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Implementation of a real-time control and monitoring prototype for a classroom of the Industrial Engineering Faculty using Zigbee technology

Implementación de un prototipo de control y monitoreo en tiempo real para un aula de la Facultad Ingeniería Industrial con tecnología Zigbee

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Abstract

The implementation proposal to create an RFID control prototype to optimize the entry of teachers and monitoring that measures the temperature and brightness levels in the classroom in the Industrial Engineering Faculty of the University of Guayaquil to achieve a Smart Campus. In this project, the Xbee wireless communication system was used to communicate the sensors with the central unit. In addition, this project proposes the resolution to the existing problems that burden the university community to improve the work environment and increase student motivation and optimizing the entry of teachers to the classrooms. Three research methods were used: bibliographic, descriptive and experimental. Reliability results of 95% of the temperature sensors were obtained. In addition, the brightness sensor nodes were verified to have an effectiveness rate of 99%. Finally, it was verified that the sensor nodes transmitted the data to the central node without any loss of data and the transmission times were efficient. Finally, it is concluded that the field tests carried out

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determined that it is a low cost, low energy consumption and easy to install system.
Keywords: Smart Campus, sensor, Xbee, RFID

Resumen

La propuesta de implementación para crear un prototipo de control RFID para optimizar el ingreso de los docentes y monitoreo que mida los niveles de temperatura y luminosidad en el aula de clases en la Facultad Ingeniería Industrial de la Universidad de Guayaquil para lograr constituir un Smart Campus. En este proyecto se utilizó el sistema de comunicación inalámbrico Xbee para la comunicación de los sensores con la unidad central. Además, este proyecto plantea la resolución a la problemática existente que agobia a la comunidad universitaria para mejor el ambiente de trabajo y aumentar la motivación del alumno y optimizando el ingreso de los docentes a las aulas. Se va utilizó 3 métodos de investigación que son el bibliográfico, descriptivo y el experimental. Se obtuvieron resultados de confiabilidad del 95% de los sensores de temperatura. Además, los nodos sensores de luminosidad se verificó un índice del 99% de efectividad. Por último, se verificó que los nodos sensores transmitían los datos al nodo central sin ninguna pérdida de dato y los tiempos de transmisión fueron eficientes. Finalmente se concluye mediante las pruebas de campo realizadas se determinó que es un sistema de bajo coste, bajo consumo energético y de fácil instalación.
Keywords: Smart Campus, sensor, Xbee, RFID

Introduction

Education is currently leaning toward a trend that is on the rise thanks to the technological boom (Sánchez-Bayón, 2015)The implementation of smart classrooms, whether in basic or higher education institutions, and thus achieve the creation of a Smart Campus (Vidal Ledo, Morales Suárez, & Rodríguez Dopico, 2014)., (Pacheco González, Flores Avila, Cano Fuentes , & Tena Chávez, 2018), since that space is fundamental for the student's educational process. (Sánchez Perales & Campos Guevara, 2014)which allows them to develop skills and assimilate knowledge that contribute to their professional progress (Navarro, 2003). (Navarro , 2003), (López, 2017).

In Ecuador in the city of Guayaquil, the Faculty of Industrial Engineering proposed to develop a project with a view to a smart faculty. (Zapata-Rios, 2018), (Bauman, 2016) with the implementation of a control and monitoring prototype. (Rodriguez Gámez, 2015), (Campoverde Ganchala & Arias Tapia, 2008)that measures temperature and luminosity levels in the classroom. (Aldean Pacalla & García Ramos, 2019), (Benítez Silva, Ríos Franco, & Estrada Atemiz, 2017), (Arana Cofre & Satán Cevallos, 2019)complementary to that within the same prototype was added an access control by RFID optimizing the entry of teachers to the course. (Piedra Arias & Santacruz Bernabé, 2019)..

With the implementation of this proposed project we propose the resolution of the existing problems that burden the university community of the faculty, improving the work environment and increasing student motivation. (Carranza Mora, Cedeño Calero, Cedeño Zambrano, & Zevallos Bravo, 2013)and optimizing the entry of teachers to the classroom.

The present project has an added value which aims to implement this prototype through Zigbee technology. (Jácome Espinosa & Castillo Imbaquingo, 2013), (Zambrano Rodríguez, Ruiz Villa, Herrera González, Gómez Poveda , & Bustamante Alzate , 2015), generating low energy consumption and the use of wireless communication devices such as Xbee as last mile devices. (Parra Balda & Torres Sánchez, 2019), (Fortuño, 2012).

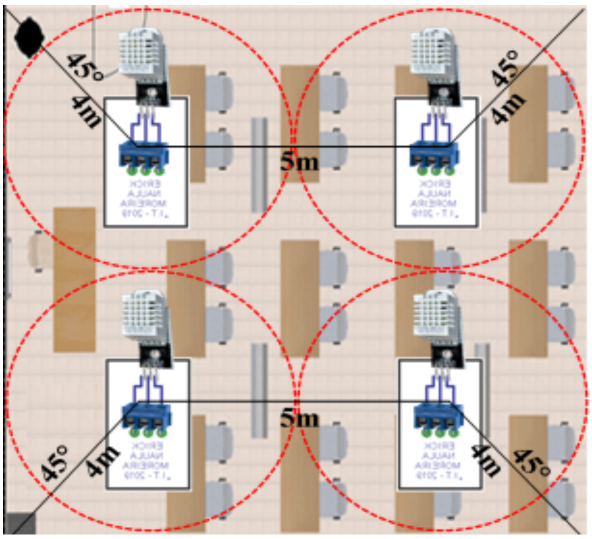
The development of the case study requires the application of electronic knowledge, in order to design the printed circuit of the sensors and their connection to the Arduino with the objective of transferring the data collected from the Arduino to the Xbee. In the formulation of the practical case it is proposed to send the temperature, luminosity and access control data collected by the sensors to the Arduino, these data will be sent to the Xbee which for the purpose of this project will work as a transmitter node.

Methodology

Three research methods will be used: bibliographic, descriptive and experimental. The bibliographic method (Prado, 2009) was used to choose the equipment, materials and software to be used and also to analyze research works similar to the present study. In addition, the descriptive method was used (OKDIARIO, 2018) was used to describe the operation of all the selected equipment to be used . Finally, the experimental method was used (Babbie, 1999) to perform the tests and create the prototype, including the programming language in which the measurement and access control devices will be configured.

This project is based on the implementation of a prototype of control and monitoring in real time, which can measure the temperature levels in the environment and in turn an access control system using RFID to provide teachers with greater ease of access to classrooms. The RFID module will be placed in the classroom door, therefore, the temperature and luminosity modules will be strategically placed in each corner of the classroom to perform their respective functions and finally the data collected from the temperature sensor, luminosity and RFID are sent to a central node located in the same classroom. The general scheme of the prototype is shown in Figure 1.

Figure 1. General schematic of the prototype



As can be seen in Figure 1, it was proposed to locate the temperature sensor nodes at 45° inclination in each corner of the classroom at a distance of 4m, separated between them approximately 5m to extend the radius of action to a distance of 16m, so that each node would cover a part of the classroom. In the case of the luminosity sensor, the location is central since the classroom has 4 fluorescent bases, dividing 2 bases for the front part and 2 bases for the back part of the classroom. Therefore, the brightness sensors will be placed on the central pillars at a height of approximately 3m so that it can fulfill its function of measuring the brightness levels needed by the students to have a good visibility. The prototype is adapted to the dimensions of the classrooms that are present in the Industrial Engineering Faculty of the University of Guayaquil with an average size of 6m wide by 10m long, which has capacity for approximately 40 students, where in the morning hours daily circulate about 160 people between students, teachers and cleaning staff.

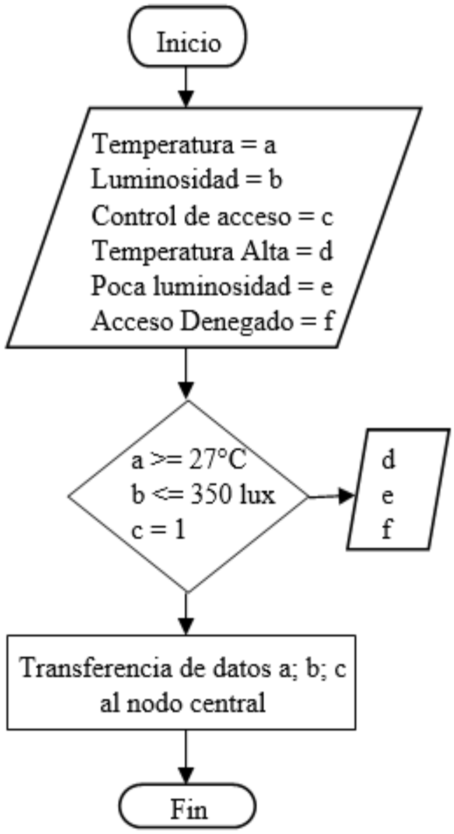
Based on tests carried out inside the classrooms to determine the placement of the sensors, it was determined that 7 sensor nodes and 1 central node should be placed. The sensor nodes are divided into 4 nodes consisting of sensors that are monitoring temperature levels, 2 sensor nodes that check the brightness of the classroom and 1 node for access control that will be for the exclusive use of teachers.

Access control will be implemented at the main entrance door of the classroom. It should be noted that the courses of the School of Industrial Engineering have a single door that is used for the entrance and exit of students and teachers.

For access, a TAG will have to be placed which will contain an ID assigned to each teacher, so that the availability of each course and the teacher who is in it at that moment can be known. Finally, the central node will be located next to the projector base which is in the central part of the classroom approximately 5m from the floor, one of the factors taken into account for the location of the central node was the maximum distance so that the data transmission is effective and there is no loss of information, and in turn will avoid the constant manipulation of the device.

The prototype will measure the ambient temperature and the existing light levels, complementary to that an RFID access control that will work with a TAG that works at the same frequency. By means of the flowchart shown in Figure 2, the general operation of the prototype can be clarified.

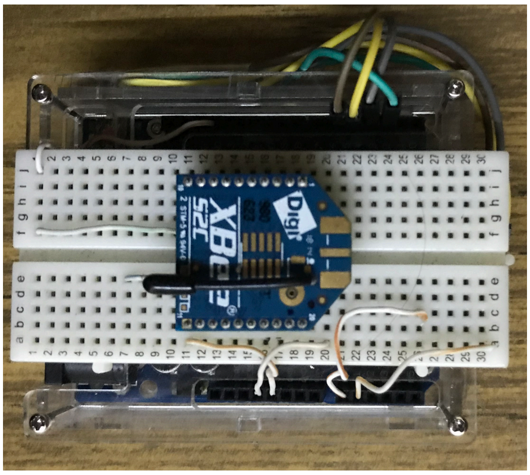
Figure 2. Flow diagram



The respective selection of the devices to be implemented was made based on their technical specifications, observing which of all the options is suitable for the operation of the prototype.

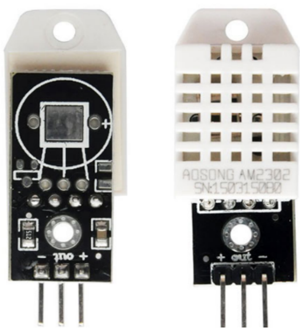
A varied amount of Arduino boards were analyzed. (Sacoto Peralta, 2019) for which it was decided to use the Arduino Uno board. An important factor in the choice of this board was its cost, since of all the other options it was the least expensive and most accessible in the market. In turn, it was found that despite being one of the cheapest on the market, it meets the necessary requirements for the operation of the prototype in terms of processing speed, data transmission rate and compatibility with a wide variety of protocols and sensors.

Figure 3. Arduino Uno.



Working with the DHT22 sensor was also analyzed (Llamas, 2016). (Llamas, 2016) despite belonging to the same family as the DHT11, the DHT22 has better features to implement it in real monitoring projects that require medium accuracy. There are not going to be problems sending collected data to the central node because the DHT22 sensor is compatible with the Arduino platform. In addition, the measurement range of this sensor is acceptable, ranging from -40°C to 125°C with an accuracy of 0.5°C, capable of measuring humidity as it uses a capacitive humidity sensor to measure the surrounding air with an accuracy of 2 to 5%. Its field of action is approximately 4 meters around and it has a sampling frequency of 2Hz.

Figure 4. Temperature Sensor DHT22.



In addition, it was chosen to work with the KY-018 sensor. (Goplani, 2017) due to the ease of acquiring it in the local market and its cost. This is a device capable of generating a voltage (0V to 5V) proportional to the light incident on it. This is based on the properties of a photo dependent resistor.

Figure 5. KY-018 Luminosity Sensor.

Finally, the RFID-RC522 RF module was chosen (Alcon Baltzar, 2016). (Alcon Baltzar, 2016)with a reading distance from 0 to 60 mm, the communication protocol is SPI compatible with Arduino.

Figure 6. RFID-RC522 Module Kit.

Through this methodology, tests will be performed and the prototype will be created, including the programming language in which the measurement and access control devices will be configured.

Prototype implementation

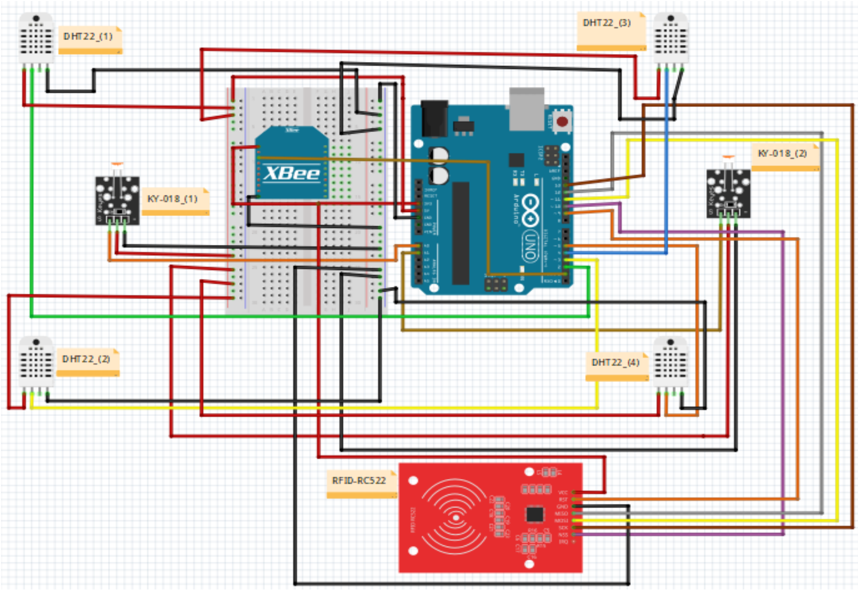
For the implementation of this project we will use the Arduino Uno, an Xbee series 2 module, a DHT22 temperature sensor, a KY-018 brightness sensor and the RC522 RFID module. Initially, the design of the simulation in Proteus of the working scenario for the operation of the prototype will be carried out. Within the program an analysis of the current and voltage consumption of each device was performed, where it was concluded to energize all sensors through the Arduino board, which can supply the prototype without any complications, after checking the proper functioning of the prototype through simulations, physical tests are performed by implementing the sensors in a real scenario. For which a small-scale prototype was assembled with the devices on a breadboard where the connection was made based on the simulation in Proteus.

In order for the prototype to perform the proposed measurements, the sensors had to be programmed in the Arduino programming environment (Arduino IDE), for which a specific function was assigned to each sensor.

Once the sensors correctly send the data to the Arduino, the same data is sent to the Xbee which will work as a transmitter and will be in charge of transmitting the information to the Xbee Router complying with the requirements of the Zigbee protocol.

The final result is the general diagram of the node connections as shown in figure 6.

Figure 7. General connection diagram of the prototype.



Results

The sensor network was implemented using UTP cabling as shown in the scaled prototype in Figure 7 and its communication and data transmission with the central node will be wirelessly based on IEEE 802.15.4.

Figure 8. Implementation of the central module with its IEEE 802.15.4 sensor network.

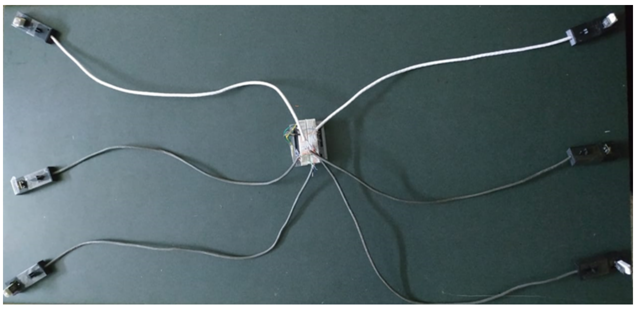


Figure 8 shows the deployment of 7 sensor nodes and the central node. The sensor nodes are distributed as mentioned in the previous section in 4 nodes that will monitor the temperature levels, 2 sensor nodes that will measure the brightness of the room and 1 node for access control that will be for the exclusive use of teachers, leaving a single central node consisting of an Arduino Uno and an Xbee Series 2, for receiving data transmitted by the sensor nodes.

The transmission protocol is fundamental, therefore, in this project the Zigbee protocol was chosen, which, despite not having very high speeds, will allow to obtain a very low level of energy consumption in the network of nodes. The temperature sensors will take measurements of the environment and display them in °C, this sensor will help to maintain the proper environment required for students, likewise the light sensors will allow to maintain the luminous flux so that students and teachers have visibility throughout the classroom area. Finally, the access control that will be implemented at the entrance door of the classroom will allow teachers to enter the classroom without the need for keys, optimizing the entry and exit times of each teacher at time changes.

In this section the respective tests and comparisons will be made to verify the percentage of error in a real scenario obtained by the prototype to be implemented. To perform the field tests in this project, similar works were taken in which comparative measurements of prototypes were made in a test scenario, testing data transmission, range and power consumption.

To perform the measurements, a mercury thermometer was required to compare these values with those of the prototype, validating the results and seeing what percentage of error and reliability is obtained. In the same area where the measurements were taken with the thermometer, field tests of the prototype were carried out to test its operation in a real test scenario. After performing the field tests, the following results were obtained:

Table 1. *Field test results*

Evaluation	*Measurement Result*
Mercury Thermometer	22°C
Prototype	20°C
Scope	4m
Power consumption	minimum
Data transmission	Optimal/Stable

Once the respective tests were completed in the classroom with the mercury thermometer and the prototype, it was determined that the values obtained between the two devices are similar with an approximate margin of error of +-5%, demonstrating that the developed prototype has a reliability of 95%, proving that it works properly and can be implemented without any inconvenience. It should be noted that the tests were only performed with the temperature sensor nodes since the required elements were available.

Similarly, the operation of the brightness sensor nodes was checked, in which when all the fluorescent lights in the classroom were turned on, they showed stable values around 450 lux, which are acceptable values; however, when 2 fluorescent lights were turned off, the difference was noticeable, since the values varied around 850 lux approximately, showing the tendency of the light sensor, the less brightness the greater the resistance, therefore it was verified that the brightness sensor nodes have a 99% effectiveness rate.

An important point to note is that when the sensor nodes sent data to the central node there was no loss and the data transmission times were efficient, since distance was not a factor that caused problems due to the fact that the UTP cable has a maximum transmission range of approximately 10 m without interference.

Conclusions

For which a scheme of operation was established for temperature and luminosity measurements, complementing it with an RFID access control system for which it was decided to work with Zigbee technology, which is one of the best communication techniques for a network of sensors of electronic development whose base infrastructure is through UTP cabling.

The needs of the university community of the faculty were also taken into account. Based on the requirements, the ideal scenario for the operation of the control and monitoring prototype was determined, so the installation of 6 sensor nodes distributed in temperature and luminosity for the air conditioning and comfort of the users was arranged.

Finally, through field tests it was possible to determine the ideal operation of the prototype and its proper connection, so that it can be implemented, demonstrating that it is a low cost, low energy consumption and easy to install system.

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