connections are physically

implemented via the matrix switch once the "submit" button is activated.

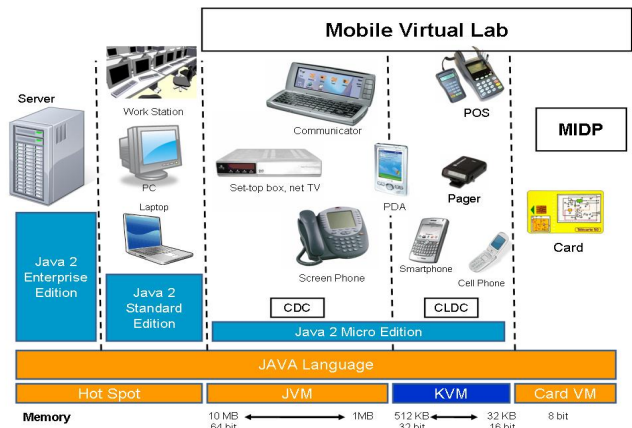


Figure 2. Java-2 Micro Edition Platform Architecture.

### V. SYSTEM DESIGN

In designing the MVL, the View Control Data architecture has been employed to separate the process of authoring experiments from the process of generating online experiments. The system architecture based on the wireless J2ME communication technology for the client tier, J2SE for the server tier and Microsoft SQL server for the data tier as dataflow diagram explains in Fig. (3). HTTP connectivity and data stream over GPRS used to utilize the remote connectivity between client and server tier [21].

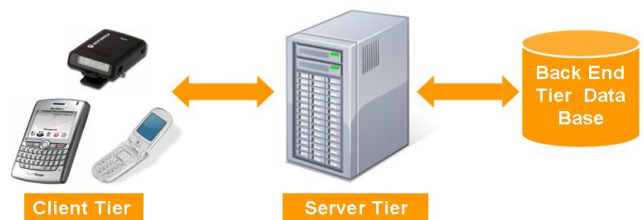


Figure 3. The Mobile Virtual Lab Dataflow Diagram.

The mobile virtual lab system has two usage cases, the experiment author usage case and student usage case. In the author usage case, the author of the experiment uses an authoring tool on a PC to draw the diagrams and to generate the required interactivity and consequently store the final experiment in the database. In the student usage case, the student launches the mobile virtual lab client application on the target mobile device.

A typical scenario of a mobile virtual lab experiment thus involves the following steps. It should be noted that the server is assumed to be running and that the client is on the experiment's web page through the Internet.

- **Registration:** a student accesses the URL to perform the experiment. The system should ask the student to first register for the lab before trying to perform the experiment. Once the student registers, a user login and password should be given for future use. It should be noted that self-registration is not allowed for any user. A student's unique key-login name is checked against a database of students' list.
- **Logging-in:** once the student has a valid login and password, he/she can login to the remote real

laboratory server and choose an experiment from the list of experiments to perform.

- **Performing the Experiment:** when a student starts performing the experiment, he/she is able to enter input values and submit them to the hardware. The hardware, then, acts upon the input parameter and generates results. The results are finally collected by the local host computer and sent back to the student's computer. The student can rerun (submit different values to) the experiment as many times as desires. Once satisfied, the student can submit the results for grading.
- **Instructor Login:** the instructor/TA login is recognized and thus taken to a different panel (page) where they can perform different tasks like viewing lists and results, grading students, and adding experiments.

The flowcharts of Fig. (4) illustrates all the necessary steps described above.

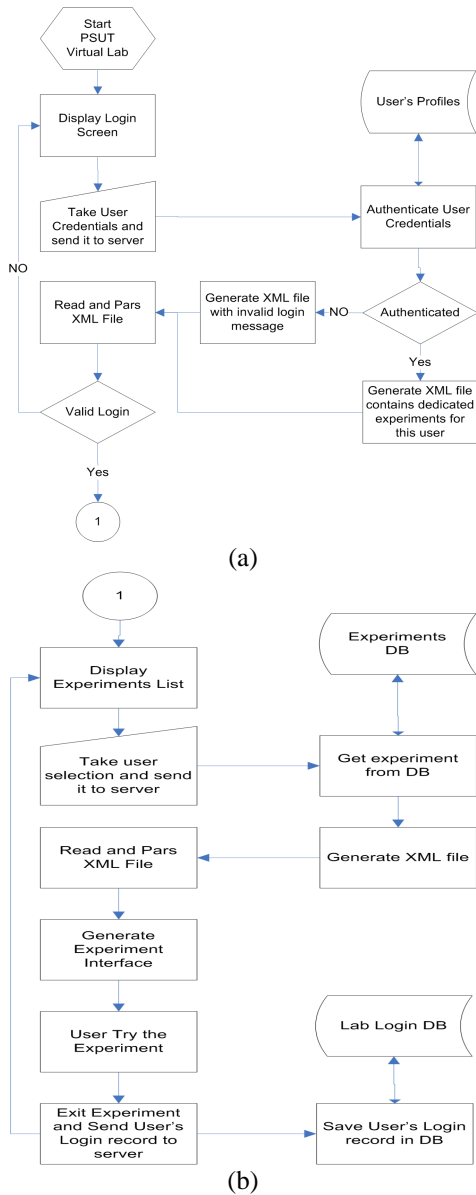


Figure 4. System Software Flowchart.

Consequently, the mobile virtual lab client tier application will send user credentials to the authentication servlet in the server tier. A servlet will authenticate user credential against user profiles database and generate result XML file as the flowchart shows in Fig. (5a). The mobile virtual lab client application will parse XML file, if valid login it will display a list of experiments dedicated for the specific student as shown in Fig. (5b). The mobile virtual lab client will then collect user selection and send it to the experiment generation servlet in the server tier. The experiment generation servlet will generate XML file which contains the experiment details based on a preset mad by the experiment author and stored in the database tier as the flowchart shown in Fig. (4). The mobile virtual lab client will eventually parse the XML file and generate the experiment interface as shown in Fig. (5c) and Fig. (5d) for various types of mobile devices. The latter figures depict and experiment which the student performs on an AND gate. The logic inputs A and B are entered by a click on the appropriate input and the output will be displayed instantly, with the corresponding truth table highlighted. Similarly, a 7-segment experiment is conducted, as another example, and the corresponding input, output, truth table are displayed. In all cases, the user will try each experiment and the login record will be sent to the server to be saved in the database.

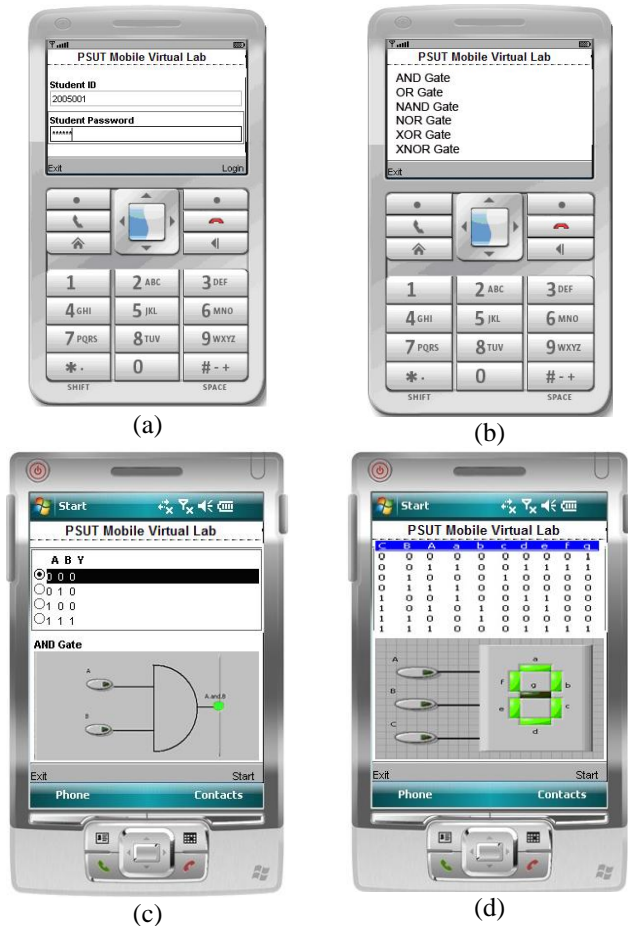


Figure 5. Flowchart.

One main advantage of the mobile system is scalability, which may be improved further using the Scalable 2D Vector Graphics API specification. This SVG defines an API for rendering 2D graphics in the World Wide Web



Consortium (W3C) Scalable Vector Graphics (SVG) Tiny format. The SVG also makes it possible for developers to create interactive graphical content, with the ability to zoom and resize on displays with different resolutions and aspect ratios. Furthermore, J2ME also defines a subset of the Micro Document Object Model ( $\mu$ DOM) API to allow user interaction and dynamic manipulation of SVG content. Developers can take advantage of the large amount of available SVG content. Because SVG is based on the eXtensible Markup Language (XML), a developer accustomed to a scripting environment can also take advantage of the robust features offered by a full programmatic environment, such as the Java language [24].

Mobile Web Services is application logic accessible to programs via standard web protocols in a platform-independent way. Web Services are the fundamental building blocks in the move to distributed computing on the Internet. Open standards and the focus on communication and collaboration among people and applications have created an environment where XML Web Services are becoming the platform for application integration. Applications are constructed using multiple XML Web Services from various sources that work together regardless of where they reside or how they were implemented. One of the primary advantages of the XML Web Services architecture is that it allows programs written in different languages on different platforms to communicate with each other in a standards-based way [24].

## VI. CONCLUSIONS

A mobile virtual laboratory was developed to enable students to conduct experiments using cellular phones, a PDA, a smartphone, Palms, Pocket PC, Tablets PCs, or any other similar handheld devices. This allows for teaching to be conducted anytime anywhere and allows resources and equipment to be shared between various collaborating institutions. Java wireless communication technologies were used in the design which implements a multi-tier architecture in order to integrate different fields of technology. The ultimate objective is to improve the scalability of the system and to allow for the use of Scalable Vector Graphics which makes it possible for developers to create interactive graphical content, with the ability to zoom and resize on displays with different resolutions and aspect ratios.

The proposed system has been tested with a real classroom and the results related to system function and teaching efficiency are positive. However, much work remains to be made in the future to accommodate new technologies to improve the delivery of video and audio streams. In addition, audio interaction should also be an option in this mobile learning system, which can further improve its quality in courses other than logic design. Finally, the mobile virtual lab should be tested further in real classrooms to address many pedagogical issues to help build an effective virtual learning environment.

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