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Research paper

Low-cost Smart Architecture for Classroom Response System Using Raspberry: RaspCRS

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Abstract

The purpose of this paper is to present a low-cost architecture based on embedded systems for the operation of a Classroom Response System (CRS). In order to validate the proposed architecture, various tests were conducted with 30 students enrolled in a renewable energy master. As part of this study, a mobile-based CRS has been developed using web-based technologies that makes the system very easy to use in educational environments. It allows the teacher to interview students using multiple-choice questions, in order to test their understanding of a concept discussed in class, the results of a question are displayed in real time on the mobile of the teacher. This tool has a strategic character because it allows improving the image of our university, pursuing the paths of smart cities. The results of test show the advantages and limitations of this architecture.

Keywords: *Classroom Response System, Embedded System, Mobile Technology, E-learning, Technology-enhanced learning*

1. Introduction

The traditional teaching methods employ a lecture format in which the majority of students are passively listening to the instructor and take notes. This method disempowers the students, they are not involved in the learning process and makes the teacher the center of the learning environment [1]. The disadvantage of this method is remarkable in amphitheaters; the problem is both related to the number of students and their timidity, which minimizes the number of questions, and generate a weak return to the teacher [2]. Seven major problems are identified when teaching large classes in higher education, namely, the absence of exchanges, the scarcity of feedback, difficulty-motivating students, inability to foster personal work, failure to consider the diversity of students, lack of clarity in objectives, lack of advice on possible improvement.
Smart cities, which are open and user-driven innovation environments to experiment and validate future Internet services, cities are increasingly playing a critical role as drivers of innovation in areas such as health, inclusion, environment, business and education [3]. In this last field, the traditional role of the teacher is considerably transformed in active learning, because he does not disseminate information directly and rather tends to support students in the acquisition. Active learning is manifested in the practice by methods focused on students [4]. In this method, the teacher is active; he moves in the rows and asks questions to the students in order to guide the formulation of hypothesis or proposes them strategies to organize the knowledge. He can include anything that the students are doing with the presented course content to enhance their understanding of the topic. Students learn concepts deeply because concepts are made relevant and meaningful to their current live Active learning

New computer technologies (mobile devices, wireless network) and the rapid growth of the internet can provide new development in the way instructor transfer knowledge to their students. The term "technology-enhanced learning" (TEL) is increasingly being used, reflecting the application of information and communication technologies for learning and teaching. Integration technologies into lessons require not only the skills to use them but also beliefs about how they can benefit teaching and learning [5-6-7]. Indeed, existing research indicated that preservice teacher's perception of the usefulness of technologies predicts their intention to incorporate them in their future teaching [8-9].
The style and preferences of modern learners are evolving with time, almost every user owns a mobile device, whether a smartphone. The number of mobile phone users in the world for 2017 is forecast to reach 4.77 billion, it's expected to pass the five billion by 2019. This rapid growth of mobile and wireless technologies open new opportunities for mobile learning and assessment, research provides evidence that mobile devices have become a learning tool with great potential in education [10]. Other study found that the majority of a university student's used their mobile devices to support learning even when they were out of their classes [11]. Wireless mobile devices are small enough to be portable, which allow learners to use them anywhere and anytime to interact with other learners everywhere to share information and expertise, Students also utilized their mobile devices to enhance their role as active responsible students when they communicated with the teachers through their email.
In this work, a novel architecture for a Classroom Response System (CRS) based on the well-known raspberry pi 3 was implemented and tested with 30 students enrolled in a renewable energy master, allowing instructors to pose questions and gather students' responses during a lecture using their own-networked mobile devices. The question is created in a web page and projected by the

teacher from his mobile to the student's mobile enrolled in a predefined module.

Student's and teachers' terminals communicate with the raspberry pi 3 via a Wi-Fi wireless network, this architecture allows students to transmit their answers to questions of types QCM, then the teacher immediately visualizes the results in statistical form on his screen. This method allow the teacher to ensure mastery of prerequisites, to check understanding, to identify obscure points, to report at the rate of progress of courses. Our ambitions are to seize a low-cost technological opportunity to evolve the lectures in our university by moving towards more interactive forms of learning.

2. Related Work

Educational innovations have challenged pedagogical practices in traditional conferences because the lecture at universities does not produce the learning goal that is presumed to achieve. Therefore, the need for increased interactivity has been emphasized, technologies and several methodologies grouped under the name of interactive engagement was developed since 1990. The use of technology in education includes classroom response systems (CRS), they are a common tool from elementary schools to universities. Within literature, the following terms can represent a (CRS), classroom communication system, interactive response system, public response system, classroom response technology [12]. These terms converge towards a tool that allows these terms an educator to ask questions during a lecture and allow each student to answer in short period to multiple-choice questions. Students' classroom responses are used to collect evaluation, attendance, or survey data on prior knowledge. This system can also be used in an informal learning environment.

Classtalk [13] is among the first CRS that offer opportunities for collections of individual responses in a classroom. Also known by “clickers” or “response pulses”, the network is used to download tasks to the student input devices, return student responses to the instructor's computer. The architecture of operation contains three main and typical components:

- **Transmitters**: that are technological devices similar to television controls, containing a keypad and some command buttons allow the student to quickly answer a question asked by the teacher;
- **Receivers**: are antennas which are plugged into a USB port in computer, they aim to collect student responses send by transmitters;
- **A central computer**: which allows interpreting, analysing and displaying the collected data in an educational environment. This computer is also connected to a video projector where the question is presented as a slide of the presentation.

Evidence shows empirically that a CRS supported environment leads to improved education by offering high levels of discussion and interactivity [14]. Other research has found that a CRS is beneficial in terms of improved participation, commitment, and motivation [15]. Raes et al suggest that the anonymity characteristics of a CRS improve collaborative learning activities benefit from a peer assessment of a class [16].

However, traditional CRS may find it difficult to support learning experiences that are associated with technology, costs and student challenges (namely: method of discussion, effort, evaluation, negative feedback) may affect the effective use of CRS. Therefore, a CRS should be used with appropriate pedagogies to maximize its performance [17]. The use of CRS is influenced by the teacher's ability to manage the discussion, allocate teaching time and develop instructions for knowledge design. In other words, teachers must redesign conferences, activities and specific equipment for the environment [18].

The emergence of heterogeneous terminals in the educational environment especially in the university environment has given birth to many studies that deal with the perception of their use on the part of students as well as for teachers [19]. In parallel with many projects aimed at improving student interactivity using mobile devices, the functional architecture of this kind of CRS is presented on the figure 1.

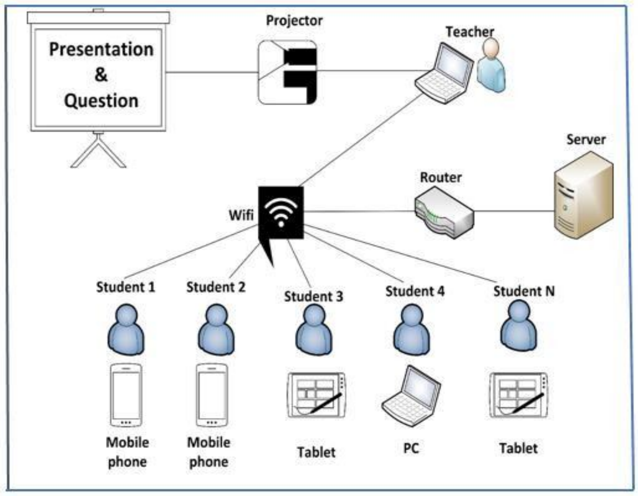

Fig. 1: Standard architecture of mobile-based CRS.

We can cite the following experiences of mobile-based CRS:

Deficall [20] is a commercial device that allows conducting surveys. In this project, participants communicate their responses via SMS using mobile phones, and the organizer consults the results on his computer connected to the Internet. The questionnaire QCM is usually created in a page web, but it can be communicated to participants via other media.

DRIM-AP (Dispositifs Radios Interactifs Multiples & Amphis Participatifs) [21] is the result of work carried out at the central school of Lyon. "Teaching is not telling ... learning is not listening". This sentence summarizes the general problem of the project, which guided the implementation of the new teaching methods. In this project, a pedagogical device has been developed to provide a solution mainly to the absence of exchanges, the refraction of feedback and the difficulty to motivate students. The DRIM-AP device is based on the operation of a wireless network and requires the provision of one or more Wi-Fi terminals per amphitheatre.

ActiveClass [22], this project is another mobile device use conducted at the University of San Diego, California, aims to improve student participation. In this experiment, the device developed relies on the use of laptop, TabletPC, PDA and takes place in a global context of Mobile Campus that provides a set of services to students. These terminals communicate with a server via a wireless Wi-Fi network.

Xquestion [23] is a propjet achieve to overcome the difficulties encountered in traditional CRS, a mobile application has been developed using web technologies, the application allows the integration between different devices and the student can use his own devices.

Livenotes [24] is a project conducted at the University of Berkeley, the student's share a whiteboard on which they can draw or write to exchange their points of view. The pedagogical principle is to rely on a collaborative work allowing the confrontation of the different interpretations of the course by the students. Each user has a writing color that can quickly identify his interventions on the shared screen. The terminals communicate in Wi-Fi with the University server, which allows recording the different notes taken during the course.

3. Implementation of RaspCRS

3.1. The proposed architecture

The architecture of the operation of our CRS solution contains three main and typical parts that describe the main actors involved in the operation of RaspCRS as shown in figure 2.

The RaspCRS contains two main modules, one for the student and the other for the teacher, on the teacher side a dashboard in the form of a web page is accessible for the teacher through its preferred heterologous terminal, this interface allows to the teacher to ask questions for students enrolled in a specific module. In the same way on the student side, a web interface is accessible for the students after the inscription in the RaspCRS system, this interface allows students to answer questions asked by the teacher through their preferred device. The server part of the proposed architecture plays the role of intermediary between the students and the constructor. This hardware part is based on the use of a Raspberry Pi 3, which is a single-board computer with wireless LAN and Bluetooth connectivity, it is the first 64-bit Raspberry Pi with a quad-core 64-bit processor clocked at 1.2GHz and 1GB RAM. It allows the execution of several variants of operating system and compatible server.

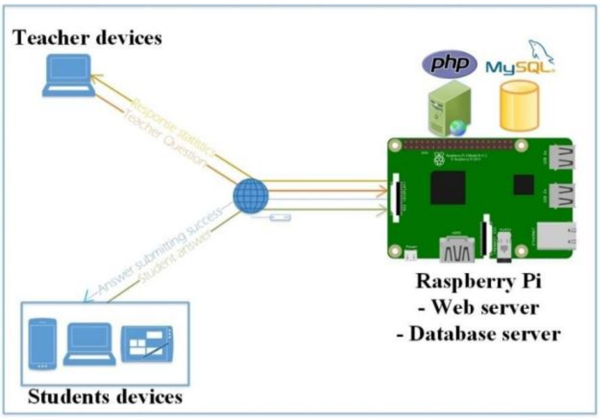

Fig. 2: Architecture proposed of mobile-based CRS

To host the develop CRS solution, we have installed on the Raspberry card the Apache web server, this term refers to the software that allows this card to analyze the HTTP requests of the users and return the file corresponding to the request. In order to be able to store the information of the classroom response system, a database management system SGBD namely MySQL was set up. In this way, the proposed architecture allows to collect the answers of the students and disseminate the results to the teacher in a server-client architecture. We used the Wi-Fi connection to enable the networked devices in the classroom because of theoretically the extended Wi-Fi and important Bluetooth connection.

3.2. The realized prototype

RaspCRS was made using the current web technologies that allow having a great ease of use of the system in an educational environment. We used in terms of development the programming language PHP, realizing interactive and accessible interfaces based on the HTML markup language, as well as CSS and Javascript technologies. These technologies produce executable applications executable on any device by following the optics of applications considered responsive, with the ability to adapt to any platform.

In terms of interface we took into consideration user profiles, questions are su[22]bmitted to teachers and students to collect their expectations; we took into consideration the context of particular use of the teacher, indeed the authentication part of the application allows to redirect each type of user to his dedicated web page. The readability at first sight of the information on the teacher's dashboard was highlighted, particularly the parts that allow him to ask questions and receive comments. Other features are presented to the constructor namely, the addition of a new module that has just taught, automatically assigns students enrolled in a path the new module. In this way, when the constructor adds a question on the form, he must select the group / module concerned by this question as shown in Figure 3.

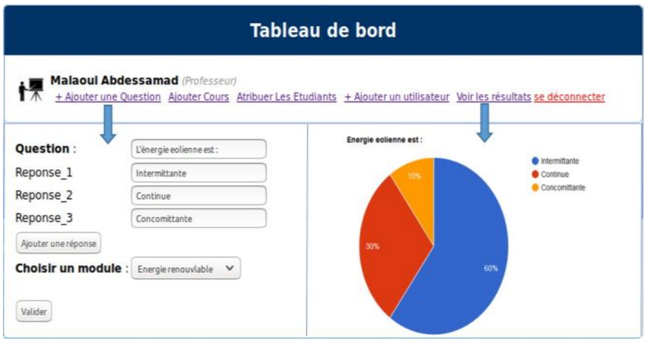

Fig. 3: The teacher side on RaspCRS

Students must connect to the same Wi-Fi network as the teacher, the latter distributes the URL allowing students to access the login page of the RaspCRS. If the student is not yet registered, he can click on a registration button allowing him to enter this information on a form and to choose a login and a password for access to the RaspCRS application.

After identification with a username and password a page web is displayed to the student containing the set of module in which he is enrolled, the student must choose the current module, during the court session once the teacher asks a question to multiple choice, it's displayed in real time on its device as shown in the following

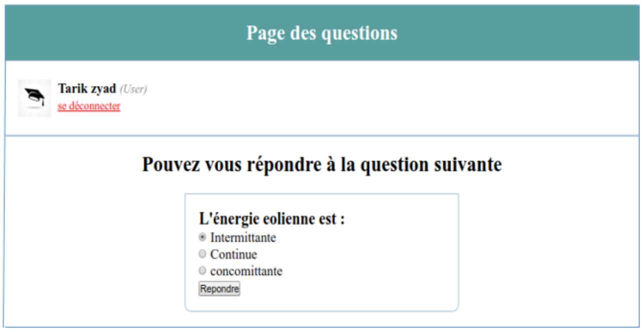

Fig.4: The student side on RaspCRS

The raspberry and a Wi-Fi router were set up in the classroom as shown in Figure 5, they aim to establish communication between the teacher and the students by dealing with HTTP requests from these two actors.

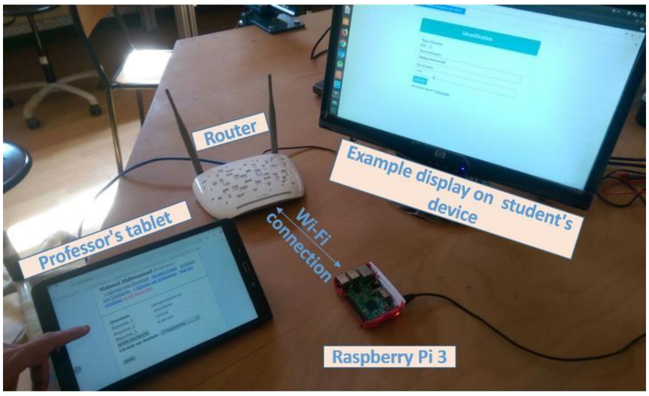

Fig. 5: The real implementation of the proposed architecture

4. Results and Discussion

This part deals with the results of our studies. In order to check the validity of the proposed architecture on a functional level, and the developed CRS solution on a pedagogical level, different test was conducted with 30 students enrolled in a renewable energy master's degree. Functionally the results were satisfactory, with a bandwidth greater than 54 Mbit/s the flexibility of the system reaches a good level, the student obtaining the questions and transmit their answers to the teacher, with an average transaction time equal to 12 seconds. Pointing out that the Wi-Fi implement on the Raspberry Pi 3 allows obtaining rates from 7 Mbit/s to 70 Mbit/s. Access to the Classroom response system has been tested taking into account the different browsers install on users' devices as shown in Table 1.

Table 1: Access test according to different browsers

Navigator	Version	Functional
M.Firefox	55.0	Yes
I.Explorer	11.0.11	Yes
G.Chrome	64.0	Yes
Android	6.0	Yes
IOS	11	Yes
Safari	5.1.7	Yes

Through the results of the table, usually these browsers have allocated access to the application, except internet explorer, which has mostly generated older versions, therefore it is strongly recommended to install the latest version of the browsers it allows to avoid problems access to the server.
Several good reasons to configure Raspberry pi 3 as a server offering educational services, teachers point of view, size of this card makes it useful as a portable device. Another alternative, is to host the classroom response system on a local server in the teacher's computer, comparing this solution with our architecture, The Raspberry Pi 3 can be turned on for a long time. As this card has a low energy and economic footprint, this makes it a good choice under a low charge.
In order to better discuss the weakness of this new pedagogy of learning especially when the number of students increases or decreases by less than 30 students, we tested the system with 10 more students using the Sysbench software for Linux that is a reference for quickly printing on the system. The results are shown in Figure 6.

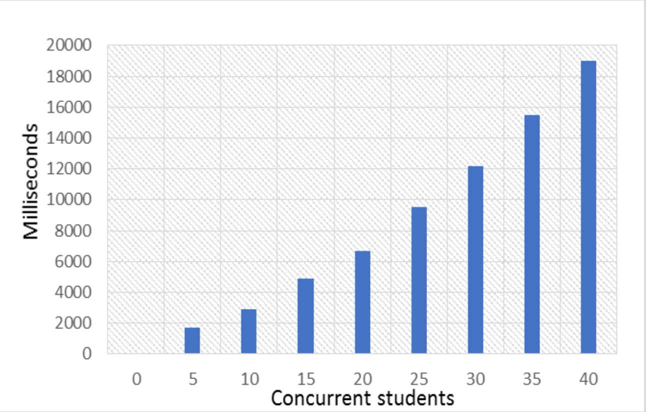

Fig. 6: The average transaction time of student's responses on RaspCRS

According to the graph The response time increases by 3300 milliseconds for 35 students, and 6810 milliseconds for 40 students. it can be noticed that the difficulties increase as the load increases, which is a remarkable disadvantage as regards the performances.
Pedagogically speaking, 80% of students reported that the interaction between them and the teacher had been improved, students claiming that this methodology helped them to get their attention, with 90% of participants giving positive feedback on this system. Answers to questions anonymously through RaspCRS made the students feel better, giving their opinions reliably and freely presenting their true understanding to the concept developed during the lessons. This methodology allowed the teacher to open a channel of communication when the rate of bad answers is high; we noticed that on average this discussion allows spreading the duration of the session by 15%.

5. Future Works

A set of questions that we ask ourselves and to which we wish to bring at least a partial answer during the next test of use. Namely, what are the parameters that influence the performance of our architecture in large sections, what is the best organization of a course with such a device, there are still great uncertainties about the real educational interest of such a device in teaching?

6. Conclusion

In this paper, we reported the motivations that led to the birth of class response systems CRS, then we focused on remarkable projects in the same field, mentioning that generally, these projects propose expensive hardware architectures. Afterwards, we presented the implementation of the proposed architecture and the tools necessary for its operation. The aim of our study is to evaluate the implementation of a mixed architecture (software and hardware) for the functioning of a system of response in classroom. The proposed CRS was developed taking into account the teaching habits of teachers and students in order to propose a simple solution in terms of use, the tests and the experimentation of this architecture were carried out with 30 students enrolled in a renewable energy master during the first session in order to validate its functioning and its teaching performance. The results were satisfactory, with a bandwidth greater than 54 Mbit / s, the flexibility of the system reaches a good level, and the students' magician considers that this solution had some knowledge to a good knowledge of the theoretical concepts.

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