Electronic System with Internet of Things Protocol That Contributes to the Rational Use of Water in Housing Units

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Abstract: The article presents the results of an investigation whose object of study was the design and implementation of an electronic system with Internet of Things protocol in order to contribute to the strategies of rational use of water in housing units. The results found were framed in the construction of a functional electronic prototype, with a high degree of integration to communication systems with IOT protocol useful in the implementation of smart cities. Likewise, an intervention process was carried out in a university academic community for its respective validation. Finally, it was concluded that the electronic prototype is functional, meets the standardized technical and engineering requirements, and contributes to people's awareness processes regarding the rational use of water.

Keywords: Electronic prototype, Water and basic sanitation, Internet of things, Rational use of water, Awareness of water consumption.

1. Introduction

Climate changes, inadequate consumption in homes, the increase and development of the population, are some of the factors that cause a greater use of water today.(Satterthwaite, 2009)(Muller, 2007)(Wardekker et al., 2010)

It is estimated that the basic consumption of water is of 20 m3 / house-month, equivalent to 133 liters / inhabitant-day and that this consumption is mainly by those who use water either to bathe, wash their hands or cook their food, among others. In residences, water meters or meters are used, which are responsible for recording consumption for later collection, but in most cases they do not record the total amount of water consumed. (Alcamo et al., 2003)(De Buck et al., 2015)(Gleick, 1996)(Mayer et al., 1999)

Nowadays, with the development and evolution of technologies, better methods have been adopted to help manage this water resource that reaches homes. A current technology that helps with the automation and measurement of water consumption in domestic networks, without being created for this, is ZigBee, since with the integration of sensors, electronic boards, wireless nodes, it manages to transfer wirelessly and in real time the consumption of water.(Gbadegesin&Olorunfemi, 2007)(Kabat et al., 2002)(S.D.T. Kelly, N.K. Suryadevara and S.C. Mukhopadhyay, 2013)(Obaid et al., 2014)(Usman &Shami, 2013)(Batista et al., 2013)

With the integration and using technologies such as ZigBee, microcontrollers, sensors among others, it is intended to obtain systems for the exact measurement of the water you consume in your home and contribute to the goals set regarding affordable and non-polluting water.(Dasios et al., 2015)(Rawat et al., 2014)(Kailas et al., 2012)(Baronti et al., 2007)(Tarange&Mevekari, 2015)

From the environmental point of view, the lack of awareness in the rational use and inadequate consumption of water, it becomes evident the measurement of water consumption in real time, which is done in a residential unit. Currently, to measure consumption of water, meters or hydrometers are used, which allow counting the amount of water that passes through them. It is evident that when measurements are taken and shown in real time to the user, water consumption decreases because awareness of the water consumed is generated. However, this rationalization of water is not due to issues of "rational water use". The main reason for this is to save money. (Tarjuelo et al., 2010)(da Silva et al., 2014)(Mattas et al., 2014)

In cities with a technological deficit, every time a person wants to know the real time water consumption of a house, he or she must go to a meter outside the house and observe the value it indicates, or he or she must wait for the reports that arrive at the houses monthly, and for that, wait for a water company official to read the meter. Therefore, the person only knows the water consumption he or she generated during the month and cannot control the consumption of each activity that uses water. (Batra et al., 2013)

The problem is greater when you want to permanently know the consumption of each tap; having a single meter this is impossible because it captures at the same time the consumption of the taps that are in use, either one or more.

Research shows that there is a lack of technology to measure water consumption at every tap in a housing unit. Therefore, from the technological point of view, the research used ZigBee technology and allows interconnecting more than 2 nodes, achieving data transfer and handling transmission speeds between 20 and 250 Kbps, operating at 2.4 GHz.

2.Methodology

The research is of an applied type with a technological approach, since it is intended to transform the knowledge acquired in the technological development of a prototype that will satisfy a previously identified social need.

From the above, an analysis was made of the different development methodologies that exist and it was concluded that the best option to apply is the prototype methodology, because it is coupled to the needs of the project, allowing us to listen to the initial requirements of the tutor to make a first functional model, with which you can interact and, if necessary, make changes in the following interactions.

Figure 1, presents the phases of the proposed methodological design, collection and refinement of requirements, modeling and agile design, prototyping, testing and evaluation, optimization.

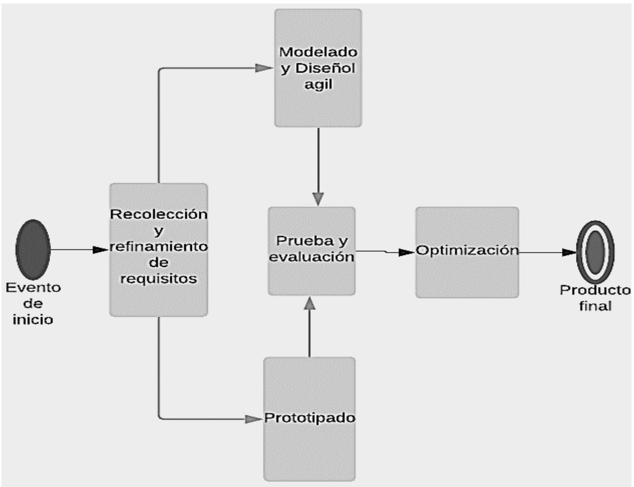

Figure 1. Phases of the prototype methodology. Source: self made.

The non-functional requirements of Usability, Availability, Mobile Application and Friendly Interface were defined.Table 1 presents the functional requirements.

Table 1. the functional requirements.

ID	Name	Description
R-01	*Usability*	*The prototype must be easy to use by the user.*
R-02	*Availability*	*The prototype must be functional so that the user can use it every time it is required.*

R-03	*Android mobile app*	*LThe application will be compatible with phones that have Android operating systems*
R-04	*Ifriendly interface*	*LThe application interface must be easy to use by the user.*

In the same way, the functional requirements of the APP were determined functionality, consumption, view consumption cost, update. Table2, presents the functional requirements and their description.

Table 2. functional requirements and their description.

I	Name	Description
R -01	*View consumption*	*The system provides the user with information on water consumption*
R -02	*View consumptioncost*	*The system provides information to the user of the cost in pesos of water consumption*
R -03	*To update*	*Sand they update the consumption data and cost of water consumption.*

Based on the functional and non-functional requirements presented in the figure 2, the usage cost diagram for the prototype.

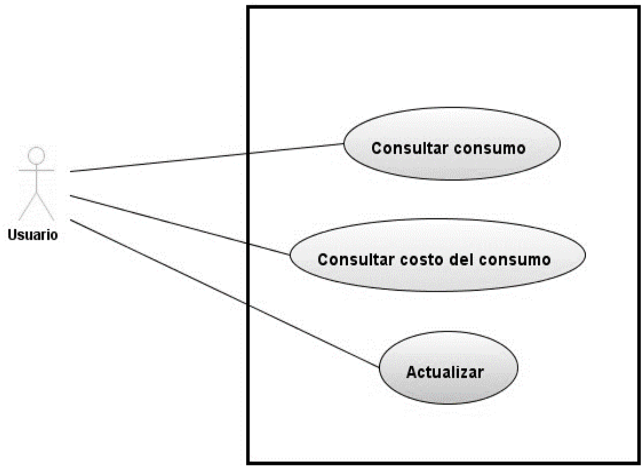

Figure 2.Casos of use

3.Results

The prototype construction was divided into 4 phases, database construction phase, node construction, mobile application construction and prototype evaluation.

Phase 1. Database Construction

The database was developed in the database management system or DBMS MySQL and an entity-relationship model was designed to implement a complete system that has several terminal nodes that send information to a central one, but that allows for the moment it only tests with a single node. The figure 3, presents the entity relationship model of the prototype.

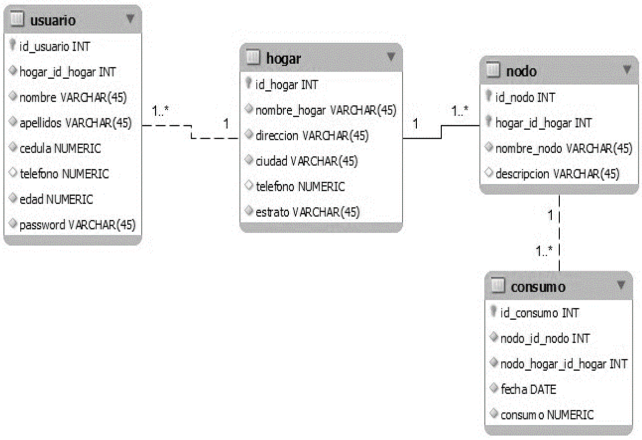

Figure 1. Model entity relation (MER) of the prototype

Phase 2. Node Construction.

For the construction of the nodes, 02 Xbee SC2 modules were used as data transmission medium. One is the emitter node, which will be in charge of sending the pulsations emitted by the flow sensor that is in the pipe, each time water comes out of the tap.Figure 4, presents the Xbee communication node coupled to the sensor.

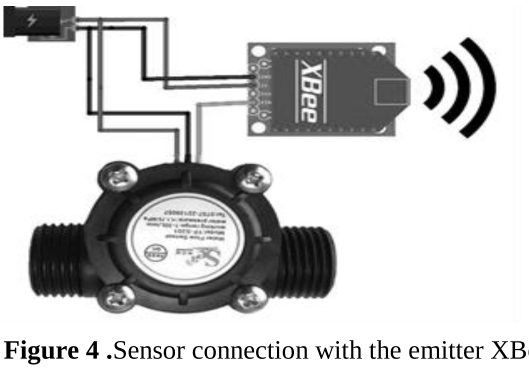

Figure 4 . Sensor connection with the emitter XBee module. Source: self-made.

The second node will receive the transmitted information and send it to pin 2 of the Arduino board that will be in charge of processing the information, the figure 5, presents the connection of the Arduino board with the XBee receiver module. Source: self made.

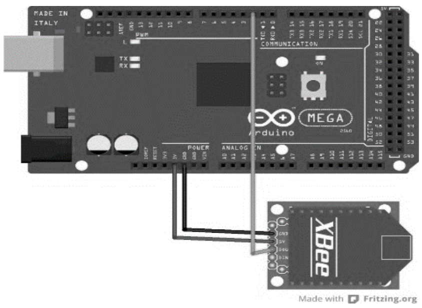

Figure 5*. Connection of the Arduino board with the XBee receiver module. Source: self-made*

Arduino boards, in this case the Mega 2560 version, have pins for different purposes such as digital inputs or outputs, analog, PWM, among others. But specifically pins 2 and 3 are programmed to perform digital pulse counts, in order to find their frequency using the attach Interrupt () function. Obtaining the frequency, a conversion to flow rate (Q) is achieved through the use of a conversion constant (K) that is supplied by the manufacturer of the flow sensor. For the flow sensor YF-S201 1⁄2, the conversion constant is K = 7.5. The average water output from the tap was calculated at 1.75 liters. However, the average output from the sensor was 1.42 liters. The measurements are sent to the database through a web service programmed in PHP, taking into account that MySQL was used for the database. Figure x presents the tools used to store consumption data.

Figure 6. **Tools used to store consumption data**

Phase 3. Mobile Application Construction.

Taking into account that a local server will be used to test the prototype, the Android Studio IDE was used to develop the mobile application, since this environment facilitates the organization of projects, separating the logical part of the views and their resources. In addition, it allows the use of databases in MySQL through the use of web services and interaction with JSON (JavaScript Object Notation) to transmit information from PHP to the application.

The application interface offers two TextView-type fields in which the total sum of water consumption to date is reflected, in cubic meters and the value of this consumption in Colombian pesos, based on the current rate offered by the water company, aqueduct and sewerage in the city of Villavicencio. Finally, the application has a button that updates the information in the database, if new records have been made by the flow sensor. Figure x, presents the graphical user interface of the App.

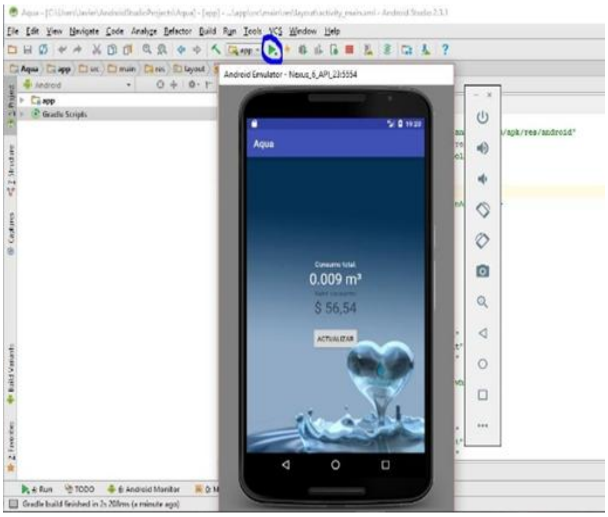

Figure 7. Viewing the mobile application.

Phase 4. Prototype Evaluation

Criteria such as functionality, ease of use, compatibility, stability, interoperability, upgrade, and the final and future cost of the prototype were taken into account to evaluate the prototype.

Finally, due to the integration of different electronic and technological components, it is possible to design and build a fully functional prototype, which measures the consumption of water from a tap in real-time and calculates the value of this consumption.

This prototype aims to test the possibility of measuring water in a tap in a housing unit, by using the Zigbee data transmission protocol.

For this purpose, a simulation of a water tap will be used, which will perform the liquid flow measurements using a hall effect flow sensor. This information will be stored in a database, to be able to verify it through a mobile application, developed in the Android operating system.

The prototype allows to carry out water flow measurements in the simulation of a tap, send the information to a central node, to process it and store the results in a database, access the information in the database through a mobile application, provide the option to update the information reflected in the mobile application if new measurements are made.

Once the prototype was validated, a measurement of the amount of water consumed in the hand washing of one person was carried out.

Figure 8 shows the histogram of the measurements of water consumption in hand washing of 377 people before carrying out the water consumption awareness process, showing that 22 people, equivalent to 6% of the population under study, consumed up to 2 liters of water for hand washing; 125 people, equivalent to 33% of the population under study, consumed between 2 and 4 liters of water; 110 people, equivalent to 29% of the population under study, consumed between 4 and 6 liters of water; 58 people, equivalent to 15% of the population under study, consumed between 6 and 8 liters of water; 30 people, equivalent to 15% of the population under study, consumed between 6 and 8 liters of water; 30 people, equivalent to 15% of the population under study, consumed between 6 and 8 liters of water, 58 people equivalent to 15% of the population under study consume between 6 and 8 liters of water, 30 people equivalent to 8% of the population under study consume between 8 and 10 liters of water, 20 people equivalent to 5% of the population under study consume between 10 and 12 liters of water, 8 people equivalent to 2% of the population under study consume between 12 and 14 liters of water and finally 4 people equivalent to 1% of the population under study consume between 18 and 20 liters of water.

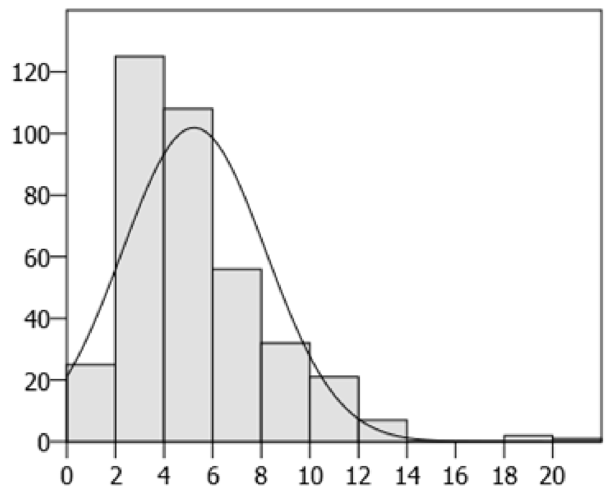

Figure 8. Histogram of water consumption prior to the awareness strategy (x-axis - Liters and y-axis - Number of Persons)

After the measurements were taken in order to determine the water consumption when a person washes his or her hands, a micro-learning intervention process was carried out, mediated by digital technologies, on water saving techniques.

After the training, the water consumption in hand washing of a person was measured again. Figure 9 shows the data obtained. It is evident that 148 people equivalent to 39% of the target population consume up to 2 liters, 164 people equivalent to 44% of the target population consume between 2 and 4 liters of water, 58 people equivalent to 15% of the target population consume between 4 and 6 liters of water, 5 people equivalent to 1.3% of the target population consume between 6 and 8 liters of water, 2 people equivalent to 0.5% of the target population consume between 8 and 10 liters of water.

The measurements made show that the training through the intervention with digital media contributed to decrease the value of the mean of 5.2 liters to 2.5 liters of water consumption. The standard deviation was kept at 0.2 liters.

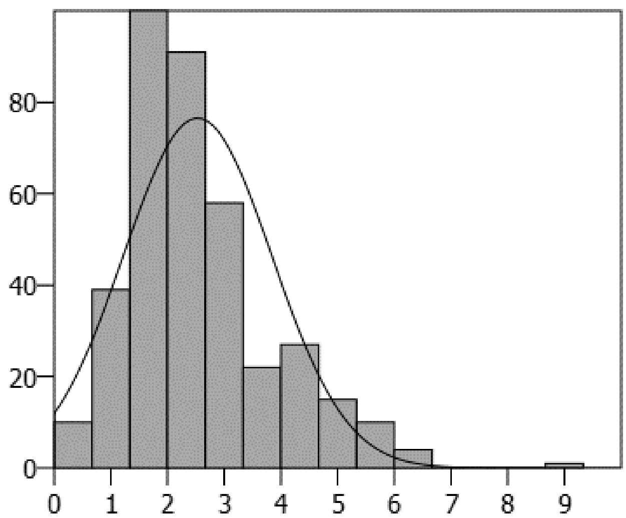

Figure 9. Histogram of water consumption after the water consumption awareness strategy intervention. (x-axis - Liters and y-axis - Number of Persons)

Similarly, the measurements made with the prototype implemented against the calibration standard instrument showed a precision of 95% with an accuracy of 94%. These results derived from the analysis of deviations with respect to modal frequency, mean, relative truncation error and uncertainty.

5. Conclusions

The integration of different technological tools such as Arduino, the water sensor, the Zigbee protocol and the mobile application facilitate the process of monitoring water consumption, helping to reduce excessive expenses that are registered in a housing unit.

With the development of this research project, it is possible to introduce the Zigbee communication protocol as a tool, since it allows transferring information from the XBee modules to the database.

XBee series 2 modules, despite being so small in size, have great functionality, as well as allowing energy savings.

The development of the database allows the information generated by the water flow sensor to be recorded so that it can then be viewed in the mobile application.

The mobile application allows you to see in real time the water consumption that you are having in the tap, in the same way to know the cost in pesos of that consumption.

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