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Cloud-based RFID access control using lightweight messaging protocol

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***Abstract*— *This article describes the development of an access control with online monitoring based on radio frequency identification (RFID) technology. Access time and date together with user tag code are sent to an online database. The entire process of identification and registration is done by a PIC microcontroller and an embedded Linux system (Raspberry Pi), that by having communication with the Internet updates a database table with the access information. The table with the data can be accessed from any computational device Internet connected. For improving the system, we implement a new version using only the Internet of Things (IoT) module ESP8266 that has a low cost and various peripherals. All information about tag actions is displayed for the user on an LCD display and each action is signaled by a specific beep.*

Keywords*— *Internet of Things; Radio Frequency Identification; Monitoring.

I. INTRODUCTION

The search for profitability, through the rationalization of processes, influences companies to know new technologies and methods of improvement. Radio Frequency Identification (RFID) "is one of those rare technologies that ‘change the world’, which will force a reconsideration of many strategies in the value chain" [1].

The concept of radio frequency identification that has recently been used for various industrial applications [2] has received a great deal of attention from researchers [3] and is gaining more and more space in the world, growing exponentially in recent years. RFID labels have a low cost and can be placed on goods, vehicles or any object that needs to be monitored [4].

Based on this principle, a people monitoring project was developed based on radiofrequency technology, where each user has an identification tag that can be registered in the system so that monitoring can be performed.

When registered tag is identified, the information is automatically sent to a local and an online database, together with date, time and the tag code, so that you can keep track of the time of entry and exit of each user.

II. BIBLIOGRAPHIC REVIEW

Currently being connected to the Internet is much more than simple connectivity and messaging. The biggest network in the world is open and people are constantly adding things to it and it is only natural that they want things to interact in a slightly automatic way [5].

Internet of things (IoT) is much more than just connecting light bulbs through the smartphone. It is not just connecting "things" over the Internet, but also making them smart, capable of collecting and processing information from the environment or the networks to which they are connected. The Internet implementation of things is totally changing the way we relate to the things that are around us, transforming security, energy, environment, traffic, mobility and logistics.

The first technology associated with the IoT concept is known as RFID (Radio Frequency Identification). RFID is a device that sends, by radio frequency, a unique identification. Today it is used in badges, vehicles and products in supermarkets, replacing other types of identification, such as the bar code. It is a technology that emerged in 1940, with the electronic communication devices (transponders) used in the planes of World War II, with the function of identifying other airplanes around. Its purpose is to transmit a code identifier by a radio frequency channel that can be associated with an object [6].

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Radio frequency identification (RFID) has been widely discussed in recent years in business, academia and the media. Several companies have been developing RFID initiatives to identify the possible applications of this technology and to map the benefits derived from its use.

Today, the Internet is an expression in the media for presenting a twist in the environments, transforming them into intelligent environments by bringing together a network of forward components, such as software and sensors, that collect and exchange data between themselves and with the user.

For its operation, the elements are identification technologies for objects, such as the already mentioned RFID and two-dimensional codes (QR code, a bar code that can make the same settings, which are then directed to websites, videos, in addition to using sensors to get information on how objects are.

They are also important: a performance of objects connected to the transmission of data in a safe way; cloud computing, and other intelligent computing, data processing and analytics technologies [7].

IoT adds the power of connecting anything to the Internet and communicating with everything. According to [8], the term "is defined as the extension of the Internet in the physical world, making possible the interaction with objects and the autonomous communication between objects". When thinking about its operation in practice, its resources extrapolate the use through physical devices, such as cars, clocks and smart TVs, being present in the most diverse services, as in banks, with technologies that facilitate purchases by approaching one cell phone. The power of connecting the real and the virtual, making static objects dynamic, incorporates intelligence into the environments of our conviviality.

According to [6], the presence of this phenomenon daily becomes frequent due to several technical factors: the RFID sensors and systems are more accessible; wireless networks are expanded; there is a wide variety of data analysis platforms with different characteristics; the evolution of sensors; the storage of information in the cloud and increasingly faster data analysis algorithms.

This [9] aims to find good logistics and management practices for the electricity generation authority. In the survey was used RFID placed on lignite coal trucks where the RFID data passes through a server and is stored in a private cloud. To perform the research, we used an RFID reader, passive UHF RFID tags, an Arduino Mega 2560 with Ethernet shield, PHP, Node.js, Jason, and for the Database system was used the Maria DB, and the protocol used was MQTT. The System is designed to operate 24 hours a day and 7 days a week.

In another paper, proposed by [10] a system of automatic detection of vehicle registration is proposed, where RFID tags are used to identify vehicles with MQTT protocol for the transfer of data from one system to another. The System is divided into two parts being transmitter and receiver, where an RFID tag is placed on the vehicle and there is a checkpoint for the reader, while the fingerprint module is placed on the vehicle where it is used to verify the authenticated data.

In another project, proposed by [11] an adjustable RFID Security System is created using IoT modules and sensors. The system basically consists of the security of devices equipped with RFID tags where through a smartphone the user can write the information of the device in the RFID tag and the computer of the module of the sensor that is directly connected to the tag can also read the information and use it, as an MQTT topic.

In the work proposed by [12] a System is created thinking about the problem of baggage loss at airports, where the System consist of the use of RFID tags. These tags are placed in the suitcases of passengers where each tag has passenger information and this informations can be accessed at a distance using the IoT principle.

In the work proposed by [13] an IoT system is made for monitoring, data acquisition and remote monitoring of cloud-based sensors. It is a very versatile system because it allows the addition of more sensors only making some small changes in the source code which is available for modifications. The System also has an alternative storage option, in which when the system is offline it avoids the loss of information. The user can query the data storage in a graphical way and the system still provides several search modes to facilitate and provide greater precision for the sensor monitoring.

In another work [14] a system for data acquisition using the concepts of IoT is developed. The system monitors the environment by means of sensors where a photovoltaic solar module is located. From the monitoring, generated voltage, ambient temperature and incident data are collected for a cloud server through the MQTT protocol.

In [15] a low-cost retro gaming system using a Linux Raspberry Pi system was developed. The system can be easily configured by beginners in the area of computing and electronics, as well as used for didactic tool. The system also has an ESP8266 module to count the coins inserted in the arcade and the data is stored in a database, constituting the principle of IoT.

In [16] a system for controlling students in a school was proposed. The system consists of using RFID technology together with the Linux system based on Raspberry Pi + where the system proposal is to have a greater frequency control of the students generating monthly reports of the students frequency. Each student has a tag in which this tag contains the information about it.

In [17] it was proposed a system to control the flow of people in a school environment using RFID. The basic

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idea of the system is radiofrequency identification technology, highlighting the development of a people flow control application that demonstrates the feasibility of an RFID system and explains how this technology can be inserted simply in institutions. In order to prove and exemplify the potential use of this technology, an experiment was conducted managing the entry and exit registration of students in a school environment.

In the work proposed by [18] a Raspberry Pi was used, a tagged RFID reader containing the tag identifications for the monitoring of swimming activities. The work consisted of designing a prototype to track swimming practice using RFID technology and the Raspberry Pi to process swimmer training information. A functional test was performed to verify the behavior of the use of these technologies in the swimming activity in a swimming pool. With the tests performed it was observed with the results, to be an efficient way of monitoring swim training, since it does not need to be a present person to record the time values of each lap, providing in an automated way the calculation of time of each lap. In addition, to obtain a complete analysis with the values of average speed, number of laps, average time and distance covered in the training.

In the proposed work, a system was developed for the online monitoring and control of people using RFID technology where they send information to an online database containing information such as the tag number and the date of registration. The table with the data can be accessed from any place because of the creation of a web site for such a query, the whole process of identification is done by a Linux embedded system based on Raspberry Pi where it has access to the Internet and updates a bank table with the information sent online and compared to ESP8266. All information about tag actions is displayed on an LCD display.

In Table 1 we show a summary of the works previously mentioned aiming at comparing with the proposed project.

Table.1: Comparative table of the projects cited.

Reference	Microcontroller	Protocol	RFID	Application
[9]	Arduino Mega 2560	MQTT	Yes	Solve the problem of coal mine logistics management Power Generation Lignite Authority of Thailand (EGAT) Mae Mao, Lampang.
[10]	Arduino UNO	MQTT	Yes	Vehicle plate detection using RFID and the MQTT protocol.
[11]	Not used	MQTT	Yes	Adjustable security system for RFID devices connected to the Internet for industrial environments.
[12]	Not used	Not used	Yes	Airport baggage screening system.
[13]	Raspberry Pi, PIC 18F2550	Not used	No	Versatile things Internet system for cloud-based sensor monitoring.
[14]	ESP8266	MQTT	No	The system monitors the environment in which a photovoltaic solar power module is located and sends the generated voltage data, ambient temperature and incident light to a server through the cloud
[15]	Raspberry Pi B +, ESP8266	Not used	No	Creating a retro game using Raspberry Pi.
[16]	Raspberry Pi B +	Not used	Yes	Frequency monitoring and verification of students in a school by using RFID technology
[17]	Not used	Not used	Yes	Flow control of people.
[18]	Raspberry Pi	Not used	Yes	Monitoring Swimming Activities.
Proposed Project	ESP 8266, Raspberry Pi B +	MQTT	Yes	Monitoring and authentication of people.

III. DESCRIPTION OF THE FIRST STAGE COMPONENTS

In this topic the components and embedded systems used for the development of the first stage are described.

Through the SanUSB development system, which is a tool composed of basic software and hardware of the PIC18Fxx5x family with USB interface, it was possible to carry out the project. The applied version uses PIC18F2550. This tool allows the compilation, burning and emulation of a program quickly and efficiently from the moment the microcontroller is connected directly to a computer via USB [19]. There are many projects that use

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SanUSB tool microcontroller board (Figure 1) as can be observed in [20].

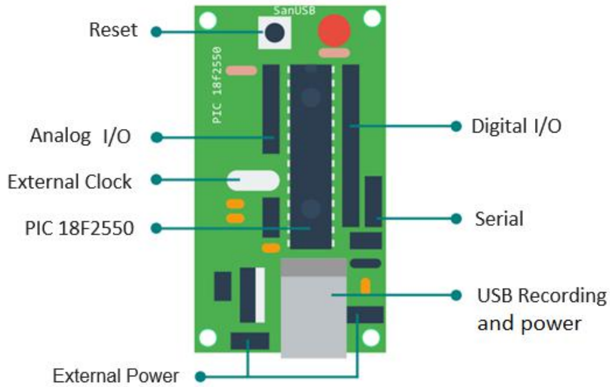

Fig.1: SanUSB tool (PIC18F2550).

The Linux embedded system based on Raspberry Pi also called RPI is a minicomputer created by the Raspberry Pi Foundation for the purpose of applying it in the area of education and for scientific initiation in computer science. RPI is suitable for systems because it is cheaper than an entire network of closed-circuit cameras and a computer system to run them. It is small enough to be installed in a location for monitoring and because it is also connected to a home network, which can alert you when something is wrong [21].

This device has reduced hardware and software factors, greater flexibility and lower cost compared to a personal computer. It is small, inexpensive, educational, and it is a mistake to describe it as only a plug-and-play device, since it is not considered a consumer device [22].

In relation to the connection to the Internet, it can be in two ways: wired network, because it has a standard Ethernet RJ45 port; or, over WiFi with an external USB dongle. The HDMI port provides digital audio and video output, making the system appear on any monitor it is connected to.

The General-Purpose Input/Output (GPIO) pins are the programmable ports of the Raspberry Pi and responsible for communicating incoming and outgoing digital signals. Pins are a physical interface between RPI and developers. Even offering a wide range of possibilities that allow the development of projects, the device does not use the digital logic system (TTL), with logic level 5V. Since the RPI has its own 3.3V logic system and does not have this protection system, improper handling by applying higher voltage to the doors can damage it, such as burning the board or a short circuit in one of the pins [23].

IV. DEVELOPMENT

In the following subtopics we have the description of the stages for the development of the project.

4.1 Tag Archives RFID System Operation

The basic idea of radio frequency identification technology is to use a static electromagnetic inductor reader and a mobile microchip with antenna, which can operate in both the order of KHz and MHz. This mobile microchip consists of a transponder or tag that does not need of the power supply, since the signal that excites it comes directly from a reader-inductor circuit that can also be used for recording. Upon being excited, the mobile circuit is powered by sending or receiving data that is recorded [24].

One of the working principles of RFID technology is electromagnetic radiation, which is defined as being waves of electrical and magnetic energy that are radiated together through space and, by radiation, the propagation of energy through space in the form of waves or particle [25].

A small part of the emitter field interacts with the transponder antenna coil, which is a certain distance from the reader coil. By magnetic induction, a voltage is generated on the transponder antenna coil. This voltage is rectified and serves as the power supply for the microchip. A capacitor is connected in parallel to the reader's antenna coil. The capacitance is selected so as to match the inductance of the antenna coil to form a parallel resonant circuit, i.e. to obtain a resonant frequency corresponding to the frequency of the reader transmission, the illustration is shown in Figure 2.

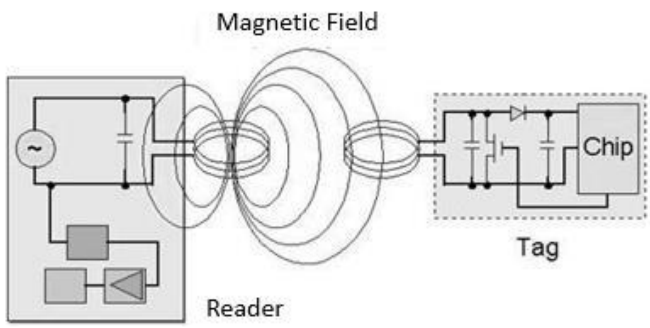

Fig.2: Principle of inductive coupling [26].

The RFID tag has 14 bytes of data, this way the first byte 02H to determine the beginning of the tag, the next 10 bytes referring to the characters of the ASCII table are referring to the identity of the tag and are unique, then the

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checksum which is the checksum of all 10 bytes of data and finally the byte containing 03H to determine the end of reading of the RFID tag as indicated in the datasheet and shown in Figure 3.

TTL Interface RS232 Data output format

1. 9600bps,N,8,1
2. CHECKSUM: card 10byte DATA entire do XOR operation

02	10ASCII Data Characters	Checksum	03

Example: card number: 62E3086CED
Output data:36H、32H、45H、33H、30H、38H、36H、43H、45H、44H

CHECKSUM: (62H) XOR (E3H) XOR (08H) XOR (6CH) XOR (EDH)=08H

Fig.3: Data Format [27].

4.2 Circuit Operation

The hardware is divided into two parts, the RPI is responsible for reading the RFID tag serially and activating components such as relay, LED and buzzer. The 18F2550 microcontroller is responsible for the LCD display, where messages are displayed according to information received from Raspberry Pi. Communication is done through the serial port with a transfer rate of 9600 bps.

Using the Raspbian operating system it is possible to perform audio with synthesized voices indicating each action of the system as: 'Tag not registered', 'Tag recognized', for greater assimilation of the actions that is happening.

The system is divided into parts. Serial reception and tag filtering are in a specific task for this use. The online posting of the data is in an infinite loop, in this way, the processes of identification and posting are independent, making the system work more smoothly, since it is not necessary to wait for the post to recognize a new tag.

With the use of multitasking programming it was possible to recognize numerous tags quickly. There is an infinite loop responsible for posting without interfering with reading. This approach was relevant to the best practical operation of the system.

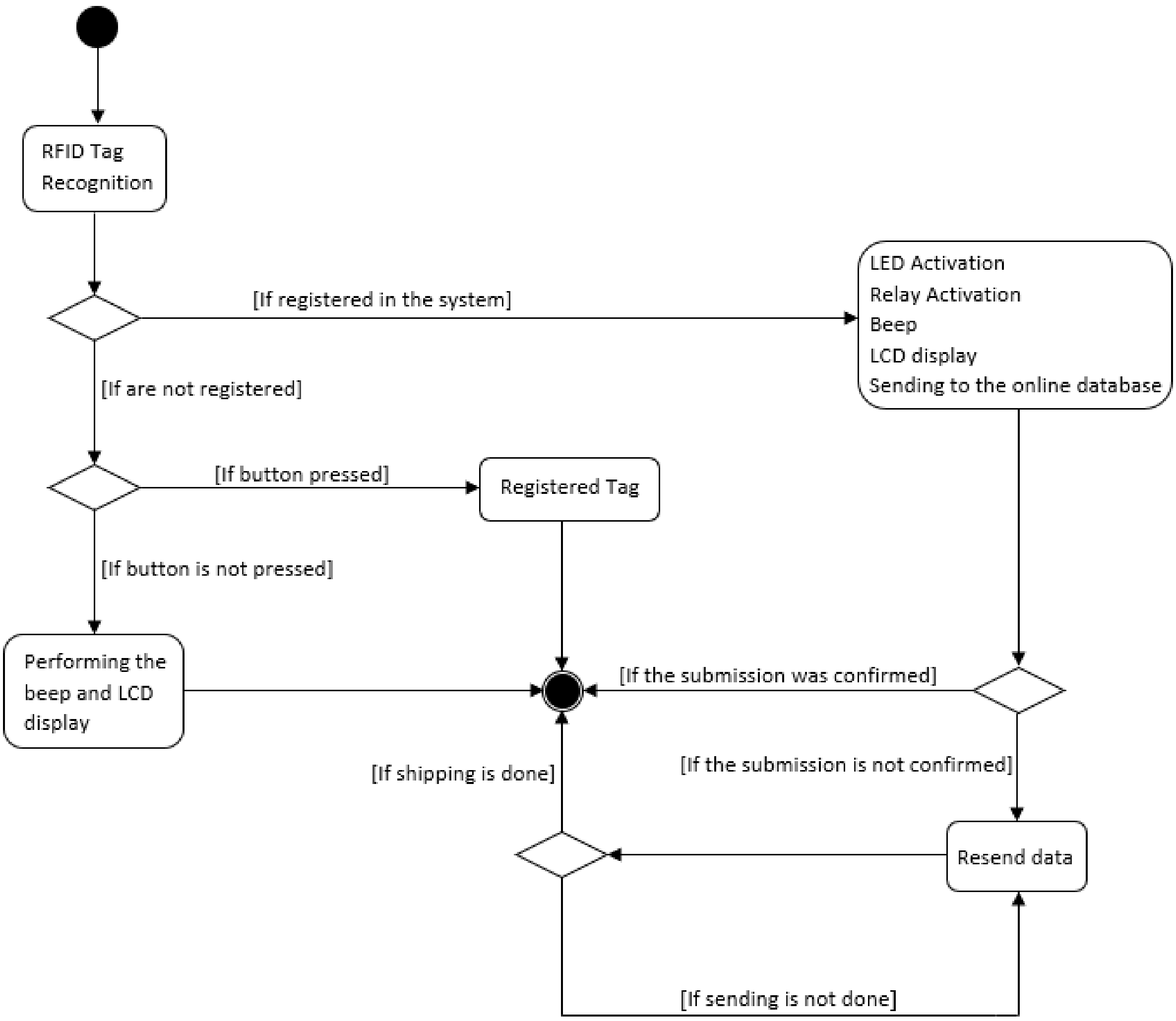

Fig.4: Identification Process Flowchart.

Initially, the RPI receives 14 bytes referring to the tag by the serial input, from the information, options can be executed as described in the topics below.

For the registration to take place, the tag must not be previously registered, and the record button must be pressed. Upon receiving the tag data, the system compares with the data already registered. If the comparison returns true, the registration cannot be performed, and a beep will be given, informing the event. If it returns false, the registration is performed and automatically the number corresponding to the new tag will be created, followed by actions such as activating the acknowledgment LED, beep indicating that the tag has been registered and finally a message on the LCD display.

If the recognized tag is not registered in the database, a beep will be sent indicating the event as well as a message on the LCD. If the tag is registered, the LED alternates the illumination according to the tag number, the relay is activated, a beep is emitted indicating that the tag has been successfully recognized together with a message on the LCD display. Finally, the tag number, the date, the time and the name of the user are sent to a database.

If there is a failure to communicate with the online database and it is not possible to send the data correctly, then the systemstores the tag number that was not posted and continues the posting process until it is done correctly, so problem with internet crash, for example, does not disturb the operation of the circuit. The steps of the operation are exemplified in the flow chart available in Figure 4.

4.3 First Stage Results

Raspberry PI B (1), microcontroller, LCD display, RFID reader, buzzer and relay shown in Figure 5 were mounted in a plastic case (2).

Fig.5: Complete System.

Based on the IoT principle, information such as date, time, and user number are automatically sent to the cloud on any server. The application in question used the storage of data initially in Google Drive.

4.4 Second stage: ESP8266 IoT module

The platform used for the development of the project was composed of an ESP8266 microcontroller that contains a 32-bit microprocessor with support for Wi-Fi connection, as well as power and programming ports - 10 digital inputs and one analog [28].

Because it was developed with a focus on mobile devices, wearable electronics and IoT, the ESP8266 has a very low power consumption, ranging from 10uA when in sleep mode and reaching a maximum of 215mA when it is operating at its maximum capacity, being able to operate in three modes: active, sleep and deep sleep.

The operation of the proposed system with the ESP8266 is like that used in Raspberry Pi, the reading and registration of the tag continue following the same reasoning. The reader of this version has a frequency of 13.56 MHz that allows, for example, the reading of student portfolios used in urban transport systems.

The date and time value are required for posting the data, but the ESP8266 module does not have an internal clock for checking this data. Initially the time was obtained from an online server that was requested whenever a tag was recognized. This method showed that since the internet connection is not stable, it takes a long time to recognize the tags. Thus, the solution used was to synchronize the time and date with an Internet NTP server only once a day, and to use interrupt of a software-emulated ESP8266 internal timer to perform the time counting, thus eliminating the need of Internet connection for this purpose, thereby increasing the stability of the embedded system.

In this step, there was also an investigation to solve the problem of scalability, so now the data is stored on a platform called Firebase provided by Google, which is a non-relational database that stores the data in the cloud. Data posted to Firebase is subdivided by user number, followed by the date and time the tag was recognized. It is worth noting that scalability is performed when a new tag is registered, because when inserting a new user, a new structure is automatically created in the database for that user.

To carry out the project was designed and built a hardware composed of components such as: ESP8266, Buzzer, Led, Relay, Transistor BC337 and LCD display. The developed circuit is shown in Figure 6.

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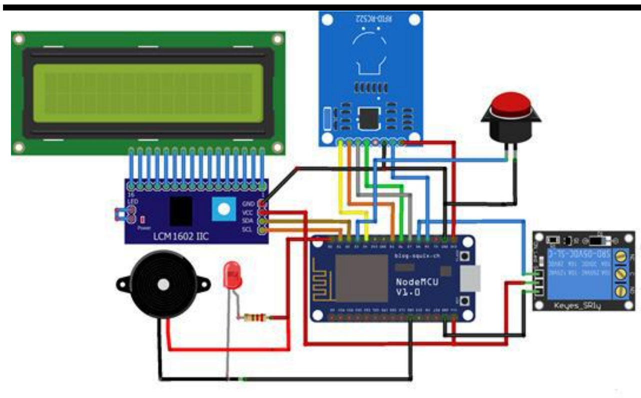

Fig.6: Circuit developed.

In this version, new features were increased due to the needs encountered during the testing period. Figure 7 shows a flowchart that best exemplifies the overall operation of the system.

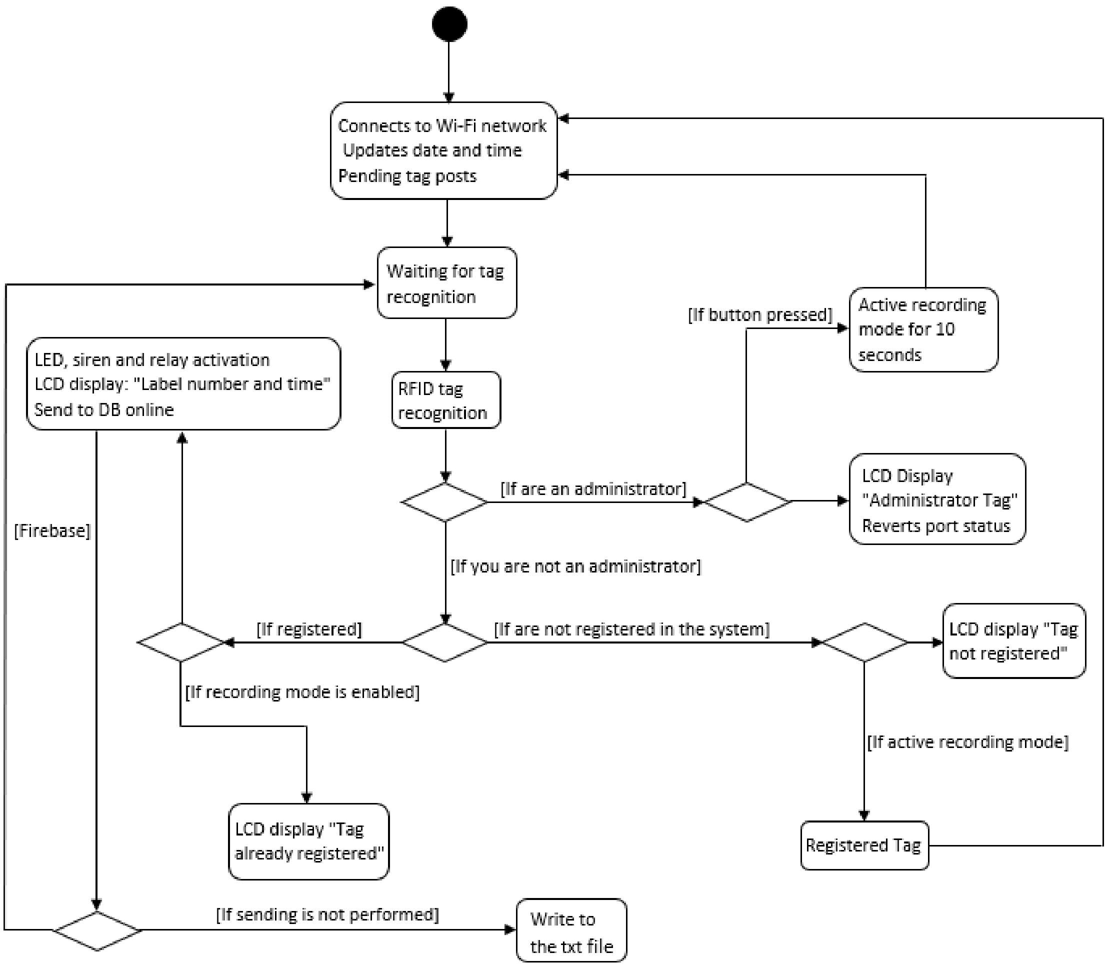

Fig.7: System Flowchart.

The system now has an administrator tag that can perform specific functions, such as: Tagging new tags and releasing or locking the port for a specific period. The tag registration has been modified with a greater security now, a new tag can only be registered when approaching the administrator tag and then pressing the button that is located at the top of the project. In this way, the system releases the register for 10 seconds, period to approximate a new tag to be registered, after this process will create a new structure in the online database Firebase.

One feature was to free the door of the environment for a period of 60 minutes when the system administrator approximates the tag due to the class period, where users who are not registered in the system have access to the environment only by pressing the button in the part of the system. It is noteworthy that in this mode, there is no user registration, there is only the port release for user access.

V. RESULTS

Aiming to minimize the final cost of the actual project, the 32-bit microcontroller ESP8266 was implemented

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replacing the embedded Linux Raspberry Pi B system, reducing around 70% of the final cost, which allows the replication of the project in other environments more economically.

Because RPI is a microcomputer and has a Debian-based operating system (Raspbian), it requires that the developed software be added as a process at system startup, a task that can be performed in different ways due to constant updates of the operating system and requires of periodic modifications, since the microcontroller, because it is dedicated to only one task, does not require configuration.

Tag data is stored in Firebase and is separated by user number, date and time as shown in Figure 8. It was developed a box with metallic material on the sides and acrylic on the front in order to obtain a resistant system encompassing all the components used, as shown in Figure 9.

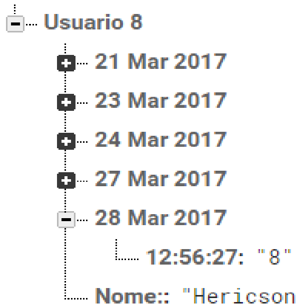


Fig.8: Cloud Data.

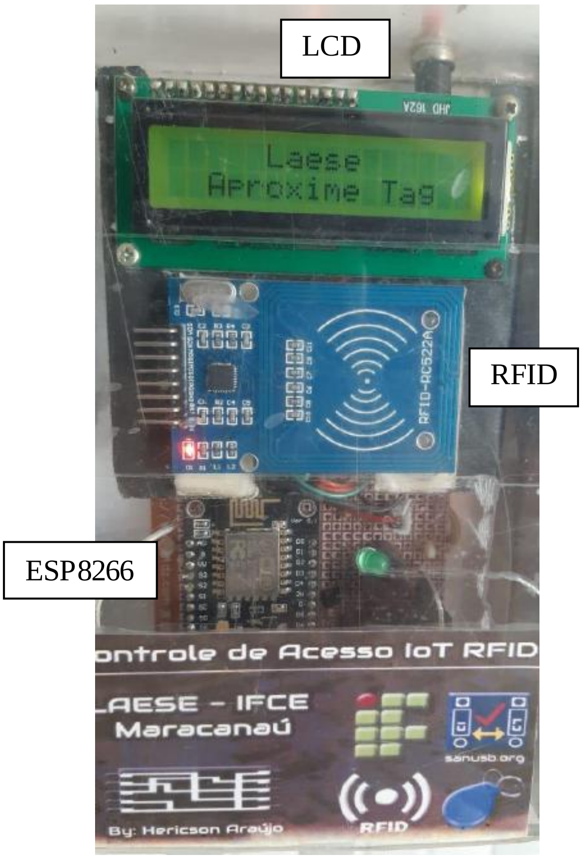


Fig.9: Developed System.

5.1 IoT Platform MQTT interface

In the subtopics below, we have a detail of each part of the site created.

In Figure 10 it is possible to observe the complete functioning of the created system. The figure is divided into sessions to better exemplify the system. In the first session "Client Slave" we have the process of collecting data where the data collection device detects and reads the tag and manages the transmission to the remote server. If the connection is not available immediately, save for later sending. In this operation a json object is sent. In the other "Server" process we have the MQTT listener service, this is a process that happens on the server, where the process is subscribed to the topic waiting for updates of the collection devices. Each received json is validated and entered into the database. Device queries to tag entries are also provided by this service. And finally, we have "Admin services" where we have the administrative panel which is an application modeled in MVC (Model, View and Controller).

MVC is an architecture or standard that allows you to divide system functionalities into layers, this division is performed to facilitate resolution of a larger problem. Where we have three basic layers, and each one of them, with its well-defined characteristics and functions.

The Model is used to manipulate information in a more detailed way, and it is recommended that whenever possible it is used of the models to perform queries, calculations and all the business rules of the system. It is the model that has access to any and all information coming from a database, XML file.

The view is responsible for everything that the end user views, the entire interface, information, regardless of its source, is displayed thanks to the view layer.

The Controller, as the name already suggests, is responsible for controlling the entire flow of information passing through the site / system. The controller that decides "if", "what", "when" and "where" should work. It defines what information is to be generated, what rules should be triggered and where the information should go, it is at the controller that these operations must be performed.

In summary, it is the parent that performs a business rule (model) and passes the information to the view. As well as the administrator can register tags, generate reports and monitor the functioning of the system. In this section we use backbone.js to prevent page refresh to display new data.

Figure 11 shows the users screen where we can register, edit, view and delete registrations, linking name to an RFID tag for later data crossing in the access reports.

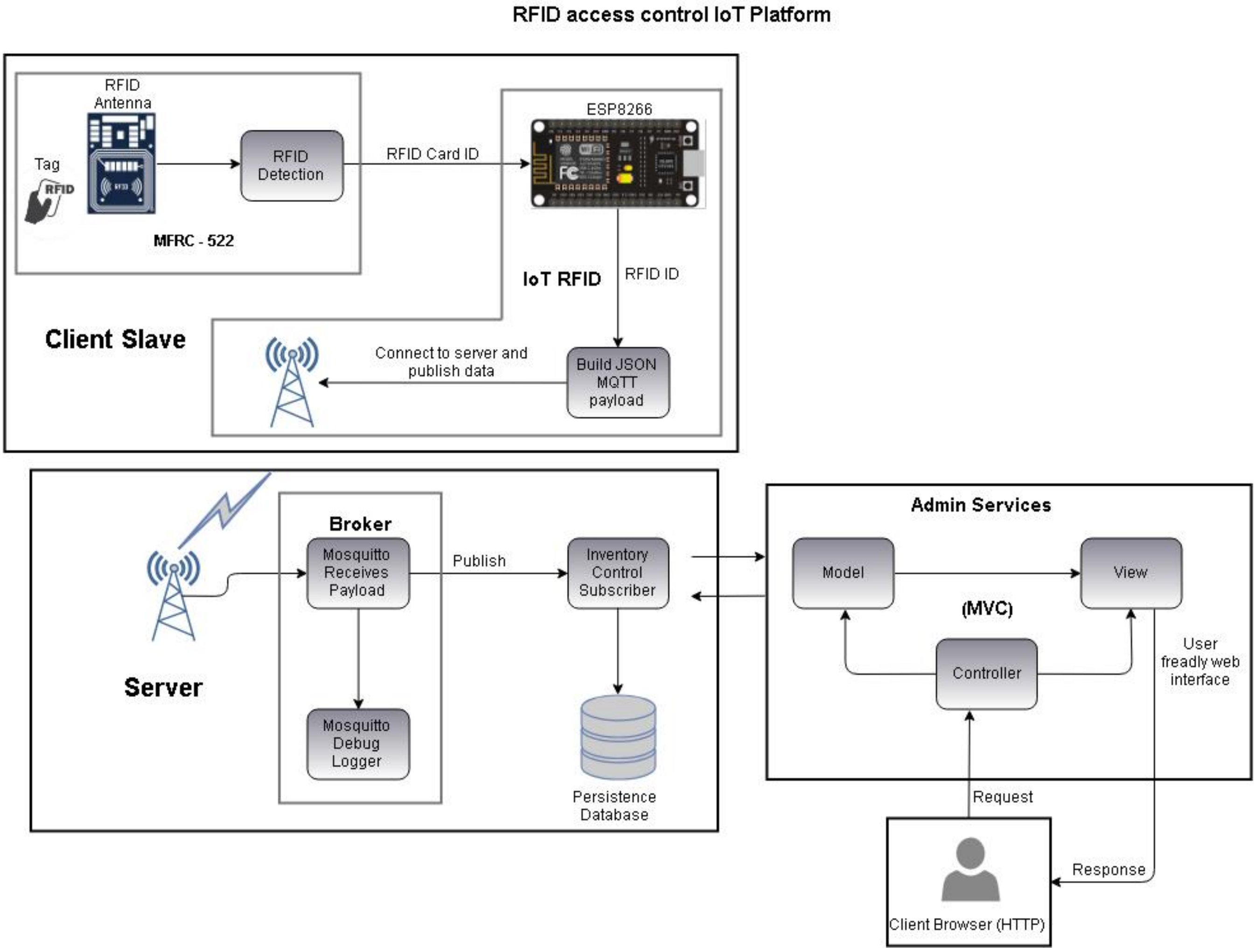
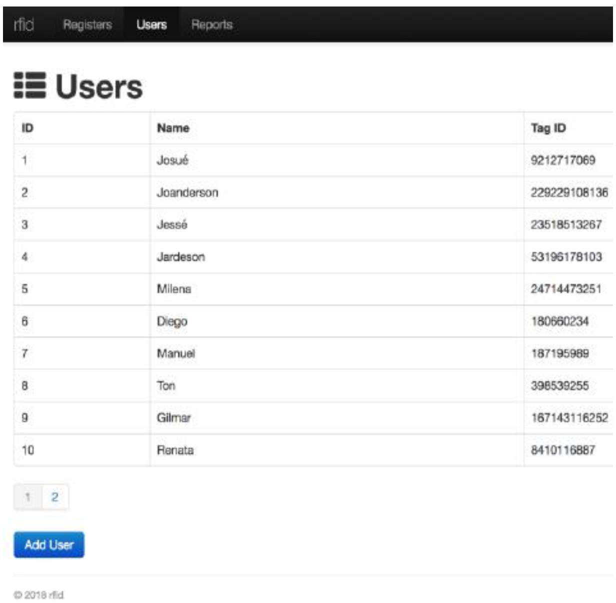


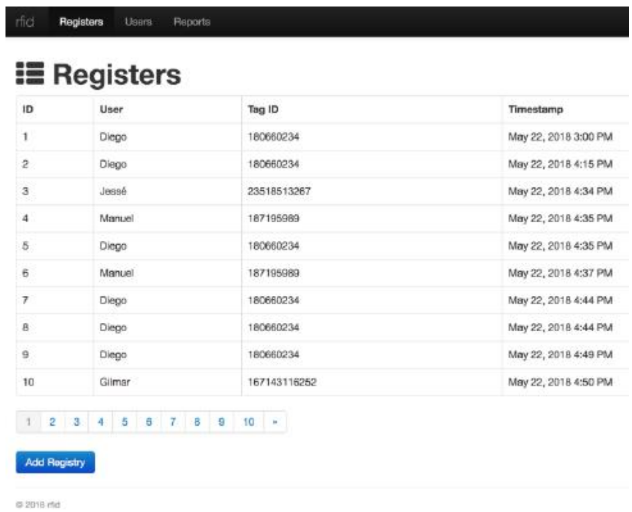
Fig.10: RFID access control IoT platform.



ID	Name	Tag ID
1	Josué	9212717069
2	Joanderson	229229108136
3	Jessé	23518513267
4	Jardeson	53196178103
5	Milena	24714473251
6	Diego	180660234
7	Manuel	187195989
8	Ton	398539255
9	Gilmar	167143116252
10	Renata	8410116887

Fig.11: Users Screen.

Figure 12 shows the logs screen, where we can include, edit, view and delete access records. The user name shown on this screen comes from the cross-reference of user data and is not editable on this screen.



ID	User	Tag ID	Timestamp
1	Diego	180660234	May 22, 2018 3:00 PM
2	Diego	180660234	May 22, 2018 4:15 PM
3	Jessé	23518513267	May 22, 2018 4:34 PM
4	Manuel	187195989	May 22, 2018 4:35 PM
5	Diego	180660234	May 22, 2018 4:35 PM
6	Manuel	187195989	May 22, 2018 4:37 PM
7	Diego	180660234	May 22, 2018 4:44 PM
8	Diego	180660234	May 22, 2018 4:44 PM
9	Diego	180660234	May 22, 2018 4:49 PM
10	Gilmar	167143116252	May 22, 2018 4:50 PM

Fig.12: Screen Registers.

In Figure 13, the screen of the last 10 accesses is shown. The update is performed via pooling, showing the tag and crossing the register to show the user name.

All screens use twitter bootstrap: 'backbonejs', 'underscorejs' and 'jqueryjs'. They update the data via pooling, making it not necessary to update using the F5 key of any of the pages to gain access to the latest data.

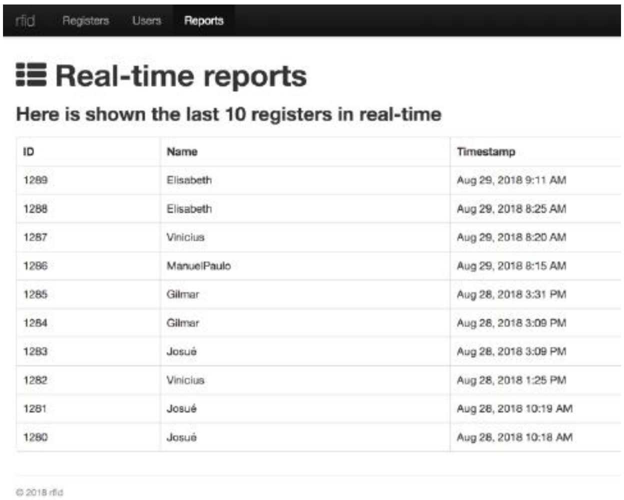


Fig.13: Screen Real-Times Reports.

In Figure 14, an example of user editing is shown. This screen is refreshed by clicking the user. User and records allow editing.

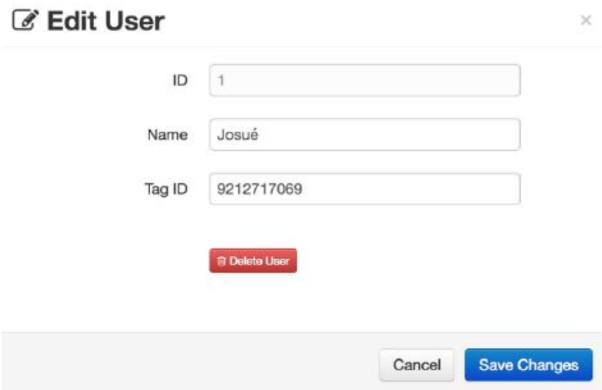


Fig.14: Users-Edit Screen.

VI. FINAL CONSIDERATIONS

According to tests performed, the embedded Linux system (Raspberry Pi) presented excellent results in the aspect of robustness, the various accessories present in the RPI were fundamental for a better use of the embedded system. The hardware division of the initial stage between the PIC microcontroller and Raspberry Pi was a very important factor because the components are well divided thus allowing a better understanding of the operation of all parts such as maintenance.

The use of multitasking in the first step allowed for greater practicality of the system by assigning specific functions running in independent processes.

Problems with Internet access are possible, in this way, an algorithm that stores the unposted data is implemented in both steps so that the posting continues until a satisfactory result is obtained.

After replacing the hardware of the Raspberry Pi for the Microcontroller (ESP 8266) several advantages were perceived, the system allows the operation with current less than 1 A which facilitates the use with energy sources with low cost. The WiFi connection in the ESP8266 Microcontroller allows the physical installation of the system, requiring only a voltage supply, which also allows greater portability.

For the time update, the interruption of an ESP8266 internal timer emulated by software was used, reducing the need for the Internet to check the time.

The need to use the Internet has been reduced to the maximum so that the project continues to function even after connection failure so that the system is robust enough to allow users to access and register using the minimum Internet connection.

Finally, the proposed project can be replicated in many environments with portability, low cost components and easy access in the Brazilian market.

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