Time Division Multiple Access for Remote Lab (TDMA-RL)

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Taoufik Elmissaoui
Innov'Com lab, SUP'COM, University of Carthage & Higher Institute of Applied Mathematics and Computer Science, University of Kairouan, Kairouan, Tunisia
elmissaoui.enit@gmail.com

Abstract—The new technologies development has enabled us to build a remote lab system for multiple disciplines. The remote lab system becomes an essential for eLearning system. Multiple solution has been provided in the literature for building remote laboratory. All existing and commercialized system do not provide the multiusers process at the same time. In fact, each student must make a reservation before using the remote lab. In this paper, we have proposed and tested a new method that enable multi student to have the benefits of the remote laboratory at the same time. Our solution is based on the Time Division Multiple Access for Remote Lab (TDMA-RL). Each student can use the laboratory equipment at a fixed slot time. Our application can manage the frame send for each learner. The remotely learner can not feel the existing of the other persons due to the equipment speed and the good management time of application. The number of users varies the equipment lab characteristics.

Keywords—remote lab system, time division remote lab, eLearning

1 Introduction

In the last few years, remote lab system has become very interesting in the learning system. In fact, the invention has multiple advantages such as: Reduce the difference between remote learning system and face-to-face system, enhance the eLearning system, reduce the equipment lab cost, centralize the management of the laboratory equipment's etc.

Multiple solution for remote lab building has been presented in the literature. *Pablo et Al* presented the possibility of opening the existing laboratory for public system. A new approach has been presented that describes laboratory can be made to support external specifications like mobile device [1].

Ian Gout proposed in [2-3] a solution for building remote lab system for electrical and information engineering disciplines. In fact, he presented in [3] a list of reported remote lab such as WebLab-Deusto that was developed by University of Deusto. Other eligible solutions for remote lab building are proposed by [11-14].

All previous related work proposes a new remote lab concept but for one user. In our paper we discussed the possibility of allowing multiple students to remotely have access to the laboratory equipment's at the same time. In fact, we proposed a new technique enable learners to have access to the remote lab equipment at the same and real time. We studied the possibility of our remote lab being operational for multiusers by using the TDMA-RL. In fact, we propose to apply Time Division Multiple Access (TDMA) technique to allow our student to remotely shared the lab equipment. Our solution is made up in a way each student will be allocated a slot time to manipulate the remote lab equipment's. In fact, our server will be able to manage the frame sanded for each student in his time slot. The time must be managed to let each student make use of the equipment without disturbing their colleagues. Our solution needs a specific equipment like camera with very high resolution, fast oscilloscope, very high internet connection etc. Our solution is based on the speed difference between human eye and lab equipment.

2 Remote lab architecture

The remote lab it is a very interesting system for e-Learning education. In our work, we use a real hardware system and not simulation. In fact, student can manipulate the laboratory equipment by internet. Our system is composed of three parts.

The first part is dedicated for student. The learner can make a registration, reservation and realize their practical work anywhere and at any time by its client panel. The client application can be supported by each terminal particularly the small device like smartphone.

The second part is the server. The server enables us to manage each student and teacher's activity. This part enables the learner and the teacher to manipulate the lab equipment by internet connection. Application for each practical work can be uploaded in the server. Teachers can update their proposed practical works. The security on connection between user and the equipment laboratory in is ensured by the server. In order to let our lab more secure, access is made available to only the registered and verified student.

The last part, it is our laboratory. Each equipment lab must be provided an internet connection. We can use some equipment like Raspberry PI to connect the lab hardware that has no internet connection. We can also use a multiple relay to let teacher conduct. In order for student to have that same face-to-face class feelings, we equipped our practical work with cameras, this will enable the user to fellow the practical activities in real time, in other words, the learner can interact remotely with the lab equipment.

Our system provides a platform for teacher to add, remove and upgrade their practical work by presenting a user guide. The Figure 1 illustrates our remote lab architecture that was developed by our university under tow Erasmus+ projects.

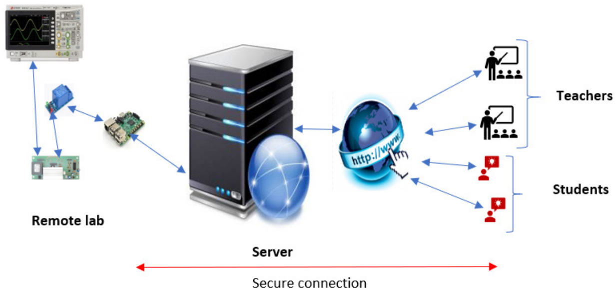

Fig. 1. Remote lab architecture

3 Human eye vision limits

Our TDRL solution is based on the human eye features. The technique proposed in this paper enabled us to provide the necessary frames for each student. The streaming sanded for each learner must contain minimum 24 images per second to be acceptable for a normal human eye.

The video contains a massive information that human brain cannot treat them simultaneously, but he gives the priority for some interested information [4]. Our human eye gives more attention for the object movement [4]. For this reason, the frame transmitted for our student must contain the important information.

According to *Watson et al*. [9], human cannot see a temporal contrast fluctuation with a frequency higher than 33 Hz.

Reis et al. in [5] illustrate that motion speed present an essential role in temporal visual by our eye. In fact, we exploit this characteristic to implement our solution.

To observe object by our eye, the light passes from the cornea and the crystalline to be focused on the retina [6-7].

The human contrast function is better than all optical system because the retina-brain processing is developed to improve the special frequency [8]. Human eyes have some aberrations to correctly see images. This induced by Myopia, hyperopia and cylinder are refractive errors [8]. In fact, when the light from air enters our eye, its properties change and caused visual aberrations. This point can describe by the following expression [8]:

$$F = Vn/\lambda \quad (1)$$

Where *F, V, n* and λ, represent respectively: frequency, velocity, index of refraction and the wavelength.

For our optical system, the light passed throw our eye organ can converge into a single point or can have a diverge from. These characteristics can cause two classes of aberrations: chromatic and monochromatic [8].

According to *P. L. Kaufman et al*. in [8], chromatic aberration represents the capability of a lens to converge all colors of light on a one point and the monochromatic aberration is caused by the lens nature.

The human eye has spatial limit that is defined by visual acuity. There are multiple criteria that enable us to specify and measured visual acuity and there are [8]:

- Minimum visible acuity-detection
- Minimum resolvable acuity-resolution
- Minimum recognizable acuity-identification
- Minimum discriminable acuity-discrimination

4 TDMA-RL technique

Our solution made it possible for multiple students to use the remote lab equipment simultaneously. Each student must have the possibility to manipulate remotely the real hardware at the real time. The Figure 2 illustrate the TDMA-RL frames of remote lab system.

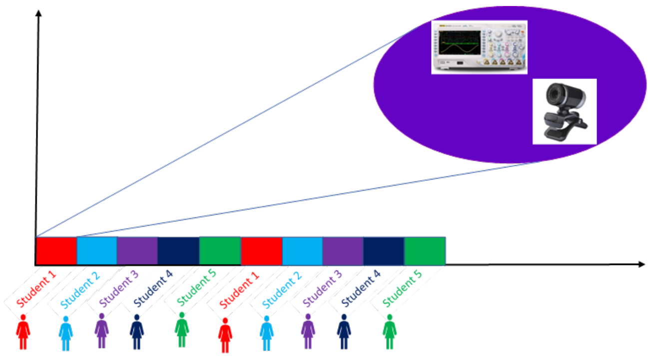

Fig. 2. The TDMA-RL frames

With the TDMA-RL technique, student can use all equipment lab dedicated for the practical work, but only in his time slot. In fact, we assigned a specific time slot for each learner. The number of user n_{users} can be estimated by the following equation:

$$n_{users} = \frac{T_{frame}}{T_{user} + G_r} \tag{2}$$

Where T_{frame} represent the total time frame, T_{users} is the time slot assigned for each user and Gr it is the guard time needed to avoid interference between users' slots.

The time slot for each student must be considered multiples times necessary for all remote lab system process steps. In fact, this time represent the some of the all-delay and can be expressed by:

$$T_{user} = T_{propa} + T_{server} + T_{lab-equip} + T_{trans} + T_{handling} \tag{3}$$

Were,

T_{propa}: It is the time taken by the signal to travel from our equipment lab to the leaner application. In fact, this depends on our network connection link (coper, wireless, optic fiber). It can be calculated according to the wave propagation in the medium used at the link tranche.

T_{server}: represent the server response time that contain the necessary delay taken by connecting, waiting, sending, receiving, page loading etc. This time vary with the server configuration. In fact, a good configuration can optimize this delay to let our server quickly as possible.

$T_{lab\text{-}equip}$: Designed the for some od delays equipment lab response. In fact, this time can contain the response time of the circuit board, oscilloscope, relay board, camera, chip for internet connection etc.

T_{trans}: it is the delay dedicated for data transmission. This delay varies according to the data size and the internet connection speed.

$T_{handling}$: it is the time taken by our application to manage the data transmitted for each user and the synchronization process between client (learner side) application and the equipment lab.

The Figure show all delay for remote lab system.

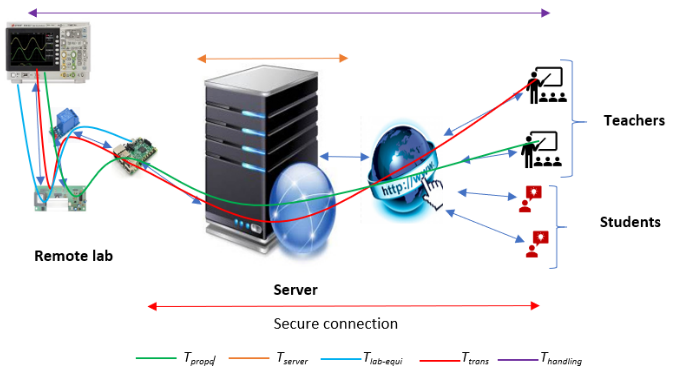

Fig. 3. Remote lab system delay

Our application allows student to share the same equipment lab. In fact, student used equipment lab fast succession one after other. Each student uses its one time slot. The time that separated two successive data for the one student do not allow eye to detect this interruption.

The theoric number of users enabled to exploit the lab equipment can be up to 8. In the practice, the number vary with the system response time and specially the practical equipment delays.

5 TDMA-RL equipment parameters

For the remote lab system, student must have the same condition as presential process. For this reason, each visualization results must be seen remotely by the learner. Besides, each practical work parameters can be remotely manipulated by the student.

Theses equipment should provide us the possibility to be operated remotely by user interface. In fact, each equipment user interface must present all functionality provided by the hardware front panel. In the other hand, the learner can adjust the equipment settings from its terminal.

In the practical work, we can find multiple equipment's that do not have internet connection. To solve this problem, we can use a module to enable us to connect these kinds of equipment to the internet.

Each practical work can have multiple scenarios that forced us to use relays to allow the student to make change according to their needs.

To let our system, work well, it will be better to have a very high speed of internet connection. We can not give an exact value because this rate definition varies with the region and the country etc.

The most important equipment needed to allow student seen the lab equipment reactivity it is the camera. This system must have a very good resolution and must provide minimum 120 Frame Per Second (FPS) with a simple time equal to 8 ms and a very good shutter speed. A very high FPS number will enable us to enhance the simultaneous student's number. In addition, the camera must be entire remotely moved to track equipment lab and their responses.

The oscilloscope must be equipped by network interface card to let student see the display in his terminal. With this kind of oscilloscope student can also control the display remotely. This system will be used by multiple students and must a make measurement for multiple waves. It must have a very good waveform capture to fellow the signal variation generated by the circuit. In fact, we propose to use a numeric oscilloscope that a very good bandwidth and memory deep. There is multiple commercialized oscilloscope that has bandwidth equal to 200 MHz and 400,000 FPS as waveform capture rate. The faster rise time is needed for accurate measurement that varies with the bandwidth according to the following expression [10]:

$$Rise\ time = 0.35/\ bandwidth \quad (4)$$

To manage our remote lab system, we must use a very fast server that enable us to have response for time less than 250 ms.

A fast server enables us to enhance system security and user number. To ensure the quality of our remote lab, it will be better to use its own server and a very good internet speed.

The remote lab system allows student to move from one practical work to another and to change the practical work scenario like changing value in electronic circuit. In fact, student can change circuit schematic by changing component and the link connection between the used components. For these goals, we need to use multiple relays. The response time relay must be optimized to ensure a very good switching in our system. The switching time must be less than 15 ms because one relay can be used multiple students and for multiple practice work.

In this part, we try an overview for probable needed for electronics and physics remote lab. In general, we must choose a very fast equipment to build our remote lab in order to make a good time response management of our system and enhance user number.

6 TDMA-RL tests

To test TDMA-RL, we used our remote lab developed by Kairouan University team with our partner under tow projects: e-LIVES: E-learning innovative engineering solutions, 585938-EPP-1-2017-1-REPPKA2-CBHE-JP funded by the European Commission under agreement number 2017-2891/001-001 and EOLES (*530466-TEMPUS-1-2012-1-FR-TEMPUS-JPCR)* project under TEMPUS program with our partner's. Under theses two project we did developped multiple paratical works like RLC circuit.

In this paper, we tested our technique with RLC circuit with a real instrumenation. In fact, student can change the crcuit sheamatic link and can also selected values for Resistance R, Inductance L and capacitor C. To let this process of switching link and compenent values we use a relay with 16.

Figure 4 ullistre our remote lab system used in our TDMA-RL test.

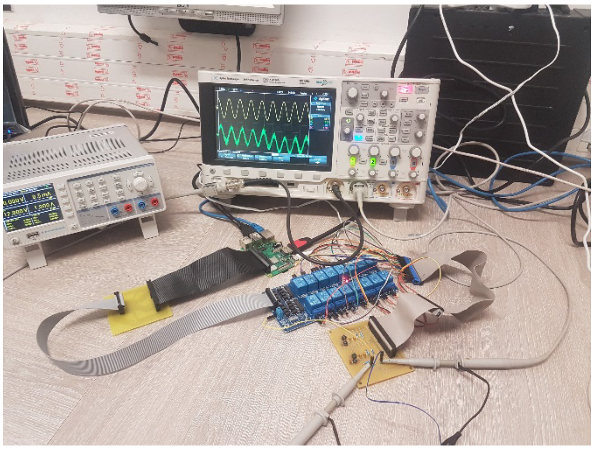

Fig. 4. Kairouan university remote lab

The possible number of simultaneous users for our remote lab varies with the equipment delay response. In this paper, we tested locally our application only for three users. In fact, each user can manipulate the lab equipment in 250 ms. The total time for three users it will be 750 ms. In our test, we did design 250 ms as a time guard to avoid interference between remote lab users. Our time guard is equal to 250/3 ms. The figure Fig.5 illustrate the frame repartition for of our system. Each student can receive a normal streaming by 25 FPS. The rate received by our student enable as to assure the quality of our remote lab service. We developed a local application with python and HTML5 to enable us to manage simultaneous the 3 users.

According to our experience each student can use our RLC circuit and can see the oscilloscope visualization. Student can also change component value and manage remotely oscilloscope settings and operations.

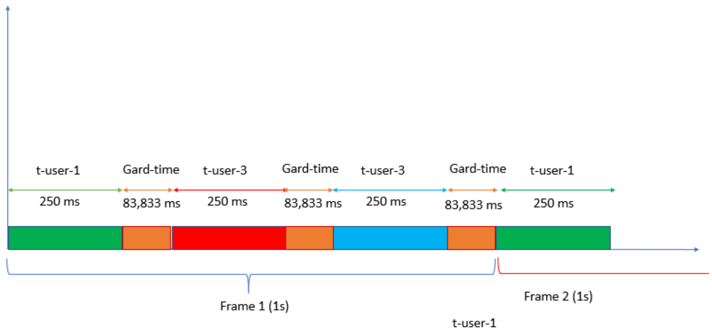

Fig. 5. Users time repartition

The Figure.6 show our remote lab manipulated by three users.

Fig. 6. Simultaneous three users

7 Conclusion

Due to the physical distancing that come with the COVID-19, institutions of learning were forced to make use of the e-Learning system to solve their educational problems. For this to be properly implemented, a full online system is needed. To make e-learning systems very interactive, just like the face-to-face system, we must build a remote lab system which would enable students carry out the practical works remotely. In this paper, we proposed and tested TDMA-RL for remote lab system. This technique allows multiple students to have simultaneous benefits of our remote service. Due to limit of equipment, who could only use 3 users to test our application. Our prototype enabled us to conclude feasibility of our TDMA-RL technique. In our future work, we will develop and tested our solution in wide area network. We will also compare our technique by other proposed and tested solutions.

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10 Author

Taoufik Elmissaoui is an associate professor in the Higher Institute of Applied Mathematics and Computer Science, University of Kairouan, Tunisia, since 2014. He is member of ELIVES project, point of contact of AFRICIM project and coordinator of the TNSI master in the Higher Institute of Applied Mathematics and Computer Science. From 2006 to 2007 he was a staff engineer with Norkatech, Tunisia. From 2007 to 2013 he was an assistant professor in the Sousse University, Tunisia. He received his PhD, master's degree and engineering degree in Telecommunications form National Engineering School of Tunisia (ENIT). His research focuses on medical radar system, Remote-lab and behind wall localization.

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