A Remote Lab Framework for serving Context-Aware Learning

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Abstract- **Remote lab access will revolutionize Context-Aware Learning (CAL) in many disciplines. The increasing convergence of the internet, wireless communications, computation and collective intelligence technologies will have unprecedented impact of wireless sensor and actuator networks (WSANs) on education. Learning in a context aware networked universal environment will support collaborative learning, problem-based-learning (active, experimental), and augmented learning. Sensors and actuators will remotely aggregate contextual data about the environment, from remote lab, and help the active engagement of the learner with material, processes and the learning context. In This paper, the overall system architecture of a general framework for remote laboratory system is designed and implemented. In order to verify the performance and efficiency of our system, we designed and implemented an irrigation kit for precision agriculture as a case study. The implemented remote lab framework can be extended to be used in many disciplines.**

Keywords- CAL, Distance Learning, Remote Lab, WSANs, Wireless Sensor Network, E-Learning.

I. INTRODUCTION

Laboratory work is considered to be at the heart of learning in the disciplines of Engineering and Physical Sciences and can have a strong impact on students' learning outcomes. Laboratory-based sessions are widely used in order to provide physical evidence of theoretical principles and to teach practical skills. When used appropriately they can enthuse, motivate and inspire students [1] [2].

Remote laboratories embody an attractive solution to conduct live experiments from any location, obtaining time saving and reduction of costs for measurement instruments, and technical personnel. Moreover, the achievement of remote control of an instrument has proved to be an optimal solution to share an instrument among different Universities or industrial users, without the need of transporting it or outing of personnel [3] [4]. Most of the remote labs focus on engineering laboratories as the engineering discipline contains the biggest portion of laboratory studies. In other words, engineering is an applied science. There is a lot of interest in remote laboratories from pedagogical point of view [5] [6].

Nowadays, Wireless Sensors network (WSN) merges a wide range of information technology that spans hardware, systems software, networking, and programming methodology [7]. A network of wireless sensors consists of a large number of energy-autonomous sensors distributed in an area of interest. Each node monitors its local environment, locally processes and stores the collected data so it can be used by other nodes. It shares this information with the other neighboring nodes by using a wireless link. Since the nodes are many and since they might be deployed in regions difficult to access, they should not require any maintenance [8].

This paper introduced a general framework for a proposed remote lab access that allows performing experiments remotely across the Internet via web interface. In addition, it introduces enhancements for the remote lab activities leading to improving its performance.

The rest of this paper is organized as follows: Section II introduces the related work. Section III introduces the design of the remote laboratory system architecture. Section IV presents the remote lab Case Study. Section V introduces the conclusion which summarizes the obtained results and proposes further work for enhancing the performance of remote laboratories.

II. RELATED WORK

Remote lab access is a relatively new concept. With the growth of the Internet and increasing connectivity, the popularity of remote labs has surged. Some interesting efforts are described below.

RMCLab [9] is a remote laboratory which targets electrical engineering courses at the University of Patras, Greece, and beginning in 2004. RMCLab incorporates an FPGA in addition to "auxiliary modules" which include differential amplifiers, PLLs, ADCs, and OpAmp circuits. The labs are broken down to employ different aspects of hardware and circuit design and analysis. The hardware is connected through PCI to a host server which integrates a signal generator, oscilloscope, and other special hardware over a custom LPT interface. Augmented client-server architecture subdivides the conventional client architecture into a client and instructor client (IC), and the server architecture into an application server (AS) and resource server (RS). RMCLab's custom design is quite specific to the available resources from the University. The individual servers coordinate access with incoming client requests with available hardware resources. While such a system can supplement large class sizes, one key drawback is portability to other classroom environments where these exact resources do not exist.

Hashemian and Riddley [10] have designed an FPGA e-Lab, remote access system targeted for digital design courses using FPGAs based on Xilinx's Spartan-3E Starter Kit. The e-Lab uses Windows XP Remote Desktop to connect the remote user with the FPGA, data acquisition hardware, and LabView, Integrated webcam and GPIO to connect LEDs, switches, and control hardware on the actual FPGA. An obvious advantage of such a system is the low start-up costs associated with acquiring the Spartan Starter Kit and software tools, but the use of Windows XP Remote Desktop slows the system.

Nedic [11] reported on NetLab from the University of South Australia which aims to address the common concerns of remote laboratories. With a similar design to the previous efforts, NetLab incorporates a variety of laboratory equipment and even goes so far as to allow collaboration between students. The paper concludes that while the remote lab setup did not directly outperform conventional real labs, the authors suggest a mix of real and remote labs throughout the education curriculum.

Corter et al. [12] developed a model that investigates the relative effectiveness of hands-on labs, remote labs and simulated labs. The labs conducted were focused on the kinematics and dynamics of mechanisms such as linkages, cams and gears. To draw a fair comparison, out of the six labs given to the class, three were given in traditional format and three were given in hands-on traditional format. In addition to the student outcomes and student satisfaction, student preferences for remote labs were related to student characteristics, in thinking style and ability. The results obtained by Corter et al show that among other criteria like preparatory instructions, lab report, and team work, "physical presence in the lab" was rated least important by the students. Also, actual learning outcomes were assessed by questions on the midterm and final that was related to the content of the labs.

Lab on the Web [13] is a virtual laboratory that aims to achieve flexibility in digital and analog circuit design keeping in mind the cost, scalability and modularity. An FPGA board is used as it allows for implementation of almost any circuit. Here, the interface to the remote lab is achieved by combining Virtual Network Computing (VNC) and secure remote desktop. Test suites were developed that are lab experiments which can be used by students. The test suites include an Analog Circuit - a simple circuit is set up which can demonstrate the use of a power supply, oscilloscope, a switch matrix and a function generator all of which can be controlled Remotely, FPGA Programming - illustrates that the FPGA can be used Remotely via the Internet, Digital Signal Processing Experiment - An analog signal is captured then using the ADC interface it is digitized. The signal is then passed to the FPGA using VHDL. This system also provides a webcam so the users can look at the FPGA board. This system was evaluated and it was found suitable for undergraduate courses.

"eLab" [14], implemented by the University of Bordeaux in France is an effort toward increasing Remote education for Electrical Engineering. The components that make up this system are a pool of instruments that can be controlled remotely, a group of servers and dedicated software. The digital circuits implemented by this lab include Differential Pair Amplifier, Linear OpAmp operation, and RC filter. Again, a camera is placed in the eLab's room that allows a live view of the instruments and servers. The eLab webpage also contains various textbooks that are required for the courses that use these labs. The web interface is a simple one that allows users to set data points, frequency values and voltages. The results of these inputs can be then measured in new pop-up window which allows users to save the output. An interesting feature in this system is that a "notebook" is automatically created that stores the results and measurements of the user.

Gurkan et. al [15] presented a remote laboratory for an optical circuit's course. The strategy used in this facility is to first introduce the students to the concepts in theory and then proceed to pre laboratory activities. The pre laboratories include an orientation video, simulation and laboratory procedures on-line. This work also includes assessment of the learning outcomes and teaching methods. Here, the students connect to the server using a Web-based client that connects to the LabView Web Server. Three experiments were conducted; Optical Source Characterization, Optical Fiber Link Attenuation and Fiber Connectors, Hands-On Skills Transferred From Remote Labs, based on performance of the students on these experiments, student success was measured. A student opinion survey was conducted too.

Austin J. Che [16] at the Massachusetts Institute of Technology (MIT), explains the benefits of setting up remote lab for biology using the iLab technology developed by MIT. Che states that a general lab for biology that can be done remotely, leads to shared costs, efficient use of resources and higher work efficiency.

From the above descriptions, it can be noted that many researchers are investigating the effectiveness of remote labs in their respective fields. Another interesting fact to note is the evaluation methods used in these facilities. Since there is no standard method of proving the effectiveness, it can be seen that the trend is to collect feedback from the students using the facility. Although, anecdotal data is arguably not the strongest means of proving facts, it is very helpful to improve the facility. Another method is to test the students and drive learning outcomes. From the standardization point of view, the most significant difference of the work described in this paper is that it is comparatively more scalable in the sense that the hardware and software are both flexible to fit in different environments.

III. DESIGN OF REMOTE LABORATORY SYSTEM ARCHITECTURE

A. System Framework .

The Framework of the proposed remote lab is shown in Fig.1

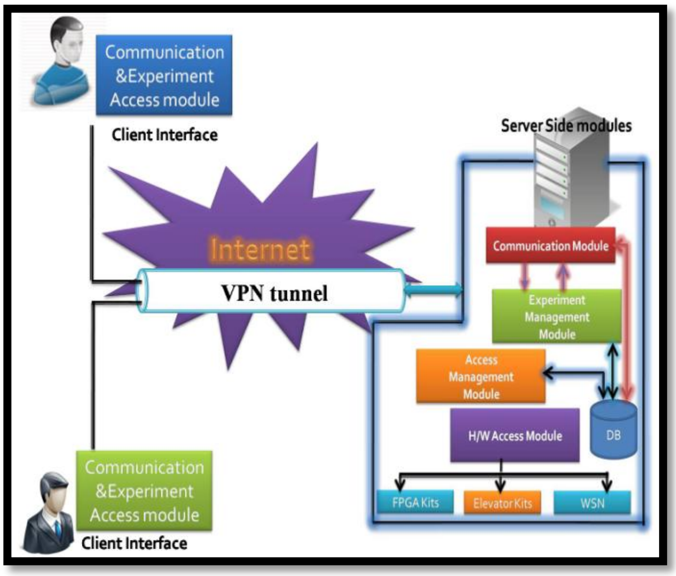

Fig.1: The Proposed Framework

B. System Structure .

The structure of the proposed remote lab access is shown in Fig.2.

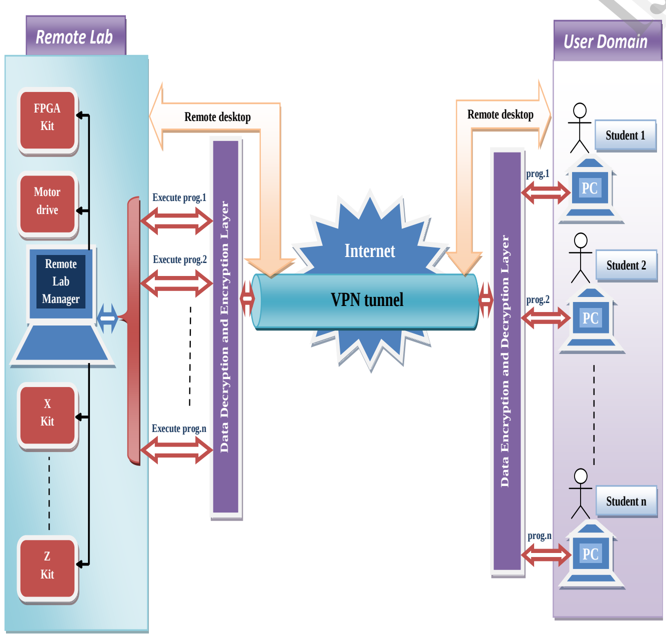

Fig.2.Remote Lab Structure

The system simply represents the remote lab with single structure of a computer to interact with the client (student) through the internet via a VPN connection. It consists of two sections, the user domain and the remote lab. The user domain enables the client in his place outside the lab to send his programs and data to the remote lab to be executed and installed on the kits connected to the remote lab manager. The second section, the remote lab, is simply the physical location for the client to execute his experiments on the kits connected to the remote lab manager through a permission access to the lab remotely.

C. Remote lab Hardware

From the standardization point of view, the hardware requirements of the remote lab in terms of the experimentation unit are dependent on the type of the experiment to be conducted. The remote lab manager, power supply unit, the electronic kits, some aided electronic circuits to connect the kits to remote lab manager terminal (i.e. USB terminal), and internet connection are typical laboratory instruments needed. They may be augmented or changed based on the type of the experiment needed to be set-up. The main requirement is that the measuring device be accessible via some well-known interface for control selection and setup, as well as remote data collection.

D. Remote lab Software

Our remote lab is programmed with java and the software needed to run the kits are different due to the kit chosen to be run by the client. Each kit has its own driver and installed on the remote lab manager. The client connects to the lab through internet in a secured tunnel with VPN technology. Our remote lab is a client/server package that contains two applications:

- *Lab Manager Application.*
- *Student Front-end application.*

→Lab Manager Application:

This application is a windows application that works as a server; the lab instructor is the administrator of this application. The operations will be done locally on the lab manager machine.

The application has the following main features:

1- Connection Administration.
2- Student administration.
3- Work Space administration.
4- Lab Terminals Administration.
5- Executing Experiments.
6- Network-Fail Safety protocol.

→Student Front-end Application:

This application works as a client and student is the user of this application. The student can do these operations:

1. Login to the Lab Manager.
2. Upload/Edit/Delete Experiments in his work space.
3. Execute experiments.
4. Get Remote desktop.

IV. REMOTE LAB CASE STUDY

A general framework is presented in this paper as a first step towards standardization of remote laboratory access. CAL is a multi-disciplinary field which merges the connectivisim learning theory, the internet of things, and wireless sensor networks. Precision Agriculture (PA) is an emerging field which relies heavily on using the information and communications technologies for data gathering from the field, information extraction, monitoring of the environment and decision making. All these facilities will help learners shift from rote text-based learning to ubiquitous context-based learning which enhances data analysis and interpretation skills in a dynamic learning environment.

A. *Prototype Irrigation Management System (PIMS)*

This section presents a PIMS that is built around a low-power mote incorporating a robust multi-node communication protocol for transmission of signals from monitoring and control devices for irrigation management. The PIMs design and implementation are characterized by:

1. Communication range between nodes,
2. Low power consumption,
3. Suitable for outdoor usage
4. High sensor performance, and
5. Low cost

The Architecture of PIMS is shown in Fig.3.

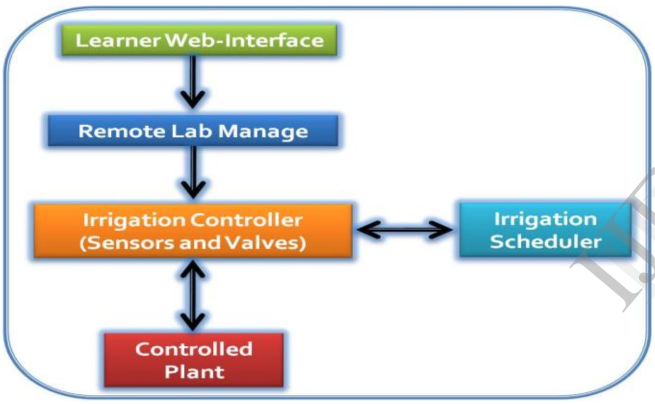

Fig. 3 Architecture of PIMS

Fig. 4 entitle the phases in which the student will get through to access the lab server, afterward the lab server will handle the wireless communication to the irrigation kit and order the microcontroller to start processing the student instructions, whether controlling the irrigation periods or reading the field temperature…etc.

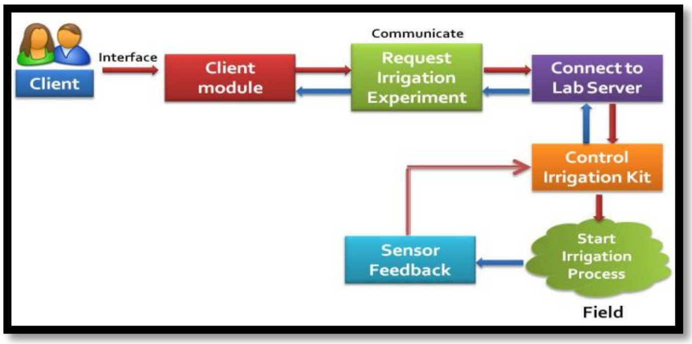

Fig. 4 Block Diagram of the phases in PIMS

B. *Implement the circuit for the Irrigation system*

The irrigation circuit will be used to control agricultural experiment, such as Green houses and automated farming; the circuit will allow the student to:

1- Determine the start and end irrigation time.
2- Store periodic irrigation durations on the kit.
3- Read the temperature in field and based on the reading he will start and stop cooling fans.
4- Read the sun light intensity and determine whether it is preferable to start irrigation or not?

In order to establish the remote interaction between the students and the remote lab a circuit with an embedded micro-controller was designed to contain all the sensors and actuators and perform the communication between the physical devices and the remote server lab.

The main components of the irrigation control circuit are:

- Microcontroller
- Pump
- Temperature sensor
- Light sensor
- Transceiver

The wireless connection between the circuit and the lab server is shown in Fig.5

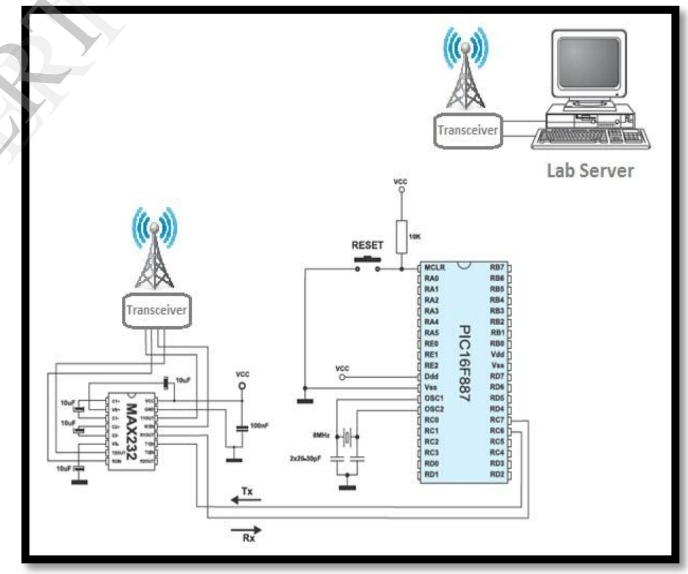

Fig. 5 Wireless Communication Irrigation circuit

C. *Simulation and Printed Circuit Board (PCB).*

The circuit has been simulated using (Proteus ISIS) to make sure of the functionality of the circuit and test the operating system on the chip. The simulation diagram of the circuit is shown in Fig.6.

The printed circuit schematic has been designed using (Express PCB) which is free software available at expresspcb.com. The printed circuit board is shown in Fig.7.

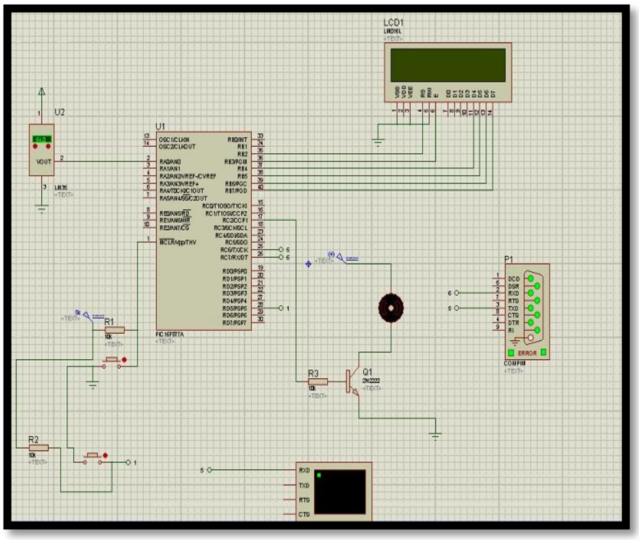

Fig. 6 Simulation Diagram Of the Irrigation Kit Circuit

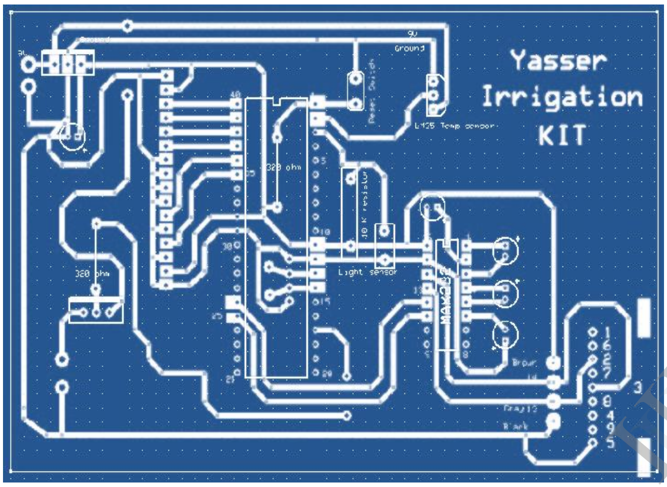

Fig. 7 Irrigation Kit PCB

The prototype of the irrigation kit and the plant is shown in Fig. 8.

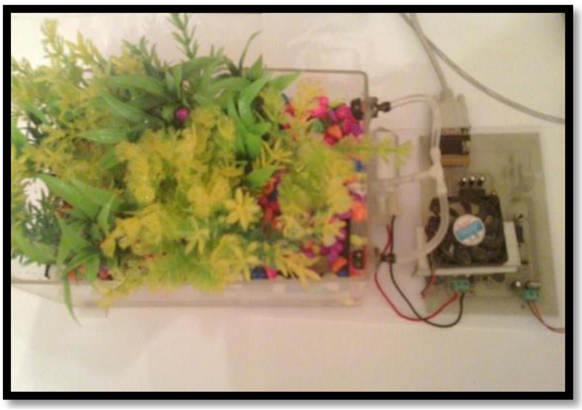

Fig. 8 Irrigation Kit with the Plant

The irrigation kit interface in the remote lab is shown in Fig. 9(a) and Fig. 9(b).

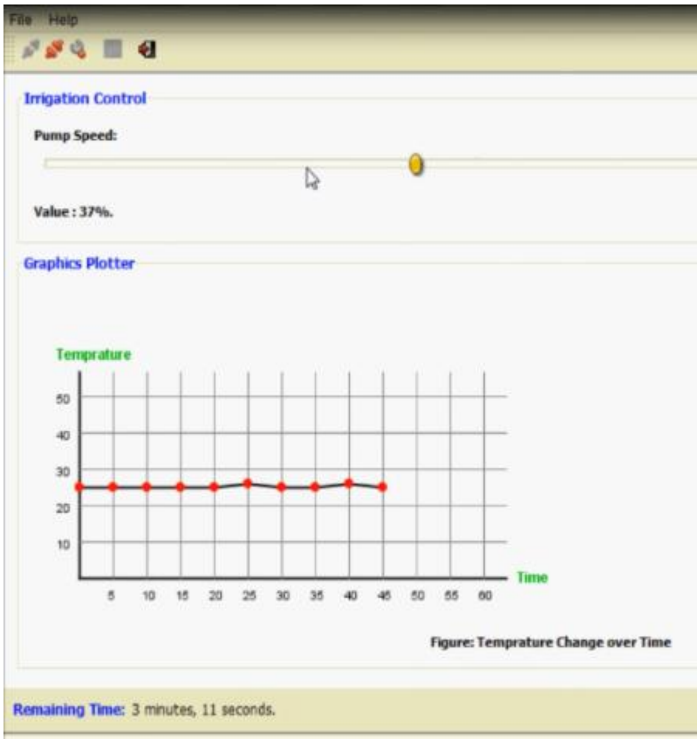

Fig. 9(a) Irrigation kit interface control in the remote lab

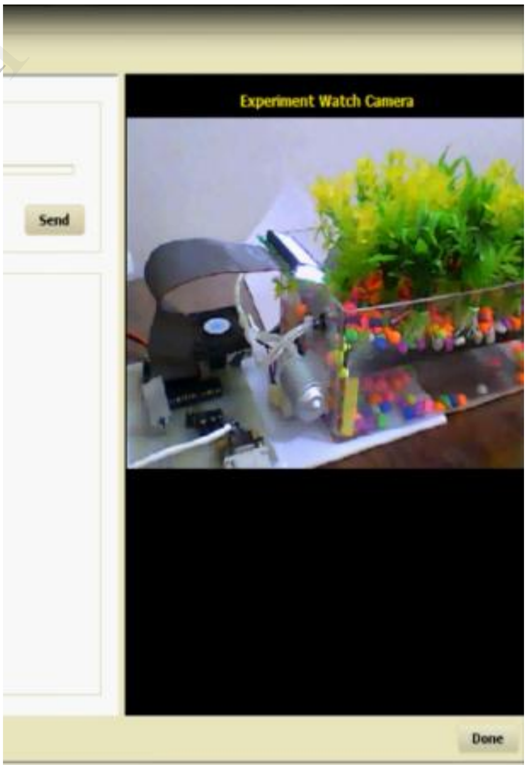

Fig. 9(b) Irrigation kit interface monitoring in the remote lab

V. CONCLUSION

In conclusion, we designed and implemented a general framework for remote laboratory which enhances the remote lab activities leading to improving its performance and makes the data transfer more secure. So, the following conclusions are drawn,

- Remote lab access reduces the waiting time of accessing the lab through direct execution users.
- Remote lab access is more secure for data transfer using VPN technology (tunnel).

The WSANs are an open research area for improving the power consumption and controlling the actuators through the internet-based systems. Precision Farming and WSN applications combine an exciting new area of research that will greatly improve quality in agricultural production, water management and will have dramatic reduction in cost needed. So, we designed and implemented an irrigation kit for precision agriculture as a case study using WSANs to verify the performance and efficiency of our remote lab frame work. The implemented remote lab framework can be extended to be used in many disciplines.

From the standardization point of view, the most significant difference of the work described in this paper is that it is comparatively more scalable in the sense that the hardware and software are both flexible to fit in different environments.

As a future work, for further analysis, the concept of ***Internet Of Things (IOT)*** can be employed to increase the interactivity between the components of the remote lab.

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