Tampere University of Applied Sciences

Design of an IoT system to collect data about the weather conditions inside of a building using RuuviTag

Alejandro Zarza Roa

BACHELOR'S THESIS
May 2019

ICT Engineering

PREFACE

The following document is my bachelor's thesis which has been developed totally in Finland, in the Tampere University (TAMK). With this report I conclude my studies in Telecommunications Engineering at the Technical University of Madrid.

I want to thank my tutor Mauri Inha all the support given, not only with the materials, but also with all the problems that I have been during the process. This thesis also would not have been possible without the help of Roger Kupari, with his patience he helped me to find new solutions when I did not know how to continue.

Finally, I am very grateful to my grandmother and to all the people that have loved me. Thank you for always being by my side.

ABSTRACT

Tampereen ammattikorkeakoulu
Tampere University of Applied Sciences
ICT engineering

ALEJANDRO ZARZA ROA

Design of an IoT system to collect data about the weather conditions inside of a building using RuuviTag

Bachelor's thesis 26 pages
May 2019

The advances that we are experiencing today in our forms of communication, are applied little by little to our day to day. I decided to take as the basis for the project these advances, the technologies we have at our disposal, and the opportunity I that I had doing the thesis in Finland.

We started from a device developed in Finland. The purpose was always to improve the quality of life of the students. Therefore, due to the harsh climatic conditions here, I decided to create a system based in internet of things that would monitor these conditions inside a home. This system had to be able to detect possible problems in real time.

The first step, was to study the tools needed to implement it, including various devices, as well as the software that could be used.

Finally, it was found that it was possible to set up a low-cost system, capable of being very efficient at detecting anomalies, and that could be perfectly adapted to an old building.

With these results we have achieved our objectives, the first one was to process an almost instantaneous report of a problem. This avoids the bureaucracy of generating a complaint to the central office, which manage the incidence. In our case, the alert can be directly reported to maintenance. Secondly, the objective was to create a low-cost and easy to implement system in an old building. This means that, for a not very high amount of money, you can adapt any installation and save costs by improving the service.

Key words: internet of things, ruuvitag, node-red, espruino, raspberry, javascript

ABSTRACT

Tampereen ammattikorkeakoulu
Tampere University of Applied Sciences
ICT engineering

ALEJANDRO ZARZA ROA

Design of an IoT system to collect data about the weather conditions inside of a building using RuuviTag

Bachelor's thesis 26 pages
May 2019

Los avances que estamos experimentando hoy en día en nuestras formas de comunicación, se ven aplicados poco a poco a nuestro día a día. Decidí tomar como base para el proyecto estos avances, las tecnologías que tenemos a nuestro alcance, y la oportunidad que tengo de hacer la tesis en Finlandia.

Partimos de un dispositivo desarrollado aquí en Finlandia. El propósito siempre fue mejorar la calidad de vida de los estudiantes. Por lo tanto, debido a las duras condiciones climáticas que se producen, opté por crear un sistema basado en el internet de las cosas que monitorizara estas condiciones en el interior de una vivienda. Este sistema tenía que ser capaz de detectar posibles problemas a tiempo real.

Se comenzó a estudiar las necesidades para implementarlo, incluido varios dispositivos, así como el software que se podía utilizar.

Finalmente se halló que era posible montar un sistema de bajo coste, capaz de ser muy eficiente detectando anomalías, y que se podía adaptar perfectamente a un edificio antiguo.

Con estos hallazgos damos por conseguidos nuestros objetivos, el primero procesar un reporte casi instantáneo de una incidencia. De esta manera se evita la burocracia de generar una queja a la oficina central, y que esta se encargue de gestionar. En nuestro caso, directamente se puede reportar la alerta a mantenimiento. En segundo lugar, el objetivo fue crear un sistema de bajo coste y fácil de implantar en un edificio antiguo. Lo cual supone que por una cantidad no muy alta de dinero se puede adaptar cualquier instalación y ahorrar costes mejorando el servicio.

Palabras clave: internet de las cosas, ruuvitag, node-red, espruino, raspberry, javascript

CONTENTS

LIST OF PICTURES & TABLES

ABBREVIATIONS AND TERMS

5G	5th generation wireless systems
BLE	Bluetooth Low Energy
HTTP	Hypertext Transfer Protocol
IoT	Internet of Things
PC	Personal Computer
TAMK	Tampere University of Applied Sciences
TCP	Transmission Control Protocol
TV	Television
UDP	User Datagram Protocol

1 INTRODUCTION

All the achieves of humans have been done to make easier our lives. That is the reason of the technology existence.

Along the history have been occurred different industrial revolutions, and after each one of those we have obtained inventions which have changed our day by day.

The brief history of our last revolutions could start with the appearance of the personal computers, it was the first step in a way with lot of changes. It supposes the information era; everything was in your hand with internet. Little by little these computers were developed in very quick machines, and their capacity of send and receive information grew exponentially.

Nowadays, we use many devices during the day, with a very high traffic of data. These devices provide us benefits but also many information. It is very important for us to process all the data that we receive, because these statistics is very useful for us, but also for the other devices in the same network. Here start the Internet-of-Things, sharing data remotely, being able to use it without being close to it.

Here we have the internet of things platforms. The IoT platforms allow us to manage all the elements connected in a network.

We cannot forget that the most buildings where we go in our free time, we live, or we work they are not new. In these cases, we need to enable these installations with new functionalities. Also, we have devices with less capacity than the others made specifically for these applications. It means a very big challenge for us.

In this thesis we will study how to convert objects not adapted in a font of information, also we will study about the new technologies that make it possible. And why it could not be possible in the past.

In this case, these functionalities are going to be applied to an old building. A student residence was taken as study case, which is controlled by an institution. This institution must control that the conditions within the houses are adequate. It will make possible to know in real time and from a central office parameter as the temperature, humidity, etc. Being able to detect if there is some problem and solve it as quick as it was possible.

2 STUDY OF THE CASE AND THE TECHNOLOGY

In order to implement an IoT system in an old installation is very important to study all the diferents technologies offered. In this point, I will explain the devices and the technologies used.

For this system it is necessary a temperature sensor able to collect data and show it in a remote PC. It will be possible with an application, that will show us a dashboard. To send this data also it will be esenctial study the connection with the device with the gateway and the gateway with the cloud.

2.1 RuuviTag

First, I will start talking about the sensor. For this project was necessary a temperature sensor based on IoT technology. This device is developed by a Finnish start-up which offers open source devices, so it was a good opportunity. [1]

PICTURE 1. RuuviTag device (Google Images)

RuuviTag is a sensor capable to collect and send many information as the temperature, air humidity, air pressure, movement and proximity. These characteristics made RuuviTag a multidisciplinary device.

Other interesting things about RuuviTag is the battery life. You can have the sensor working for years due to his very low power consumption.

The specifications [2] are in the next picture. It is very important to see the conditions in which the device can work.

- Nordic Semiconductor nRF52832 System-on-Chip Software Radio
    - ARM® Cortex™-M4F CPU
    - 512kB Flash Memory + 64kB RAM
    - Hardware support on-chip for Bluetooth 5
    - Support for multiple protocols including
        - Bluetooth Low Energy (default protocol)
            - Bluetooth Mesh support coming
        - ANT
        - Wirepas Connectivity
        - Other 2.4 GHz proprietary
    - Up to +4 dBm TX power
- STMicroelectronics LIS2DH12 accelerometer
    - 3-axis, ±2 g / ±4 g / ±8 g / ±16 g, 1 Hz - 5.3 kHz
    - Ultra-low power consumption
        - 2 µA @ 1 Hz
        - 6 µA @ 50 Hz
        - 0.5 µA @ Power-down
    - 2 independent programmable interrupt generators for freefall and motion detection
- Bosch BME280 environmental sensor
    - Ultra-low power consumption
        - 3.6 µA @ 1 Hz humidity + pressure + temperature
        - 0.1 µA in sleep mode
    - Operating range
        - -40 ... +85 °C, 0 ... 100 % rel. humidity, 300 ... 1100 hPa
    - Temperature
        - Typical absolute accuracy ±0.5 °C @ 25 °C, ±1 °C @ 0-25 °C, output resolution 0.01 °C
    - Relative humidity
        - Typical accuracy tolerance ±3 %, Hysteresis ±1 %
    - Air pressure
        - RMS Noise 0.2 Pa, equiv. to 1.7 cm
        - Offset temperature coefficient ±1.5 Pa/K, equiv. to ±12.6 cm at 1 °C temperature change
- Embedded NFC™-A tag antenna
- 1000 mAh CR2477 Li/MnO2 battery (included)
    - Up to several year battery life (depending the software used)
- Max operating temperature: -40 °C to +85 °C (electronics and enclosure)
    - Recommended -20 °C to +65 °C (above these limits an extended temperature range battery is required, not included)
- 2 buttons
- 2 LEDs
- 45 mm diameter (circuit board)
- 52 mm diameter (enclosure)
- 25 g total weight (enclosure and battery included)
- Waterproof enclosure (included)
    - High-quality & long-lasting polycarbonate
    - Gore IP67 certified vent membrane
    - Lubricated industrial-grade O-ring

PICTURE 2. RuuviTag specifications

This device gives us very high accuracy. Mostly we will have conditions from 0ºC to 25ºC, so the accuracy will be ±1ºC. Also, it achieves the conditions inside our building, so it will be working without any kind of problem.

Finally, RuuviTag also has ultra-low power consumption, being able to consume 0.5µA in power-down conditions.

2.2 Bluetooth Low Energy

All IoT project are thought to be working for years. Could you imagine that each six months you needed to change a battery of a device? It sounds reasonable, but now it is moment to think in a smart home. In a smart home are around tens of IoT devices, so now it is better to have devices working in long time.

That is the reason why our device use BLE for IoT applications. BLE is based on WPAN standard. The main differences between Bluetooth and BLE are the optimization, while BLE sends short data pieces transmission, Bluetooth uses continuous data streaming. Also, BLE has longer transmission ranges. [3]

TABLE 1. Comparations

	Bluetooth V 2.1	Bluetooth 4.0 LE	Bluetooth 5 LE
Range	<100m	<100m	<400m
Max range (free field)	100m	100m	1000m
Frequency (GHz)	2.402-2481	2.402-2481	2.402-2481
Max data rate (Mbit/s)	1-3	1	2
Application throughput	0.7-2.1 (Mbit/s)	<305(kbit/s)	<1360(kbit/s)
Topologies	Point-to-point, Scatter net	Point-to-point, Mesh network	Point-to-point, Mesh network t
Network standard	IEEE 802.15.1	IEEE 802.15.1	IEEE 802.15.1

Also, is very interesting the possibility to use the device in a mesh network principally because it provides us multiple paths to connect multiples devices, it is power efficient, and is a secure network because it is encrypted but also in the application level [4].

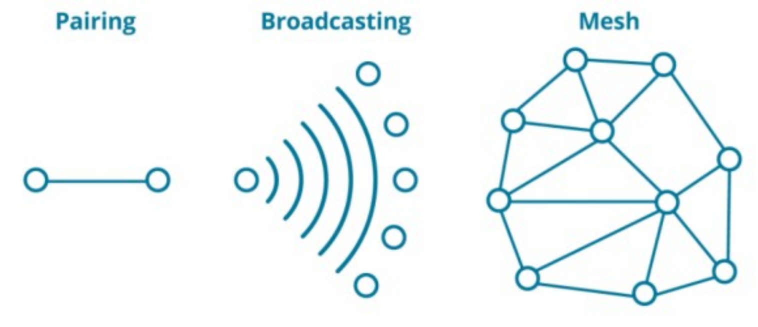
In our case, we are going to have our devices in a building, so I obtained the BLE connection in the second floor. The results are shown in the following table [5].

TABLE 2. BLE simulations

	BLE
TX Antenna Height (m)	6
TX Power (dBm)	4
TX Antenna Gain (dB)	0
Frequency (MHz)	2400
RX Antenna Height (m)	1
RX Antenna Gain (dB)	-6
Structure Loss (dB)	11
Sensitivity (dBm)	-93
Margin (dB)	20
Range (m)	77

As I mentioned, this project are thought to an old building. This is one of the biggest challenges for the IoT developer. Here is where it exist a big importance of the adaptation of these places. For that reasons, the developer have to find existing technologies compatibles with the old insfrastructure.[6]

Finnally, for the BLE we have three diferent topologies, and it is very important to know the differences between them. The existent types are point to point, broadcast and mesh. Each one is made for differents uses. The first one, point to point (1:1), and it is optimized for the data sending. Mostly used in peripherical devices of the PC, but also in hands free speaker, fitness trackers. The second one is the broadcast, establishing one-to-many device comunications (1:m), and it is perfect for location services or indoor navigation. The last one, mesh, is used with many-to-many (m:m) devices, and it is idealy for control many devices. These device can establish a secure communication with each other.[7]



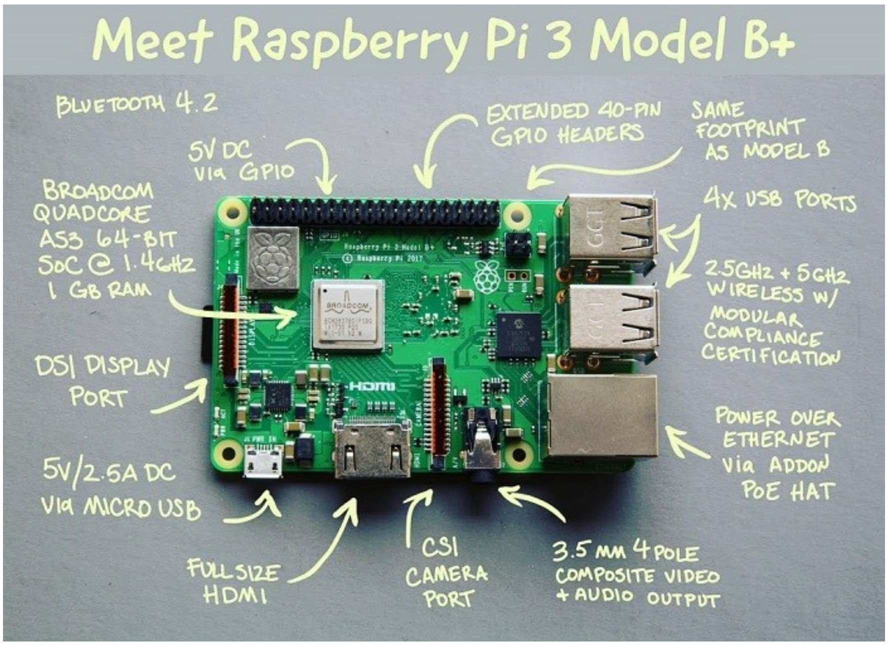
PICTURE 3. Bluetooth topologies (rs-online)

2.3 Raspberry Pi

In this project it is needed a transceiver station. This base receives the data and send it to the cloud. As a base it was use the Raspberry Pi 3 Model B+. The reason of the choose was that Raspberry is like a small computer able to send the BLE data to the cloud, in order to be controlled remotely. Likewise, the price of the device, which is very cheap. [8]

The Raspberry has the following specifications: [9]

SoC: Broadcom BCM2837
CPU: 4× ARM Cortex-A53, 1.2GHz
GPU: Broadcom VideoCore IV
RAM: 1GB LPDDR2 (900 MHz)
Networking: 10/100 Ethernet, 2.4GHz 802.11n wireless
Bluetooth: Bluetooth 4.1 Classic, Bluetooth Low Energy
Storage: microSD
GPIO: 40-pin header, populated
Ports: HDMI, 3.5mm analogue audio-video jack, 4× USB 2.0, Ethernet, Camera Serial Interface (CSI), Display Serial Interface (DSI)



PICTURE 3. Raspberry Pi 3 Model B+ parts (Google Images)

The Raspberry properties fits perfectly with this project. It is a low-cost computer that can be controlled by a remote computer but also with his own screen, keyboard and mouse.

2.3.1 VNC Viewer

The raspberry is a computer, also it needs a screen, keyboard and a mouse to interact with it. This device also offers you the possibility to interact with him using a viewer.

VNC viewer is a tool that allows us to be inside of the Raspberry. The use of this tool is totally free, and it is very easy and intuitive. Only you need to know the IP of the Raspberry.

2.4 Software

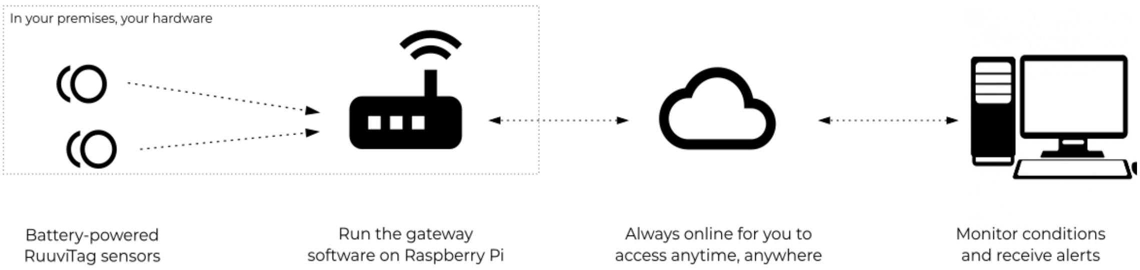
In our system it was necessary work with software in two parts of the project. The first software needed was Espruino, required to work with RuuviTag. The second one was Node-Red, used in the Raspberry Pi.

Espruino is an open-source firmware, in which you can charge a JavaScript program in your device. It is very beneficial for this project because we can manage out IoT device with his free app for our browser [10]. As it was mentioned before, this software has been used with RuuviTag to give the instructions about what must do the tool. Espruino uses Web Bluetooth, and it makes possible interact with RuuviTag. [11]

The second software used is Node-Red. This software is installed in the Raspberry and it works as a programming tool in which you can connect the all the parts of an IoT system. In this case, this implementation is done in the Raspberry, due to Raspberry receive BLE data, and by means of a creating flow, this data is sent to a browser. Because of this it is possible to check the weather conditions inside of every apartment of a residence. Also, this tool is very useful because it is conceivable to create an alarm if it were necessary. [12]

3 DESIGN AND IMPLEMENTATION

My principal idea was to connect de RuuviTag with the Raspberry Pi. Raspberry Pi works as gateway to the data, and send the data received by BLE via Wi-Fi. The picture 4 shows the design of the system.



PICTURE 4. System design (meazurem.com)

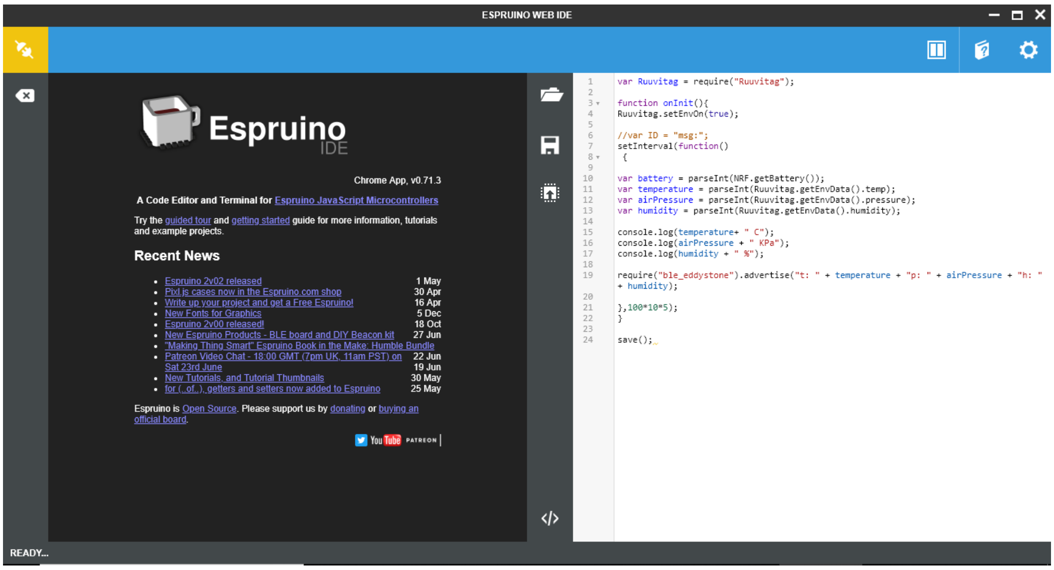
3.1 RuuviTag

The first step was to charge the RuuviTag with a JavaScript program. In this program there were the instructions that the device needed to follow.

Before, it has been said that we used Espruino to load the code inside the device. I have been working with Google Chrome as a browser. In Chrome exists the possibility to download the application of Espruino Web IDE.

Work with Espruino Web IDE is very intuitive. First, you need to write the JavaScript code in the editor's window. After that, you need connect the device. Espruino uses BLE.

Once you have connected your device, you can load the code into the device. The left windows show if has been loaded successfully and if you have return values you can see them there.



PICTURE 5. Espruino Interface

Our RuuviTag can do many different things. In this case we only need to know the weather data. So, in the following picture there are only instructions to ask about these data and the battery of the device.

```
var battery = parseInt(NRF.getBattery());
var temperature = parseInt(Ruuvitag.getEnvData().temp);
var airPressure = parseInt(Ruuvitag.getEnvData().pressure);
var humidity = parseInt(Ruuvitag.getEnvData().humidity);
```

PICTURE 6. Code

In order to know if the data collected is good, has been included instructions to show them on the console. These instructions are in the picture 7.

```
console.log(temperature+ " C");
console.log(airPressure + " KPa");
console.log(humidity + " %");
```

PICTURE 7. Code

Also, we must include an advertise, shown in the next picture. This advertise is going to be sent to our gateway in hexadecimal format. In the next point we are going to see how to do manage these data.

```
require("ble_eddystone").advertise("t: " + temperature + "p: " + airPressure + "h: " + humidity);
```

PICTURE 8. Code

3.2 BLE - Wi-Fi connection

In this project, all the data assemble is sent via Bluetooth. It is useful if your controller is not very far from the device. In our case, we have an institution which manage all the residences in a city. This institution has a central office, not necessarily close to all the residences. This motive was the principal to think on sending the information via Wi-Fi.

One of the most important part of the project is the use of Raspberry Pi as gateway. To configure it, it is necessary enable Raspberry Pi as a Wi-Fi hotspot. In order to avoid having it connected to an Ethernet cable.

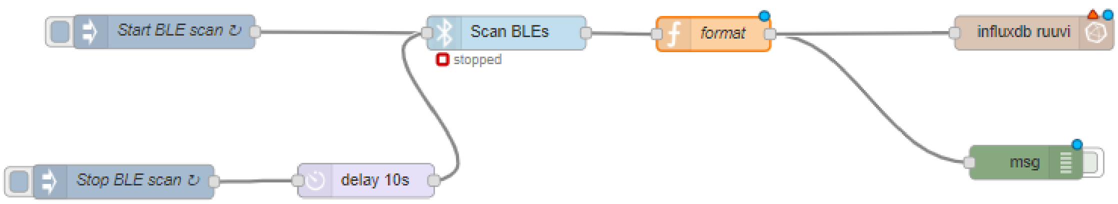
First, will be necessary to install an access point software, also a DHCP server to allow devices connection with a network address, it is possible executing the following instruction:

```
sudo apt install dnsmasq hostapd
```

To configure it as a server, we will need to have a static IP address for the wireless port. The DHCP server has a configuration by default, now it is required to change them.

Once configurated the DCHP is time to do the same with the access point host software. In this case this permit us to change the band.

Once we have configured the Raspberry as a router, to do the gateway functions. The designed of the flow is made with node-red. In our case, the BLE scanner is reading every 10 seconds. After read, the data, it is uploaded to database.



PICTURE 9. Node-red

3.3 Database

In the database we used InfluxDB. This is an open-source database specialized in IoT systems. The protocols accepted by InfluxDB are HTTP, TCP and UDP. [13]

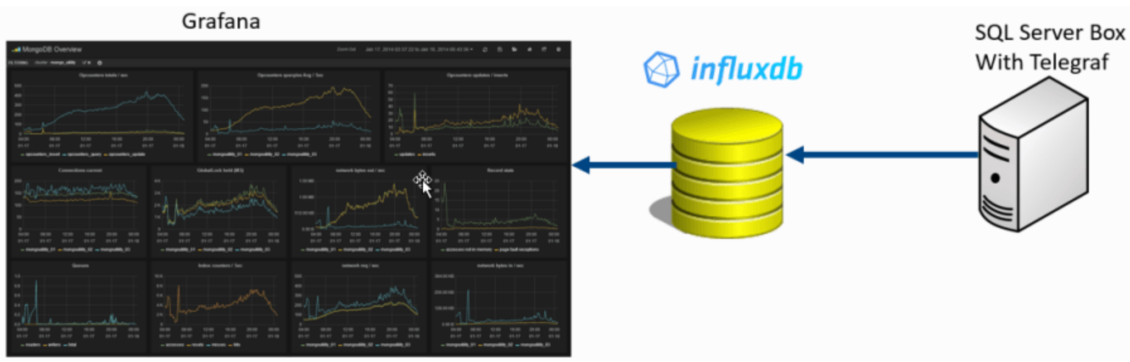
This database collect the data received from the differents devices connected. The main advantages of this database is the speed taking data and the high availability storage.

3.4 Grafana

Grafana is a free software, which is used to show different metrics. It can be used with InfluxDB.

This dashboard can be designed according to our requirements. Also allows the configuration of alerts, it is very important to advise us that something it is going wrong.

With Grafana you can have users and check the status of the system with your logging account, being able to see it remotely, not only in one computer.

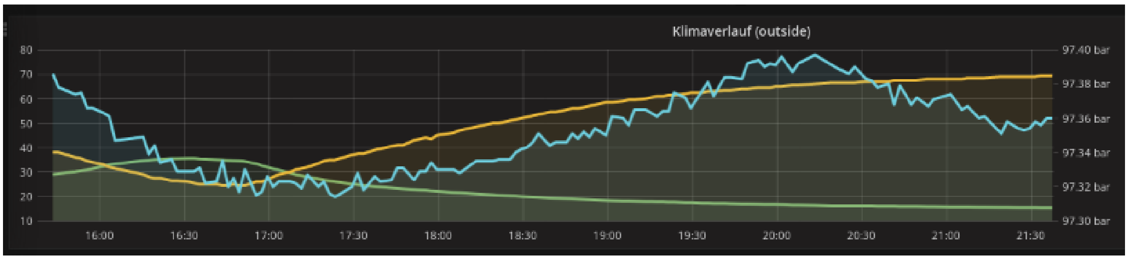


PICTURE 10. InfluxDB and Grafana

4 RESULTS

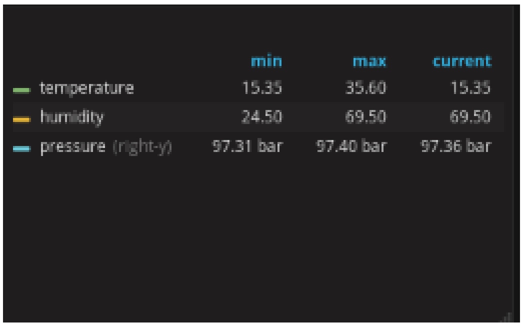
As a result, we would have the device connected with the Raspberry sending data every time. The Raspberry process this information with scan BLE. With the flow created in node-red we could charge this data in a database.

These data are taken to show it graphically. Grafana allows us to print the graphs with the different measures. For the first graph, it shows the condition registered by one RuuviTag in one of the flats.



PICTURE 11. Graphic 1

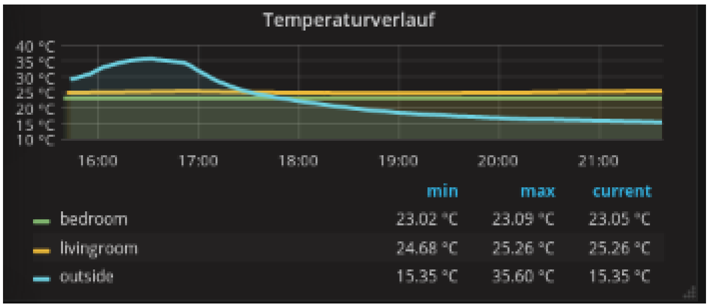
These are the statistics shown in the graphic:



	min	max	current
temperature	15.35	35.60	15.35
humidity	24.50	69.50	69.50
pressure (right-y)	97.31 bar	97.40 bar	97.36 bar

PICTURE 12. Statistics graphic 1

Also, Grafana allows us to check more than one device in the same graphic. It is useful to compare the different temperatures registered in one building.



	min	max	current
bedroom	23.02 °C	23.09 °C	23.05 °C
livingroom	24.68 °C	25.26 °C	25.26 °C
outside	15.35 °C	35.60 °C	15.35 °C

PICTURE 13. Graphic 2

In other part of the dashboard we can print the numerical values registered. Also, the temperature outside the building.

PICTURE 14. Data in numbers

In order to achieve another objective, we can configure an alarm in Grafana. If something is going wrong a message is going to appear in the alert screen. Could happen that nobody is checking the dashboard, in that case also can be configurated to send an e-mail to the technical support. In this mail could be specified the building, the flat and the device which launch the alert.

5 DISCUSSION

This thesis shows the procedures to create an IoT system, which can collect the weather conditions inside of a building and show them remotely. The data receives are very important to detect problems in the flats.

5.1 Other projects and methods

Nowadays, the IoT projects are growing exponentially. Also, we have new devices, provides by start-ups. New codes open source, given by people who are not necessarily doing a thesis. All of us are looking for new solutions which improves in a determinate point our lives.

The method followed has been, first find a device and then think about a problem that we can fix with this device and the IoT technology.

5.2 Limitations and fortes

It was very difficult to do an exhaustive study of the project. In this case, this system is implemented in a concrete installation. My area of knowledge is not the infrastructure and materials of a building. So, this system needed to be implemented by people who knows about IoT technology and materials properties. Despite of this, I have search information about behaviours of the devices used in similar conditions.

It has been demonstrated that you can implement an IoT system without spending too much money. All the software used is free, and the devices are not expensive. Also, it will help you to save money in the future, because you can detect problems on time and fix them before it gets worst, and if you are providing a service you will have your costumers always comfortable in their flats.

One strength more is that you don’t need a special installation. Everybody can do it from their homes, only with the IoT device, internet connection, a computer and a Raspberry.

5.3 Context

As I said before, nowadays we are working to add IoT technology in our day by day. It represents a big challenge for us, because we are not living in a monitoring world. We are used to interact with our smartphone, our smart TV but not with our fridge or with our oven. That is the reason why we say that we are in a transition time, and in this time, we need to work to adapt our old infrastructures.

Likewise, it is possible because of the 5G apparition. This new technology allows us to share more information in less time, making possible to have much more devices connecting between them.

5.4 Conclusions

As a conclusion, the research has proved that we can add IoT devices in old installations. Always we have looked for having in real time the data of the weather conditions in a flat, also with an advice if there were something wrong.

We have achieved the main goals of the thesis. First, we are connected one device able to communicate via Bluetooth with a remote central. It was possible with the use of the Raspberry. Secondly, it shows the information in real time, with numbers and with a graph drawn in the dashboard. Finally, we could set an alarm in order to generate a quick report to maintenance department.

5.5 Future work

In this investigation only have achieve one sample about how to do a biggest project. For the future, my recommendation is to make it real. It will be necessary explore more about the materials, try the devices in the real conditions and having the properties. Once you have this study is very easy to implement it with the tools that have been mentioned before.

REFERENCES

[1] Ruuvi. Hello friend, we’re ruuvi. (Read: 31.4.2019) https://ruuvi.com/about-us/

[2] Lauri Jämsä. RuuviTag Datasheet 4/2018. (Read: 31.4.2019) https://blog.ruuvi.com/datasheet-52fb00265c60

[3] Jon Gunnar Sponås. Things you should know about Bluetooth range. (Read: 2.5.2019) https://blog.nordicsemi.com/getconnected/things-you-should-know-about-bluetooth-range

[4] Beacon Zone Blog. Advantages of bluetooth mesh. https://www.beacon-zone.co.uk/blog/advantages-of-bluetooth-mesh/

[5] LinkLabs. BLE Range: What Can You Expect In This Use Case?. (Read: 2.5.2019) https://www.link-labs.com/blog/ble-range

[6] Jakob Nielsen. Bluetooth low-energy technology for IoT applications. (Read: 2.5.2019) https://www.powerelectronicsnews.com/news/bluetooth-low-energy-technology-for-iot-applications

[7] Bluetooth. Topology Options. (Read: 2.5.2019) https://www.bluetooth.com/bluetooth-technology/topology-options/

[8] RaspberryPi. What is a Raspberry Pi?. (Read: 7.5.2019) https://www.rasp-berrypi.org/help/what-%20is-a-raspberry-pi/

[9] MagPi. Raspberry Pi 3: Specs, benchmarks & testing. (Read: 7.5.2019) https://www.raspberrypi.org/magpi/raspberry-pi-3-specs-benchmarks/

[10] Espruino. Frequently Asked Questions. (Read: 13.5.2019) https://www.espruino.com/FAQ#what-is-espruino-

[11] François Beaufort. Interact with Bluetooh devices on the web. (Read: 13.5.2019) https://developers.google.com/web/updates/2015/07/interact-with-ble-devices-on-the-web

[12] Nodered. Flow-based programming for the Internet of Things. (Read: 13.5.2019) https://nodered.org/

[13] Influxdata. Infrastructure and application monitoring. (Read: 13.5.2019) https://www.influxdata.com/customers/infrastructure-and-application-monitoring/

[14] Grafana Novedades. Grafana sistema de monitorización. (Read: 15.5.2019) https://ackstorm.com/grafana-sistema-monitorizacion/