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Department of Electronic, Telecommunications and Computers Engineering

Home Energy Management System

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Final Report for the Curricular Unit of Final Course Project of Bachelor's Degree in Electronic, Telecommunications and Computers Engineering

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We declare that this document is an original work of our authorship and that it fulfills all the requirements of the Code of Conduct and Good Practices of the *ISEL*

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Thank you all for being an integral part of this journey.

"Engineering is achieving function while avoiding failure."
- Henry Petroski

Abstract

In pursuit for sustainable energy solutions, European energy cooperatives such as REScoop advocate for efficient systems that optimize home energy consumption. This project contributes to advance open-source residential systems integrating sensors to monitor energy usage. The system provides users with insights to facilitate informed decisions, minimizing energy waste and reducing its consumption. Motivated by existing closed-source solutions and products from companies like Shelly, and Tuya, this project aims to design and implement an open-source, expandable household solution to control appliances and monitor energy consumption. Key components of the proposed solution include low-power and small footprint microcontrollers like ESP32-S2 or ESP32-C3, environment (temperature, humidity and luminosity) and energy consumption sensors, and the Home Assistant application on a Raspberry Pi 5 ("Cofy-Box"). The prototype of the proposed system architecture shows real-time energy analysis and remote home appliance control, contributing to efficient energy management in domestic environments.

Keywords

- Renewable energy
- Energy efficiency
- IoT (Internet of Things)
- Smart home
- Raspberry Pi
- ESP32 microcontroller

Resumo

Em busca de soluções de energia sustentável, cooperativas de energia europeias como a REScoop defendem sistemas eficientes que otimizem o consumo de energia doméstica. Este projeto contribui para o avanço de sistemas residenciais de código aberto, integrando sensores para monitorizar o uso de energia. O sistema fornece aos utilizadores dados para facilitar decisões informadas, minimizando o desperdício de energia e reduzindo o seu consumo. Motivado por soluções e produtos existentes de código fechado de empresas como Shelly e Tuya, este projeto visa projetar e implementar uma solução doméstica expansível e de código aberto para controlar aparelhos e monitorizar o consumo de energia. Componentes chave da solução proposta incluem microcontroladores de baixo consumo e compactos, como o ESP32-S2 ou o ESP32-C3, sensores de ambiente (temperatura, humidade e luminosidade) e de consumo de energia, e a aplicação Home Assistant em um Raspberry Pi 5 ("Cofy-Box"). O protótipo da arquitetura do sistema proposto mostra a análise de energia em tempo real e controlo remoto de eletrodomésticos, contribuindo para uma gestão eficiente da energia em ambientes residenciais.

Palavras-chave

- Energia Renovável
- Eficiência Energética
- Internet das Coisas
- Casa Inteligente
- Raspberry Pi
- ESP32 microcontrolador

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1. Introduction

In seeking sustainable and efficient solutions in the energy sector, European energy cooperatives promote efficiency by implementing innovative systems. The first chapter discusses the project's motivation, objectives, system requirements, and report outline.

1.1. Motivation

The project aims to create an open-source residential system incorporating sensors to track energy consumption, offering users feedback to make informed decisions, thereby minimizing waste and reducing electricity costs. The primary motivation is to provide a system that delivers insights into household electricity consumption, enabling automated decisions to maximize renewable energy integration.

Optimizing energy consumption at home is crucial, particularly with systems capable of controlling appliances to operate during periods of higher renewable energy availability, such as solar. Given the use of personal data and the vulnerability of closed systems to hacking, adopting such systems raises serious concerns.

This project builds on a previous study by REScoop, which proposed a controlled home environment that can monitor and manage the energy costs of each appliance. However, the study did not provide a final product or specify optimal components. Our goal is to develop and publish an open-source system that can be easily adopted by the IoT community and expanded for more complex use cases.

1.2. Objectives

The project aims to implement an embedded system, designed to analyze each section's energy consumption within a household. This initiative seeks to effectively reduce electricity usage.

The sensor data collected by the “Cofy-Cookie” in each section of the house is transmitted to an application called "Home Assistant", deployed on a Raspberry Pi, which will be referred to as “Cofy-Box” throughout the report. This application facilitates the analysis of each monitored section, providing insights into the consumption of individual components. The "Cofy-Cookie" is able to receive commands from the “Cofy-Box” to control home appliances such as washing machines and heaters & AC.

1.3. System Requirements

The system requirements for the project are as follows:

- Analyse the current and voltage flowing in an electrical line using the *PZEM-004T V3* sensor.

- Use an ESP32 MCU to transmit data obtained from the sensor via Wi-Fi to the "Home Assistant" application.

- In the application, installed on a Raspberry Pi, it is possible to analyze the data sent from different areas.

- From the application, send a message back to the desired microcontroller to control the respective device on or off.

- Connect the microcontroller to a Solid State Relay (SSR), or electromechanical relay, that implements the instruction given to the ESP32 (MCU) by "Home Assistant."

- Set up a Wi-Fi router, which will serve as the base for the system to work standalone but also within any given Wi-Fi network available.

In **Figure *1***, it is possible to see the initial project scheme.

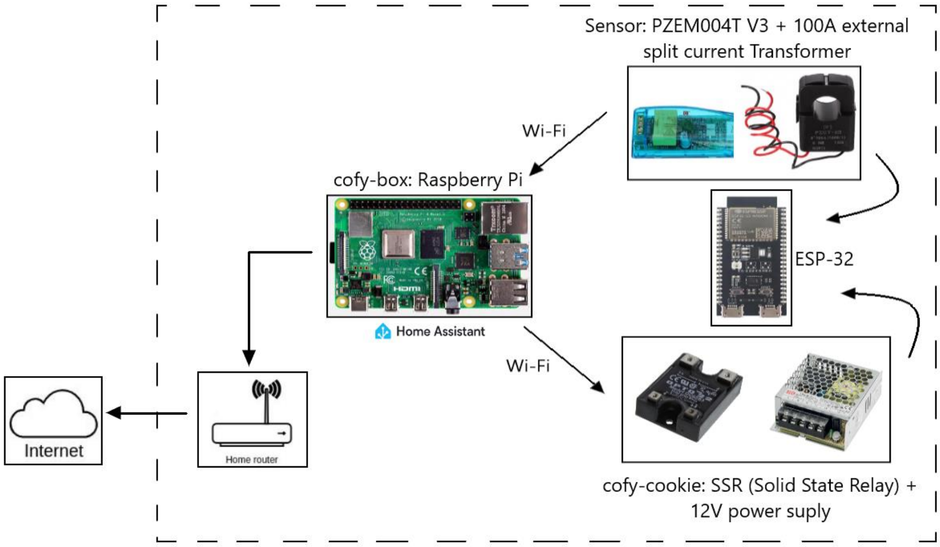


Figure 1. *Initial Project Scheme.*

Besides using the Solid State Relay shown in **Figure *1***, it is also possible to use a relay. Subsequently, when implementing the "Home Assistant" application, the usage of a *Raspberry Pi* or an *Orange Pi* will be a task undertaken during the selection process to identify the most optimal solution.

1.4. Report outline

This report is organized as follows. Chapter 2 presents the background, reviewing literature and existing technologies pertinent to the development of the home automation system. Chapter 3 describes the proposed home automation system, detailing the planned architecture, key components, and their functions. Chapter 4 covers the implementation of the Cofy-cookie, while Chapter 5 details the implementation of the Cofy-box. Chapter 6 discusses the results, providing data and performance analysis of the implemented system, as well as discussing these results. Chapter 7 offers conclusions and future work, summarizing the findings and suggesting possible improvements and extensions for future research. Finally, Chapter 8 lists the references, including all bibliographic sources and resources used throughout the report.

2. Background on Home Automation

This section is dedicated to explaining the foundation of this project, as it took some inspiration from different articles and reports available online and from some companies that already provide closed-source products that have almost the same purpose as this work. There are some comparisons for different materials that could be used in this project and justifications of why each component was chosen.

2.1. Related Works

After research and analysis of scientific articles and reports available online, several sources were identified that cover the technologies utilized in this project. While many articles and reports were reviewed, the one referred to below provides a comprehensive explanation of the theoretical basis for the current project. There is also mention of some companies that are dedicated to domotic technologies that already sell products that come close to the project at hand, with closed-source software and hardware.

2.1.1. REScoopVPP

The project report "Smart Building Ecosystem for Energy Communities" by REScoop [1], is focused on the description of an open-source energy monitoring and optimization system. It uses a range of existing open-source technologies to integrate and control legacy and new appliances into a smart building ecosystem. Helps in understanding the Hardware behind the final product as well as real-life options to use the device.

This work delivered an idea of how to get consumption data from different elements of a house and how to deliver them to a user, even though they don't specify which components can make part of the Cofy-Cookie. For the Cofy-Box, there are some examples of software that make part of their project, one of them the "Home Assistant" as can be seen in ***Figure 2***.

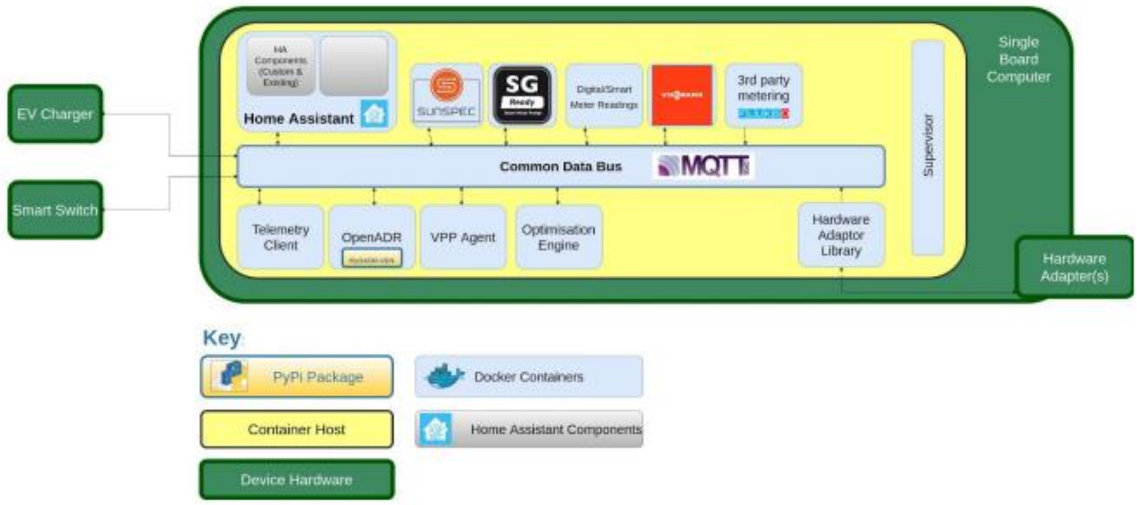


Figure 2. *REScoop's Architecture.*

REScoop made a very simple scheme that allows an easy understanding of how their project is going to work in **Figure *3***, however, they did not specify all the components for its implementation. The challenge for the current project is to find the best hardware components and applications that make this idea the safest and cheapest way to control energy consumption and the working time of household appliances.

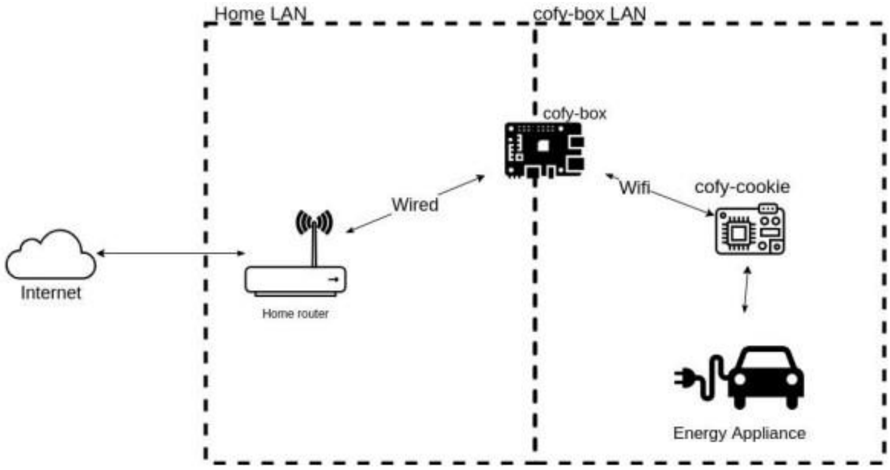


Figure 3. *REScoop's Model*.

2.1.2. Shelly

The advisor of this project provided equipment from Shelly, a company that dedicates their work to many areas, one of them being domotic devices. The devices provided were Shelly Plus 1 and Shelly Plus ADD-ON, shown in **Figure *4*** and ***Figure 5*** respectively. The first device is an interrupter with a relay controlled by Wi-Fi and it can be installed in almost any appliance at home. The other device is used to make measurements of temperature and humidity, light intensity, and movement, for example.

Figure 4. *Shelly Plus 1.*

Figure 5. *Shelly Plus ADD-ON.*

These devices are closed-source, which can present adversity. This project as an open-source aims to become a solution to this issue.

2.1.3. Tuya

Tuya is another company dedicated to providing IoT solutions for many areas, one being house domotic. Different from Shelly, Tuya doesn't provide measurement devices to install in home appliances, but they provide software and equipment to have in a smart and efficient home. As a closed-source product, it doesn't provide the reliability and flexibility that is provided by the proposed project. **Figure *6*** shows one of the most used smart switches by this brand.

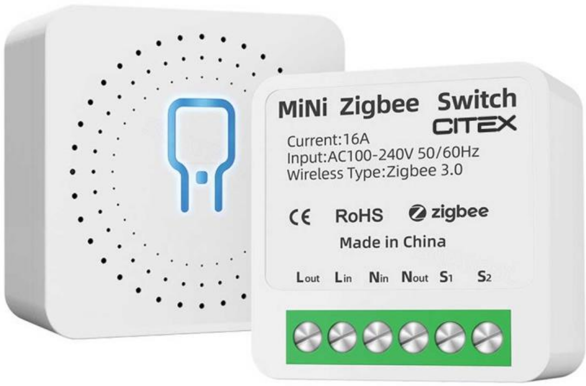


Figure 6. *Tuya Switch.*

2.1.4. Other Solutions

As for other solutions, there is the ***Hue Bridge*** from ***Philips***. This device is used to control smart lamps, it uses a different protocol for communication with the lamps called ***Zigbee***. It also uses ethernet to be connected to the lamps. It is used through their application, where you can also add automation for your smart lamps.

NOUS E1 is another solution that was found, which is a device that can control up to 128 smart devices that work with Zigbee connectivity or Bluetooth

2.1.5. Comparison of Available Solutions

Several solutions were reviewed for their applicability to the project's goals. REScoopVPP provides insights into open-source energy monitoring but lacks detailed hardware specifications. Shelly and Tuya offer closed-source solutions with limited customization, while Philips Hue and NOUS E1 focus on proprietary ecosystems like Zigbee for specific smart home functionalities. Each solution's balance of functionality, openness, and integration capabilities makes it interesting to explore a solution to take the best from each.

2.2. Relevant Technologies

In this section, there is a brief explanation of each component and technologies involved in the project and a comparison between components to show which ones are the best possible for this project.

2.2.1. Single Board Computer

The communication between a household appliance and the user is facilitated through an application installed on a Raspberry Pi. Specifically, the application utilized is Home Assistant, with the scientific report [13] detailing the ease of its implementation on *Raspberry Pi* and the advantages it offers over alternative applications. This report shares many similarities with the project being discussed, providing ample evidence that the Home Assistant is a good method of exploring IoT within a domestic setting. **Table *1*** shows the comparison.

Table 1. *Single Board Computers considered in the Initial Study.*

Single Board Computer Comparison		
Model	Raspberry Pi 4	Orange Pi zero
RAM Memory	4GB	0.5GB
CPU Speed	4 x 1.8 GHz	4 x 1.2 GHz
Wi-Fi Version	Wi-Fi 4 (802.11n); Wi-Fi 5 (802.11ac)	Wi-Fi 4 (802.11n)
Bluetooth	yes	no
HDMI Output	yes	no
USB Type-C	yes	no
Operating Voltage	5V	5V

Raspberry Pi 4 was the chosen computer to use in this project, there was the option to use an *orange Pi Zero*, but after studying the hardware, it was decided that it wasn´t recommended due to the lack of computer power. *Raspberry PI 4* also has better and newer features, for example, support for newer Wi-Fi protocols, Bluetooth, HDMI output, and USB Type-C. In **Figure** *7*, you can see the comparison made between the 2 computers and better understand the reasoning for this choice. This comparison was based on [7].

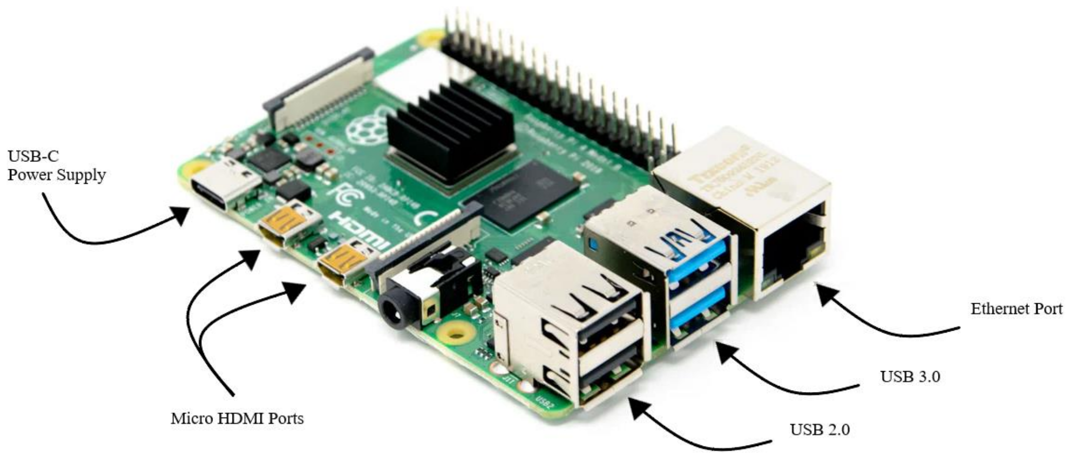


Figure 7. *Raspberry Pi4 used in the project.*

2.2.2. Microcontroller.

The project needs a microcontroller to implement the Cofy-Cookie. It will gather information from the sensors and communicate them with the Home Assistant serving on the SBC. The microcontroller needs to be able to talk to the server, so it needs Wi-Fi.

The article specified in [4] explains in detail the ESP-32 and its use, which will be an important device in this project. This microcontroller already has a Wi-Fi module and is connected to BLE (Bluetooth Low Energy) via a chip, so it is very powerful and can be a good choice for creating an IoT application system. In [5], there is also the comparison between different versions of the ESP32, so it was also used for this project.

This last one along with [8], helped extract a comparison table between the *ESP32-S2*, *ESP32-S3,* and *ESP32-C3*, which were the models frequently used for this kind of project.

Table 2. *Microcontroller Comparison.*

Microcontroller Comparison			
Model	ESP32-S2	ESP32-S3	ESP-C3
Frequency (MHz)	240	240	160
SRAM (KB)	320	512	400
ROM (KB)	128	384	384
Flash (MB)	Up to 4	Up to 8	Up to 4
SPI (MB)	4	4	3
USB	Yes	Yes	Yes
Wi-Fi	802.11 b/g/n, 2.4 GHz	802.11 b/g/n, 2.4 GHz	802.11 b/g/n, 2.4 GHz
Bluetooth	No	Yes	Yes
GPIO	43	45	22
CPU	single-core	dual-core	single-core
Price (€)	7.52	14.1	8.46

According to Erro! A origem da referência não foi encontrada., the most efficient choice for the project will be the *ESP32-C3.* The C3 contains sufficient ROM memory and SRAM capacity, offering the necessary resources for interfacing with various peripherals. The C3 also has Bluetooth and the S2 does not have this feature, even though this project is very unlikely to use a Bluetooth connection since the use of Wi-Fi is optimal for further distances. Moreover, the *ESP32-C3*, as seen in **Figure *8***, provides an efficient performance with its single-core CPU, when compared to a dual-core CPU. Therefore, considering these factors, the *ESP32-C3* emerges as the most suitable option for our project.

The project also incorporated a solution for using the ESP32-S2 microcontroller, as seen in **Figure *9***, which was solicited to be also considered by this project's advisor.

Figure 8. *Esp32-C3 used in the project.*

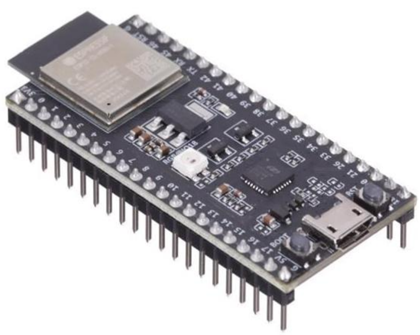


Figure 9. *Esp32-S2 used in the project.*

2.2.3. Temperature and Humidity Sensor

A component integrated into the "Cofy-Cookie" is the temperature and humidity sensor. This sensor interfaces with an MCU ESP32, with specific parameters outlined in this paper [2]. Although this work primarily evaluates the connection between the sensor and an Arduino, understanding the necessary response times for accurate data is important to understand the use of this component.

The research made, and based on [9], showed two sensors with the potential to be used. **Table *3*** shows the different specifications of each.

Table 3. *Humidity and Temperature Sensor Comparison.*

Humidity and Temperature Sensors		
Model	DHT11	DHT22
Measures	Temperature and Humidity	Temperature and Humidity
Interface	One-wire	One-wire
Supply Voltage	3 to 5.5V	3 to 5.5V
Current Supply	0.5 – 2.5 mA	1 - 1.5 mA
Temperature Range	0º to 50ºC	-40 to 80ºC
Resolution	Humidity: 1% ; Temperature: 1ºC	Humidity: 0.1%; Temperature: 0.1ºC
Price (€)	6,99	10,99

The following figures, **Figure *11*** and **Figure *10*** represent the temperature and humidity sensors compared in the previous table.

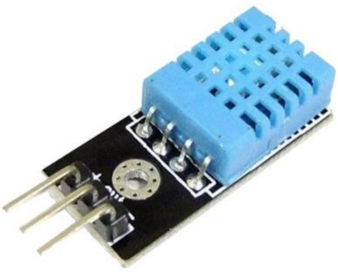


Figure 11. *DHT11.*

Figure 10. *DHT22.*

For communication, both DHTs use one wire which makes it easier to use, than SPI. Even though, in DHT11, the temperature range does not include negative temperatures and the resolution is less accurate due to having a bigger interval, this sensor is sufficient for the case study as the ambient in which the work will be performed does not require more specification.

The MCU utilized in the Cofy-Cookie is an ESP32, operating at a voltage of 3.3V. Similarly, the temperature and humidity sensor DHT11 employed in this project operates at the same voltage level as the MCU.

2.2.4. Power Consumption Sensor

To keep track of the power consumption on an electric wire, or line, it is necessary to use a sensor, which was decided would be the *PZEM-004T V3*.

The *PZEM-004T V3*, represented in **Figure 12**, is a multifunctional sensor module that functions to measure power, voltage, current, and energy contained in an electric current. The paper specified in [3], explains a lot about the use of this device and will be important to understand how to implement it in the project at hand.

PZEM-004T V3 has a serial UART (Universal Asynchronous Receiver/Transmitter) that works with 5V, to allow the communication to work at 3.3V with a board such as *Raspberry Pi* or *ESP32* a resistance of 1kΩ must be used, so with this modification, UART can work at 5V or 3.3V [6].

Another option could be the power consumption sensor represented in **Figure 13**. The downsides of this sensor are that the wire has to pass through the printed circuit board (PCB), making its usability more complex, and the fact that it does not have a box that isolates the 220V, which implies a more careful experiment.

Therefore, the PZEM-004T V3 will be the chosen sensor for the current project. It was provided by the advisor of this project and after exhaustive research it was concluded that this module is the most utilized in this type of work, for its accuracy and efficiency.

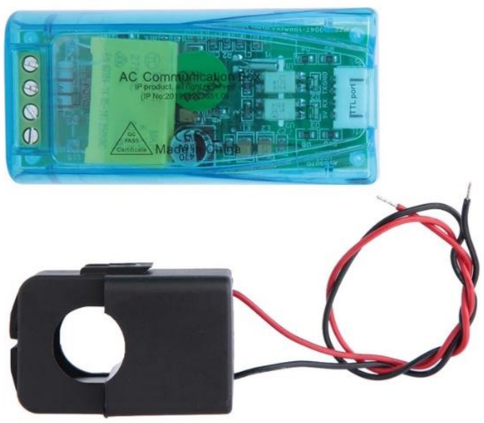


Figure 12. *PZEM-004T V3.*

Figure 13. *JSY-MK-109.*

2.2.5. Light Sensor

The decision to include a light sensor in the energy optimization system was driven by the need to monitor ambient light levels. Effective management of lighting can significantly reduce energy consumption, especially during daytime when natural light is available. For this purpose, a Light Dependent Resistor (LDR) was chosen due to its simplicity, reliability, and sensitivity to changes in light intensity. The LDR is a widely used sensor for detecting light levels because it offers several advantages:

1. **Cost-Effectiveness**: LDRs are inexpensive, making them a cost-effective choice for the implementation.
2. **Ease of Integration**: With three simple connections—VCC, Ground, and Analog Out—LDRs are easy to integrate into existing systems.
3. **High Sensitivity**: The change in resistance in response to light intensity makes the LDR highly sensitive, providing accurate measurements over a wide range of lighting conditions. This change is better explained in chapter 3.3.3.
4. **Low Power Consumption**: LDRs consume minimal power, which is ideal for applications focused on energy efficiency.

These factors collectively make the LDR a good choice for monitoring ambient light and optimizing energy usage in the household energy management system. ***Figure 14*** shows the ldr used in this project, a module with the resistor included.

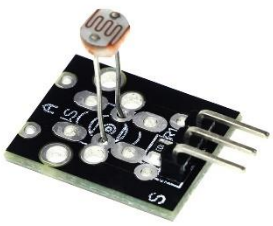


Figure 14. *LDR used in the project.*

2.2.6. Electronic Switching Device

To make the user's instructions happen, there is a need for a switching device to be able to control the appliances through the application. By researching on the Internet, there were a few options to implement. The most common were the Solid State Relay and the Electromechanical Relay.

Solid State Relays use semiconductor devices for switching, which means that they consume very little power. They can operate on as little as a few milliwatts. Eletromechanical Relays, on the other hand, use electromechanical contacts to switch the current. This process requires more power [10]. However, the project will include the Relay, since it was the available solution for the project, the relay is represented in **Figure *15***.

Figure 15. *Eletromechanical Relay.*

2.2.7. Domotic Application

There was the need for an application to give the user the ability to control household devices and with an interface to see each sensor's measurements. Among these, two applications stand out: Home Assistant and OpenHAB.

While there are minimal differences between them, Home Assistant holds a notable advantage over OpenHAB due to its extensive array of open-source programming options. Additionally, Home Assistant is recognized for its robust automation engine, user-friendly interface, and powerful integrations, yet not by a significant margin. Therefore, Home Assistant will be employed for this project to maintain alignment with the original concept.

2.2.8. IOT Communication Protocol

After evaluation, the MQTT (Message Queuing Telemetry Transport) protocol was selected for facilitating communication between the device and the server. MQTT is widely adopted in the IoT industry for its lightweight and efficient operation .

MQTT operates on a publish-subscribe model, where devices (publishers) send messages to a broker, and other devices (subscribers) receive messages from the broker based on their subscriptions.

Small Packet Size: MQTT messages are compact, minimizing the data transmitted over networks. This feature is particularly advantageous for IoT devices operating on constrained networks with limited bandwidth.

Low Overhead: The protocol utilizes an efficient binary messaging format, resulting in minimal network overhead. This efficiency reduces data transmission times and conserves power, which is critical for battery-operated devices.

Retained Messages: MQTT brokers can store the last message sent to a topic, allowing new subscribers to receive the most recent status immediately upon connecting. This feature is useful for applications requiring real-time data updates.

Session Persistence: MQTT supports persistent sessions, enabling clients to reconnect and resume communication with the broker seamlessly. This ensures continuous operation even in the event of network disruptions.

Due to its lightweight design and efficient use of network resources, MQTT enhances energy efficiency in IoT applications. Devices can frequently enter low-power states for extended periods.

Compared to protocols such as HTTP, which are request-response based and typically involve higher overhead, MQTT offers advantages in responsiveness and resource utilization. These characteristics make MQTT a preferred choice for IoT deployments requiring efficient, scalable, and reliable communication.

In conclusion, MQTT's design principles and feature set make it a robust choice for IoT communication, balancing efficiency, reliability, and scalability across diverse deployment scenarios.

3. Proposed Home Automation System

This chapter provides the proposed system architecture. It begins with an introduction to the system overview, which includes a description of the main components and the interaction between them. The next sections focus on each component that was chosen and explain why were they chosen in the previous chapter.

3.1. System Overview

After researching all the alternatives for the elements to use in this project, **Figure 16** represents, the block diagram to be implemented for this work. It also represents the working state of this project.

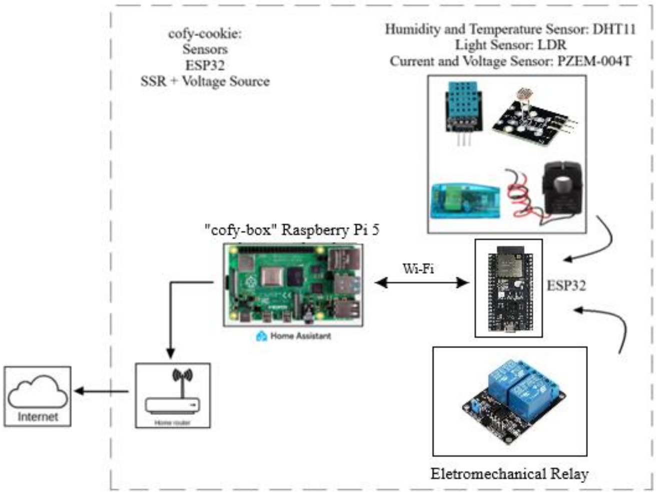


Figure 16. *System Overview.*

The previous figure gives an image of the system itself. The top right of the figure shows the Cofy-Cookie that contains the sensors. These communicate with the ESP32, which is located right under them in the figure. The ESP32 then sends the information through Wi-Fi to the Raspberry Pi 4 that has the home assistant application running, allowing the user to see the measurements taken by the sensors, and to send back information for the Cofy-Cookie with the SSR (bottom right of the figure). These allow the user to take action based on the information. The Raspberry Pi 4 is also connected to a home router, configured by the authors, to connect it to the internet as seen on the left side of the figure.

3.2. Cofy-Box

The Cofy-Box serves as the intermediary between the user and the Cofy-Cookie, facilitating communication. It consists of a *Raspberry Pi 5*, a single-board computer, with a Home Assistant image to oversee all Cofy-Cookie measurements, installed in an SD Card that must have at least 16GB of space, so it can have the image used on this project, this will be explained later on this report. The decision to utilize a single-board computer for the Cofy-Box is driven by the goal of reducing expenses, conserving energy, and optimizing memory usage in handling incoming data from the Cofy-Cookie and user interactions.

3.3. Cofy-Cookie

To have a working project that can be compared with the schematics previously presented, and as this work is an open-source project, this section explained how each component connects to others to have a functional Cofy-Cookie. Arduino IDE will be used to program both ESP32.

3.3.1. ESP32-S2

The microcontroller used for the system will be the ESP32-S2, as said before. **Figure *17*** shows the overview of each block of the MCU.

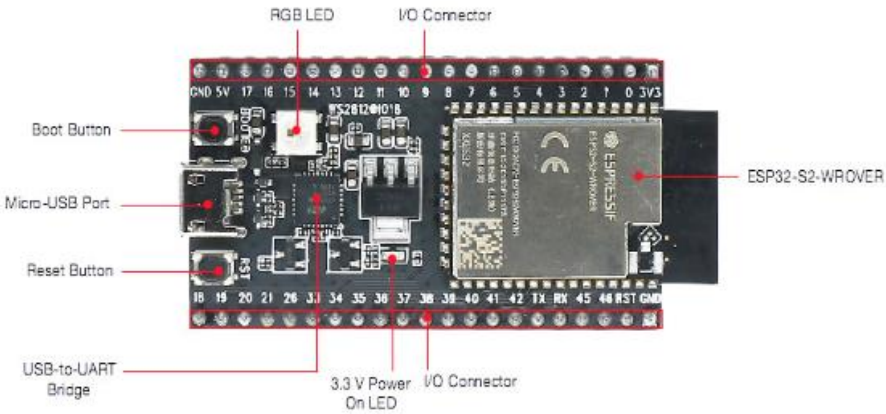


Figure 17. *ESP32-S2 Overview.*

Figure *18* shows the pinout of the chip, where it is possible to see where each pin is located, and the availability of so many GPIO ports, as well as a 3.3V pin and a 5V pin, 1 reset pin, and 2 grounds. It is not possible to see in the figure, but there is an Rx in pin 44 and a Tx in pin 43.

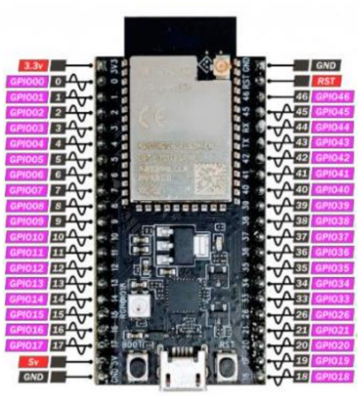


Figure 18. *ESP32-S2 Pinout.*

3.3.2. ESP32-C3

To showcase the project's adaptability with various components, an alternative microcontroller, the ESP32-C3, was also tested. This decision was influenced by the project's minimal GPIO pin needs, which arise from the use of a small number of sensors.

As it is possible to see in **Figure *19***, there are much fewer GPIO pins in this microcontroller than in the ESP32-S2 but there are enough for the project that is being designed.

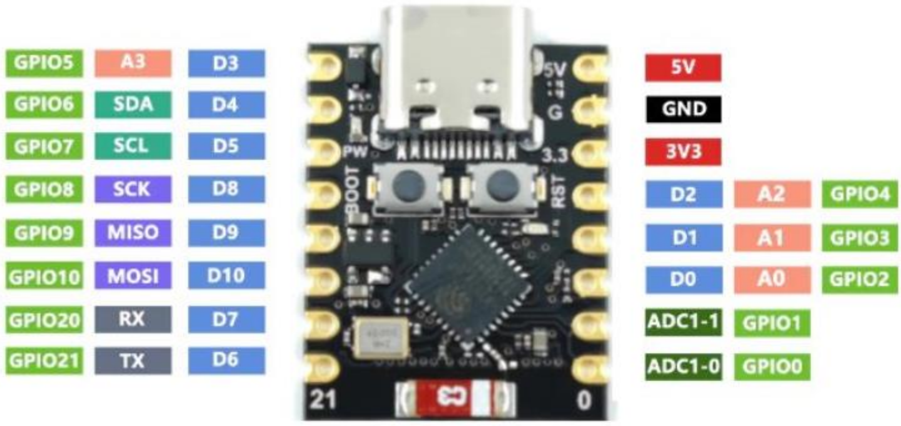


Figure 19. *ESP32-C3 Pinout.*

3.3.3. LDR

To optimize energy savings during daytime, an ambient light sensor was integrated into the system. This sensor utilizes a LDR, which exhibits variable resistance depending on the intensity of ambient light.

The LDR features three connection pins: VCC, Ground, and Analog Out. The measurements made on the LDR available to work, revealed that in complete darkness, the LDR exhibited a resistance of 1.91 MΩ, whereas under full light conditions, the resistance dropped to 41 Ω. This significant variation in resistance allows the LDR to effectively detect changes in light levels.

The process begins by reading an analog value from a Light Dependent Resistor (LDR), which returns a value between 44 and 4096, which were the values read in complete dark and complete light. This raw value is then inverted by subtracting it from 4096, so higher light levels result in higher values. This inverted value is normalized by dividing it by 4096, producing a number between 0 and 1. Multiplying this normalized value by 100 converts it into a percentage. Thus, higher light intensity results in a higher percentage, with full light translating to 100% and no light to 0%.

The LDR operates on the principle that as light intensity increases, its resistance decreases accordingly. This relationship is governed by Ohm's Law, where the current flowing through the LDR is inversely proportional to its resistance. **Figure *20*** shows the LDR used in the project.

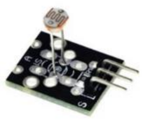


Figure 20. *Light Dependent Resistor.*

3.3.4. DHT11

The sensor chosen to measure temperature and humidity was the *DHT11*. This sensor comes with 3 pins to connect to the microcontroller. **Figure** ***21*** shows the pins and what each pin does. Pin1 from left to right is the VCC, the power supply from 3.3V to 5.5V. Pin2 is the Data pin which outputs both temperature and Humidity through serial data and connects to any GPIO. Lastly, Pin3 is the ground connecting the sensor to the ground of the circuit.

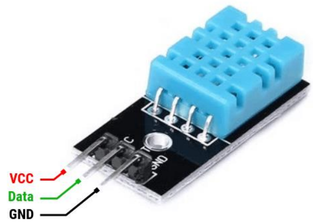


Figure 21. *DHT11 Pinout.*

3.3.5. PZEM-004T V3

The *PZEM-004T 3* will be used to measure current. In ***Figure 22*****,** from bottom to top, the left pins are: Pin1 is the ground, which connects the sensor to the ground of the circuit. Pin2 is the Tx pin that will connect to the Rx pin of the microcontroller, for communication. Pin3 is the Rx pin that will connect to the Tx pin of the microcontroller, and Pin4 is the power supply of 3,3 - 5V. The pins on the right side of the component from top to bottom are: Pin1 and Pin2 connected to the load terminals, being Pin1 connected to the load part that goes through the current transformer. Pin 3 and Pin 4 are the cables that make the connection between the *PZEM-004T V3* and the current transformer.

Figure 22. *PZEM-004T V3 Pinout.*

In the PZEM's manual, there is a table that shows the results of the measurements made by the device. **Table *4*** shows these results.

Table 4. *Measurements Results.*

Register address	Description	Resolution
0x0000	Voltage value	1LSB correspond to 0.1V
0x0001	Current value low 16 bits	1LSB correspond to 0.001A
0x0002	Current value high 16 bits	
0x0003	Power value low 16 bits	1LSB correspond to 0.1W
0x0004	Power value high 16 bits	
0x0005	Energy value low 16 bits	1LSB correspond to 1Wh
0x0006	Energy value high 16 bits	
0x0007	Frequency value	1LSB correspond to 0.1Hz
0x0008	Power factor value	1LSB correspond to 0.01
0x0009	Alarm status	0xFFFF is alarm, 0x0000is not alarm

3.3.6. Eletromechanical Relay

The Electromechanical Relay used in this project features a single circuit. In **Figure *23*** on the down side of the relay, Pin 1 is used for ground connection, while Pin 2 connects to a digital port of the microcontroller for control. The relay is powered through Pin 4 (VCC), which operates between 3.3V and 5V. On the top side, the terminals function as a traditional switch for controlling the load connected to the relay.

Figure 23. *Eletromechanical Relay.*

4. Cofy-Cookie Implementation

This chapter details the implementation process of the Cofy-Cookie system. It includes assembling the Cofy-Cookie device, developing code to handle sensor measurements, Wi-Fi connectivity, and MQTT protocol integration with the broker. The chapter delves deeply into the mechanisms used for transmitting measurements to the server.

4.1. Hardware Implementation

The Cofy-Cookie is the the module that deals with the sensors of the project, connecting the sensors to the ESP32-S2.

After consideration of each component's pins and ways of communication, the proposed circuit schematic can be observed in ***Figure 24***, mounted on two breadboards, and tested.

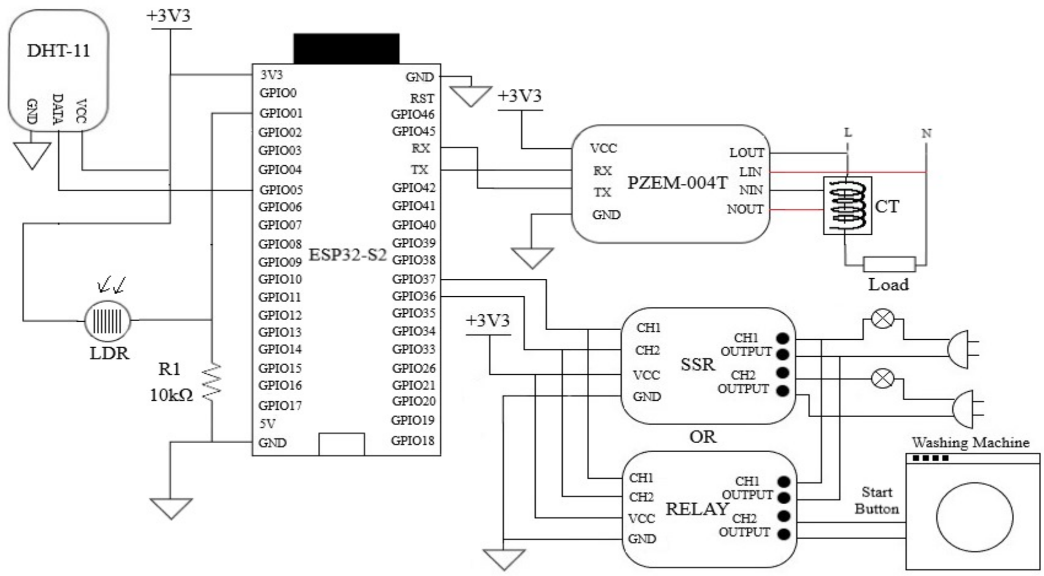


Figure 24. *Electronic Circuit using the ESP32-S2.*

The system will also be implemented using an ESP32-C3, as shown in ***Figure 25***. It is the same circuit, on a different microcontroller. The MCU's are both from the same manufacturer and their development tools are the same. Thus, it is possible to reuse the same development to have alternative implementations.

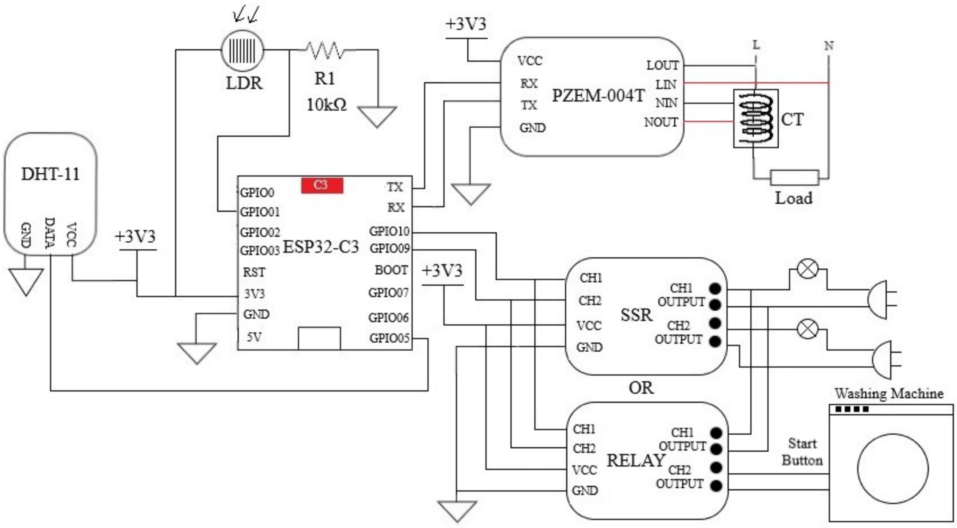


Figure 25. *Electronic Circuit using the ESP32-C3.*

The Cofy-Cookie was mounted on a breadboard connecting all the sensors to the ESP32-S2. **Figure 26** shows the Cofy-Cookie used to test the project, mounted on a breadboard.

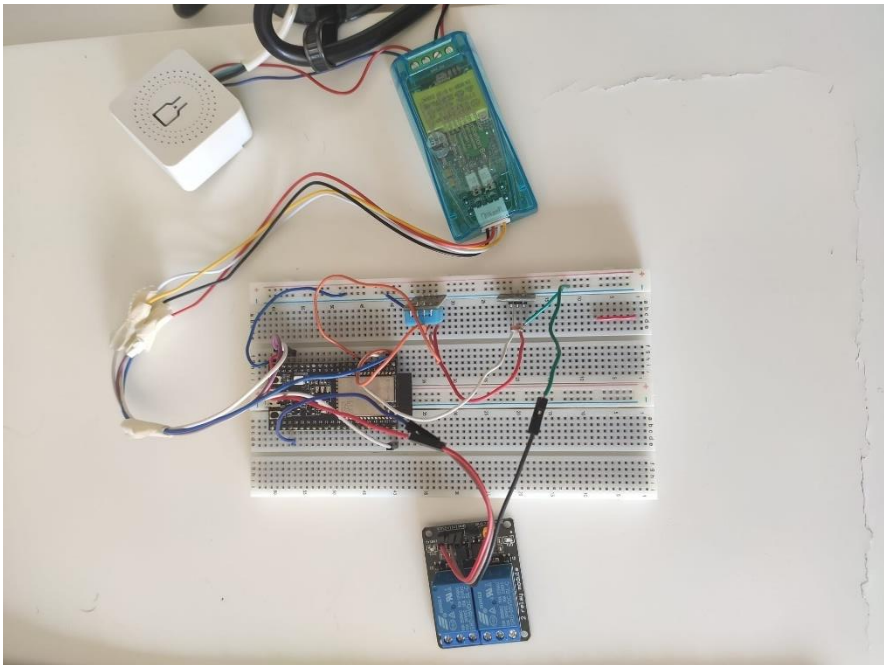


Figure 26. *Cofy-Cookie Mounted on Breadboard.*

4.2. Firmware

The firmware used to program the board used, ensuring the Wi-Fi connection and the MQTT protocol communication is the Arduino IDE due to its ease of use and extensive library support, which facilitates the integration of sensors into projects. This software makes it easy to write programs to implement on different boards, use preinstalled libraries, compile, and debug.

The code consists of 3 functions for reading the measurements. One for the *DHT11*, reading temperature and humidity measurements, one for the *PZEM-004t,* reading all the electrical values and one for the *LDR,* reading the light measurements, having the last one converting the analogue value into a percentage.

Dealing with the relay is done by reading the messages received by MQTT on the topic defined for the relay, dealing with each message in different ways, and turning the relay on or off.

Other than these main functions, there was the need for a function to connect the esp32 to the Wi-Fi and the configuration of the MQTT client.

The program reads the sensors in the main loop and publishes them on the indicated topics.

The Flow chart for the project itself is shown in attachment 1 of the report.

4.3. Wi-Fi Communication

Wi-Fi in this project plays a role in enabling communication between the ESP32 microcontroller and an MQTT broker. The primary purpose of integrating Wi-Fi is to facilitate remote monitoring and control of various sensors and devices connected to the system.

Initially, the ESP32 was configured to connect to a designated Wi-Fi network using the setup_wifi() function. This initialisation step enabled the ESP32 to establish a stable network connection for MQTT communication. A router was configured with network credentials, including the SSID and password, to ensure a secure connection. Using the Wi-Fi library available for the ESP32, the device was set up to connect to the selected Wi-Fi network. This process involved initiating the connection and verifying successful connectivity.

4.4. MQTT Protocol

This project utilizes the MQTT protocol to establish communication between the ESP32 microcontroller and a Raspberry Pi running Home Assistant, which hosts the MQTT broker. Several steps were undertaken to ensure a reliable connection.

The MQTT client on the ESP32 was set up to establish a connection with the MQTT broker running on the Raspberry Pi. This setup involved specifying the broker's IP address and utilizing the default MQTT port, 1883.

To handle incoming MQTT messages, a callback function named 'callback()' was implemented. This function processes messages received from subscribed topics, enabling the ESP32 to respond to commands and data requests from Home Assistant or other MQTT-enabled devices.

In this project, specific MQTT topics were defined to facilitate the transmission of sensor data and control signals between the ESP32 and the MQTT broker:

1. **home/sensor/dht/temperature**
   This topic receives temperature readings from the DHT11 sensor and publishes messages containing the current temperature in degrees Celsius.
2. **home/sensor/dht/humidity**
   This topic receives humidity readings from the DHT11 sensor and publishes messages containing the current humidity level as a percentage.
3. **home/sensor/ldr**
   The home/sensor/ldr topic publishes luminosity readings obtained from the LDR sensor, indicating ambient light levels as a percentage.

4. **home/sensor/pzem/voltage**
   This topic publishes voltage readings obtained from the PZEM-004T device, providing real-time data on electrical voltage in volts.
5. **home/sensor/pzem/current**
   The home/sensor/pzem/current topic publishes current readings obtained from the PZEM-004T device, indicating electrical current in amperes.
6. **home/sensor/pzem/power**
   This topic publishes power consumption readings obtained from the PZEM-004T device, indicating electrical power consumption in watts.
7. **home/sensor/pzem/energy**
   The home/sensor/pzem/energy topic publishes cumulative energy consumption readings obtained from the PZEM-004T device, indicating energy usage in kilowatt-hours.
8. **home/sensor/pzem/frequency**
   This topic publishes frequency readings obtained from the PZEM-004T device, indicating electrical frequency in hertz.
9. **home/relay/state**
   This topic controls the state of the relay connected to the ESP32. Messages published on this topic indicate whether the relay is activated (ON) or deactivated (OFF). Remote control of the relay via MQTT commands enables flexible and convenient operation of connected devices within the home automation system.
10. **home/relay/command**
    The home/relay/command topic accepts commands to control the relay connected to the ESP32. Messages published on this topic, such as ON to activate or OFF to deactivate the relay, dictate the operational state of the relay. Subscribing to this topic allows the ESP32 to execute commands received via MQTT, ensuring seamless integration and operation within the home automation ecosystem.

Each MQTT topic in this project is designed to enhance integration and facilitate efficient operation within the MQTT-based home automation system.

5. Cofy-Box Implementation

This chapter details the implementation process of the Cofy-Box system. It covers the assembly of the Cofy-Box itself and provides a step-by-step explanation of installing and using Home Assistant on the Raspberry Pi to integrate our system.

5.1. Hardware Implementation

The Cofy-Box functions as the central server module within the system. It consists of a Raspberry Pi connected to the Wi-Fi network established by a configured router. The Raspberry Pi operates an MQTT broker and hosts the Home Assistant application. This setup enables users to access project-specific functionalities, including monitoring electricity and environmental measurements captured by the Cofy-Cookie's sensors. Additionally, users can activate devices such as home appliances using a button interface provided by the Cofy-Box. In ***Figure 27.*** Raspberry Pi 5 used as server.is the Raspberry Pi 5 used as a server.

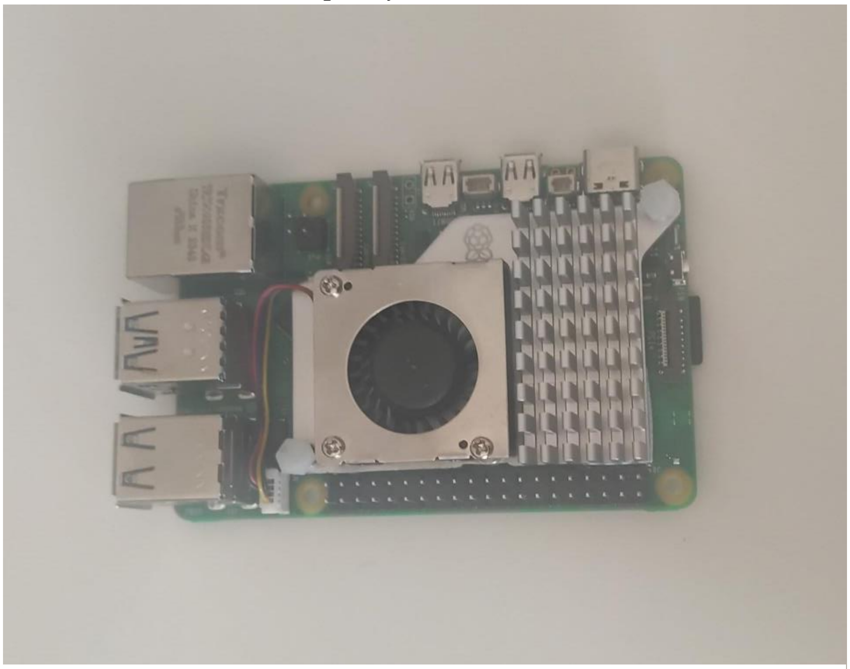


Figure 27. *Raspberry Pi 5 used as server.*

5.2. Raspberry Setup

The Raspberry Pi Imager was installed and a 64GB SD card was used to set up the Raspberry Pi Imager. The Raspberry Pi OS Lite, which requires at least 16GB of space, was installed on the SD card. During the OS installation process, a name was assigned to the host, and the wireless LAN configuration was set using the previously established network settings.

5.3. Home Assistant Setup

After testing the Wi-Fi connection on the Raspberry Pi, CasaOS was installed via the command line. CasaOS allows the installation of various applications, with Home Assistant being the primary application for this project.

Once CasaOS is installed, the next step is to enter the Raspberry Pi's IP address in a browser, which will redirect to the account creation page on CasaOS. Following this, Home Assistant can be installed from the app store and opened like any other application.

5.3.1. Configuration YAML

The configuration YAML file is used in Home Assistant to define and manage various integrations, including sensors and switches. In this project, it sets up MQTT sensors for monitoring temperature, humidity, luminosity, voltage, current, power, energy, and frequency, as well as an MQTT-controlled switch. This configuration enables real-time data collection and remote control of devices

5.3.2. Home Assistant Overview

The configuration.yaml file in Home Assistant allows users to easily customize and manage the application according to their preferences. In this example, a 'HOME' tab displays electricity and environment metrics, while a 'Bedroom' tab provides the same measurements and includes the ability to control a button connected to the circuit's relay.

Figure 28 shows the Home Assistant Home page showing the user every measurement from the sensors.

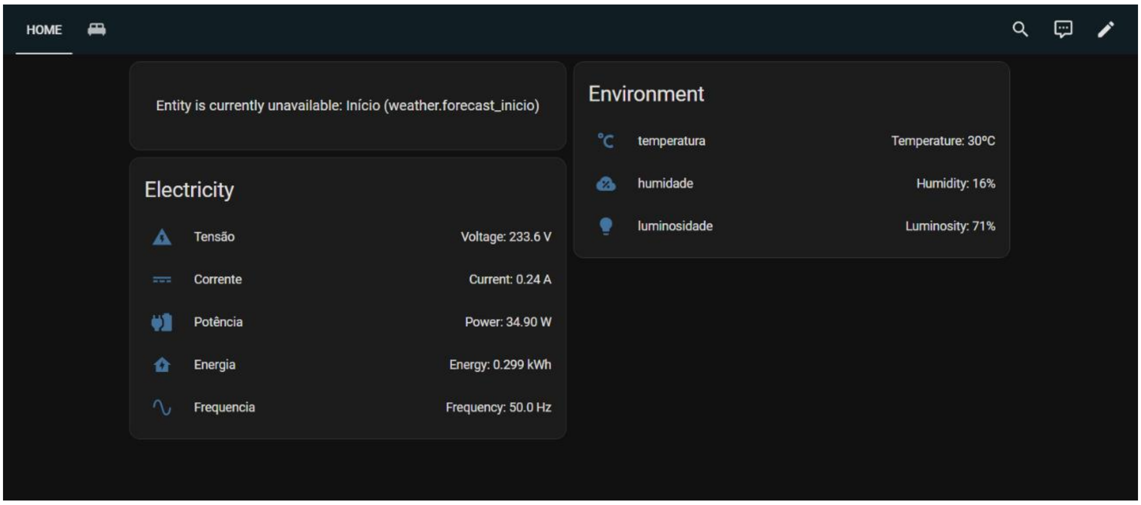


Figure 28. *Home Assistant Home Page.*

5.3.3. Security

Security is a part of the project. In Home Assistant, administrators can create different user accounts and manage permissions, ensuring that only authorized individuals can access specific features. This setup allows the admin to control who can interact with various parts of the Home Assistant system, preventing unauthorized changes and maintaining system integrity.

5.3.4. Different Devices Usage

The full system was tested on different devices such as smartphones, computers and tablets and seen working in any of them, proving it can be easily accessed by any user with the right credentials, on any device.

6. Results & Discussion

This chapter presents the results obtained from the implementation of the Cofy-Cookie and Cofy-Box systems. It also includes a discussion of the findings and challenges encountered. The primary focus is on the performance of the sensor data collection, Wi-Fi and MQTT communication, and system integration with Home Assistant.

6.1. Sensor Data Collection

The Cofy-Cookie module successfully collected data from various sensors, including temperature, humidity, light intensity, and electrical parameters. The data was continuously monitored and transmitted to the Home Assistant for visualization and control.

Temperature and Humidity: The DHT11 sensor provided temperature and humidity readings. **Figure 29** shows the temperature and humidity values shown by the Cofy-Cookie.

```
Temperature: 30°C
Humidity: 16%
Temperature: 30°C
Humidity: 16%
Temperature: 30°C
Humidity: 16%
Temperature: 30°C
Humidity: 16%
Temperature: 30°C
Humidity: 16%
```

Figure 29. *Temperature and Humidity Measurements.*

Light Levels: The LDR sensor measured ambient light levels, converting the analog values into percentages. It was tested in bright light using a smarthpone’s lantern and the sunlight exposure, medium light using ambient light in the afternoon of a summer day and completely covered indicated zero light using a pen cap over the sensor and zero sunlight exposure, this is shown in **Figure 30**.

```
Luminosity: 55%
Luminosity: 56%
Luminosity: 0%
Luminosity: 55%
Luminosity: 93%
Luminosity: 47%
Luminosity: 0%
Luminosity: 94%
```

Figure 30. *Luminosity Values.*

Electrical Parameters: The PZEM-004T sensor measured voltage, current, power, frequency and energy consumption. This sensor was tested by reading the measurements with a computer as its load for different power consumption profiles. The measured values can be seen in **Figure 31**.

```
Voltage: 234.4 V
Current: 0.19 A
Power: 27.60 W
Energy: 0.316 kWh
Frequency: 50.0 Hz
Voltage: 234.5 V
Current: 0.00 A
Power: 0.00 W
Energy: 0.316 kWh
Frequency: 49.9 Hz
Voltage: 234.0 V
Current: 0.18 A
Power: 24.30 W
Energy: 0.316 kWh
Frequency: 50.0 Hz
```

Figure 31. *Electricity Measurements.*

6.2. Wi-Fi and MQTT Communication

The ESP32 microcontroller connected to the designated Wi-Fi network without any issues. The MQTT protocol facilitated reliable communication between the Cofy-Cookie and the Home Assistant running on the Raspberry Pi.

- **Connection Stability**: The Wi-Fi connection remained stable throughout the testing period, with minimal disconnections.
- **Latency**: There was no relevant latency observed.
- **Message Reliability**: All MQTT messages were successfully transmitted and received, with no data loss or corruption.

This communication can be seen on **Figure 32**, a capture taken with the application wireshark with a filter showing only the messages sent to the MQTT broker.

No.	Time	Source	Destination	Protocol	Length	Info
34	4.649603	192.168.7.112	192.168.7.116	MQTT	219	Ping Request, Publish Received (id=55186)
35	4.652110	192.168.7.112	192.168.7.116	MQTT	213	Ping Response
36	4.652194	192.168.7.116	192.168.7.112	TCP	54	6378 → 8123 [ACK] Seq=1 Ack=325 Win=251 Len=0
41	5.650775	192.168.7.112	192.168.7.116	TCP	214	[Continuation to #35] 8123 → 6378 [PSH, ACK] Seq=325 Ack=1 Win=249 Len=160
42	5.702294	192.168.7.116	192.168.7.112	TCP	54	6378 → 8123 [ACK] Seq=1 Ack=485 Win=256 Len=0
49	7.649500	192.168.7.112	192.168.7.116	TCP	207	[Continuation to #35] 8123 → 6378 [PSH, ACK] Seq=485 Ack=1 Win=249 Len=153
50	7.691934	192.168.7.116	192.168.7.112	TCP	54	6378 → 8123 [ACK] Seq=1 Ack=638 Win=256 Len=0
128	24.338702	192.168.7.116	192.168.7.112	MQTT	70	Ping Request
129	24.344897	192.168.7.112	192.168.7.116	TCP	407	[Continuation to #35] 8123 → 6378 [PSH, ACK] Seq=638 Ack=17 Win=249 Len=353
130	24.377864	192.168.7.116	192.168.7.112	TCP	66	6383 → 8123 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 WS=256 SACK_PERM
131	24.382346	192.168.7.112	192.168.7.116	TCP	66	8123 → 6383 [SYN, ACK] Seq=0 Ack=1 Win=32120 Len=0 MSS=1460 SACK_PERM WS=128
132	24.382403	192.168.7.116	192.168.7.112	TCP	54	6383 → 8123 [ACK] Seq=1 Ack=1 Win=65536 Len=0
133	24.382628	192.168.7.116	192.168.7.112	MQTT	1177	Publish Received (id=21332), Publish Ack (id=28270), Publish Ack (id=20052), Publish Release (id=23162), Publish
134	24.384505	192.168.7.112	192.168.7.116	TCP	54	8123 → 6383 [ACK] Seq=1 Ack=1124 Win=31872 Len=0
135	24.386883	192.168.7.112	192.168.7.116	MQTT	292	Publish Ack (id=21584), Publish Release (id=11604), Connect Ack
136	24.386883	192.168.7.112	192.168.7.116	TCP	436	[BoundErrorUnreassembled Packet]
137	24.386915	192.168.7.116	192.168.7.112	TCP	54	6383 → 8123 [ACK] Seq=1124 Ack=621 Win=65024 Len=0
138	24.397891	192.168.7.116	192.168.7.112	TCP	54	6378 → 8123 [ACK] Seq=17 Ack=991 Win=254 Len=0
153	27.347490	192.168.7.116	192.168.7.112	MQTT	1071	Publish Release (id=26415), Publish Complete (id=28526), Publish Received (id=20295), Publish Message[BoundErrorUı
154	27.355462	192.168.7.112	192.168.7.116	TCP	291	[Continuation to #136] 8123 → 6383 [PSH, ACK] Seq=621 Ack=2141 Win=31872 Len=237
155	27.355462	192.168.7.112	192.168.7.116	TCP	88	[Continuation to #136] 8123 → 6383 [PSH, ACK] Seq=858 Ack=2141 Win=31872 Len=34

Figure 32. *MQTT Wireshark Capture.*

6.3. System Integration

Integration of the Cofy-Cookie with Cofy-Box (Home Assistant) was successful, allowing for real-time monitoring and control of the connected devices.

- **Sensor Data Monitoring**: All sensor readings were accurately displayed on the Home Assistant dashboard.
- **Relay Control**: The relay connected to the ESP32 responded promptly to MQTT commands, enabling remote control of home appliances.
- **User Interface**: The Home Assistant dashboard provided an intuitive interface for users to interact with the system, featuring tabs for overall metrics and specific room controls.

As for the Home Assistant it was configured so the user is able to see every measurement in the Home Page, this can be seen in **Figure 33**.

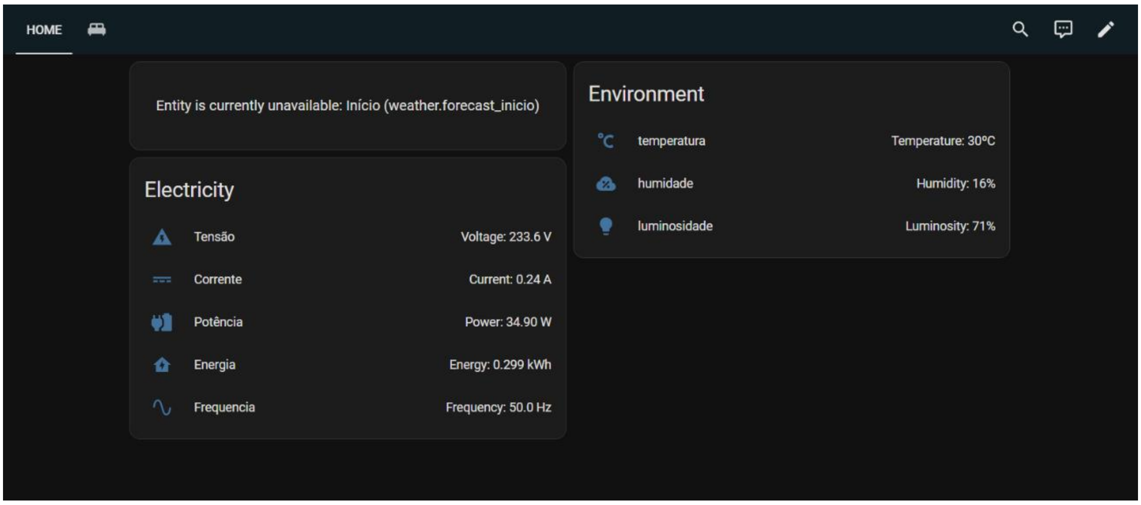


Figure 33. *Home Assistant's Home Page.*

6.4. Analysis of Results

The data collected from the sensors was consistent and reliable. The temperature and humidity readings were within expected ranges, and the light intensity measurements effectively reflected ambient conditions. Electrical parameter readings provided valuable insights into power consumption values.

Sensor Accuracy: The DHT11, LDR, and PZEM-004T sensors demonstrated acceptable accuracy for home automation applications.

System Performance: The Wi-Fi and MQTT communication were robust, with stable connections and low latency, ensuring timely updates and control.

If the user is allowed, they can also access the Bedroom Page and turn on the lights as well, and see every measurement. This is shown in **Figure 34**.

Figure 34. *Home Assistant's Bedroom Page.*

7. Conclusions & Future Work

This chapter provides an overview of the conclusions drawn from the Cofy-Cookie and Cofy-Box implementation and outlines potential areas for future development. The project began with a survey of the required hardware specifications and the establishment of specific milestones to achieve the project's objectives. Following this, the implementation phase involved setting up the server, connecting various components, and ensuring energy-efficient operation. Through this approach, the project successfully met its goals, paving the way for further enhancements and expansions in home automation and energy monitoring systems.

7.1. Conclusions

The implementation of the Cofy-Cookie and Cofy-Box systems demonstrated a successful solution to creating an integrated home automation and energy monitoring solution. Key conclusions from the project are as follows:

1. **Sensor Data Collection**: The Cofy-Cookie module effectively collected and transmitted data from various sensors, including temperature, humidity, light intensity, and electrical parameters. The data was consistent and reliable, enabling real-time monitoring through Home Assistant.
2. **Wi-Fi and MQTT Communication**: The ESP32 microcontroller maintained stable Wi-Fi connectivity and reliable MQTT communication with the Raspberry Pi, ensuring data transmission and control of connected devices.
3. **System Integration**: The integration with Home Assistant allowed for efficient monitoring and control of the system. The intuitive dashboard provided users with easy access to sensor data and remote control capabilities.
4. **Sensor Accuracy and Performance**: The sensors used in the project demonstrated acceptable accuracy for home automation applications. The system's performance in terms of data collection, communication, and control met the project's objectives.
5. **Low Power Consumption and Secure Implementation**: One of the goals of the project was to implement a low power consumption and secure solution. The open code solution demonstrates its security. The fact that it works with the components proves that a low-power solution can be effective.
6. **Scalability**: The project was seen working with multiple different devices such as different Raspberry’s and different microcontrollers, showing the potential to use a variety of different components.

Overall, the project achieved its primary goals of creating a reliable and efficient home automation and energy monitoring system, demonstrating its potential for broader applications.

7.2. Future Work

While the project was successful, several areas for future enhancement and expansion have been identified.

1. **Enhanced Sensor Range**: Future work could focus on incorporating sensors with a bigger range of values, such as a sensor that can measure negative temperatures for countries that have these kind of temperatures.
2. **User Interface**: Developing a more customizable and user-friendly interface for Home Assistant could enhance user experience, this could be adding new areas of the house or seeing the measurements in different presentations such as graphic form.
3. **Expanded Functionality**: Adding new sensors and control mechanisms, such as security cameras, advanced energy management features like live-cost for the energy in the area, or additional environmental sensors, for example wind sensors, could be an interesting addition to the system's capabilities.
4. **Security**: Implementing SSL/TLS encryption for MQTT communication enhances security by encrypting data transmitted between devices and the MQTT broker. Embedding static CA certificates in the device firmware ensures the authenticity of the broker while using secure passwords and Regular firmware updates enhance the system's defenses against potential threats.
5. **Integration with Other Systems**: Investigating the integration of the Cofy-Cookie and Cofy-Box systems with other home automation platforms and IoT devices could increase compatibility and functionality. This could be the different devices that have been talked in this report like shelly devices or tuya devices.

Annexes

1. Flowchart of the implemented code for the Cofy-Cookie

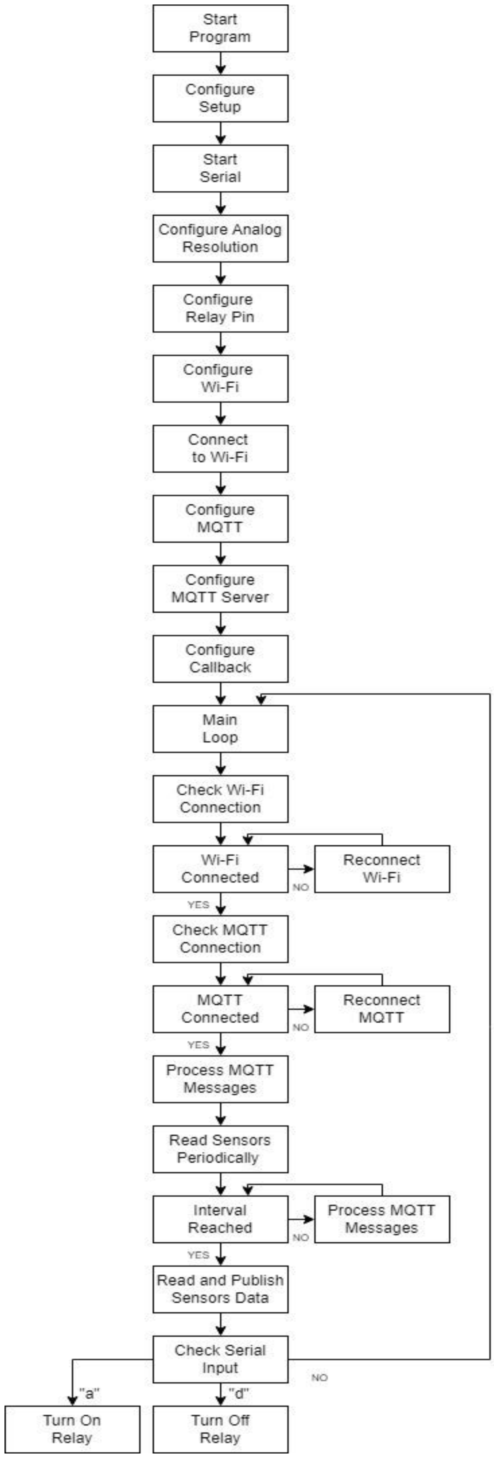


Figure 35. *Flowchart of the Cofy-Cookie.*

2. Raspberry Pi & Home Assistant installation tutorial

This chapter provides a tutorial of how to install Home Assistant using a Raspberry Pi. The steps are as follows.

1. Remove the SD card of the Raspberry Pi;

2. Insert the SD card into a computer with access to the Internet;

3. Download the Raspberry Pi Imager from the Raspberry Pi official website: *https://www.raspberrypi.com/software/*;

4. Open Raspberry Pi Imager;

5. Select which device you wish to use in this tab as shown in **Figure 36**:

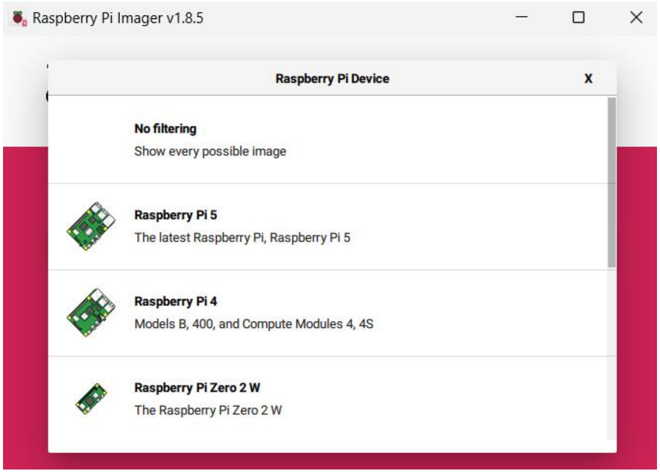


Figure 36. *Choosing Raspberry Pi Device.*

6. The Raspberry Pi OS used is located in the Operating System tab, as shown in **Figure 37** and **Figure 38**.

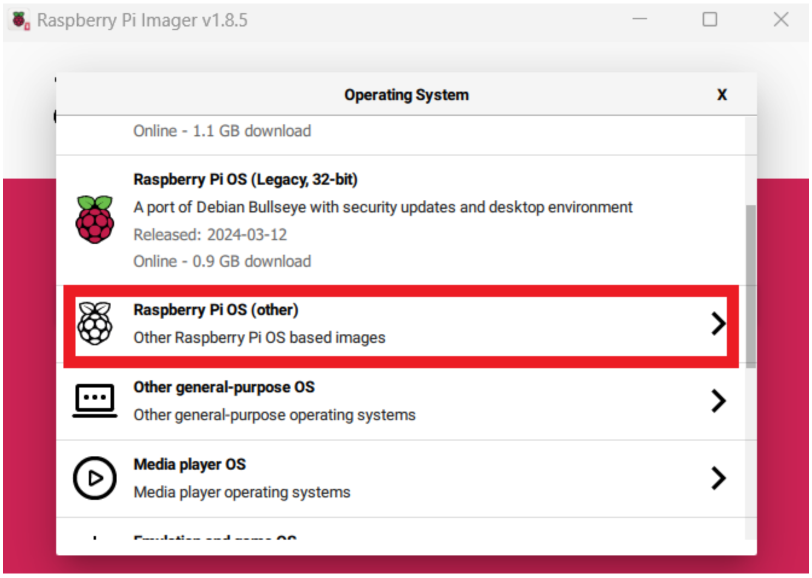


Figure 37. *Choosing the Operating System.*

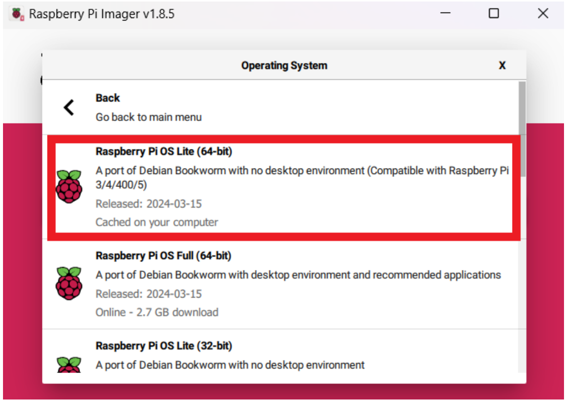


Figure 38. *Choosing the Operating System (64-bit).*

7. Confirm your choices, and then select the edit settings button as seen in **Figure 39**.

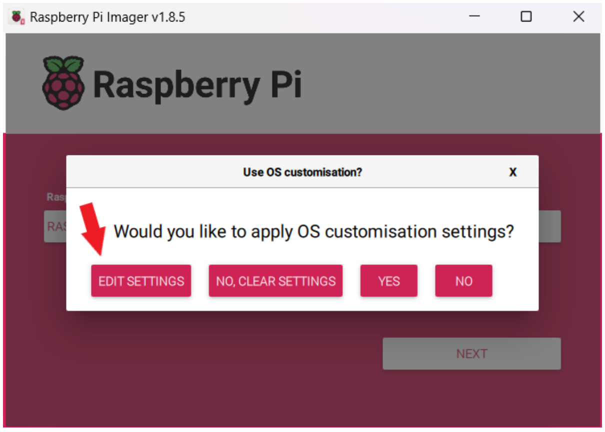


Figure 39. *Selecting edit settings.*

8. In the next tab, pick the names and passwords to add to your device and confirm the network that you will use to communicate with your Raspberry Pi, as seen on **Figure 40**. After these steps hit the save button and start the image installation.

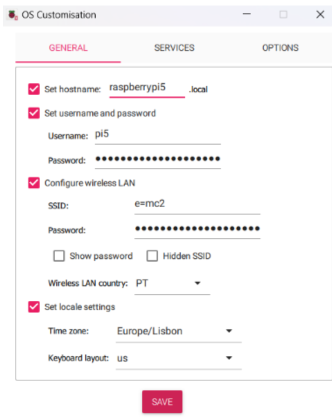


Figure 40. *Wireless LAN Configuration.*

9. After the image installation is completed, remove the SD card from the computer, and insert in the Raspberry Pi again, and turn it on.

10. Using a computer connected to the network that was previously configured in the Raspberry Pi, using the command prompt of your computer, try to reach the Raspberry using the command: ping -4 *chosen_hostname*.local. **Figure 41** shows the command.

```
Linha de comandos

C:\Users\camis>ping -4 raspberrypi5.local

Pinging raspberrypi5.local [192.168.2.3] with 32 bytes of data:
Reply from 192.168.2.3: bytes=32 time=22ms TTL=64
Reply from 192.168.2.3: bytes=32 time=6ms TTL=64
Reply from 192.168.2.3: bytes=32 time=25ms TTL=64
Reply from 192.168.2.3: bytes=32 time=13ms TTL=64

Ping statistics for 192.168.2.3:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 6ms, Maximum = 25ms, Average = 16ms
```

Figure 41. *Ping Command.*

11. Now it is possible to see the Raspberry Pi address on the chosen network. Accessing the Raspberry Pi using the command: ssh *chosen_name@Raspberry_address*, then hit the enter button and insert the chosen password. **Figure 42** represents the command.

```
C:\Users\camis>ssh pi5@192.168.2.3
pi5@192.168.2.3's password:
Linux raspberrypi5 6.6.20+rpt-rpi-v8 #1 SMP PREEMPT Debian 1:6.6.20-1+rpt1 (
2024-03-07) aarch64

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
Last login: Tue May  7 15:47:51 2024 from 192.168.2.2
pi5@raspberrypi5:~ $
```

Figure 42. *ssh Command.*

12. Insert the following command and fix the following parameters: ClientAliveInterval and ClientAliveCountMax must not be commented and the first one must have value 1000000 instead of 0. Then save this changes and exit with the controls ctrl+o and ctrl+x respectively. This is shown in **Figure 43** and **Figure 44**.

```
pi5@raspberrypi5: ~

pi5@raspberrypi5:~ $ sudo nano /etc/ssh/sshd_config
```

Figure 43. *ssh Configuration.*

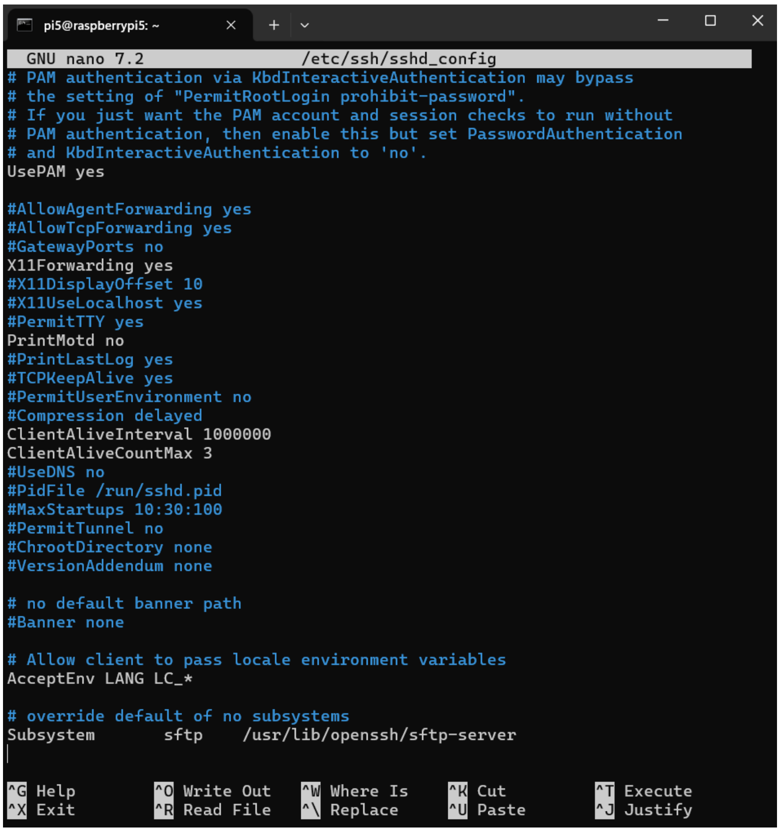


Figure 44. *ssh Configuration.*

13. Do the commands separately as it is shown in the figure below and as it is possible to see in the last line of the command response if there are packages to upgrade do the following command: sudo apt upgrade. **Figure 45** shows the update being made, and **Figure 46** shows the command to upgrade the packages.

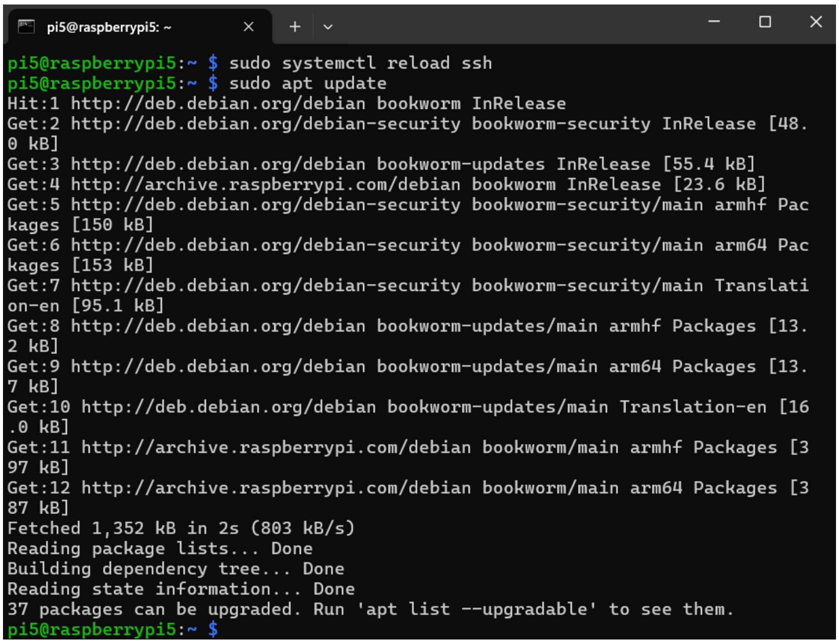


Figure 45. *Update Command.*

```
pi5@raspberrypi5:~ $ sudo apt upgrade
```

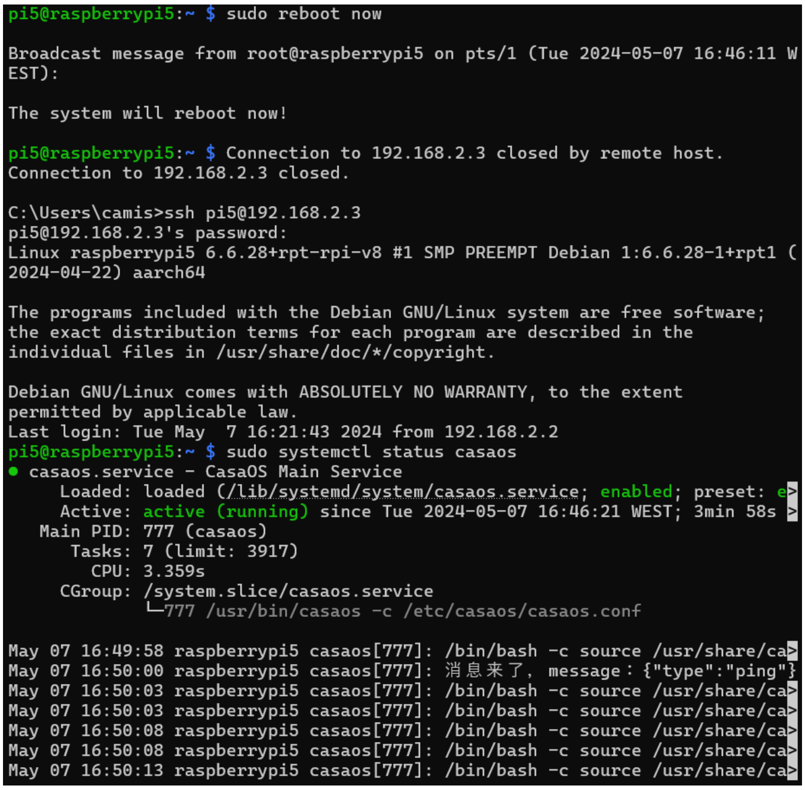
Figure 46. *Upgrade Command.*

14. After the upgrade finish copy the following URL that will install CasaOS in your Raspberry Pi. This is the image containing the operating system where the Home Assistant application can be installed on. The command is represented in **Figure 47**.

```
pi5@raspberrypi5:~ $ curl -fsSL https://get.casaos.io | sudo bash
```

Figure 47. *CasaOS installation.*

15. After installing CasaOS in your Raspberry Pi do the following commands in your computer prompt to see if the image is running by checking the Active parameter after the command: sudo systemctl status casaos. The status of the CasaOS image is seen in **Figure 48**.



```
pi5@raspberrypi5:~ $ sudo reboot now

Broadcast message from root@raspberrypi5 on pts/1 (Tue 2024-05-07 16:46:11 W
EST):

The system will reboot now!

pi5@raspberrypi5:~ $ Connection to 192.168.2.3 closed by remote host.
Connection to 192.168.2.3 closed.

C:\Users\camis>ssh pi5@192.168.2.3
pi5@192.168.2.3's password:
Linux raspberrypi5 6.6.28+rpt-rpi-v8 #1 SMP PREEMPT Debian 1:6.6.28-1+rpt1 (
2024-04-22) aarch64

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
Last login: Tue May  7 16:21:43 2024 from 192.168.2.2
pi5@raspberrypi5:~ $ sudo systemctl status casaos
● casaos.service - CasaOS Main Service
     Loaded: loaded (/lib/systemd/system/casaos.service; enabled; preset: e>
     Active: active (running) since Tue 2024-05-07 16:46:21 WEST; 3min 58s >
   Main PID: 777 (casaos)
      Tasks: 7 (limit: 3917)
        CPU: 3.359s
     CGroup: /system.slice/casaos.service
             └─777 /usr/bin/casaos -c /etc/casaos/casaos.conf

May 07 16:49:58 raspberrypi5 casaos[777]: /bin/bash -c source /usr/share/ca>
May 07 16:50:00 raspberrypi5 casaos[777]: 消息来了, message：{"type":"ping"}
May 07 16:50:03 raspberrypi5 casaos[777]: /bin/bash -c source /usr/share/ca>
May 07 16:50:03 raspberrypi5 casaos[777]: /bin/bash -c source /usr/share/ca>
May 07 16:50:08 raspberrypi5 casaos[777]: /bin/bash -c source /usr/share/ca>
May 07 16:50:08 raspberrypi5 casaos[777]: /bin/bash -c source /usr/share/ca>
May 07 16:50:13 raspberrypi5 casaos[777]: /bin/bash -c source /usr/share/ca>
```

Figure 48. *CasaOS status.*

16. Insert the IP address of the Raspberry Pi in a new searching tab in your computer and if this is the response that you obtain then the image was successfully installed. ***Figure 49*** shows the page to create the account.

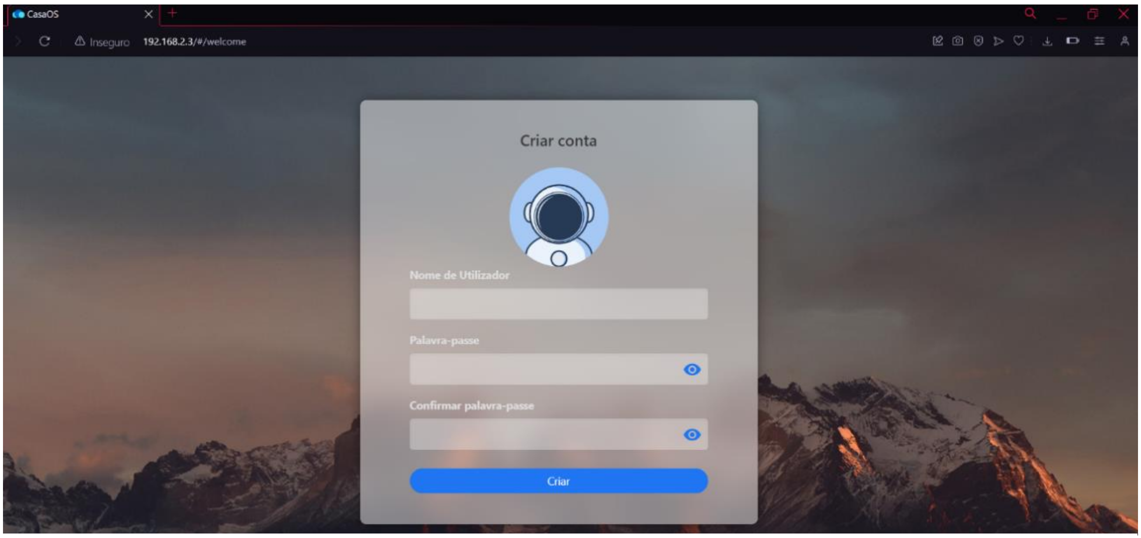


Figure 49. *CasaOS Creating Account.*

17. After creating your account you will reach the main menu showing the files installed as well as the App Store to install every application available. This overview page is shown in ***Figure 50***.

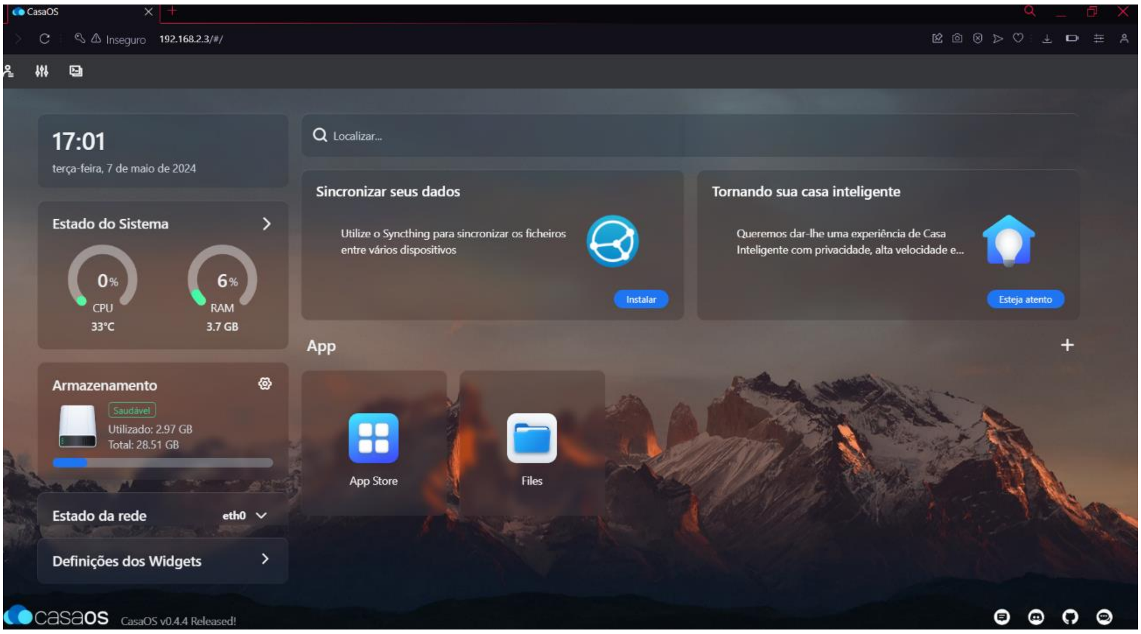


Figure 50. *Overview Page.*

18. After installing the the Home Assistant, open it's application and create your account. After having a similar menu as the shown bellow your Home Assistant is officially operative and ready to customize. ***Figure 51*** shows the Home Assistant Page.

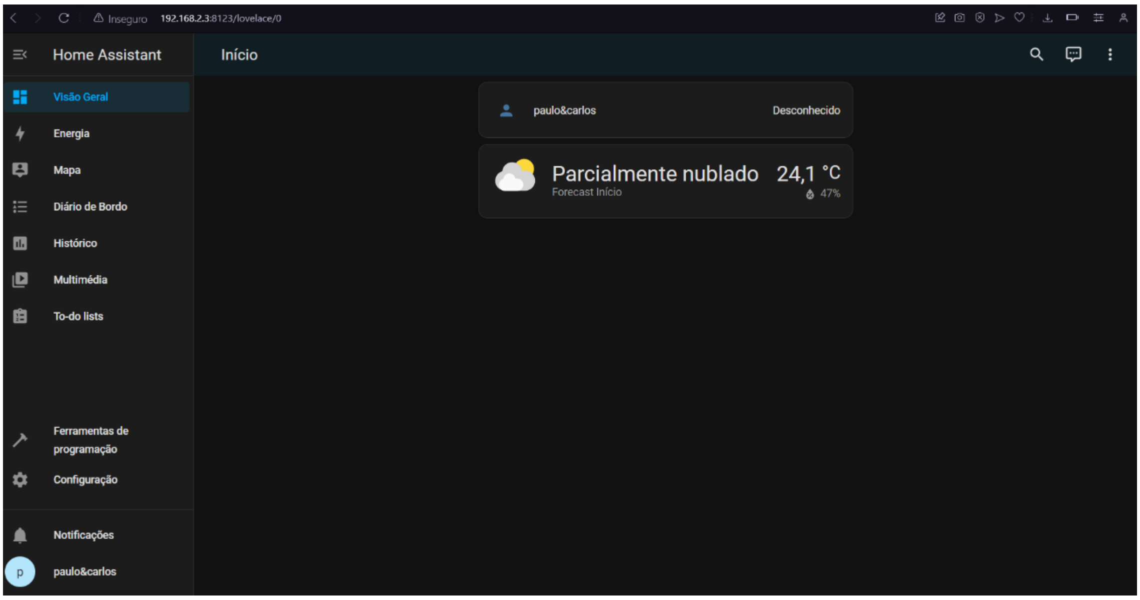


Figure 51. *Home Assistant Page.*

3. GitHub & Cloud Repository For The Project.

https://github.com/prodrigues0201/Home-Automation-System

https://iselpt-my.sharepoint.com/:f:/g/personal/a47118_alunos_isel_pt/EkJ-swr02_ZPjP9zOjrB2B8BsubsjIcEtycCEWxVvByj5w?e=WBco3R

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