Multi-User And Real-Time Flexible Remote Laboratory Architecture for Collaborative and Cooperative Pedagogical Scenarios

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Abstract—An advanced multi-user and realtime INTernational-REmote-LABoratory (INT-RE-LAB) architecture is presented in this paper. The INT-RE-LAB is developed and localized in four different host universities. The software part is based on the use of a free license server Node.js written in JavaScript. It offers lightweight Html/JavaScript clients. The integration of socket.io module enables a real-time operation mode of this Client/Server communication. Associated with hardware architecture, collaborative remote handling of resources is enabling in the same way as a chat communication used in Internet. Each remote action performed by one user is instantaneously visible in other users'web interfaces. The hardware part includes a mini-computer that executes node.js server and hosts Mysql. Mini-computer "Pcduino" directly controls specifically developed relays circuits. These circuits offer the required flexibility and reusability for current remote laboratories. Different redundant remote practical works integrate the INT-RE-LAB have been developed for the new EOLES "Electronics and Optic e-Learning for Embedded Systems" bachelor.

Index Terms—remote laboratory, real time, cooperative, collaborative, INTernational-REmote-LABoratory.

I. INTRODUCTION

After several years of development and progression, the new generations of remote laboratories tends to flexible and reusable architectures [1] [2] [3]. Point of view of teaching, the aim is to reproduce and ensure the learning offered in a face-to-face laboratory to a remote user. Several examples of remote laboratories have been developed in this background [4] [5]. Some of remote laboratories developed for a single application also remain relevant [6], it allows to provide specific and unique solutions such as remote control of equipment's designed to be handled in face-to-face labs [7]. An old version of the remote laboratory presented in this paper is based on the use of Ajax with the use of a computer as a web and databases server and an Arduino as Ethernet interface to the relay cards (FHI)[8.

II. DESCRIPTION OF THE INTERNATIONAL REMOTE LABORATORY NETWORK ARCHITECTURE

A. General description

The network architecture of the INT-RE-LAB is described in Fig. 1. It is composed of 4 identical and redundant REmote LABoratory (RE-LAB) based on 3 identical
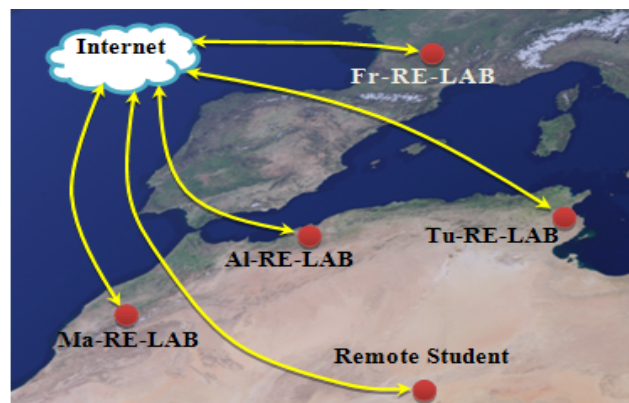

Figure 1. Network Architecture of the INT-RE-LAB

Local Area Networks (LAN) provided by each University (Al-RE-LAB: Mostaganem University-Algeria, Fr-RE-LAB: Limoges University-France, Ma-RE-LAB: University-Marrakach-Morocco, Tu-RE-LAB: Kairouan-University-Tunis).

Remote students with a unique login and password provided by the Central Authentication Service (CAS) server can access indifferently the 4 remote LABs.

To complete understanding of their theoretical course materials, the INT-RE-LAB provides them different lab skills by controlling remote electronics and optics practical experiments. In such context, it is highly necessary to provide them the capability to work on different experiments based on an identical architecture.

III. DESCRIPTION OF THE REMOTE LAB ARCHITECTURE

A. Software architecture based on node.js

The software architecture of the remote laboratory is based on using node.js to implement the client-server system written in JavaScript. Communication between clients and server is provided by socket.io module offering real-time data exchange. The distant user access is provided using MySQL database managed by the server using MySQL Module installed on Node.js.

The client-server architecture and databases are hosted on a low cost mini-computer (PCDuino) equipped with the Linux operating system on a free distribution "Lubuntu". The client manipulates in its web page the SVG electronic circuit. Commands are sent in real time to the server and PCDuino digital outputs are set to high or low voltage as demonstrated in Fig. 2.
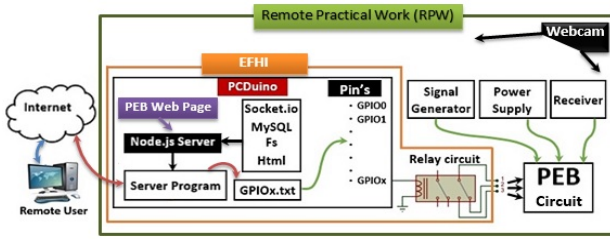
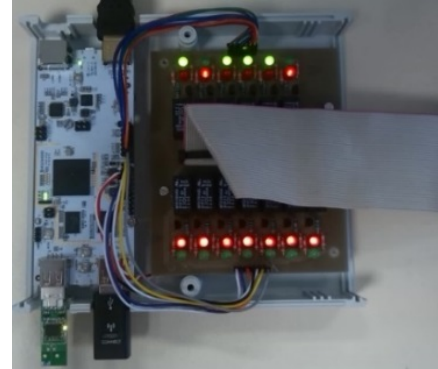Figure 2. General software/hardware architecture of remote practical works

Figure 3. Picture of a Remote Practical Work (RPW) of the INT-RE-LAB
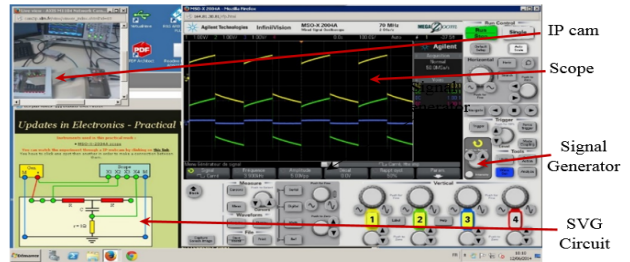
B. Hardware architecture based on EFHI/PEB

Hardware architecture of the remote laboratory is composed mainly of an EFHI (Flexible Ethernet Hardware Interface) and PEB (Practical Evaluation Board) provided for each practical work. The new version of the board EFHI consists of a PCDuino platform that controls a 13 relays card by its digital outputs (Pins) called GPIO. Fig. 3 illustrates the remote laboratory in real test.

C. New EFHI/PEB structure

The new version of the EFHI illustrated in Fig. 4 has been developed to meet the needs of remote laboratories implemented under the European Tempus program that prepares L3 Bachelor program L3 named EOLES "Optics and Electronics e-Learning for Embedded Systems". This bachelor has the particularity of fully remotely learned including practical work of different teaching units.

IV. WEB CLIENT INTERFACES STRUCTURE

A. Web interface structure

HTML client's remote laboratory are provided by a server program written in JavaScript and running with node.js. Node.js is a free platform built in JavaScript language, easy to install and building fast scalable network applications. Node.js is lightweight and efficient, perfect for data-intensive real-time applications that run across distributed devices.

The web client can be loaded on each request from a remote user by specifying the IP address of server in PCDuino. The design of electronic circuits on the web pages is made in SVG "Scalable Vector Graphics". This language producing a lightweight and dynamic graphics through JavaScript functions associated with OnClick event.

B. Remote manipulation of practical works

After authentication, the remote user connects as a client to the server that runs on PCDuino. The practical work
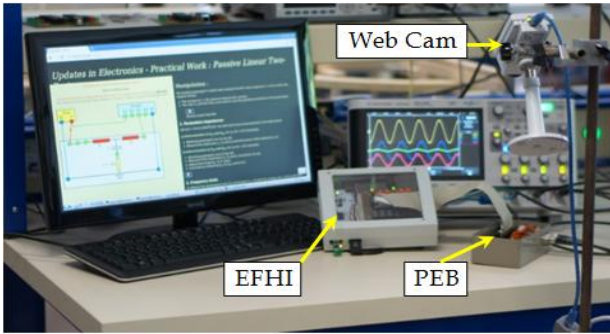

Figure 4. EFHI in real test with 4 relays used Picture of a Remote Practical Work (RPW) of the INT-RE-LAB

Figure 5. Student desktop in real manipulation of a remote practical work
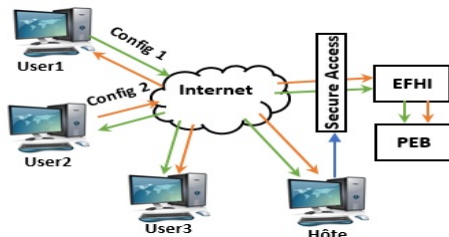

Figure 6. Chat aspect for collaborative remote lab manipulation

involves loading web interface designed for the current PEB (Client), the front faces of different instruments and captured image by IP cam focused on the remote laboratory for real-time projection of remote user manipulations. In Fig. 5 a screenshot of a real remote manipulation is illustrated.

V. OPERATING OF THE REMOTE LABORATORY

A. Chat aspect for collaborative remote lab manipulation

The principle of Internet Chat is based on broadcasting the message sent by a user to all subscribers. This aspect is also included in remote learning platforms like Moodle or virtual classroom as Adobe Connect or BigBlueButton.

This principle has been applied in the software architecture of the remote laboratory presented in this paper. Handling of each user is transmitted and applied to the web user's interface simultaneously with applying to real remote practical work. This principle applies to all users as the classical internet Chat. See Fig. 6.

B. Application in the EOLES bachelor Tempus program

The platform of this remote laboratory was adopted by the Preparatory Committee for EOLES project. It will be made according to the practical work will be installed in

member universities of the project and allow students to perform their practical work. Reproduced Flexibility, reusability and ease design of EFHI and practical works PEB justify the choice of this platform to be adopted for EOLES program.

VI. PEDAGOGICAL SCENARI FOR COLLABORATIVE AND COOPERATIVE REMOTE PRACTICAL WORK

Thanks to the software and hardware flexibility of all RPW of the INT-RE-LAB, other pedagogical scenario can be implemented depending on the pedagogical objectives desired by the tutor/teacher.

A. Scenario 1: Authority/Tutor demonstration

In this case, the tutor entirely controls the RPW and applies the configuration on the PEB-circuit. Fig. 7 shows that students receives in real-time the RPW configuration changes made by the tutor. So they are observers and are not authorized to modify the circuit configuration. This scenario can be used by the tutor to demonstrate the operating mode of the RPW to all students. Collaborative work is reduced only to synchronous questions or discussions between tutor and students in the virtual class. They also have the front panel of instruments in their screens to allow them to follow the demonstration made by the tutor.
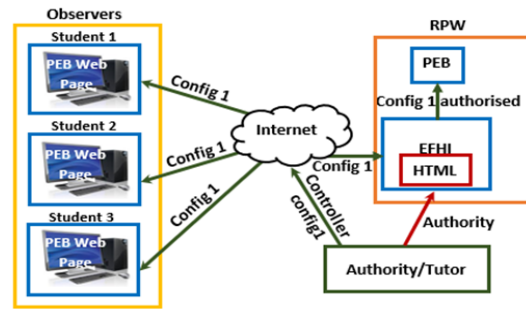
B. Scenario 2: Unique student modification under host control

Fig. 8 shows a second possible scenario. The tutor gives authorization to a unique student to control and configure the RPW at a time. When a student has permission to configure the PEB, the others become observers and configuration is shown in real-time in student's web interfaces. Student 1 applies configuration "2" (config2) to the PEB circuit and the other student and the tutor are observers. In this scenario, the tutor asked the student 1 to perform the RPW following his advices and also the other student's opinions and recommendation given in the associated virtual class. The tutor can change at any time the student's rights to involve another one in the conduct of the RPW.
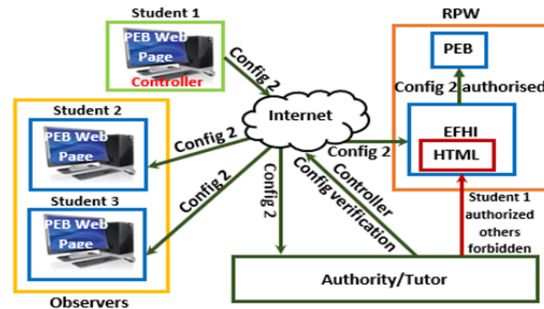
C. Scenario 3: Programmed successive access to RPW

In this third scenario, each student has a time slot with granted PEB modification rights to apply the different configurations required in a text document to perform an individual RPW. The student can successively access to the RPW during scheduled "T" time slot: student 1 performs his individual work from t0 to t0+T. Student 2 does the same later, between t1 and t1+T with (t1 > t0+T) and so on for all students. Fig. 9 represents the pedagogical method of individual RPW realization. A collaborative and cooperative work is possible if two students have authorization to manipulate RPW in the same time slot.
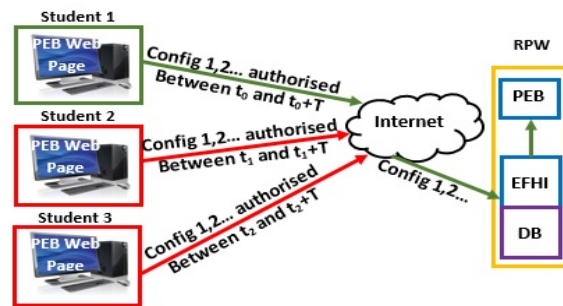
VII. SURVEY RESULTS

The L3-EOLES course, a fully online 3rd year Bachelor degree in Electronics and Optics for Embedded Systems, is the most prominent outcome of the EOLES project, a 3-year European TEMPUS project involving 15 institutions, four from Europe and eleven from the North African countries of Algeria, Morocco, and Tunisia [9]. The courses have started in September 2014.

Figure 7. Demonstration session and authorization architecture for scenario 1

Figure 8. Demonstration session associated with remote class

Figure 9. Authorization to one student access at a time slot

For this first edition, 22 undergraduate students are enrolled, 45 students are selected for the second 2015-2016 edition. Five main technical units of the bachelor program have been involved in RPW as shown in Table I: 20 RPW have been finally developed for this 1st edition and 44 PEBs have been designed.

They were surveyed to access their perception and their opinion for all the TU. A specific question has been proposed to the student concerning the RPW.

The students have to give a racing to all RPW of each TU. The minimum score is (1) corresponding to "Strongly disagree". The maximum score is (5) corresponding to "Strongly agree". The Table II shows the number of students' responses for all TU with RPW. All students who have been assiduously trained have answered to this questionnaire. It can be observed that the mean value of students 'answers is always higher than 3. It means that, for these students, for which ones it was the first experience with RPW, the perception of the INT-RE-LAB was rather positive. This result encourages its further development enhancement. As a consequence, the program of the TU will be slightly modified in the next edition to develop specific courses to specifically learn operating working mode of the EFHI.

TABLE I.
RPW IN THE FIRST EOLES EDITION

TU	Realized PW
TU04 Analog electronics for embedded systems	4
TU06 Wave and propagation for embedded systems	3
TU07 Power electronics and embedded systems	3
TU10 Signal processing	4
TU11 Instrumentation	4

TABLE II.
RPW SURVEY RESULTS

TU with PW	Number of student's responses	Mean value/5
TU04	18	3.66
TU06	19	3.66
TU07	17	3.14
TU10	18	3.84
TU11	18	3.52

VIII. CONCLUSION

The architecture of a remote laboratory developed and presented for the preparation of EOLES "Electronic and Optic e-Learning for Embedded Systems" bachelor practical works that is launched in September 2014. It is a flexible architecture adaptable to several disciplines in the teaching of EOLES units.

The software architecture of the remote laboratory provides real-time communication using HTML/JS/SVG clients. By using the Chat principle, the server program provides a new technique for collaborative work to one or more remote users to manipulate in real time hardware resources of the remote laboratory.

The main originality of this architecture concerns the capability now given to teacher and student to work with different pedagogical methods implemented in various collaborative and cooperative operating modes in a multi-user context. The achieved flexible architecture also allows further exploring other new innovative pedagogical methods for collaborative work of group of students performing the same remote practical work at a time.

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