Implementation of an Arduino Remote Laboratory with Raspberry Pi

Atilano Fernández-Pacheco, Sergio Martin
Electrical & Computer Engineering Department
UNED - Spanish University for Distance Education

***Abstract*—Popularity of Arduino has grown in the last years, mainly as part of the Internet of Things, which is producing a relevant impact in several economic sectors (industry, transportations, energy, agriculture, home automation, etc.). Several national and European policies have been set-up to train the EU companies to the adoption and diffusion of the IoT technologies. In this paper, we describe the development of a remote lab of Arduino to give support to on-line IoT learning experimentation environments, which are very important to provide quality on-line education programs on IoT.**

Keywords—Remote lab; Arduino; Raspberry; IoT

I. INTRODUCTION

Laboratory practicum are fundamental so that students can assimilate correctly the theory concepts and can acquire skills that they will be able to use in his professional career when finish his degree [1] [2]. Therefore, these labs are essential for the development of the students and the university must assure the amount, variety and quality of the practicum. Traditionally, laboratory practicum has been done in the classroom. The schedule has stipulated previously.

Try to organize laboratory practicum in group as small as possible in order that teachers can teach with personalized attention and students use all devices and instruments correctly and safety. Moreover, make sure to guarantee the maintenance of equipment and devices that have been used during the practicum.

Nowadays, it is more common to offer students the highest flexibility when they are carrying out their studies and they can choose the best moment during the day to study in order to work and study at the same time and to balance the family life. In this context, it is a vital importance for us to get the remote laboratory ready where student can access on-demand to resources.

Other fundamental point is that remote laboratories maximize the use of this type of laboratories which operative 24/7 and are accessible from anywhere. With this, we optimize from economical point of view. As they are accessible from anywhere, it is possible to offer higher education to a lot of people, which would be impossible in other context [3].

This paper is intended for students, teachers and professionals who are interested in remote learning and technology laboratories.

The main goals of this paper are:

- Describe the state of the art of remote laboratories.
- Show the architecture of an Arduino remote lab based on Raspberry Pi.
- To show the possibility of using this kind of laboratories in Internet of Thing (IoT).

II. STATE OF THE ART

According to the Gartner Curve, IoT is an emergent technology near to expectation peak, as it is possible to see in Figure 1 [4].

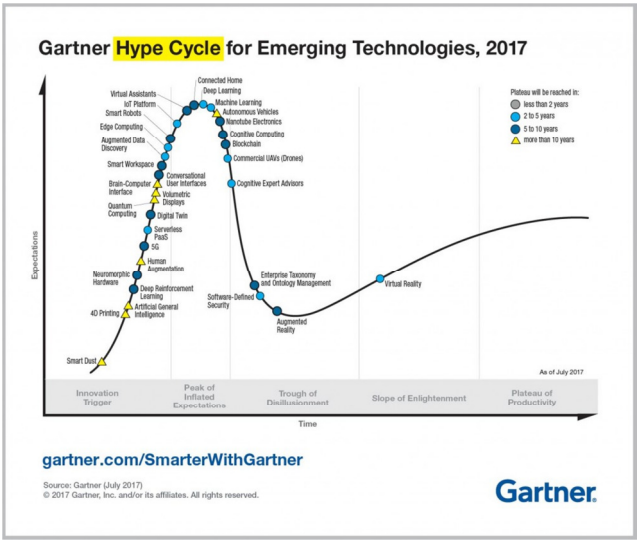

Fig.1.Emerging Technologies according to Garnet Curve [4].

IoT is a concept that is referenced to digital connection among common objects with the Internet.

The first time IoT was used by Kevin Asthon in the Auto-ID Center in MIT was in 2019 where they were searching in the identification by radiofrequency in network (RFID) [5] and sensor technology.

For instance, in a supermarket all products would be connecting to the Internet through identifier sensor. With this solution, problems such as: break of stock, food expired and exactly number of the products eliminated.

Nowadays, the scope of IoT has been extended with advanced connection of devices, systems and services that goes beyond the classic M2M (Machine to Machine).

IoT not only has a huge social impact, but can also support the employability and boost the competitiveness of European

companies. It is widely considered as one of the most important key drivers for the implementation of the so-called Industry 4.0 and for the digital transformation of the companies. Relevant impact of this technology is expected in a wide range of sectors [6].

The economic importance of IoT is underlined in several studies: to give an order of magnitude, a recent study of the European Committee estimates that the market value of the IoT in the EU will exceed one trillion euros in 2020 [7].

The European Commission is aware of the great potential of IoT and in the past has supported several projects for the development of IoT-based applications, protocols and policies for the secure, safe and privacy preserving deployment, mainly in the FP7 and Horizon 2020 programs. Actually, the EC plans to unveil a strategy for IoT, launching a series of large-scale pilots with an investment of more than 100 million euros [7].

The huge expected growth of IoT in the next years and the planned investments in the sector foresee a high demand of professionals in the sectors. According to a report from the Vision Mobile projects, while in 2014 just 300,000 developers contributed to the IoT, 4.5 million developers by 2020 are expected, reflecting a 57% compound annual growth rate and a massive market opportunity [7]. European Universities and VET providers are not ready to face this educational challenge. Very few European Universities and VET providers offer courses on IoT nowadays. On the contrary, US Universities and private companies regularly offer courses on IoT to face the demand of professionals.

Therefore, it is important that education centers will be supplied of labs where the students can learn skills about this technology with the objective to improve the skills of students and his future employment.

There are a lot of remote laboratories around the world. These labs are not circumscribing to specific topic else they cover a lot of knowledge areas. For instance, programing, control system, etc.

All labs try to move students closer to where they are able to carry on theoretical knowledge, which students have learnt previously so they would experiment and would check results.

Besides, as a general rule, these labs have an access profile. There are two security levels: which user can access and what each user can do in the application.

Moreover, all labs must introduce controls that try to avoid errors to a greater or lesser extent and protect equipment and devices. In lab software, without hardware elements, these controls must not allow impossible use cases to execute.

These kind of remote labs have been increased in other Spanish university such as UPV/EHU that has been ready for students to use. Yet, it is not difficult to find dozens of remote labs around the world [8].

These remote laboratories have a lot of advantages:

- There are no time restrictions.
- It's possible to include easy controls to avoid wrong uses, which might be potentially dangerous for the equipment.
- Increase the maximum amount of students who would use these labs at greater extent to the fact that there are no space restrictions. This factor has a limitation that is the number of concurrent users.
- To increase the number of students who can use this equipment to reduce the cost per student.

The principal qualities that must accomplish a remote laboratory are [9]:

- High-availability. One strong point is the possibility to be used without restriction of time and on-going availability. This point is essential when laboratory is being designed and planned its architecture.
- Concurrency. The labs have to support the fact that different users use it simultaneously; all users must be working at the same time. Otherwise, there will be a queue of requests and the system will take time to process.
- Low operating cost. These kinds of labs have to be used continuously so its construction and its operation must cost at the lowest as possible.
- The remote lab must have the control of avoiding a wrong use. In other words, the system must try to be preparing for one bad use, which can cause damage to devices.

The use of remote labs about IoT in on-line and blended training programs will ensure good competences assimilation by students.

The remote lab shown below in this document allows the students to experiment the Internet of Things.

IV. ARCHITECTURE

In this section, architecture will be explained in the different parts. The main device is an Arduino board that is connected to others devices such as: led cube, mechanic crane, sensor etc. Moreover, compilation, load and execution of sources codes are run by the Arduino board.

Thus the lab helps users with a full environment where the development is tested and the behavior is visualized. Besides, if devices send information about his state, IoT laboratory is deployed.

Arduino MKR1000 Wi-Fi is the board that has been chosen because this board has been designed especially to IoT. This board has a more powerful processor that Arduino Uno or Mega. Besides, it has a Wi-Fi WINC15000 chip to connect to the Internet, which allows sending data to devices from the Internet.

Arduino board with SIM and GSM/GPS connection would have been chosen but this option was dismissed because this board costs more plus a recurrent cost to send data through SIM card. In addition, the device is used inside the laboratory

with Wi-Fi. Moreover, WIFI signal has better stability and this point is fundamental to increase user experience.

On the other hand, Raspberry is the hardware that has been chosen as an application server. The reasons are very similar which have been showed previously. It is possible to deploy a full server with a lot of performance and a lot of interesting characteristics with a reduced cost. Beside, community development of Raspberry is very great. Raspberry is based on Linux system for that it is very easy to deploy a web server. Other interesting characteristic is the possibility to migrate with simple steps as a traditional Linux server. So Raspberry Pi is perfect to deploy a web sensor [10].

In addition, the architecture (Figure 2) adds one WebCam so that student could visually check the behavior of the test, which the student has done. This point is very important because if you visualize the testing, you will resolve issues more easily. Moreover, help the student get closer to the laboratory.

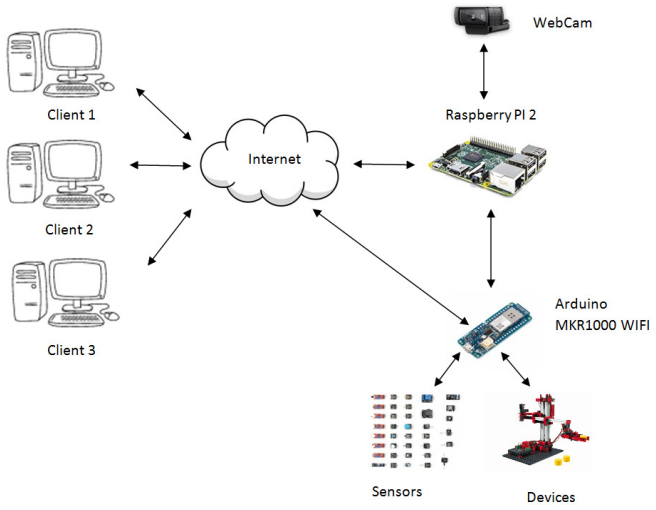

Fig.2 Remote lab architecture [3]

Each device needs to be set up with a specific configuration. Only it is necessary to include file information about: processor, port, device name, bauds and define a default configuration in one configuration

After each execution, the system loads a default configuration, which leaves the device ready for the next execution in the board. This point is essential in order to assure the maintenance of the infrastructure.

Although the system can support a lot of users currently, only one can be executing at the same time. For that, it is necessary to introduce mechanisms of synchronization in order to regulate the different executions.

Thus, when one user is executing his program, the system is blocked during three minutes. During that time, if other user tries to execute another program, he cannot do it and the system shows a notification indicating the time that the device will be unlocked.

It is easy to check that the architecture is simple but robust at the same time. Moreover, chosen elements that are easily purchased have a very big community development. Thus, in case there are some issues, it is easier to fix them.

Although User Experience (UX) is not the most important point in this kind of development, we must try to achieve enough quality (Figure 3).

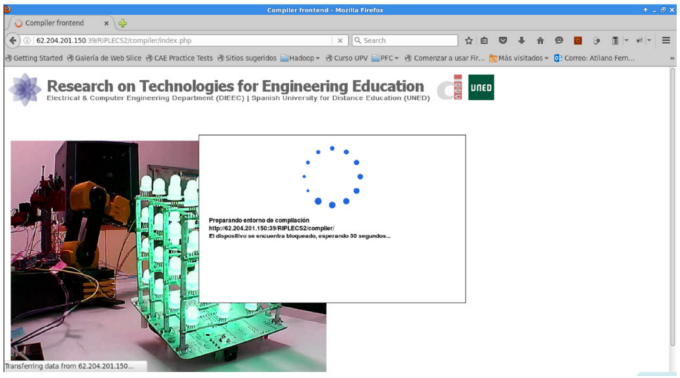

Fig.3 GUI of Remote Laboratory

V. PROPOSED EXPERIMENTATION

The numbers of experimentations that the students can perform are very varied and different. For instance, relating to IoT, the students would deploy sensors connecting to the Internet through Arduino board and backend application, which gathers this information and makes decisions depending on it.

Other simple experimentation, it is connected a led cube (include Arduino Board) to Raspberry. Students would test important ranges of simulations.

VI. CONCLUSION

Laboratories are essential for students to understand and consolidate theoretical learning. Besides, in the contemporary world, remote laboratories offer the users the flexibility of the use of them and optimize resources. Therefore, students will adjust much better to the necessity that they have.

On one hand, with this type of laboratories, we will be able to get closer to the students through the newest technology as is IoT [11]. On the other hand, low initial investment and low operating cost are determinated to carry out this kind of project.

Arduino and Raspberry are two platforms, which allow us to do a lot of things. Both offer to the community a high performance and excellent balance between the cost and the quality.

Other vital point that we can't forget is UX due to the fact that whichever system must have high usability and must be user friendly.

VII. ACKNOWLEDGMENTS

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