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Design of an IOT Domotic System using the MQTT protocol

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ABSTRACT

Summary-The human being since ancient times has sought the ease of doing things, as well as the comfort and security of your home, on the other hand, in times of technology seeks to take control, and monitoring of their home in addition to automate processes, which is why for the investigation of this work was used agile methodology Kanban to develop the case study, this time a home automation system IoT using the communication protocol Mqtt. The results of this project were positive, achieving the implementation of process automation in a home. This future project can become a service that can be provided to different companies or homes depending on the needs and implement solutions that automate processes.

Key words: Mobile application; Virtual Private Cloud; IOT; MQTT protocol; Home automation system.

1. INTRODUCTION

Since years ago man has evolved technology little by little with the aim of making it easier and less laborious to perform an action, so about 100 years ago began the automation of homes, the introduction of electricity in the home led to the first automated appliances, such as the kettle in 1889 and the washing machine 1904 [1].

The current trend in the area of comfort, safety and monitoring applied to homes, have led to the development of new areas of knowledge such as home automation in IOT [2] that arises from the need to integrate technological elements that are currently part of the home, thus allowing a general control and monitoring of these elements through a central node, giving the man the possibility of giving an optimal management of each of these. This integration is achieved through the interconnection of private networks within the home, with the possibility of remotely manipulating them through external communication networks that are easily accessible to residents [3].

For the development of this project we opted to use the Kanban agile methodology of software development, recognized as such in 2004. It consists of the following steps: dividing the work into tasks, dividing the development of the project into phases, limiting the number of tasks to be performed in each phase, visualizing the progress of the tasks by means of POST-IT cards on a dashboard and finally monitoring the entire project to obtain performance metrics [4]. For Manzaba Kanban the main objective is to manage in a general way how the activities are being completed [5]. For Perez the objective of Kanban is to manage in a general way how tasks are completed [6]. Therefore, regarding the above mentioned, Kanban divides the work in cards making the development easy to manage in a general way, besides it is based on 3 main rules [5]:

1. Display the workflow.
2. Determine the work in progress limit.
3. Measuring the time to complete a task

As a result of the above, we chose this methodology which is easy to implement and work in small groups, and which divides the work into parts through visual cards that are easy to organize and manage.

This project will be applied in a home in Lima Peru, where certain processes will be automated, such as the lighting and payment of a light bulb, measurement of temperature and humidity of the environment, access control, among others, this will be developed following the agile methodology already mentioned above.

The aim of this research project is to design an IOT home automation system using the MQTT protocol for real-time communication.

In the present investigation, section II describes the methodology with which the project will be carried out, followed by section III where we define the case study applied explaining in detail, finally in section IV the results and discussions will be described.

2. METHODOLOGY

For the design of the IOT home automation system, we will use the agile Kanban methodology that is very efficient and easy to use in the management of this project, this involves several technologies, such as vpc service (Virtual Private Cloud) from AWS (Amazon Web Services) that we will use to host our website that will connect with the MQTT communication protocol and this at the same time will communicate with a microcontroller esp8266 or esp32, In addition to developing a mobile application for Android as for

IOS that will facilitate the use of the home automation system without having to use a PC, all data will be stored in a MySQL relational database to avoid loss of information.

The methodology has the following stages:

2.1Acquisition and configuration of Amazon VPC and communication protocol

A VPC consists of a collection of virtual machines, storage and network resources that provide multi-client security to enterprises renting space in the cloud. Enterprise clients connect to VPCs via Internet VPNs running on the public operator network. Having a virtual private machine in the cloud, brings us great benefits also isolates us from other users and we can configure the system to our requirements and greater convenience, so we used the services of Amazon VPC or CPV that is very easy to purchase and configure, emphasizing that this service is free for one year to make the tests we require.

For the administration of our server we will use a simple and intelligent hosting control panel like Vesta that has a user-friendly web interface. VestaCP is one of the most widely used open source web control panels today, thanks to its simplicity of operation, robustness and speed. It has been designed to make web hosting easy, as it is based on a series of scripts that facilitate the usual work and at the same time allows each of the applications to be configured manually [8].

To avoid errors in the communication of our services, we enable some specific ports in aws and in our Vesta panel, then to make our website more secure, we add an ssl certificate stating that it is an encryption protocol designed to provide secure communications and data transfers over the Internet [9].

2.2Development technologies

Currently there are several options for web development technology, mobile, desktop, microcontrollers, in addition each technology has a variety of development framework, with respect to the project will use php as a backend with the framework or Codeigniter framework in version 3 that works with a style of MVC software architecture that is the most widespread for the development of applications where they must handle user interfaces, this focuses on the separation of data or model, and the view, while the controller is in charge of relating these two [10], in addition this framework has a large community that provides value and is very safe and lightweight compared to other frameworks, for the front-end or visual part will use an administrative template based on the tagging language of html, css and the design framework Bootstrap 4 which then modified to our requirements, also use JavaScript to make the website more intuitive and therefore communicating with our protocol.

The data will be stored in a relational database mysql, then develop the mobile application in the programming language dart and design will use the framework flutter, a perfect complement to intuitive designs for the user, to connect our application with our devices use a special library, all development will be done through visual studio code software that is intuitive, has plug-ins that facilitate the coding of our project.

2.3Programming and hardware selection

In this phase we will select the device or microcontroller that meets our expectations and that we will use for the development of the project, also the logical part will be made that later we will record it in the microcontroller giving way to a solution.

2.4Testing and operation of the system

In this phase, we will start testing our devices, we will also explain the data flow of the solutions provided at the moment and we will show the connection diagram of the electronic part.

3. CASE STUDY

This research was correctly developed following a project development methodology. The following will describe the development, operation of the system and the application of the project in a house by automating processes that the person tends to perform, as well as providing security to the home and turning it into an intelligent environment.

3.1 Acquisition and configuration of Amazon VPC and communication protocol

It was considered pertinent to develop the project with the most economic cost possible and also to be able to work in a real environment using online services and not at a local level, that's why aws services were selected as the first free tool for the reason that, when creating your account, you can create a free vps for one year.

Once the account has been created we acquire the instance or vps with the Ubuntu server 18 operating system as shown in Figure 1, to be able to access the server aws gives us a key pair or unique password in the form of a file that we must keep very well since if it is lost we will not be able to access the server, later on we reserve a fixed IP address so that every time the server is restarted, it does not change its IP, When we created our instance, we also created a security group in which we configured the ports or input rules that are displayed in Table 1, this in order that our IOT system works perfectly without any problem and to be able to connect from SHH and FTP to make modifications and prepare our work environment

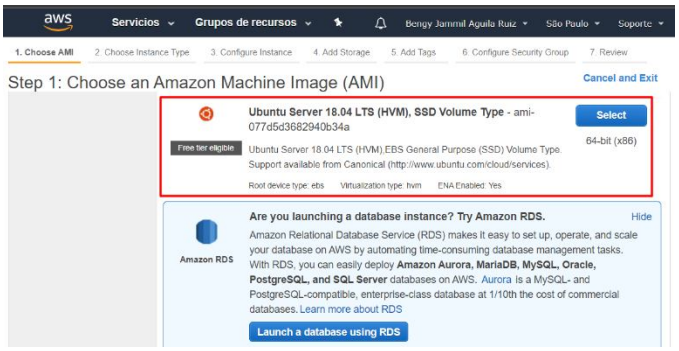


Figure 1: Instance selection or private VPS.

Table 1: Open TCP ports.

Type	Protocol	Port range	Source	MYSQL
HTTP	TCP	80	0.0.0.0/0,::/0	HTTP
Custom TCP	TCP	8083	0.0.0.0/0,::/0	VESTA
Custom TCP	TCP	18083	0.0.0.0/0,::/0	EMQX
Custom TCP	TCP	8883	0.0.0.0/0, ::/0	EMQX
Custom TCP	TCP	8090	0.0.0.0/0,::/0	EMQX
Custom TCP	TCP	1883	0.0.0.0/0,::/0	EMQX
HTTPS	TCP	443	0.0.0.0/0,::/0	HTTPS
Custom TCP	TCP	8093	0.0.0.0/0,::/0	EMQX
Custom TCP	TCP	12000 - 12100	0.0.0.0/0,::/0	FTP PASSIVE
SSH	TCP	22	179.6.206.239/32	SHH-MY IP
Custom TCP	TCP	21	0.0.0.0/0,::/0	FTP
Custom TCP	TCP	8094	0.0.0.0/0,::/0	EMQX
MYSQL/Aurora	TCP	3306	0.0.0.0/0,::/0	MYSQL

For the administration of our hosting, for the VPS, Vesta has been implemented, which is a free VPS service and easy to use, in addition Vesta asked us for a domain at the time of installation, which as well known, most of these domain services are paid, but in the end we managed to implement another free service that gave us the domain, called Freenom, in which we managed to acquire our domain for free, which is: proyectosiotbjar.ga, then an SSL certificate was implemented for greater security of our system, as shown in Figure 2, where you can see the administration panel of Vesta, along with the secure URL, using the HTTPS protocol.

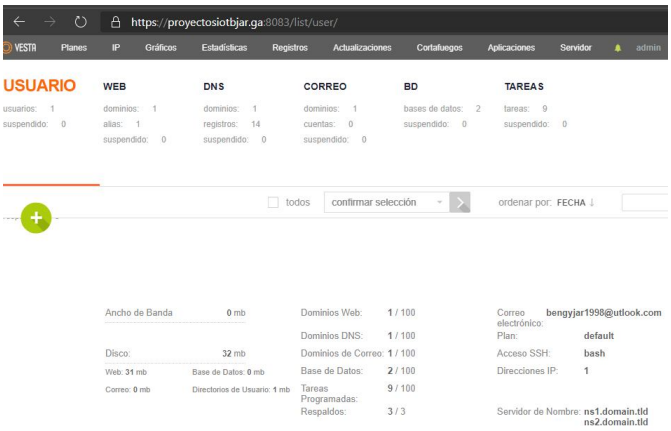


Figure 2: Administrative panel with ssl certificate

The communication protocol used is MQTT, since MQTT is a lightweight protocol for message communication between devices that do not require much processing and do not require a large bandwidth for it [11]. It also handles its own standard of publish/subscribe based on topics in which clients send and receive messages that are managed by a central element called a broker [11] as shown in Figure 3, such service will be used through EMQ X Broker which is a highly scalable and highly extensible distributed MQTT message agent written in Erlang / OTP [12], which has a configurable system and uses real-time socket connection

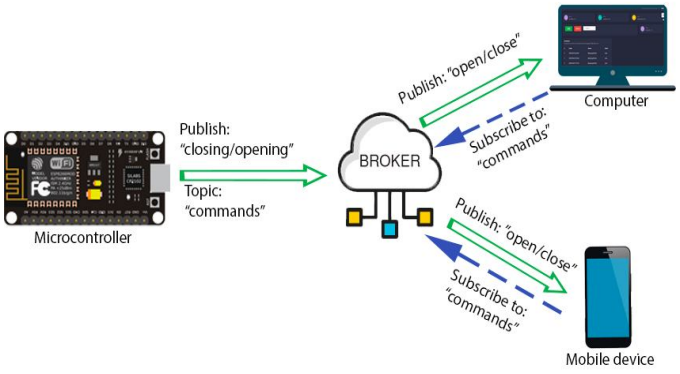


Figure 3: Illustration of the MQTT standard "publish/subscribe

Finishing with the configuration of our vps we went to install the EMQX administrator, for this we connected through Putty and with a command generated from the same official page of EMQX, we executed it resulting in the successful installation of this, as shown in Figure 4, then we created the MYSQL database in Vesta and configured EMQX to make connection with it.

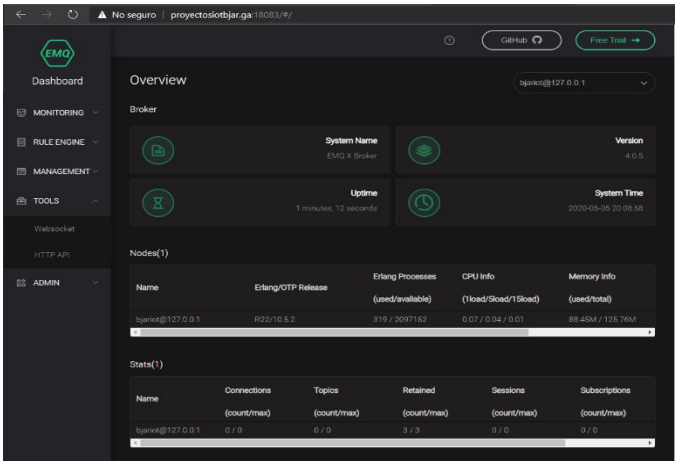


Figure 4: EMQX administrative panel

3.2 Development technologies

As a first step in this phase we developed the website using the Atom development IDE, the design was developed based on an administrative template made in html, css and JavaScript that was later modified to our taste to meet our requirements, therefore, the logical part was programmed in php with the codeigniter framework in version 3 using the MVC development pattern.

Later for better user comfort, a Dart web interface was chosen which is still under development, for the interaction and reception of data from the server, some libraries were used which stand out among the main ones, that of MQTT based on JavaScript which is subscribed and communicates in real time Figure 5, also for the security and integrity of the user's data, you must log in to access the system also has a section where the devices are registered with their respective unique identifiers. The interface presented in Figure 6, represents one of the parts of the system, in this case the access to the house by means of rfid card assigning access permissions, the temperature and humidity of the environment, the turning on and off of a light bulb, the energy consumption and a table with the accesses to the system, later with the advance of the project more functionalities will be implemented.

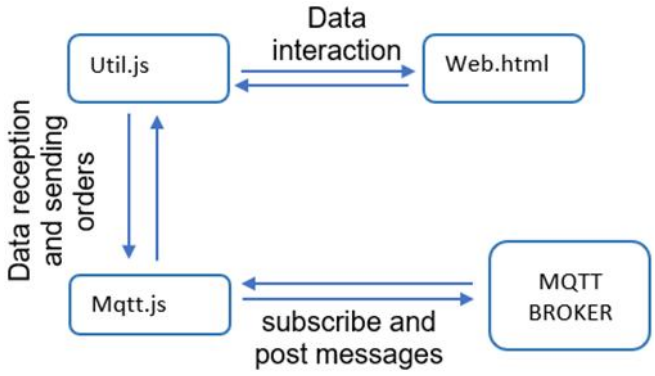


Figure 5: Data flow in the web system with MQTT

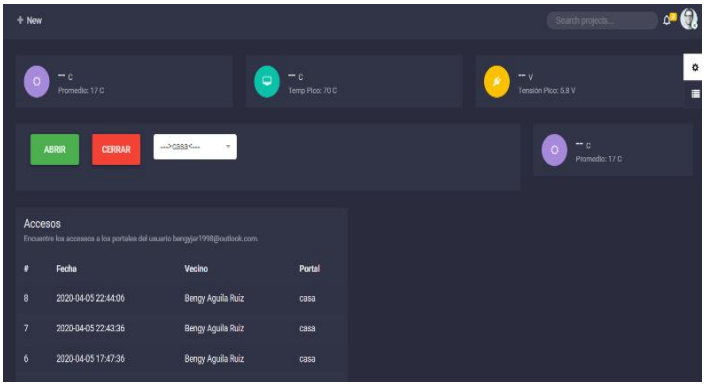


Figure 6: Domotic website

After having finished part of the system, we proceed to upload it via ftp, for this Atom installed the plugin remote-ftp then configure it to connect and upload all our files, this plugin was chosen because of how easy it is to use and the efficiency with which it works facilitating our work, also while maintaining the active connection can make changes in real time making it update almost instantly on our server.

As a second step we proceeded to the programming of the mobile application, for this we used the Visual Studio Code IDE and the dart language for the logical part, then for the interface we used Flutter resulting in a friendly interface application, the base application has a login interface, and different sections depending on the number of rooms, in the Figure 7 we can see the mobile application in the section of the bedroom, where you can turn on and off lights, measurement of temperature, humidity, among other more functionalities, also before the development of the application mentioned had developed another mobile application not very intuitive that was used as a basis for testing.

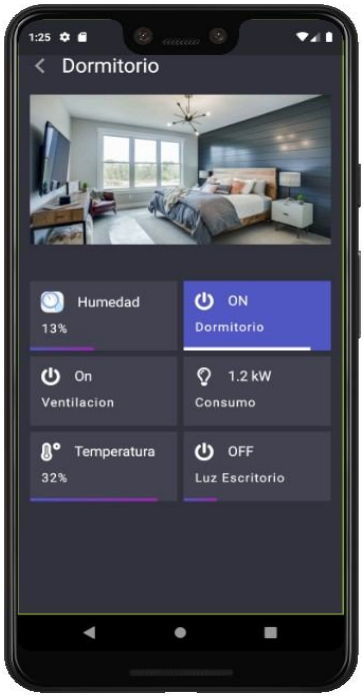


Figure 7: Interfaz de la aplicación móvil.

3.3 Programming and selection of hardware

It was considered appropriate to select a device with wireless connectivity, many of them use different connectivity such as WIFI, Bluetooth, Zigbee, Lora WAN among other protocols, in addition the device must meet our needs is why among the modules enabled for WIFI and can connect to the Internet, ESP8266 is one of the most popular in the open source community. The ESP8266 receives a lot of attention for its low price and features, including 2.4 GHz transceiver power [13], also integrate the TCP/IP protocol, so this device was selected to use mainly.

The programming of the device was done in the Atom IDE with its PlatformIO plugin which is an "Open Source" development ecosystem especially for IOT environments, the code was written in the C++ language where the MQTT library was integrated and others to make the communication with our website and mobile application, In addition, a unique identifier per device was entered in the code, as well as the user and password of our WIFI network to connect the device. Therefore, the domain, port, user and password must be configured to connect to MQTT as shown in the Figure 8 where I show part of the code with the configurations made, later the codified was uploaded to our microcontroller which was connected to our computer through a micro USB cable using the computer port.

```
#include <Arduino.h>    //Libreria
#include <ESP8266WiFi.h>  //Libreria
#include <PubSubClient.h> //Libreria
#include <SPI.h>      // incluye libreria bus SPI
#include <MFRC522.h>    // incluye libreria especifica para M

const String serial_number = "123456789";

#define RST_PIN 0 //D3      // constante para referenciar pin
#define SS_PIN 2  //D4      // constante para referenciar pin

MFRC522 mfrc522(SS_PIN, RST_PIN); // crea objeto mfrc522 envi

const char *ssid = "usuario";    // mi usuario
const char *password = "clave"; //Mi clave


const char *mqtt_server = "proyectosiotbjar.ga"; //Mi dominio
const int mqtt_port = 1883;           //Puerto
const char *mqtt_user = "web_client";
const char *mqtt_pass = "1212123";
```

Figure 8: Part of the device's main code

3.4 Testing and operation of the system

This section describes the simulation of the data flow to carry out the processes involved in the project. We start with the development of the entrance to a house through an Rfid card, being monitored at all times and having to give permission for the entrance to the house.

An esp8266 was used as the base microcontroller and in addition to an electronic lock and the RC522 RFID reader module, this radio frequency identification (RFID) module contains electromagnetic fields to identify and track the card connected to objects [14].

The electronic connection diagram and the process flow shown in Figure 10 are then displayed in Figure 9 for better understanding.

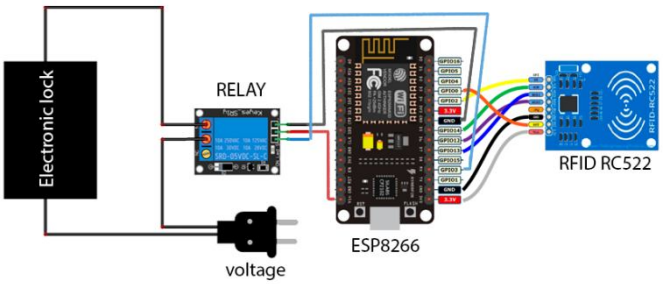


Figure 9: Illustration of the connection diagram

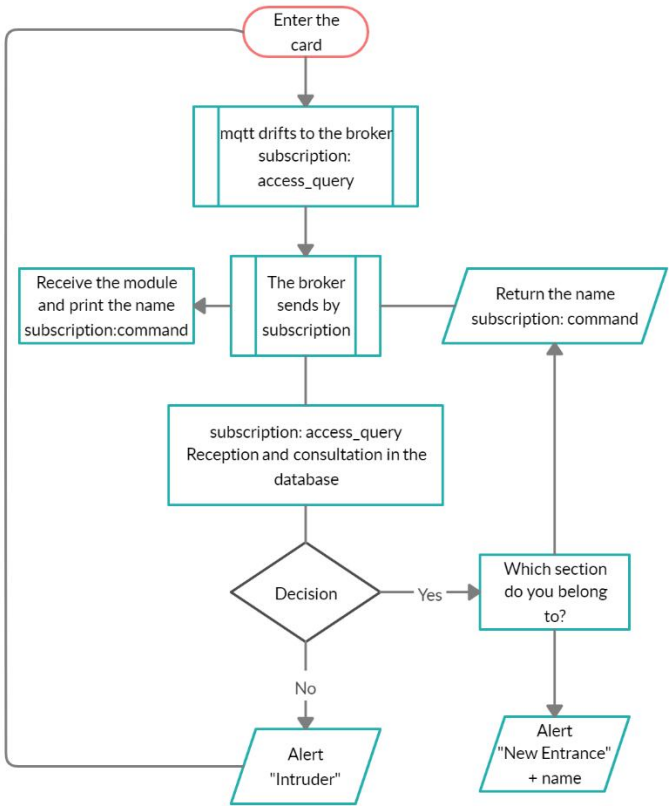
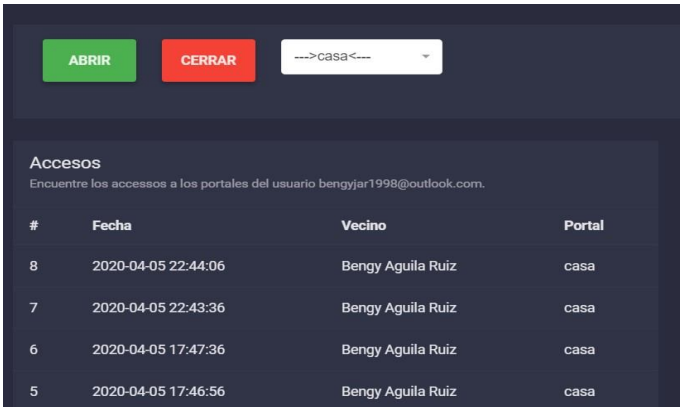


Figure 10: Illustration of the data flow

The diagram in figure 5 represents the data flow of the access process to the house, in this case MQTT derives the data by subscription, that is, every device that is subscribed to a



particular topic, will receive and can send information by means of message publication, which is how MQTT manages its protocol, Once it is confirmed that the user exists and that the entry was registered in the database, then it sends an alert to the system and it returns the name of the user, in addition another person will decide through the panel whether to open the door or not, to perform the action must press a button from your cell phone or web as shown in Figure 11 without the need to stand up, for an invalid person, this would be a very useful solution since without this solution then he would have to make a great effort.

Figure 11: Illustration for opening the door and the entry registers.

Continuing with the project, in this section we made tests with the automation of the turning on and off of a light bulb, besides the measurement of humidity and temperature of the environment where the device was installed.

For the development of the process as a motherboard is being used the esp8266, we also used the DHT11 sensor, also used a relay and a switch, all these devices were joined to give way to a solution, as it is well known many times we are lazy to get up and move to turn off the light, then this is how this process was born, also measured the temperature and humidity of the environment that can later be synchronized with a heater to make our environment more pleasant and warm.

Below is the connection diagram of our solution in Figure 12 and 13

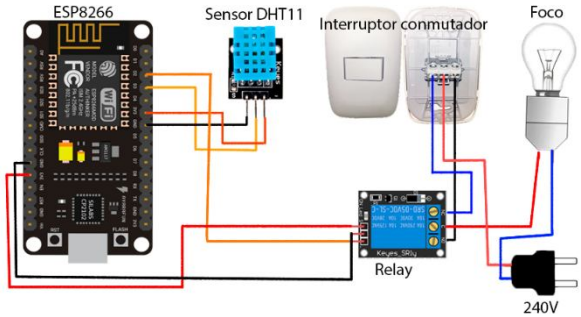


Figure 12: Connection diagram

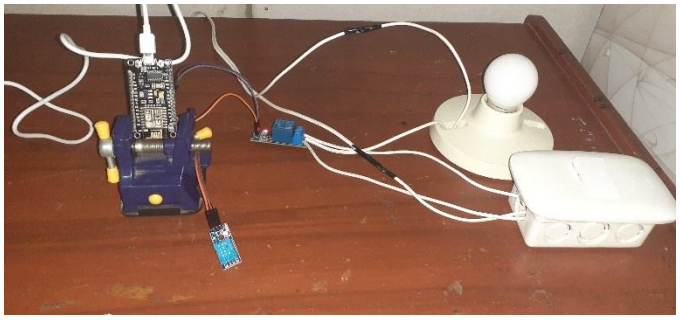


Figure 13: Connection diagram implemented

The esp8266 will connect to our WIFI network and will subscribe to designated topics, where our Broker will send the data to the devices subscribed to the same topic, in this case a basic app was used as a demo and test run, the app can be seen in Figure 14, in this the user will visualize the temperature and humidity of the environment, also there is a button to turn off the light without getting up.

The switching function works in the following way, the user can turn off the light from the cell phone, but also from the switch, if the light is off then with the switch we can turn it on, but also turn it off from the cell phone, it doesn't matter which state it is in, as long as we press the button or switch we will change the state of the light

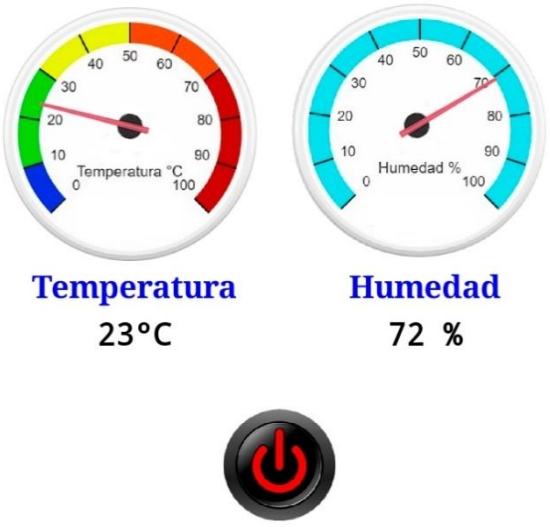


Figure 14: Mobile test application.

As the project progresses, more automations will be implemented that will make the user's life easier, such as detecting gas leak in a home, watering the garden automatically or programmed, opening the blinds, detecting intruders when no one is home, these and many other solutions can be implemented, also over time the project can be applied at an enterprise level, implementing a set of sensors that provide solutions and automate processes that are required.

4. RESULTS AND DISCUSSION

4.1 About the Case Study

As a case study, the IOT system was properly developed using different tools and following the structure of the Kanban methodology.

As a first comparison, we investigated a work about a surveillance and control system of electronic devices based on IOT [15], this work takes the control of the electricity consumption of lanterns, besides automating the process of the on/off of the same, these processes are monitored from a web interface, In both cases the communication is done by MQTT through WIFI, as a master device they use a raspberry pi and an esp8266 as a slave, all the data is stored at server level in the cloud, this project is very innovative in addition to providing knowledge and automating processes.

The project mentioned covers the distance of internet connection, therefore they used a raspberry pi which is placed near a streetlamp by means of wiring and where the slaves are connected to it or also the direct connection, in comparison to our project which for now is directed more at home level therefore we use direct connection by WIFI, In addition we take for granted that the WIFI network reaches every part of the home so we do not use a master device for now, adding that we cover more services than him and that in the future in both projects we will implement more services or solutions that will give more value to our work.

As a final comparison we investigated a work about an intelligent home automation system based on Arduino [1], this work developed as an example a system for measuring temperature and humidity which is connected to a computer through the serial port and through a software developed in C #, by pressing a button performs the action of measuring and storing data in a SD memory, this work is based more on explaining the different types of communication Arduino in addition to taking into account the radiation of each device and care of the environment, the latter is very important and we must always keep in mind the care of our environment.

Compared to the above mentioned with our project, we do not address the issue of radiation, we only focus clearly on the development of the project, something that I highlight and that is important, is to facilitate and meet the needs of the home, so opt for a communication with the MQTT protocol through WIFI which connects to the Internet facilitating communication from anywhere in the world, compared to the project mentioned that uses communication by serial port, in addition to being at the local level, it would use a lot of wiring for an automation, of course this depends on many factors and requirements.

4.2 About the Methodology

It is considered important that for the development of a project we must follow an order, that is why in the project the agile methodology Kanban was applied, where it was divided in different stages developing them successfully using different tools and technologies that facilitated the development and cost of the project, in addition good practices were used as it is the architecture MVC, therefore, in each stage it is explained with diagrams and images what was developed during the project.

As a first comparison regarding the methodology used in the project of the surveillance and control system of electronic devices based on IOT [15] and our project, it can be said that in his project he has not used an agile methodology or development methodology ,mentioning that it is not a requirement to develop an investigation, besides he has divided his project in two categories covering one the problem of the other, also he explains in detail with diagrams and images.

As a final comparison as far as the methodology used in the project of an intelligent home automation system based on Arduino [1] and our project can be expressed that it has not used a development methodology, but it is well structured except for the title that does not agree much with what was developed, it is based more on explanation than on the development of the system

5. CONCLUSIONS

In this work as a first conclusion we can say that developing a system with agile methodologies specifically if it is in a small group of people, a good option is Kanban as used in this work, as a second conclusion we can say that we can make a basic IOT home automation system at very low cost and we can implement it in homes, also as a final conclusion we can say that with a home automation system we can automate processes that we commonly perform such as standing up to turn off or turn on a light bulb, in this case automating the process, this would be done from a mobile phone or web page, also adding that we can automate many other processes as the case may be, it is worth mentioning that the human being always seeks to make the least effort possible to a task or action, this is how this project was born and how many technologies will be born that will make our lives easier.

It is convenient to mention that in the future this project will cover the topic of IOT without internet connection, that is to say, in a local way. The project can also be expanded in the way of providing process automation services in different areas such as agriculture, livestock, etc.

REFERENCES

1. D. Chioran and H. Valean, “Arduino based Smart Home Automation System A Simple and Efficient Serial Communication Method,” vol. 11, no. 4, pp. 67–73, 2020. https://doi.org/10.14569/IJACSA.2020.0110410
2. M. Barrera Durango, N. Londoño Ospina, J. Carvajal, and A. Fonseca, “Análisis y diseño de un prototipo de

sistema domótico de bajo costo," Rev. Fac. Ing., no. 63, pp. 117–128, 2012.
3. D. F. M. Sandoval and C. R. R. García, "Creación de un sistema domótico de seguridad y consumo energético para hogares: homenode," Universidad Santo Tomás, 2015.
4. P. A. C. de la Cruz, "Aplicación de Kanban en el desarrollo de un sistema web para administración del consultorio odontológico Fitoc Dental," Pontificia Universidad Católica del Ecuador, 2012.
5. J. G. Manzaba, "Aumento de la productividad en la gestión de proyectos, utilizando una metodología ágil aplicada en una fábrica de software en la ciudad de Guayaquil," Rev. Tecnológica ESPOL – RTE, vol. 27, no. 2, pp. 1–36, 2014.
6. M. J. Pérez, "Guía Comparativa de Metodologías Ágiles," Univ. Valladolid, p. 174, 2012.
7. K. Kang, J. Park, S. Hyoung, and J. Y. Oh, "(12) United States Patent," vol. 2, no. 12, 2014.
8. A. Fernández Suárez, "Desarrollo de una aplicación web para gestionar proyectos," Universidad de La Coruña, 2019.
9. L. S. Huang, A. Rice, E. Ellingsen, and C. Jackson, "Analyzing forged SSL certificates in the wild," Proc. - IEEE Symp. Secur. Priv., pp. 83–97, 2014 doi: 10.1109/SP.2014.13.
10. A. Trueba Espinosa, J. Camarena Sagredo, M. Martínez Reyes, and M. López García, "Automatización de la codificación del patrón modelo vista controlador (MVC) en proyectos orientados a la Web," Cienc. ergo-sum, vol. 19, no. 3, pp. 239–250, 2012.
11. F. Moreno Cerdà, "Demostrador arquitectura publish / subscribe con MQTT," 2018.
12. G. J. G. Vásconez, "Diseño e implementación de un sistema de adquisición de señales ECG en tiempo real utilizando la tecnología long term evolution (lte)," Universidad Nacional de Chimborazo, 2019.
13. Yoppy, R. H. Arjadi, H. Candra, H. D. Prananto, and T. A. W. Wijanarko, "RSSI Comparison of ESP8266 Modules," 2018 Electr. Power, Electron. Commun. Control. Informatics Semin. EECCIS 2018, pp. 150–153, 2018, doi: 10.1109/EECCIS.2018.8692892.
14. U. Koppikar, S. Hiremath, A. Shiralkar, A. Rajoor, and V. P. Baligar, "IoT based Smart Attendance Monitoring Systems using RFID," 1st IEEE Int. Conf. Adv. Inf. Technol. ICAIT 2019 - Proc., pp. 193–197, 2019 doi: 10.1109/ICAIT47043.2019.8987434.
15. A. K. Gupta and R. Johari, "IOT based Electrical Device Surveillance and Control System," Proc. - 2019 4th Int. Conf. Internet Things Smart Innov. Usages, IoT-SIU 2019, pp. 1–5, 2019 doi: 10.1109/IoT-SIU.2019.8777342.