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M.Sc. THESIS

REMOTE MANAGEMENT OF SMART DEVICES THROUGH POWER LINES

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FOREWORD

I would like to thank my family and my lovely wife for all their support through this ordeal, I want to thank my supervisor Dr. Mustafa DAĞTEKİN for his support and for helping me through this journey.

July, 2018 KHALED ALSHAKH SULIMAN

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

LIST OF SYMBOLS AND ABBREVIATIONS

Abbreviation	**Explanation**
AC	: Alternating Current
APT-GET	: Advanced Package Tool
ADC	: Analog to Digital Converter
ARM	: Advanced RISC Machines
CoAP	: Constrained Application Protocol
CPU	: Central Process Unit
CPU	: Central Processing Unit
DC	: Direct Current
DS	: Dedicated Server
EEPROM	: Electrically Erasable Programmable Read-Only Memory
EEPROM	: Electrically Erasable Programmable Read-only Memory
E-IoT	: Edison – Internet of Things
EMR	: Electromechanical Relay
EoP	: Ethernet Over Powerline
GPIO	: General Purpose Input/Output
GPU	: Graphics Processing Unit
GUI	: Graphical User Interface
IDE	: Integrated Development Environment
IoT	: Internet Of Things
IP	: Internet Protocol
L2C	: Layer 2 Control
LCD	: Liquid Crystal Display
LED	: Light Emitting Diode
MIU	: Metering Interface Unit
MQTT	: Message Queuing Telemetry Transport
PC	: Personal Computer
PIP	: Package Management System
PIR	: Passive Infrared
PLC	: Power Line Communication
RAM	: Random Access Memory
RP	: Raspberry Pi

SD : Secure Digital

SoC : System On A Chip

SSR : Solid State Relay

TCP : Transmission Control Protocol

TLS : Transport Layer Security

USB : Universal Serial Bus

VPS : Virtual Private Server

Symbol **Explanation**

A : Ampere

V : Voltage

ÖZET

YÜKSEK LİSANS TEZİ

GÜÇ ŞEBEKELERİ ARACILIĞIYLA AKILLI CİHAZLARIN UZAKTAN YÖNETİMİ

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Cihazları birbirine bağlamaya yönelik muazzam ilgi "Nesnelerin İnterneti" veya IoT teriminin doğmasına yol açmıştır. O zamandan beri kullanıcıların ev aletlerini uzaktan kontrol, yönetim ve izlemesine, ve aynı yerdeki merkezi bi cihazın başka bir cihazı yönetmesine izin veren Akıllı Ev Sistemi ve Ev Otomasyonu sistemi sağlayan birçok uygulama geliştirildi. Akıllı cihazların geliştirilmesi bu teknolojiyi kaldırabilecek bataryaların geliştirilmesi ihtiyacını doğurdu. Bu türden bataryalar güç tasarrufu sağlamak ve cihaza uzun ömür kazandırmak için Lityum hücreleri kullanır. Yapılan çalışmalarda Lityum bataryalarını yanlış kullanmak bu hücrelere zarar vermeye yol açabilir. Aşırı şarz Lityum bataryaların bozulma sebeplerinden biridir, bir kısa devre bataryadaki güvenlik metotlarnı atlayıp bu metotların devreye geçmesini önleyebilir.

Ayrıca birçok Akıllı Ev Sistemleri uygulamasında kullanılan Kablosuz Ağ (Wi-Fi) teknolojisinin biçok dezavantajı ve güvenlik problemi bulunmaktadır. Bu sorunlar Akıllı Ev Sistemlerini riske atmakta ve kullanımını güvenilmez kılmaktadır.

Bu tezde cihazlardan veri almak ve vermek için Güç Hatları Haberleşmesi kullanan Akıllı Ev Sistemi tasarladık. Bu sistem düğüm bazlı çalışmakta ve her düğüm gereksinimine göre ev içine dağıtılmaktadır. Her düğüm farklı bir metod ve farklı bir kullanım sağlayabilir. Bütün düğümler birbiriyle güç hatları üzerinden haberleşir ve merkezi bir kontrol ünitesi düğümlerin düzgün çalıştığını garantiye almak için onların yönetimini ve izlenmesini sağlar. Biz elektrik prizini izleyen ve kontrol eden bir bir düğüm üzerinde yoğunlaşıyoruz. Bu prize Lityum bataryayı şarz edebilen bir şarz cihazı bağlıdır. Geliştirilen algoritma elektrik hattını izler ve elektriği ne zaman keseceğine karar verir böylelikler bataryaya aşırı sarzdan dolayı zarar gelmez. Gücü açma veya geri bağlama kararına birçok faktör etki eder. Bunlar çevreye ve güç hattından geçen akıma bağlıdır. Bu algoritmayı etkileyecek bütün olasılıkları simüle eden bir tatbikat kiti geliştirildi.

Temmuz 2018, 71 sayfa.

Anahtar kelimeler: IoT, PLC, Akıllı Ev, Raspberry Pi, Arduino

SUMMARY

M.Sc. THESIS

REMOTE MANAGEMENT OF SMART DEVICES THROUGH POWER LINES

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The tremendous demand for connecting devices to each other lead to the discovery of the term "Internet of Things" or IoT. Since then many more applications have been developed to provide Smart Home Systems and Home Automation Systems to make the users able to control, manage and monitor the home appliances remotely and to let a central device control another device at the same place. The development of smart devices led to the need for developing batteries that can handle such technology. These types of batteries use Lithium cells to save power and to provide the device with extended life duty. The studies show that abusing Lithium batteries can lead to damage to the cells. Overcharging is one of the reasons why Lithium batteries get damaged, a short circuit can bypass the safety methods inside the batteries and prevent them to work.

Moreover, the Wi-Fi technology that is being used in many applications of Smart Home Systems has many disadvantages and security problems. These issues are compromising the Smart Home Systems, also make them unreliable to use.

In this thesis, we developed a Smart Home System that uses the Power Line Communication to send and receive data from the appliances. It is node based; each node is distributed in the home depending on the need of each node. Each node can provide a different method and different type of usage. All the nodes communicate with each other through power lines, and a central controller will manage and monitor the nodes to make sure that they are working properly. We focus on developing a node that monitors and control an electrical socket. A charger connects to the socket to charge a Lithium battery. The developed algorithm will monitor the power line and determine when to cut the power off, so the battery will not be damaged by overcharging. Many factors will affect the decision of cutting the power off or reconnect it; this will depend on the environment and the current flow through the power line. A demonstration kit is developed to simulate all the possibilities that can affect this algorithm. The algorithm will monitor the flow, calculate the average of the current and keep records of these values. If the device starts to withdraw current more than the recorded average, that will indicate to a problem in the battery and cuts the power in the plug to prevent any farther damage in the device.

July 2018, 71 pages.

Keywords: IoT, PLC, Smart Home, Raspberry Pi, Arduino

1. INTRODUCTION

Since the word “Internet Of Things” was known by people, it has been a hot topic for the last few years. However, it is not a new concept, 20 years ago, a researcher at MIT “Kevin Ashton“ presented the word IoT as “a collection of devices which interact with each other, collect data from the environment and exchange them to achieve a goal or to control devices based on the collected data” [1]. At that time many obstacles were encountered during the evolution of IoT such as how to connect the devices to each other and what kind of wireless should be used in the devices, for those reasons the term IoT was only presented by the industrial devices. Nowadays IoT is used to connect industrial devices with everyday devices. One of the IoT applications focuses on building smart homes and home automation systems. This type of system contains a primary controller and some sensors, the sensors collect data from the environment and send them back to the central controller to analyze them and do specific commands depending on the analyzed data. The smart home system provides information for an internal home environment like heating, gas, electricity, lightning, appliances (TV, NAS, Refrigerator, Washing Machines, etc.). Homes nowadays contain various devices that control the appliances for better power management for avoiding the damage to specific home devices or avoiding some dangerous situations like fires by using gas sensors. Also, all the provided data by these devices can be sent to the homeowners using the internet so they can monitor and control the appliances, (temperature, lights, security cameras, etc.) from anywhere around the world.

There are many ways to connect the internal devices, some of the earlier proposed systems used a network cable to transmit data between the devices and send them to the controller. Others used wireless transmission like Wi-Fi. However, specific devices like sensors faced a problem with Wi-Fi because microcontroller requires a lot of configuration to use Wi-Fi and it requires an external module to transmit data, later a protocol called ZigBee [2] was proposed to make it easier to communicate with different devices that are not configured to talk with each other by default. The ZigBee protocol gained much popularity, and it was used in many home automation systems to send data from the sensors to the central controller. Nowadays ZigBee protocol is outdated, and many sensors now connect to an Arduino system and then send data over Wi-Fi or the ethernet cables. Another type of home automation can be built based on PLC (Power Line Communication) to send data and commands to the devices over the power lines. The recent studies based on PLC focus on how to send data over the power line without noise and receive data without any loss. Devices and sensors cannot be attached to a PLC chip directly, it needs a module to connect them to each other.

Wi-Fi-based system nowadays can be compromised [3]. According to the recent research, the Wi-Fi system is not secure enough and can be hacked. Ethernet cable-based systems need to implement wires through the walls to achieve the goal, that is easy for new houses, but it is hard for old ones.

In this thesis, we are proposing a system can be implemented on any type of home because it uses the ethernet over powerline adapters to transmit data through powerlines without any need for additional setups, so we can focus on the system itself, by this method we are converting the home electricity wires to a local network and attach as many devices as we want.

The system contains the central controller that holds the server in it to control all the attached devices, and this central controller is connected to an Ethernet over powerline adapter so that it can communicate with other devices in the same house. The sensors and the appliances are connected to the central controller via a sub-controller, and the sub-controller will be connected to the powerline adapter to send and receive data from the central controller. In addition to controlling appliances, it collects data from sensors and sends them to the user via the Internet. The primary focus is on power management and preventing the damage of lithium batteries in smart devices (phones laptops, etc.). According to [4], [5] many exothermic reactions happens inside the cells that release heat and cause an increase in battery temperature. Also, overcharging can damage the battery if the cell voltage is not measured correctly by the control system or use a charger that is not for charging this type of batteries, and to prevent this we will monitor the current flow that is being drawn by the charger and determine when to disconnect the power off the charger. Even if the new lithium batteries have a safe method that can prevent damage to the battery, an internal short circuit can still occur and damage the battery [6]. The cause of the internal short circuit may be a manufacturer's error or temperature increase.

1.1. LITERATURE SURVEY

The human imagination has always been the limit of IoT and smart home application development. The author in [7] developed a smart home system that starts from controlling the home lights and adapts the lighting depending on the required condition, switching it on or off and reducing the electricity consumption of unused lighting. Also, this smart home application controls the home appliances and gather information from them such as temperature, power consumption, status, etc. The paper discusses the need for intrusion detection and how it can alert the user by email or text messages, monitoring suspected activity and take the necessary action, and it discusses the usage of FLIP, which is an open source IoT platform designed and developed by Frugal Labs in India based on an Arduino system.

In [8], the author develops a way to integrate both ZigBee and PLC network with an Ethernet connection to make sure that the collected data from the environment is transmitting to the server. This system contains a variety of sensor devices. In addition, it studies the architecture of the implemented system and its subsystems. The sensors used in this paper have two types: wired and wireless sensors. Furthermore, the architecture of the installed network depends on the deployment of the sensor nodes for monitoring the area (humidity, temperature, current, etc.), the collected data processed by an embedded system and transmitted to the user terminal through an embedded self-organized wireless network. A Wireless network communication like ZigBee wireless communication technology, used to transmit data in two-way to a short distance, it uses the international licenses 2.4GHz, 868MHz, and 915MHz, it can cover a distance up to 75 meters and provides the application layer and the network layer. This paper also discusses the uses of power lines to transmit data at high frequencies by using an adapter to separate the high frequency from the power line. The system architecture design of the IoT is divided into three: the layers perception layer, the network layer, and the management layer. In addition, the sensing layer divides the home adapter layer into three types: the electrical equipment, the instrumentation, and the environmental adapters.

A cheap system was developed in [9] with high flexibility by utilizing Wi-Fi connection to connect the sensors in the home and send its collected information to a server with an Android application to control the system.

[10] discusses a humanoid [1]application that supports Raspberry Pi, it also discusses the used techniques based on Java automation system, home automation which uses GSM for communication and home automation that uses SMS to receive commands. The proposed system is a framework that displays home computerization to an Android phone application. The application controls the system and sends data to the Raspberry Pi module through Wi-Fi, according to the paper the usage of this system has good scalability, offers security and accept vendors readily.

The need for connecting smart devices to each other increased in present days and providing a cost-effective solution is a challenge. In [11] the author presents a methodology to have such a system. The Wi-Fi technology can provide an interlink of multiple devices, and it is an excellent medium to connect them through the default frequency 2.4GHz, and this provides 24-hour control and monitor of smart devices and appliances. This study aims to provide a low-cost system, and this system consists of Wi-Fi-based sensors and a middleware hub that acts as coordinator and sensor node. The sensors are temperature, humidity, gas leaking, flame sensor and security system.

The author in [12] discusses a new way to use technology to provide a low power sensor attached to the network in order to sense the environment or collect data and analyze them, then provides a terminal for the user to control the sensor, so it’s a simple home automation system that can be extended to provide more functionality. The system consists of a group of sensors, a Raspberry Pi module that acts as a server and a Bluetooth for communication, and it is being controlled through the user-friendly interface via an Android application. The sensors are responsible for collecting data and sending them to the Raspberry Pi and managing the appliances that are connected to the Raspberry Pi. The system also collects reports, processes data and sends them to the cloud via Wi-Fi, and automatically adjust the environment for what the user sets the preferences. The system discusses future adjustment of the system by adding more home automation appliances like wearable devices and email notification.

An enhancement was proposed in [13], a design for home automation system at low cost to monitor and access multiple devices by a mobile phone from anywhere in the world using multiple protocols such as HTTP, CoAP, and MQTT. It contains a standalone Raspberry Pi module without

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[1] a machine with appearance and characteristics of human

any need for expensive equipment and complicated components. The primary controller is a Raspberry Pi and an Arduino module that acts as a client for controlling the appliances. The main controller and the client are connected to each other through Wi-Fi with Java support. The system is tested in a virtual home network before sending it to a real home automation system; all the information is controlled from a web-based server that, in turn, is being controlled by a smartphone. To be more cost effective using Arduino with the NRF module will reduce the cost of the system, and it will also help to achieve multiple in-home displays.

This system in [14] uses the Raspberry Pi to collect data from sensors and upload them directly to the web server where the user can access the data from a web-based application to monitor and manage the devices that are connected to the Raspberry Pi. The data is collected from the sensors such as a PIR sensor, a gas sensor, and an LDR sensor.

Another design and implementation of home automation system presented in [15] to provide security and energy-saving techniques by monitoring and scheduling the working hours of the devices. The design contains an Arduino module and a Raspberry Pi module-based system. It provides a way to the visitors at the door to communicate with the homeowner; the system captures the visitor image to display it on the LCD with a sound to notify that there is someone at the door. Also, it provides a range of sound messages to let the visitor know about the situation. The system provides a user-friendly interface with economic benefits, in addition to the Raspberry Pi and the Arduino, the system contains sensors, relays and Hall Effect sensor that are connected to the Arduino which sends the information to the Raspberry Pi that acts as a server. The server contains an algorithm to provide a smooth and secure interaction between the homeowner and the server.

In [16], the author proposes a real-time monitoring system and remote control of swimming pool. The system contains a Raspberry Pi that acts as a server; the gateway allows bidirectional communication between the user and the sensors that are connected to the system via Arduino. The author presents the design and the implementation of the system, so the user can easily use it. The main point of this study is to provide a low cost and flexible way to adjust the system for any additional need. The system can monitor the water temperature, water level, air temperature, humidity and air pollution. Also, it remotely controls the water pumps and lights. The system is divided into two-part: the hardware and the software. The hardware contains the main components that build the system (Raspberry Pi, Arduino, sensors, pumps, and lights). The software also has two parts the web platform and the Python script, these two sections communicate with each other through the communication protocols (USB and MQTT).

Researchers in [17] present a smart home system that controls the lighting system and provides more security feature using the built-in light sensor in an Android device powered by an algorithm to implement a daylight harvesting system. The cost of this system will be much less than a commercial system. The system is based on an intelligent Led system mobile application and controller. The mobile application provides the interface for the user to control the system and read from the light sensor to achieve closed-loop feedback. An Arduino device controls the LEDs; the LEDs have multiple channels red, green and blue. The Raspberry Pi module acts as a server that provides the user with an interface between the LEDs and the mobile application. The security features that the system uses are TCP over TLS and An X.509 self-signed public key. Also, the user interface needs a username and a password for security. The cost is the setup of the main controller, the Xbee module is about 59.44 USD and 49.17 for each LED.

Another application is made in [18] which provides a smart home monitoring system, controlling system and a door permission system to interact with the visitors of the home or the office. The system can be controlled from a user interface GUI or the Web; the user will interact with the system through the internet to send and receive data, and to monitor the on/off status of appliances. The main component of the system is a Raspberry Pi and an Arduino, the server is hosted on the Raspberry Pi and can be accessed from the IP address. The Raspberry Pi sends the information to the Arduino module to control the appliances. The system proposed a low cost and flexible smart home automation system. This paper also discusses providing a way to reduce the wastage of the electricity.

An electric energy saving system proposed in [19] for a smart home. Built with a combination of a smart meter, a smart plug, and a smartphone with a database center. The smart meter contains a power meter to read the raw voltage and current signals, then the information will be saved to a database in an EEPROM device and delivered to the smart meter interface. The smart plug can measure the power data and analyze it by different loads; the information is displayed on the LCD then transferred to the MIU through the ZigBee module. After that, all the information is transmitted to the phone by the Wi-Fi module. This paper presents a low-cost system by using microprocessors to build a smart measuring system.

[20] discusses the ability to provide a platform for managing energy by analyzing the data that had been collected by an IoT system. The system monitors and controls a large variety of devices in the building. The collected data from all these devices lake the ability of handling, analyzing and managing them. The proposed platform includes the functions and the features that can handle energy management and analyzation for such a big data.

The author in [21] discusses two major topics the first one is: provides a way to synchronize the devices in the smart system. The accuracy of these devices depends on the time of arrival (ToA) of the transmitted data because the Wi-Fi suffers from a multipath issue (the Wi-Fi signals reaches the destination antenna by two or more paths [22]) and a noise issue during data transfer. The second topic is that it lists three different networks that satisfy a complex communication system. The first network is the home area network, the second one is the advanced metering infrastructure or the field area network and the third one is the Wide Area Network. These three networks can be a system of multiple systems connected to each other, the metering system is synchronized to ensure a robust and secure system. Also, the paper suggests a detection mechanism that can be used to forward time synchronization to the "last mile" [1] link and inside the end user home.

Another system in [23] built with ZigBee for a smart home with the integration of Arduino Uno, which is acting as the main controller. The sensors connect to the main controller and send collected information to it. The received data from the sensors are transferred to the cloud via the Arduino Shield that provides an Ethernet interface to the Arduino.

Implementation of fire detection system proposed in [24] by using a sensor web node controlled by Raspberry Pi. The reason for using a Raspberry Pi is that it has many peripherals that can be used to add more features. The paper also discusses the types of a home automation system, which are: individual systems that control only one appliance, a distributed system which allows the appliances to communicate with each other internally through power lines and a centrally based system where appliances send data and communicate with a central controller.

[1] refers to the final user that receives telecommunication service

The requirements of a smart home application are few, and that is what makes the power line communication a good candidate for building a smart home system. In [25] the author uses an environment for testing based on the Cypress 3274 evaluation kit, the paper discusses the impact of connecting multiple devices to the network on the data transferred. Home automation systems based on PLCs are cheap, easy to deploy, more secure than Wi-Fi and they also support a lot of smart grid systems. This paper proposes a cheap system based on the narrowband Power Line Communication for build and develop a communication system between different applications.

A smart home system was built in [26] to monitor and manage the power of a home using the low bandwidth power line communication and present several methods to ensure the accuracy of the energy monitoring. The system uses the Insteon protocol[1] with the implementation of the author architecture to monitor and control the entire home.

The study in [27] is based on Edison-IoT to build a mixed type of connection (wireless and wired) to cover all the areas, not just in a home or a building but in everywhere to avoid shadowed zones. This system reuses the smart DC grid system in a building with integrating solid-state lamps and advanced ICT system. The E-IoT uses MQTT protocol to transfer data to the registered devices in the network; also, it uses CoAP to receive and send requests in the model of HTTP. E-IoT brings innovation application within twice the time that other application can offer, it is easy to deploy in a ready infrastructure without any need for additional installations.

The author in [28] provides an algorithm to learn the human interaction with the appliances and the user preferences. The algorithm is used for energy saving and reducing power consumption without affecting the comfort of the user. This system is web-based to connect objects depending on location, time, collected data and the prediction of the system. The energy saving comes from studying the user preferences and the surrounding environment.

An intrusion detection system was developed in [29] to improve the security of a home using sensors at the primary and the secondary doors. The system detects the user’s actions and records the user behavior to determines if this action is an attempt to break or if it is reasonable behavior.

[1] bridge between powerline communication protocols and wireless protocols

Multiple sensors are used in each entry to collect data; the collected data is analyzed with an algorithm to identify the normal behaviors and sending an alarm if they are not.

The author in [30] designed an electrical outlet that can be controlled by a server to manage and control home devices for energy saving purpose. The server collects and analyzes the data of the electricity consumption from the same outlet and based on the collected data the server manages the appliances to achieve a low power consumption.

Lithium cells are widely used in smartphone and laptops, According to [4], [31] we should consider the safety of the cell, the cells maybe get damaged if they are being abused by external effect or by thermal stability issue when it is temperature increased. The abuse test shows that overcharging causes an overheating and problem in the battery.

2. MATERIALS AND METHODS

2.1. MATERIALS

The system consists of multiple nodes, and these nodes will connect to one central node that acts as a server. Each node has a Raspberry Pi 3 that connect to the server via Ethernet over power line adapters. Also, the node will have multiple sensors and relays to collect data and send them back to the server. The server will analyze the data and will perform various actions depending on the analyzed data. The homeowner can access the server by opening a website from any browser; the website will show the information of the connected devices and let the user control some of the provided features.

2.1.1. Raspberry Pi

In this system, we are using a Raspberry Pi module. The Raspberry Pi was created by "Eben Upton.", his goal was to design a low-cost system that helps to improve programming and hardware skills, but the small size of Raspberry Pi (credit card size) and its low-cost price. Makes it accessible and it was adopted by electronic admires for building projects that require features more than what a basic controller can provide. Nowadays the Raspberry Pi is being used in data mining by using clusters (connecting more than one RP by one algorithm). It is also being used widely in robotics due to its small size. Most of the smart home systems are based on Raspberry Pi architecture.

In our system, each node contains a Raspberry Pi, and the RP connects to the Ethernet over Power Line Adapters. The EoP Adapters will connect all the nodes to the main controller (server) through power lines.

The server will hold the algorithms that are required to manage the required action and send them to the devices, the main aim of the server to observe the current flow of an electrical plug to the lithium batteries and determine when to cut the power off. Cutting the power off will help to prevent the damage of the lithium batteries, this type of batteries usually used in smartphones and laptops.

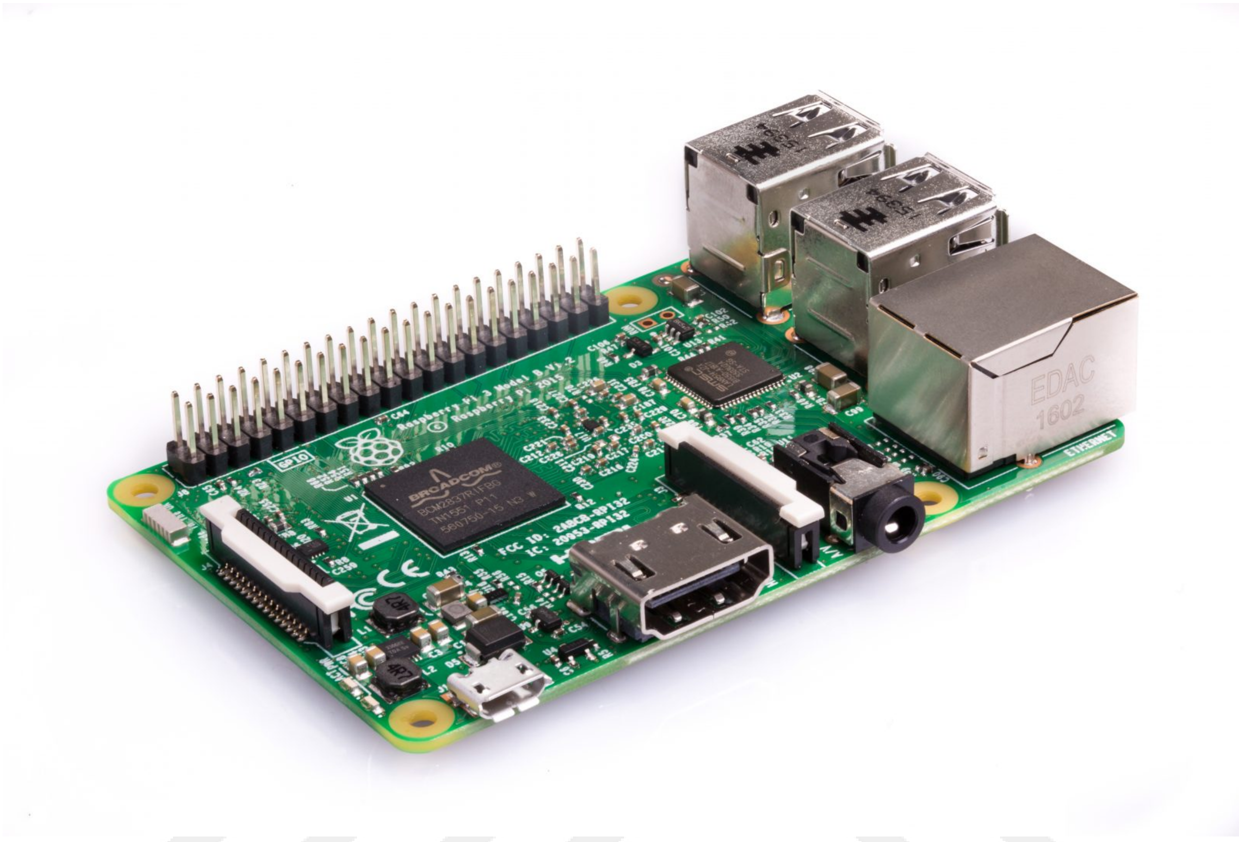

Figure 2.1: Raspberry pi 3 (https://www.raspberrypi.org).

2.1.1.1. Raspberry Pi Hardware

The Raspberry Pi has an open hardware except for the main chip (Broadcom) which control the main parts of the RP (USB, CPU, Graphics, etc.). The small size of the RP makes it a good candidate for using it in many systems and the GPIOs helped to connect it with a large variety of another devices and sensors. The RP also has many connectivities such as USB, HDMI, Ethernet, SD card slot, Audio Jack, Camera interface and LCD interface. The RP version that we are using in this system is Raspberry Pi 3; it has Broadcom BCM2837 (50% faster than the RP2), 1.2GHZ quad-core ARM Cortex, 1 GB of memory.

Table 2.1: List and comparison of raspberry pi versions.

	RP 3	RP Zero	RP 2 Model B	RP 2 Model B+
SoC	BCM2837	BCM2835	BCM2836	BCM2835
CPU	Quad Cortex A53 @ 1.2GHz	ARM11 @ 1Ghz	Quad Cortex A7 @ 900GHz	ARM11 @ 1Ghz
GPU	400MHz VideoCore IV	250MHz VideoCore IV	250MHz VideoCore IV	250MHz VideoCore IV
RAM	1GB SDRAM	512MB SDRAM	1GB SDRAM	512MB SDRAM
Storage	Micro SD	Micro SD	Micro SD	Micro SD
Ethernet	10/100	None	10/100	10/100
Wireless	802.11n / Bluetooth 4.0	None	None	None
Video Output	HDMI / Composite	None	HDMI / Composite	HDMI / Composite
GPIO	40	40	40	40

2.1.1.2. Raspberry Pi Software

The main system of the Raspberry Pi is called “Raspbian” and it is a Linux based system. However, many other systems can be installed on the Raspberry Pi such as Debian or Ubuntu or even Windows IoT. The RP performance is lower than the new PCs and laptops but still provides a complete system that can provide all the necessary tools.

2.1.2. Arduino

Arduino is a microcontroller-based board that has both a physical part and a software part; it is an open-source device that has widely been used in electrical projects. The physical part consists of the microcontroller itself and other components such as GPIOs and USB port. The software part is the IDE that helps to program the microcontroller without any need for additional hardware like other types of microcontroller chips. In this system, we are using the Arduino UNO.

2.1.2.1. Arduino UNO Hardware

The Arduino UNO is open source hardware based on the ATmega328P chip; it is the most popular chip in the Arduino family, it has 14 GPIOs, USB port, Reset Button and can be powered up by AC to DC adapter. The Arduino UNO has all the tools to support a microcontroller.

Figure 2.2: Arduino (https://www.inventables.com).

2.1.2.2. Arduino UNO Software

The Arduino UNO like any Arduino uses the Arduino IDE to write the code to the microcontroller. It is also an open source software can be installed on Linux based systems or Windows.

2.1.3. Grove Shield

Grove shield is a part of the Seed Studio products. Seeds is a company that builds and develops modules, these modules can be connected to the different type of boards such as Raspberry Pi and Arduino. The modules can be sensors, cameras, displays, etc. This will help to connect many modules that Raspberry Pi and Arduino do not support by default.

2.1.3.1. Grove – Base Shield V2

In this system, we use the Arduino breakout shield to connect the sensors to the Arduino through it. This is the new version of the brick shield it has four pins with multiple signals for each connector, so we do not need to worry about the compatibilities between the shield and the electronics bricks, using this shield helps us to connect all the modules are developed by Seed Studio to the Arduino.

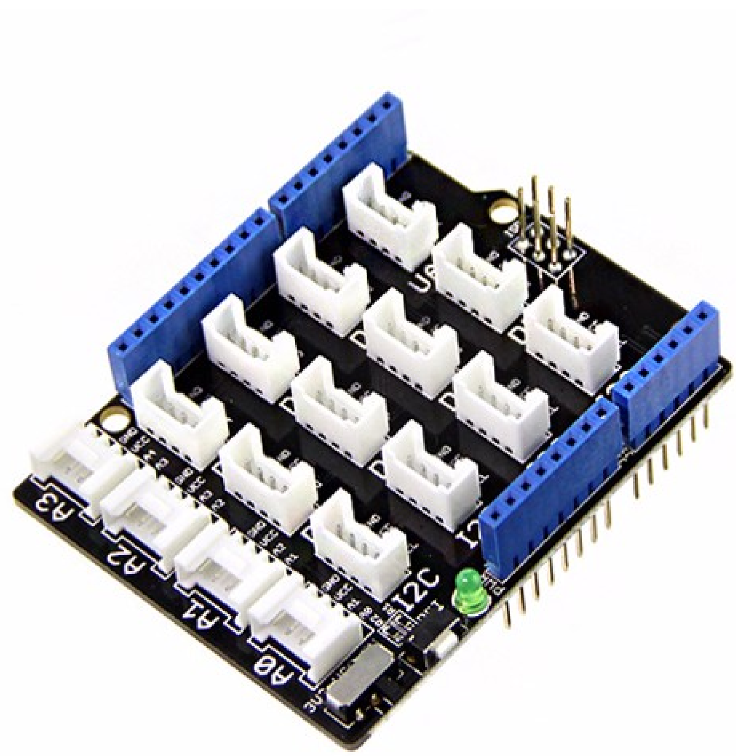

Figure 2.3: Base shield V2 for Arduino (https://statics3.seeedstudio.com).

Table 2.2: Grove shield connectors.

Specification	Name	Qty
Analog	A0/A1/A2/A3	4
Digital	D2/D3D4/D5/D6/D7/D8	7
UART	UART	1
I2C	I2C	4

2.1.4. Ethernet over Powerline Adapters

The power line networking is a wired network that uses the power lines as cables to transmit data. They are mostly invisible in the walls, and there is no need for new wires. It needs at least two adapters to activate the network and starts sending and receiving data. It is like wiring a regular network cable between the router and the desired device, but instead of using a dedicated network cable it is going to use the power line to connect the device to the router.

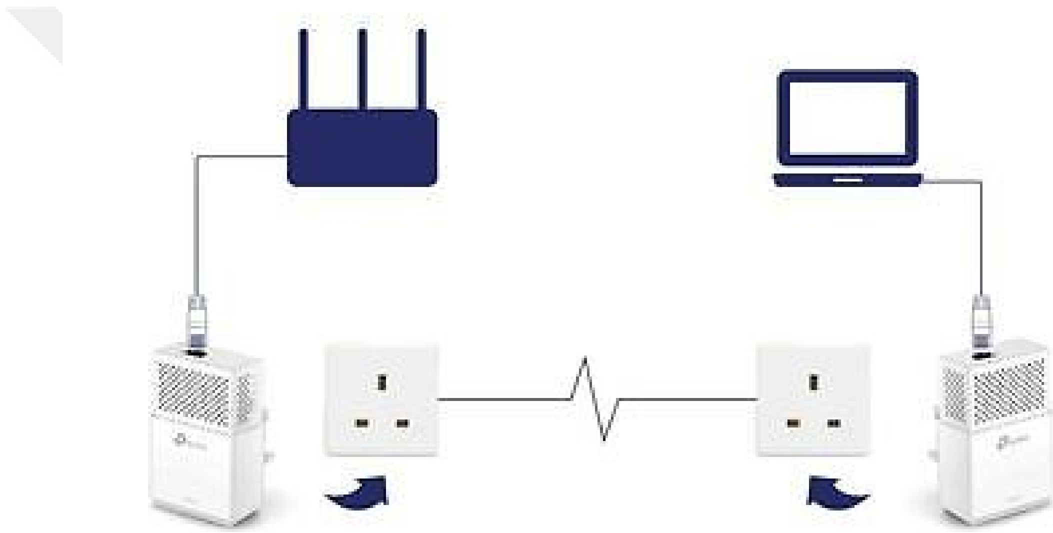

Figure 2.4: EoP diagram.

The procedure starts by plugging in the first EoP Adapter to the electrical plug near the router, then connect the adapter to the router with a network cable. On the other side, we connect the second adapter to the electrical plug at the desired place, then connecting the second adapter to the required device. The usage of Ethernet over Powerline method instead of Wi-Fi has several advantages like speed, security, reliability and ease-of-use [32]. In this system, we are using the TP-Link TL-PA7010 Powerline Adapter.

Figure 2.5: EoP adapter (http://www.tp-link.com).

The usage of Ethernet over Power line adapters helps to reach any area at home without any additional setup. It also connects all the nodes to each other to gather information from the physical environment and send them back to the server using power lines. A standard kit of these adapters can reach 100m of distance with the speed of gigabit/second, because of that it is more reliable than using the Wi-Fi [25]. It is also much faster and can reach areas that it is not possible for Wi-Fi to reach.

It is also possible to use the same system in a large building without and need for new wires,

Moreover, that is a useful feature that this system can provide.

2.1.5. Sensors

Sensors are used to collect information from the physical environment. There are many types of sensors that are used in any situation and different environments. The information will be the detected input from the environment. The input could be gas, light, humidity, pressure, heat, motions, force, voltage, acceleration, etc.

Sensors, in general, converts the information measured from the physical environment into a format which can be understandable by electronics. The output of the sensor can be voltage or current depending on the sensor. This output is inherently an analog signal which has a continuous waveform. This analog signal can be further converted into a digital signal which can be further processed by digital devices such as microcontrollers and similar digital circuits. The conversion from analog to digital involves sampling the analog signal at a certain rate which produces a discrete signal and quantization, after which the sampled signal is rounded to the nearest digital level depending on the accuracy of the analog-to-digital converter. These levels are represented by a series of binary digits. Physically, these digits are transferred to other modules in the system using a series of voltage or current pulses in which a HIGH voltage represents a binary “1” and a LOW voltage represents a binary “0”. The full binary word can be transferred in parallel or in series, also depending on the type of the ADC.

Depending on whether analog-to-digital conversion present in the sensor module, the sensors can be called an analog or a digital sensor.

2.1.5.1. Current Sensor

These kinds of sensors are used to provide an output corresponding to the current of AC or DC that are required to measure. One important thing to put in mind that when selecting a current sensor is whether we are measuring an AC current or DC current. Another important thing we need to consider is whether the sensor needs to be attached to the line or it is in line with the circuit.

There are many types of current sensors, but the most popular are Hall Effect Sensor and Inductive Sensor.

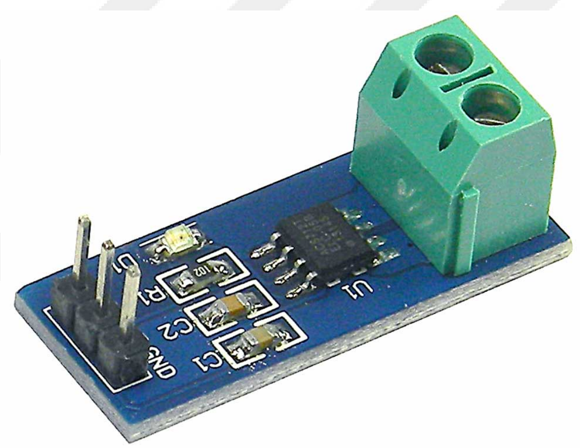

Figure 2.6: Hall effect sensor.

Hall Effect Sensor is a combination of a semiconductor material and a magnetic when the semiconductor placed within a magnetic field, the electrons and holes start moving the sides of the semiconductor [33]. A magnetic field is generated from the movement of these electrons, the output voltage of the sensor is a direct response to the generated field. Using this type of sensor in this system will lead to an error in the output because it will be affected easily by an external magnetic field.

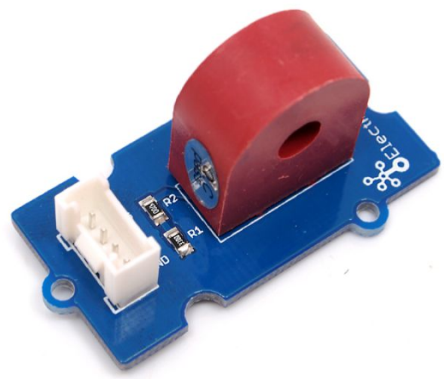

Figure 2.7: Inductive sensor.

Inductive sensors have good results for measuring AC. It contains a coil with a hole in the center of it, to allow a wire to go through it. When the current pass through a conductor becomes magnified and output a voltage depending on the measured current. In this system, we use the Grove Current Sensor (shown in Figure 2.7), the output of this sensor is analog and can measure small current (less than 0.5A). This sensor is ideal for measuring the current that is used by smartphone and laptop charger.

2.1.5.2. Sound Sensor

The main part of the sound sensor is a microphone and amplifier; it provides a digital output corresponding to the sensed sound. Also, it provides an analog output that represents the sound value.

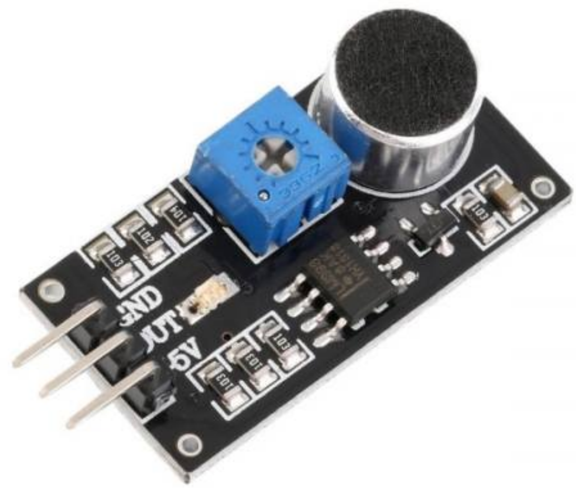

Figure 2.8: Sound sensor.

2.1.6. Relay Board

Relay Boards are switches that are controlled by contacts charged with an electrical current. They control the circuit by switching another circuit on or off. That allows a small current from the first circuit to control a high current circuit without any problems; this happens by opening and closing contacts in the second circuit. That means a 5V battery can switch on or off a 220V circuit.

There are two types of Relay Boards, Solid State Relay, and Electromechanical Relay. The relay contact is open and closed by a magnet in the EMR and electronically in the Solid-State Relay without any relay contacts. The Solid-State Relays are very popular, and they are the most used relay boards. The SSR life depends on it is contacts, when it burns out the relay should be replaced with another one. In the EMR it depends on the number of operation that the contact can perform without current. Usually, the EMR has a less-life cycle than the SSR [34].

Figure 2.9: 1-way relay.

We are going to use a one-way relay; this relay will switch the power on or off. It will be installed in the node and wired with the power socket. Either the Raspberry Pi or the Arduino can control the relay and sends information about the desired situation.

2.1.7. PIR Motion Detector

The PIR sensor refers to the Passive Infrared sensor, these types of sensor used for detecting motion in a specific range. These sensors are usually made of pyroelectric sensor that can detect infrared radiation released from an object. The hotter the object becomes, the more radiation is released from it.

The sensor we use outputs digital pulse, high when it detects motion and low (idle) when there is no motion detected

Figure 2.10: PIR sensor.

2.2. METHODS

The system is based on nodes distributed around the home; each node will connect to a central server that will monitor the environment. In this thesis, we focus on the nodes that have a charger connected to them, especially if the charger is used to charge a lithium battery. So, the system can prevent the damage that could harm the batteries from overcharging.

The nodes are connected to the server via power lines using Ethernet over Power Line Adapters; this setup helps connect as much as we want of the nodes without any additional wiring. Also, the system is not constrained by distance, because most of the wireless system cannot be implemented on a large scale without wireless repeaters due to the limitation of wireless range. Moreover, using the power line communication save us from worrying about the data loss and noise that the signal will gain in wireless systems. This system can be implemented in a large scale setup, and it is more secure and reliable than wireless systems [25].

The nodes are implemented to control a whole room or just one wall plug depending on the wiring system in the home. Also, each node helps collect the data from the physical environment and send them back to the server for monitoring purposes. The node contains a Raspberry Pi that acts as the primary controller for each node. The Raspberry Pi module connects to the EoP Adapter via the ethernet cable and connects to the sensors and relays directly or via Arduino controller. The Arduino module helps to read data from analog outputs from a sensor that do not supply digital outputs because it has its own analog-to-digital converter. In this system, we are using a current sensor by Grove – Seed Studio, this company provides an electric board that set on the top of Arduino and Raspberry Pi.

The Raspberry Pi connects to the Arduino through a USB cable to transmit the data from the Arduino to the RP. The Arduino will read data from the sensor and send them back to the Raspberry Pi; the RP will keep sending the data to the server and wait for the commands from the server. The server will contain the main algorithms that are needed to control the system. Also, the server can be accessed from the web at any time by the user.

2.2.1. System Architecture

The architecture is based on nodes; all nodes will be connected to a central server that could be on a cloud server (a server hosted by companies) or dedicated server in the same house. Each node will be able to connect to the server whenever it is by just defining the domain name of the server or its IP.

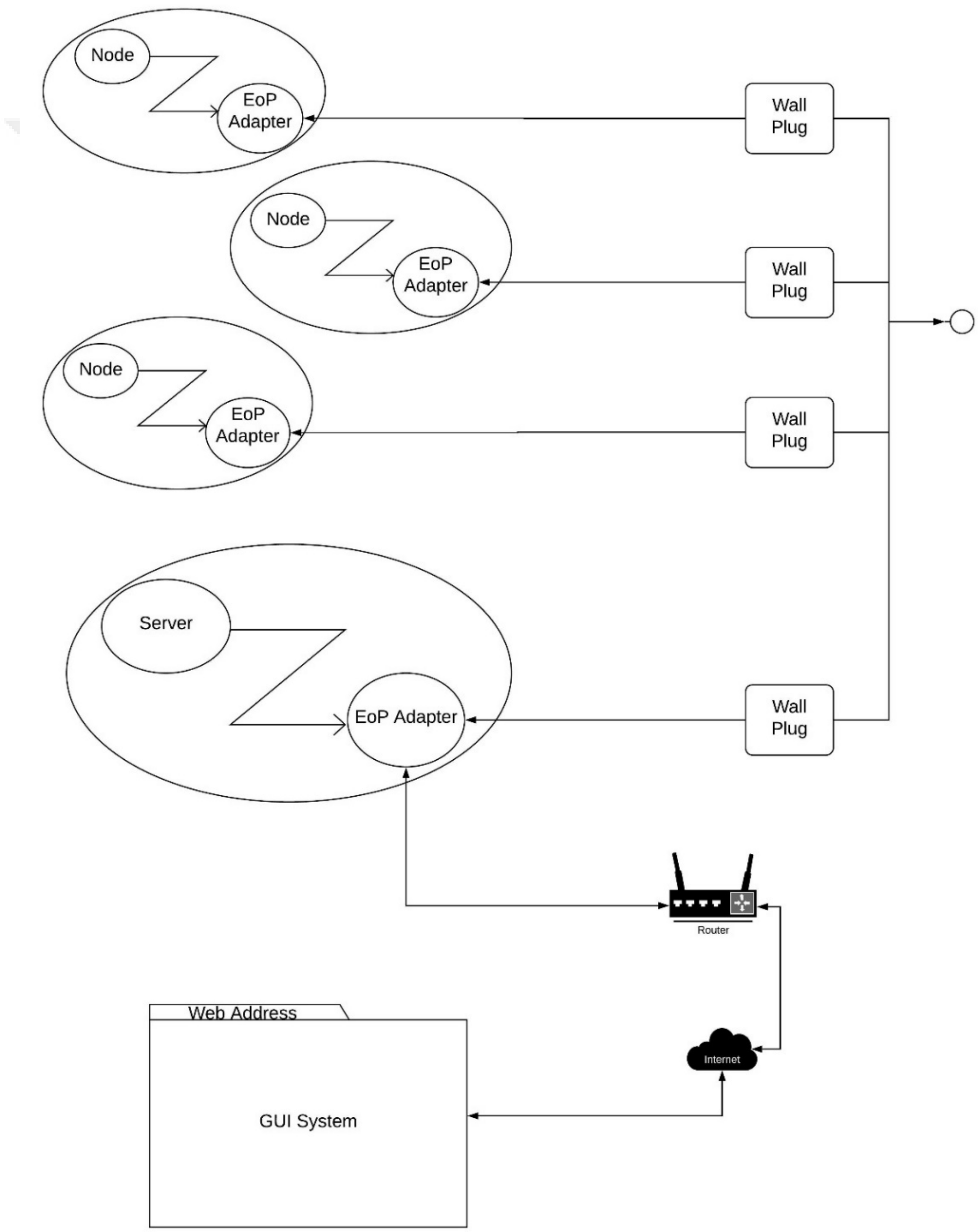

Figure 2.11: System diagram.

2.2.1.1. Server Architecture

The server is the brain of the system that will control all the nodes. The server could be a dedicated device in the same home that the nodes are or cloud-based system, a cloud system means a server that hosted by companies that provides VPS or DS services to customers. It will contain the system that will hold the codes and algorithms to manage the nodes. The system is Linux based, and we install the server on it. In our test system, the server is a VM that simulates the dedicated server in the same home where the nodes are. The server connects to the router directly or by Ethernet over Power Line Adapters depending on the router and the server positions at home. A home server usually consists of Raspberry Pi with Ubuntu v.16.04 installed and is connected to the router directly via Ethernet cable.

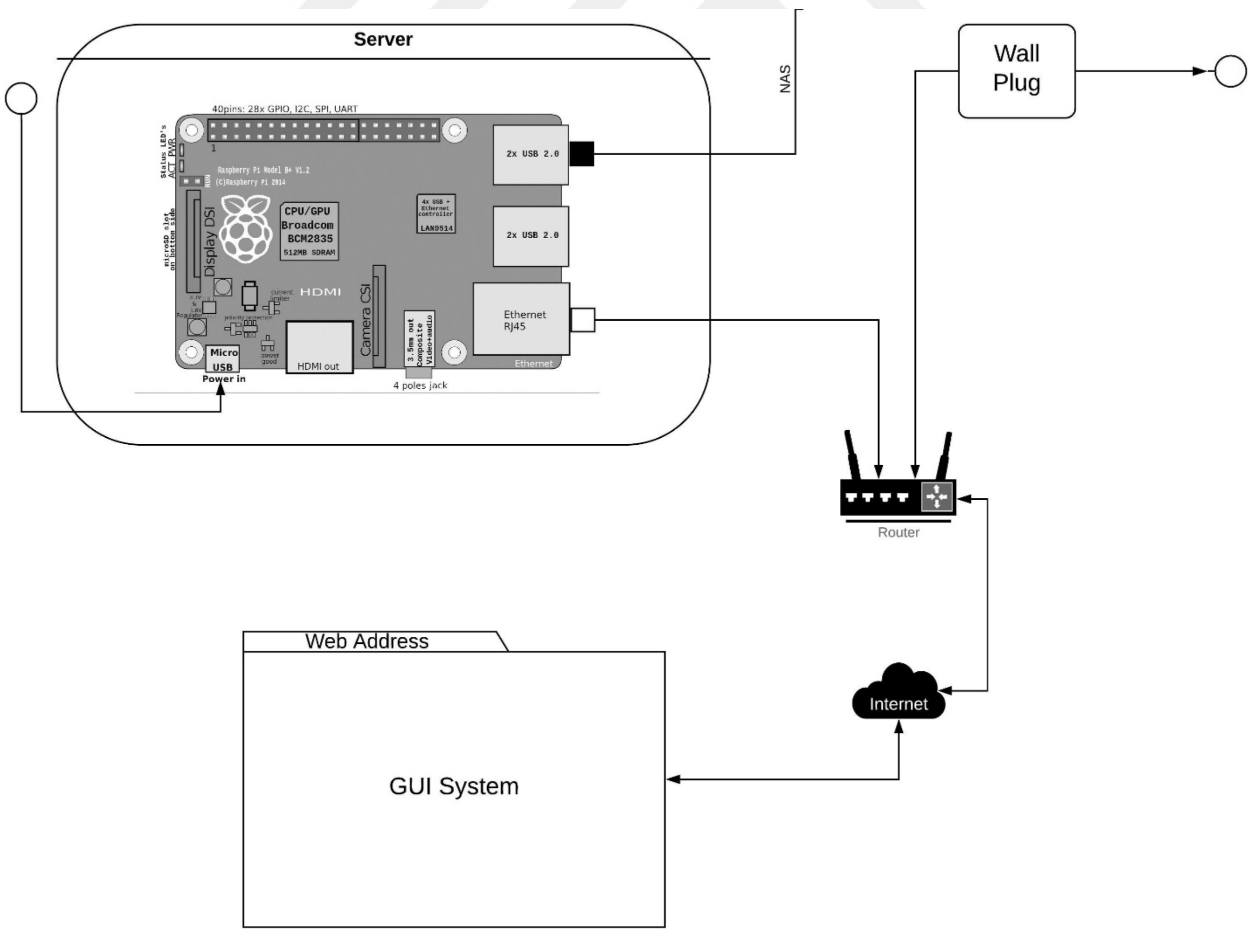

Figure 2.12: Server design.

2.2.1.2. Node Architecture

The nodes are distributed around the home to collect data and monitor the environment. They are also responsible for sending information to the relays. For reliability, the nodes send the information directly to the GUI interface to avoid any delay, so when monitoring the environment, the nodes send the data without passing the server to get real-time information from all connected nodes.

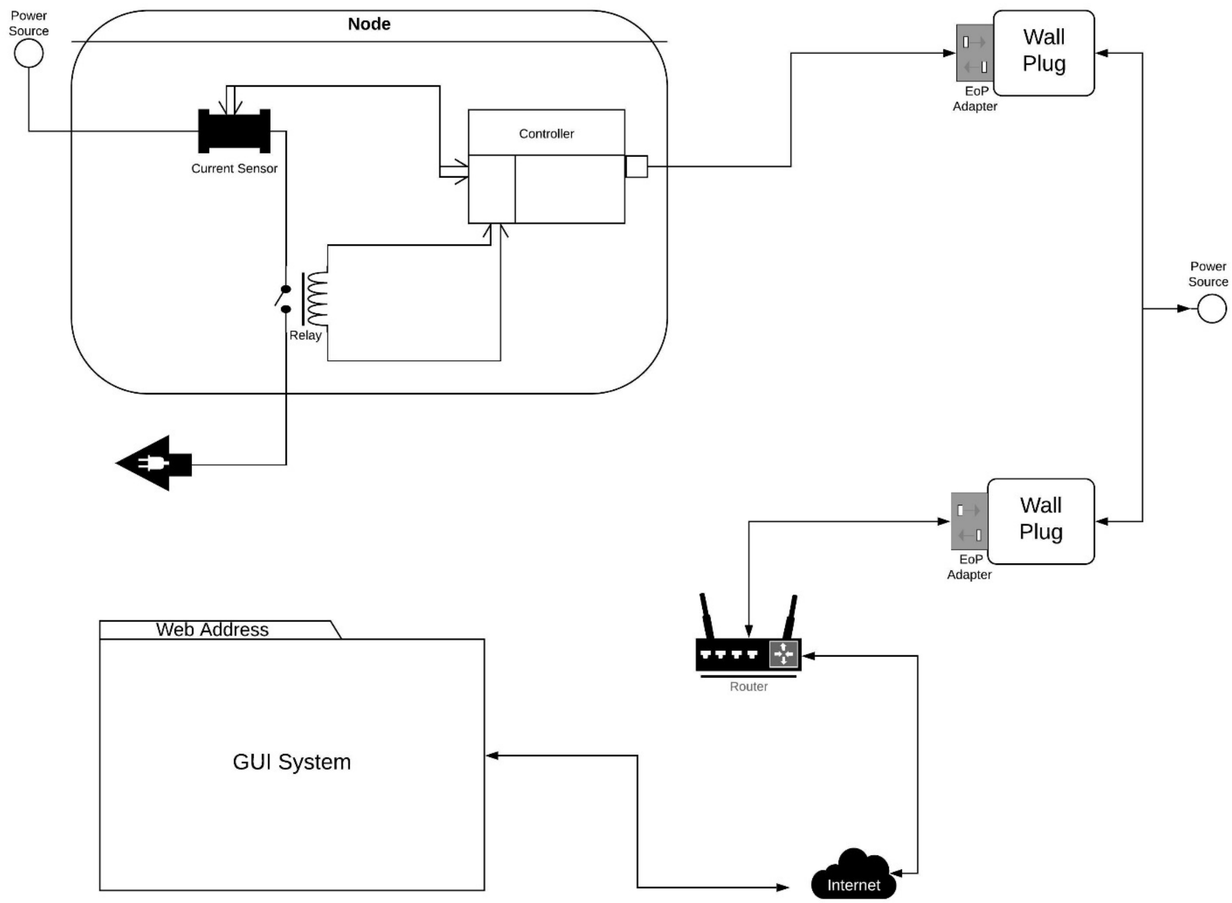

Figure 2.13: Node architecture.

Figure 2.13 shows the node connection to the server and main controller inside the node. The controller contains a Raspberry Pi that communicates with the server and the GUI. A second part of the controller is the Arduino to read the sensor data and send them back to the Raspberry Pi.

The focus of our test node will be cutting the power on or off in the wall plug to prevent the damage that can accrue to lithium batteries from overcharging. According to the author in [31], overcharging batteries will damage them especially when not using the original chargers, or according to [4] a short circuit can occur in the protection board that protects the battery from the overcharging, and that will lead to battery overcharging. The node we built contains a Raspberry Pi, an Arduino, Current Sensor, Sound Sensor, and Relay. The list below explains each part of the system:

- Raspberry Pi: Read data from Arduino via USB and send them to the server.
- Arduino: Read data from the sensors and send them back to the RP.
- Current Sensor: will measure the current in the electrical line that connects to the charger.
- Sound Sensor: Determine if there anybody in the room to keep informing that no need to cut the power off.
- Relay: receive information to switch the powerline on or off.
- EoP Adapter: to send the data to the server through powerlines

The controller will keep the relay output set to “high” while there is sound in the room if the current sensor is equal to zero for few minutes and if there is no sound in the room the relay output will set to “low” and cut the power. In Figure 2.14 the flow of sensing the environment is shown.

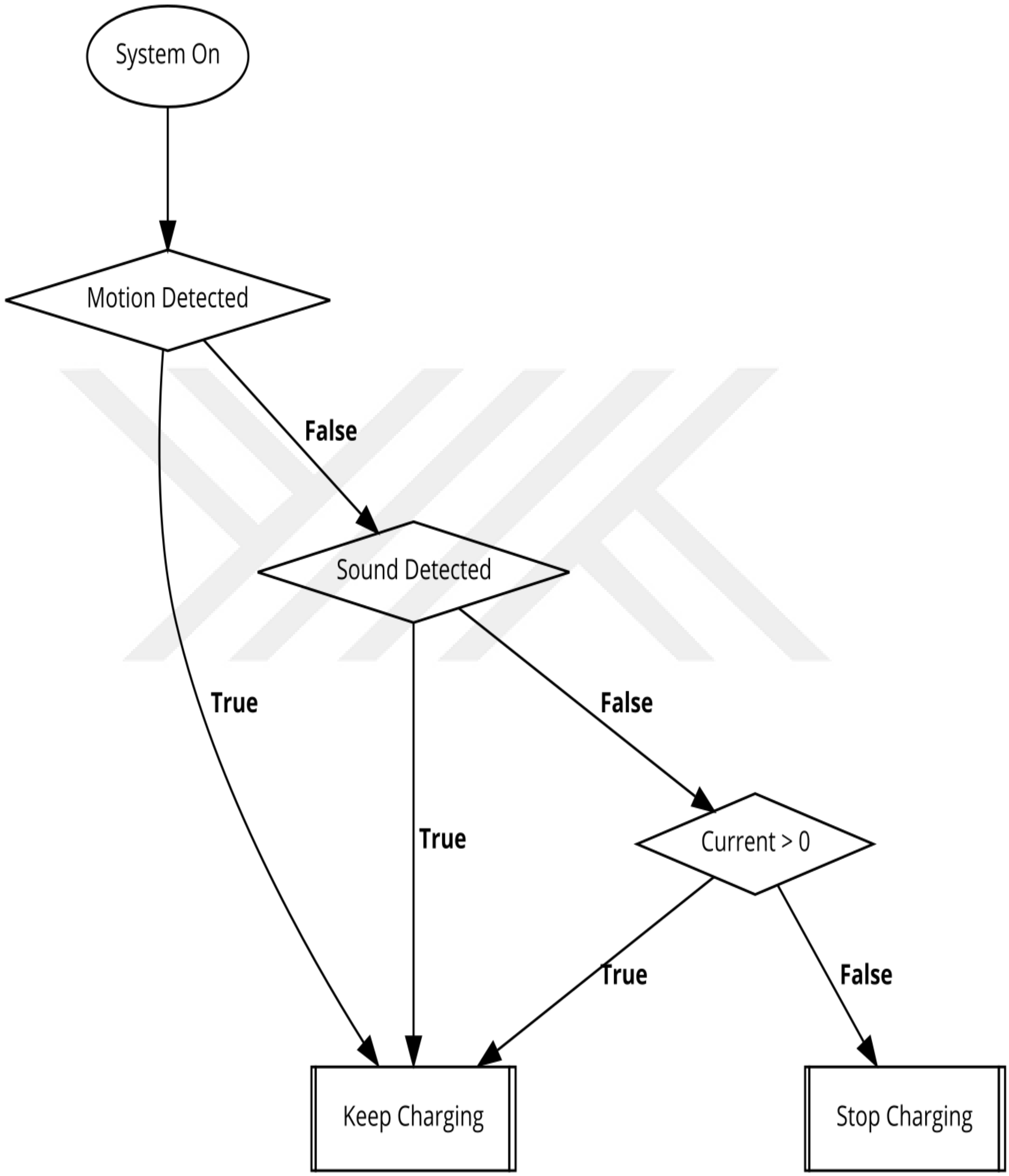

Figure 2.14: Current and sound sensor.

2.2.2. Connecting the Arduino to the Raspberry Pi

There are three ways to connect the Arduino to the Raspberry Pi; the first way is to connect them with a USB cable, it requires to add a simple code to the Python script that our application is programmed in. The second way is to connect them using GPIOs through the L2C pins in the Raspberry Pi. The third way is to buy a breakout board that connects both devices.

In our system, we are connecting them via USB, a simple procedure below shows how to make the connection; two parts are needed

- Arduino
- Writing a Simple application on the Arduino to communicate with the Raspberry Pi

A “Hello World” simple code that will show how to write an app in Arduino, Arduino app need to run two functions; one for setup and the other one is the loop function

```
Function Setup()
     Initialize: serial port to 9600
END FUNCTION
FUNCTION LOOP
     Print “Hello World” To Serial
     WAIT 1 SEC
END FUNCTION
```

The code will send a "Hello World" each second to the serial port so we can read from the RP.

To read the code that the Arduino is sending we need to do few steps before writing the code

- Install "pyserial" library using terminal via pip
- Install "python-serial" library using terminal via apt-get package installer
- Determine which USB port Arduino is connecting to by running "`ls /dev/tty*`" in the terminal
- Running this code before and after connecting the cable will show which port it is.

Below is a simple code to read from the USB port using Python

```
DECLARE serial Library

Function Read()

     Initialize Serial Equals To Serial Fucntion /

          From Serial Library

     Assign Serial Value To Read (`USB PORT`, 9600)

     Return data

EndFunction

Function Main()

     Call Read()

     Print read value

EndFunction
```

2.2.3. Connecting Current Sensor to Arduino

We use the Grove Electricity Sensor to read current values from the power line; there are few steps need to be done before reading the values from the sensor (Figure 2.13) shows the general aspect of using the current sensor

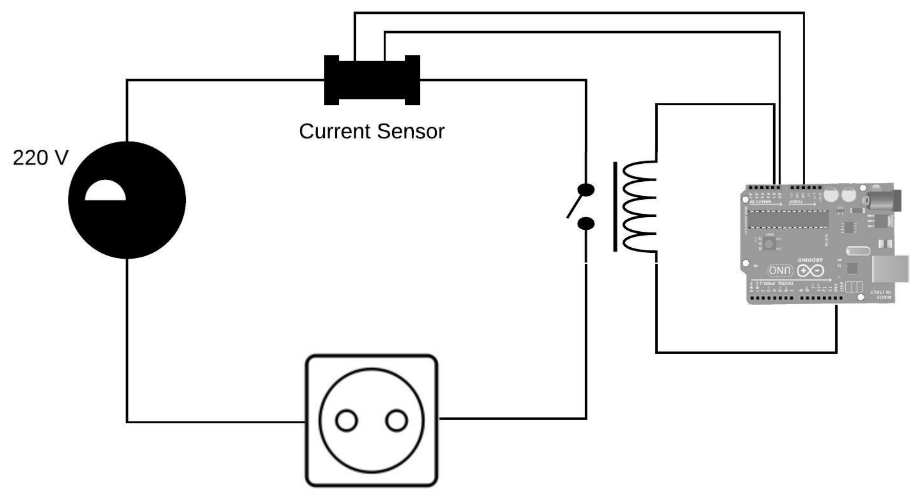

Figure 2.15: Wiring current sensor.

Figure 2.15 shows how to wire a current sensor with relay and connect to the Arduino. The current sensor will output an analog signal that is corresponding to the current measure. When it is idle the output of the current sensor is 2.5V half of the maximum output of the sensor, which is 5V. We need to convert these numbers to readable values, most of the current sensors will describe the relationship between the output voltage and the required value that we need to measure in the datasheet. It also depends on the maximum current that the sensor can handle. To read the value we need:

- Initialize the GPIO status to read
- At the loop function, we read the value
- Convert the output value to a readable value (Ampere)

Then the Arduino will send the value to the Raspberry Pi; a simple code is shown **Error! Reference source not found.** to read the value from Current Sensor in Arduino.

```
Function Setup()

    Initialize: serial port to 9600

    Initialize: PIN(number) to input

END FUNCTION

FUNCTION LOOP

    Read from PIN(number) and set to value

    Convert Value to Ampere by this method /

        Current = value/1024*5/800*2000000

    Send Data to Raspberry

END FUNCTION
```

Arduino has a 10-bit analog-to-digital converter. The transformer on the sensor has a 2000-to-1 ratio and the current output of the sensor is determined by measuring the voltage across an 800-ohm resistor which has range between 0 and 5 volts. So, the measured voltage is translated into current in milliamperes by using the following equation.

$$I_{measured} = \frac{1}{1024} \times V_{measured} \times \frac{1}{800} \times 2000000 \tag{2.2}$$

2.2.4. Connecting Sound Sensor to the Raspberry Pi

The sound we are using is a basic type of sound sensors that can detect if there is any sound in the environment and outputs a value. That detected value corresponds to the volume of the detected sound. The Figure 2.16 shows how to connect the Current Sensor to the Raspberry Pi.

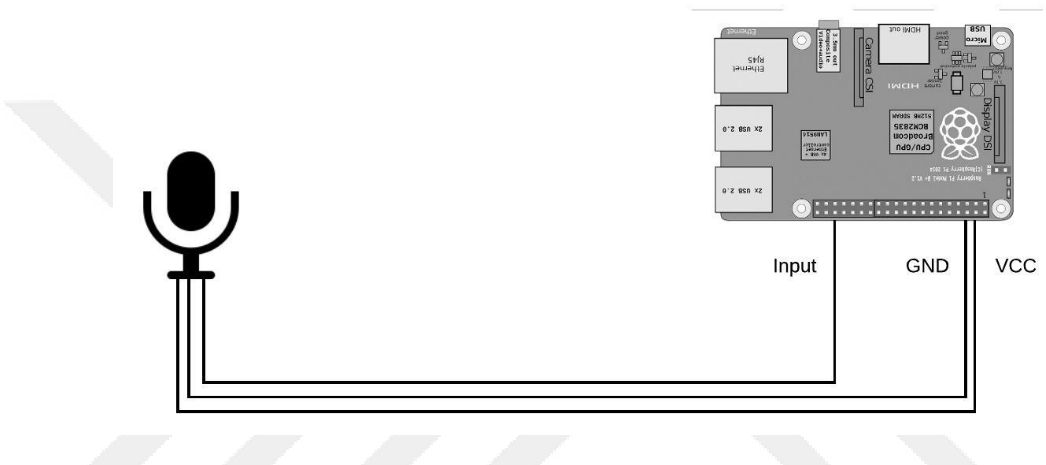

Figure 2.16: Connect sound sensor to Raspberry pi.

After wiring the sensor, we need to configure our script in the Raspberry Pi to read the incoming data from the sensor. Like the current sensor, we need to convert the input data depending on the provided relation between the incoming voltage and the sound value in the datasheet of the Sound Sensor. In our system, we do not need to measure the sound volume we just need to detect if there is a sound or not. To do that we just need to monitor the incoming value, and if it is greater than zero, that is mean there is sound, and we are not going to cut the power. The requirement for reading the value from the sensor are:

- Install the GPIO library in python using pip
- Importing the library into the python script
- Initialize the GPIO pin to input
- Read the value in while loop
- Detect whether it is zero or not

The code represents the same steps as shown in the previous list and where to initialize the pins.

```
DECLARE GPIO Library

Initialize pin(number) to read

Function Read Sensor()

     Read from pin(number) and assign to value

     If value > 0

          Return true

     Else

          Return false

EndFunction

Function Main()

     Call Read Sensor() and assign to status

     If status == true

          Set Relay output to 1

     Else

          Set Relay output to 0

EndFunction
```

2.2.5. Connecting the Relay

The relay can connect to both Raspberry Pi and Arduino because it can handle digital and analog signals as input. The relay is responsible for whether to let the current pass through the line or not as is shown in Figure 2.15. In this system, we are using a one-way relay module, which means it is only capable of handling a single line. For each line we need to control, we should use a one-way relay module. Also, in this system we use the Arduino to control and send data to the relay, the code provided below shows how to initialize the pin and send data that we are receiving from the Raspberry Pi to the Relay.

```
Function Setup()
     Initialize: serial port to 9600
     Initialize: PIN(number) to output
END FUNCTION
FUNCTION LOOP
     Read from serial port and assign to value
     If value = 1
          Set relay output to LOW
     Else if value = 0
          Set output to HIGH
END FUNCTION
```

2.2.6. Connecting the Passive Infrared Sensor

We are going to connect the PIR Sensor in a second node. The node monitors the environment with a motion detection sensor. The sensor sends high voltage to the Raspberry Pi when it detects motion and low voltage (idle) when there is no motion. The system determines when to cut the power off or when to keep it on. The detection will affect the system judgment on the first node.

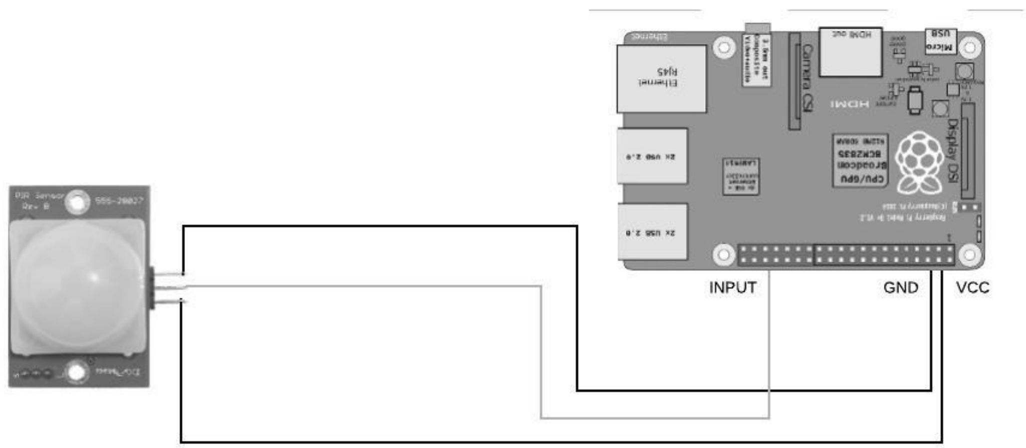

Figure 2.17: Connecting PIR sensor.

So, if there is any movement in the same room the system keeps the power on. The steps for connecting the PIR sensor to the Raspberry Pi is shown below:

- Install the GPIO library in python using pip
- Importing the library into the python script
- Initialize the GPIO pin to input
- Set a sleep time for 2 seconds to stabilize the sensor
- Read the value in while loop
- For each loop set a sleep time for 0.2 seconds to avoid multiple detections
- Detect the value if it is 0 or not

A simple code below shows how to write a code that connects the sensor to the Raspberry Pi

```
DECLARE GPIO Library

Initialize pin(number) to read

Function Read Sensor()

     Read from pin(number) and assign to value

     If value > 0

          Return true

     Else

          Return false

EndFunction

Function Main()

     While True

          Sleep (2)

          Call Read Sensor() and assign to status

          If status == true

               Sleep (0.2)

               Return “motion detected”

          Else

               Sleep (0.2)

               Return “no motion detected”

EndFunction
```

2.2.7. System Compilation

To use the system, we need to assemble and configure it as describe in the list below:

- Programming the server to detect and communicate with all attached nodes
- Configure the scripts in the nodes so they can communicate with the server and the GUI System to send live data
- Distribute the nodes according to their jobs
- Connect the server and the nodes to the EoP Adapters so they can communicate with each other

The system works as follows, after connecting the charger to the socket:

- The Arduino module sends the current values to the Raspberry Pi every second
- The Raspberry Pi sends the current levels and sound values to the server
- An algorithm in the server script receives the data and analyze them
- The algorithm makes sure that there is a device connected to the charger by monitoring the changes in the current levels
- When the device is fully charged the current value will equal to zero with little oscillatory
- After a while, if the current values keep oscillating around zero the system checks for sound in the same room the charger in
- If there is sound the system will do nothing
- If there is no sound the system sends information to the node to cut the power off
- After some time, the system sends information to the node to reset and power on the charger
- If the current values are more than zero that means the device is still attached and go through the procedures again
- If the device disconnects from the charger, the current values equal to zero without vibration in the values (absolute zero)
- The system will keep the power on and keep monitoring the line until a device is attached again

3. RESULTS

In our test system, we are using two nodes that connect to the server through Ethernet over Powerline Adapters; the first node consists of a wood board attached to it:

- A Raspberry Pi 3 module.
- An Arduino UNO module.
- Base Shield.
- Grove Electricity Sensor.
- One-Way Relay module.
- Sound Sensor.
- Electric Socket.

The second node consists of the wood board also attached to it:

- A Raspberry Pi 3 module.
- One-Way Relay module.
- Sound Sensor.
- PIR Sensor.
- Electricity attachments.

The two nodes send information to the server to determine when to cut the power in both nodes.

Also, each node affects the decision of cutting the power in the other node, the system analyzes the data that is receiving from them to determine if there any person in the room

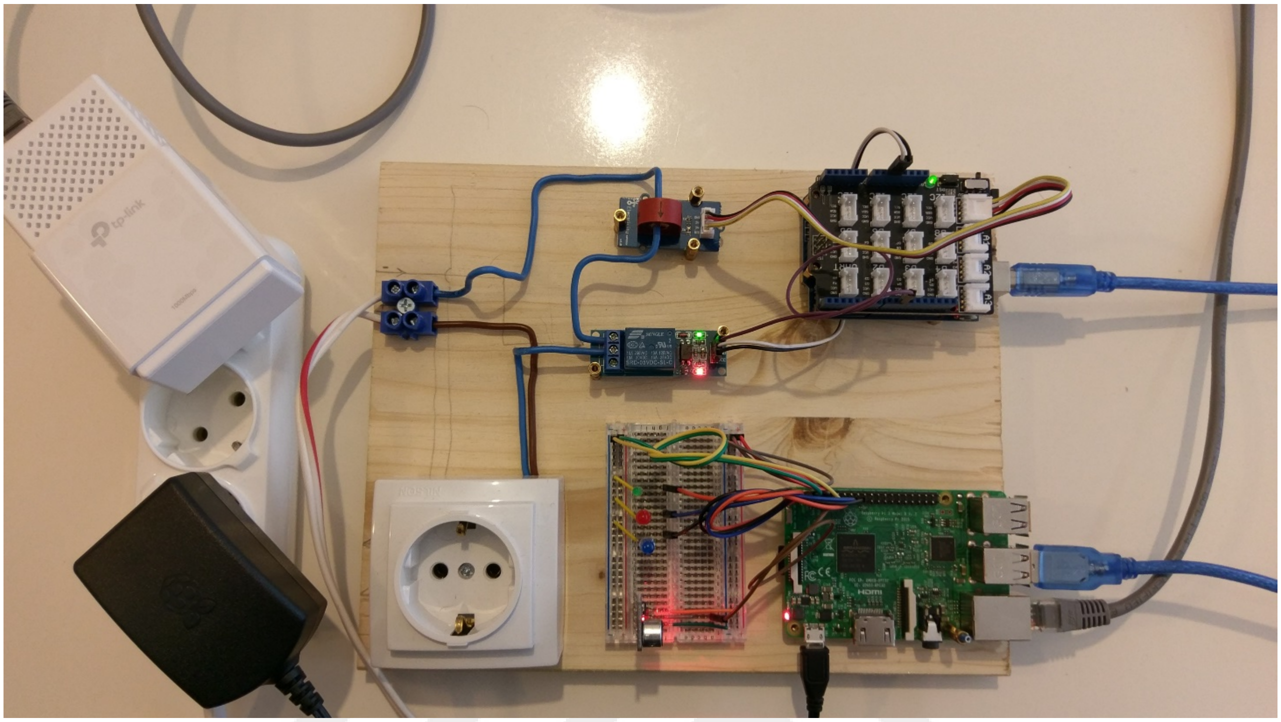

Figure 3.1: The first node.

As shown in Figure 3.1 the Raspberry Pi is connected to the EoP Adapter by ethernet cable to provide connection to the router, so the Server can access the node and send information to it.

The EoP Adapters connect to each other through the power line and provide a different type of lights (LEDs) to indicate the situation of the adapter.

The Base Shield set on the top of the Arduino to provide more connectivity and to support more sensors that Arduino by default does not support.

The four PINs in the front of the Base Shield provide direct access to PINs (A1, A2, A3, and A4) that the Arduino support with an additional power pin to get sensitive data that Arduino cannot get. These PINs are analog PINs.

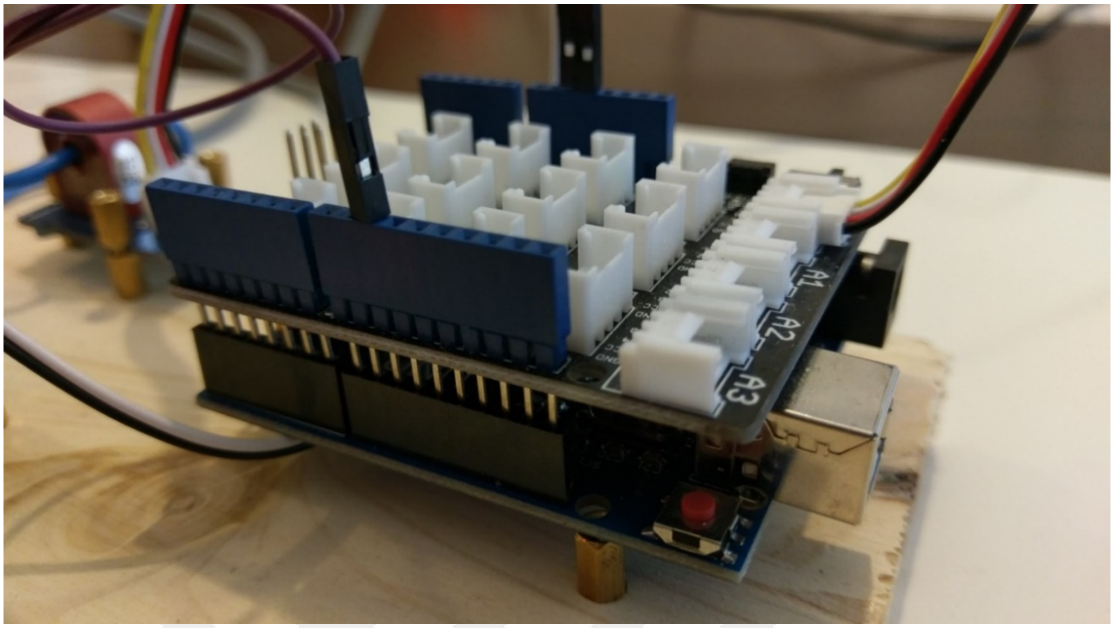

Figure 3.2: Base shield on top of Arduino.

The Raspberry Pi in the node handles the sound sensor and the notification LEDs to indicate the situation that the node in. By default, when the node is working normally, and the smartphone is charging, the Green LED is lighting on.

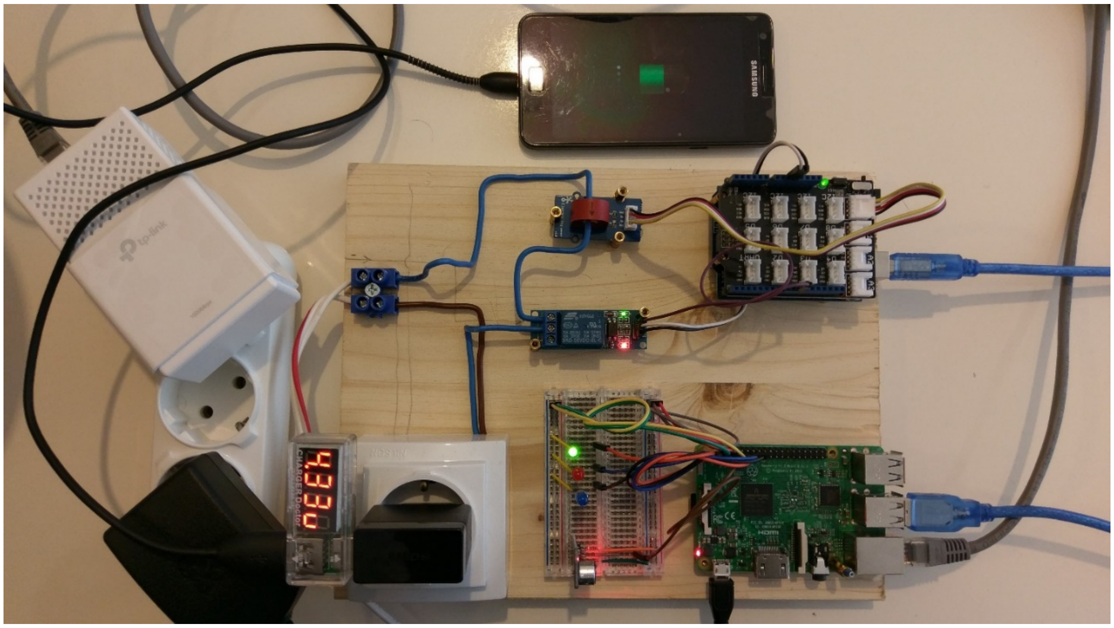

Figure 3.3: Node is charging the phone.

The green LED on the relay indicates that the power is on and there is a current flowing to the socket. The relay is receiving information from the Arduino.

The small device attached to the charger is a DC sensor to make sure that the numbers we are getting from the AC Sensor are reasonable, by comparing the values we get from the current sensor with the value from the attached device.

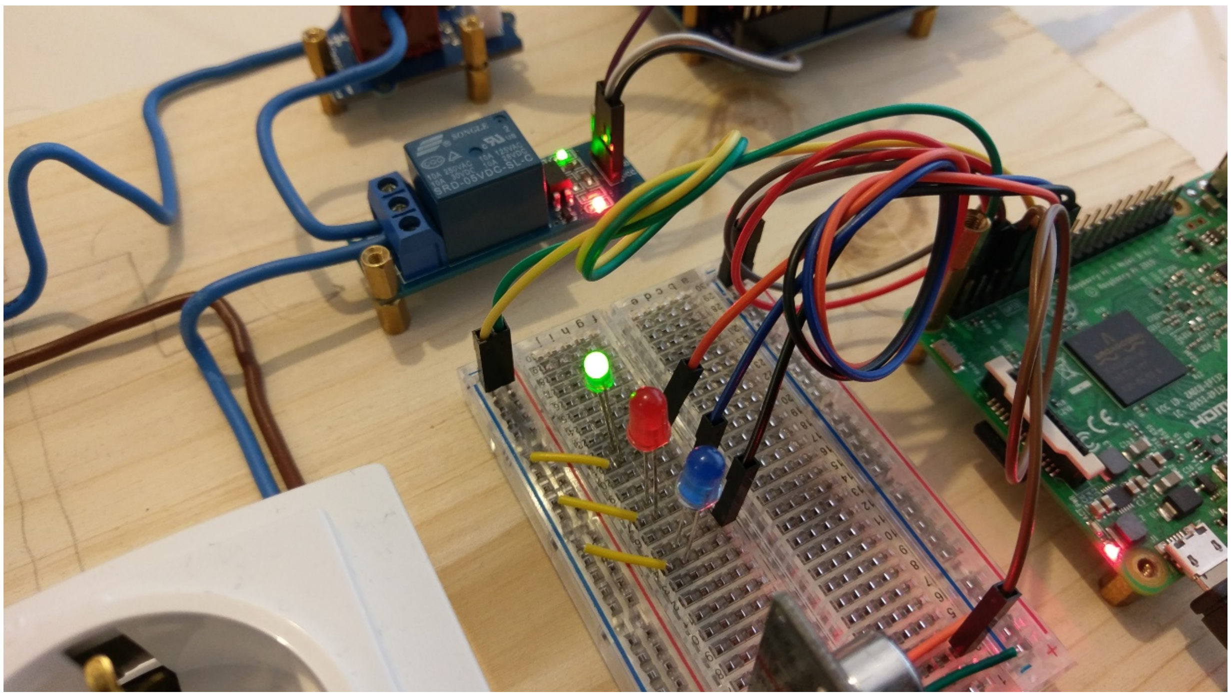

Figure 3.4: Green LEDs on.

The Figure above shows the Green LEDs when the node is charging also the connection from the Raspberry Pi to the Breadboard. The Figure below also shows the connection of the RP.

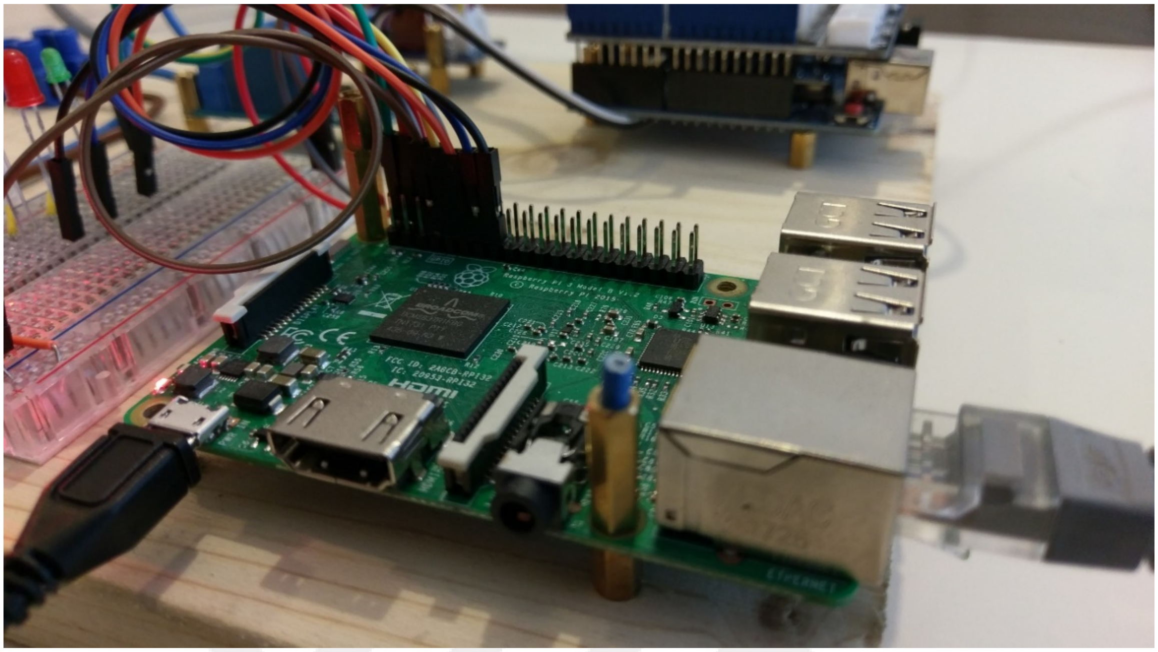

Figure 3.5: Raspberry pi connections.

When the phone is fully charged and there is no sound in the room the Raspberry Pi sends information to the Arduino to cut the power off, at this time the red LED will light to indicate that there is no power and the charger is not working.

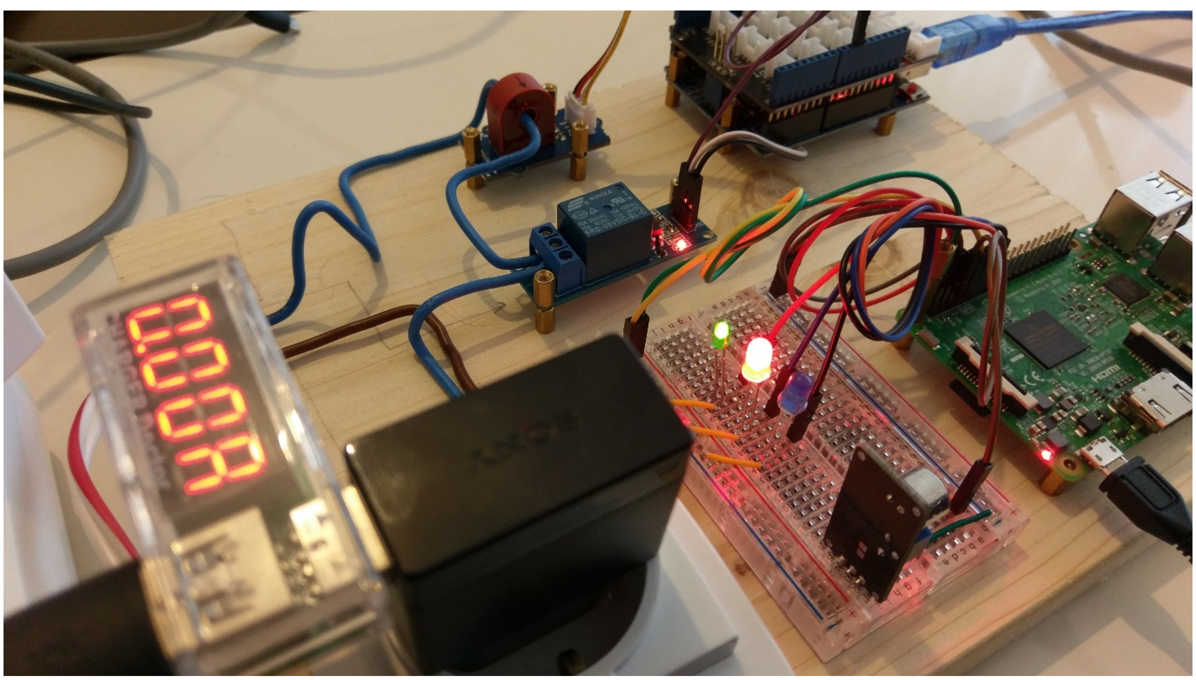

Figure 3.6: Red LEDs (cutting the power).

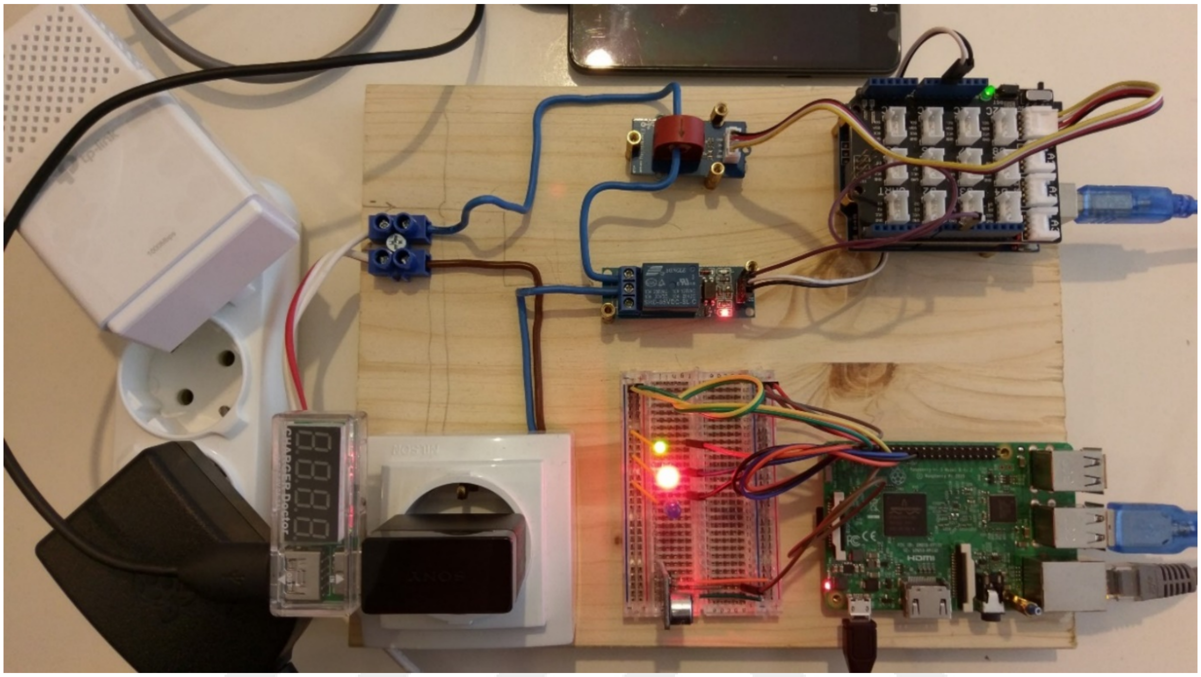

Figure 3.7: Node is not charging the phone.

The Green Led on the Relay also turn off to indicate that is no current flow. Also, the DC Sensor is not working because there is no electricity on the line.

As shown in Figure 2.14 the server does not activate the relay until there is a sound in the environment or if a user overrides the default procedure of the algorithm and reactivate the relay from the GUI. The user interface shown in Figure 3.8 when the relay is set to Off.

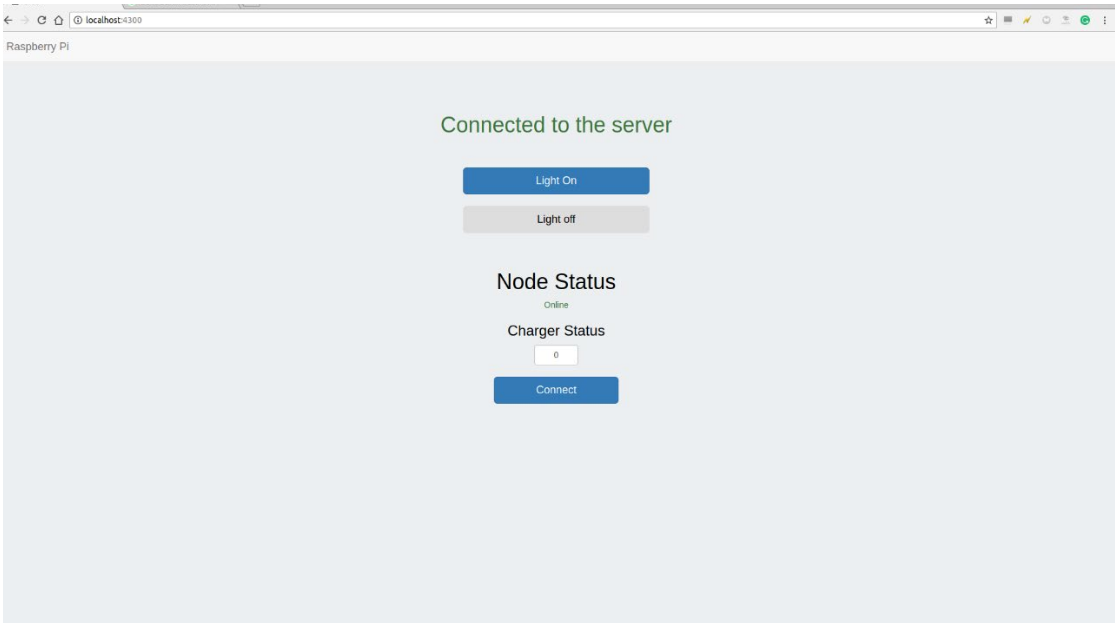

Figure 3.8: User interface (not charging).

When the relay is set to off, and there is a sound in the room, the blue LED will light to indicate that there is a sound. The Raspberry Pi catch the sound and send information to the Arduino the set the Relay On.

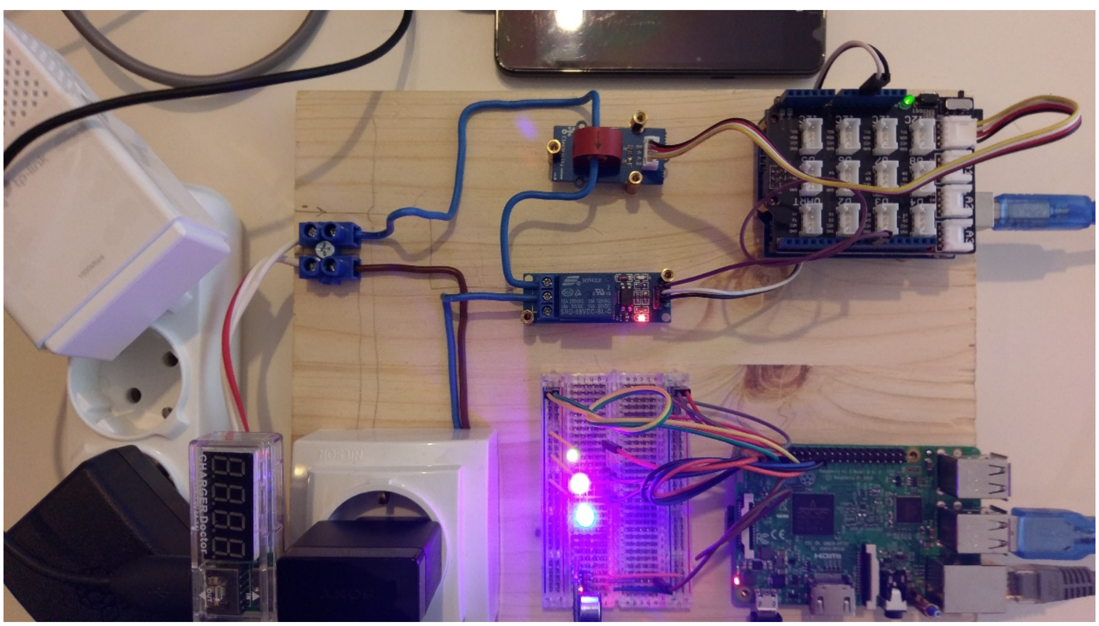

Figure 3.9: Node when detecting sound.

After reconnecting the power and set the relay to On, information about the current sensor measurement is sent to the User Interface in real time.

The figure below shows the second node when it is on and the relay is set to high

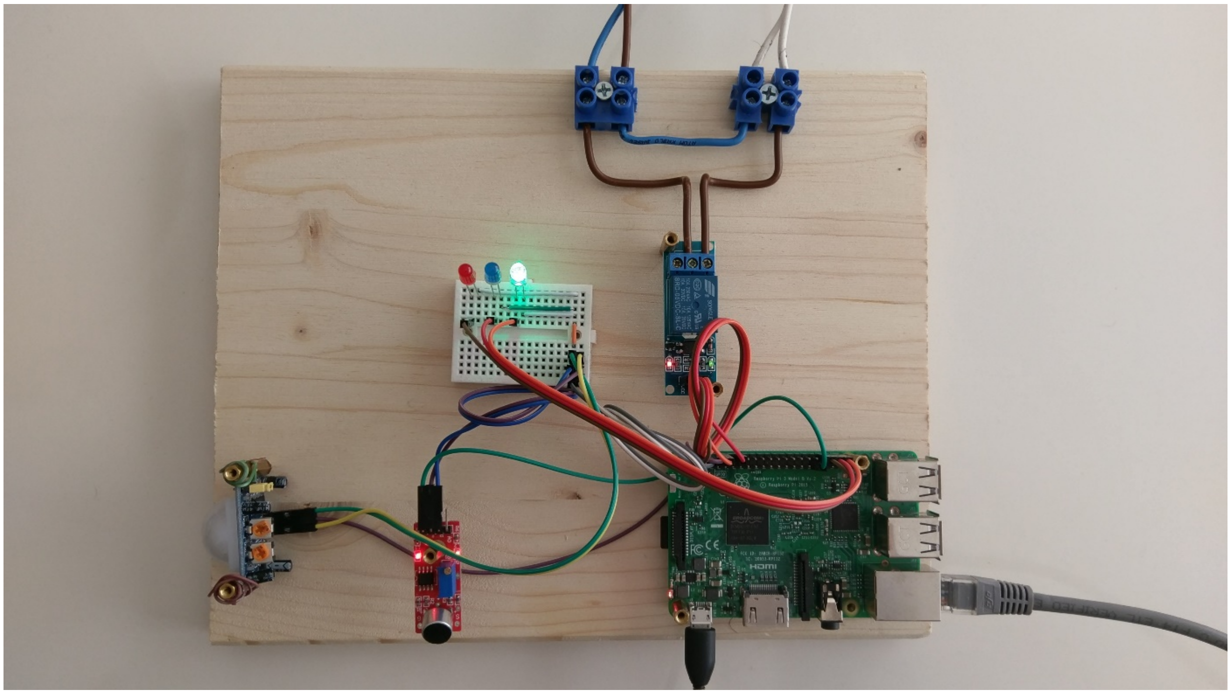

Figure 3.10: Node 2.

Like the first node, the Raspberry Pi is connected to the server through the power line adapter to transmit and receive data. The green LED indicates that the node is running and connected to the server.

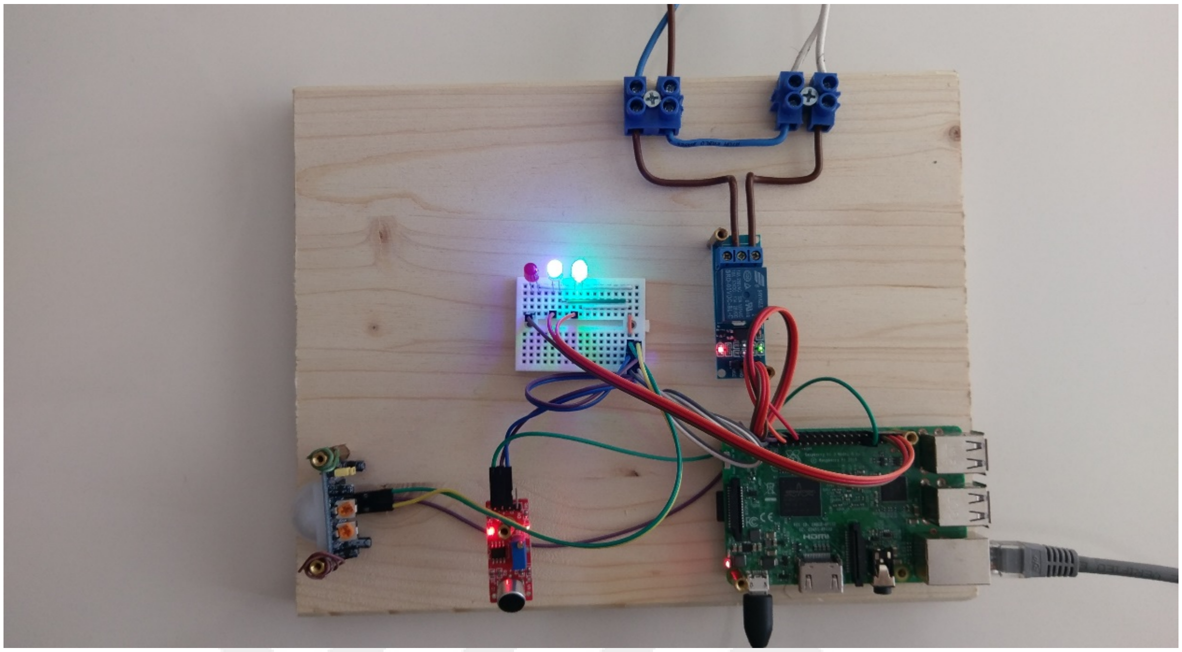

Figure 3.11: Node when detecting motion.

The blue LED turns on when motion is detected, an algorithm will keep tracking the motion detection sensor and determine when to cut the power

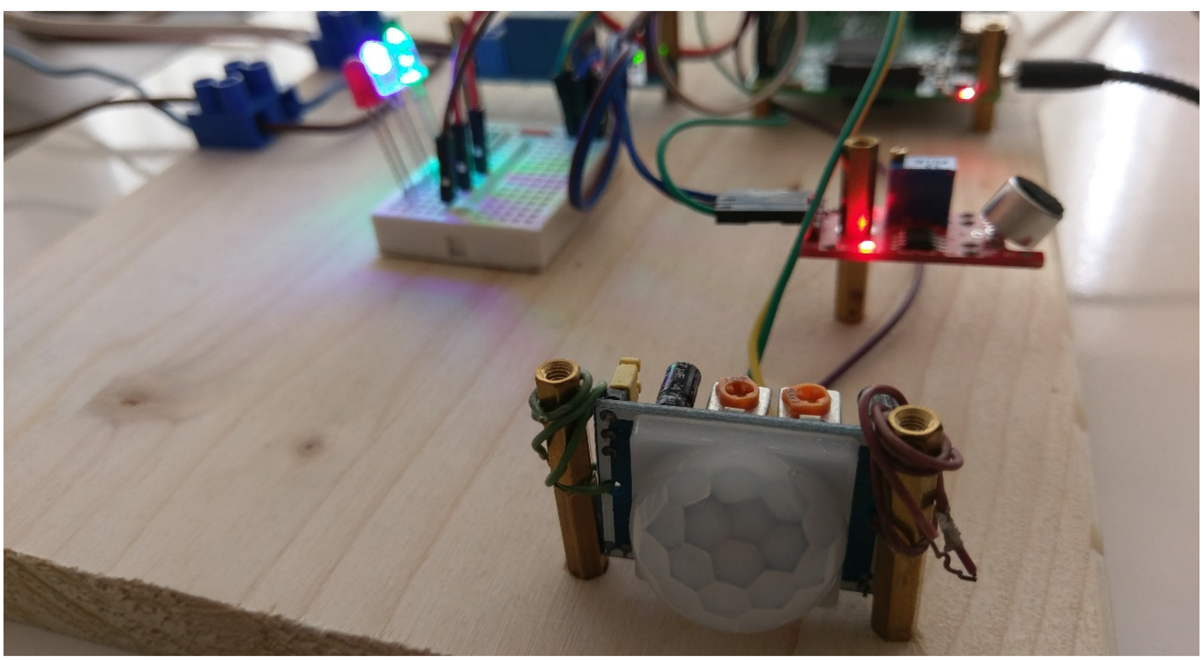

Figure 3.12: PIR sensor when detecting motion.

When motion is detected the relay keeps passing electricity to the connected device. Also, the rely keeps working if a sound is detected. The red LED lights on if the sound is detected

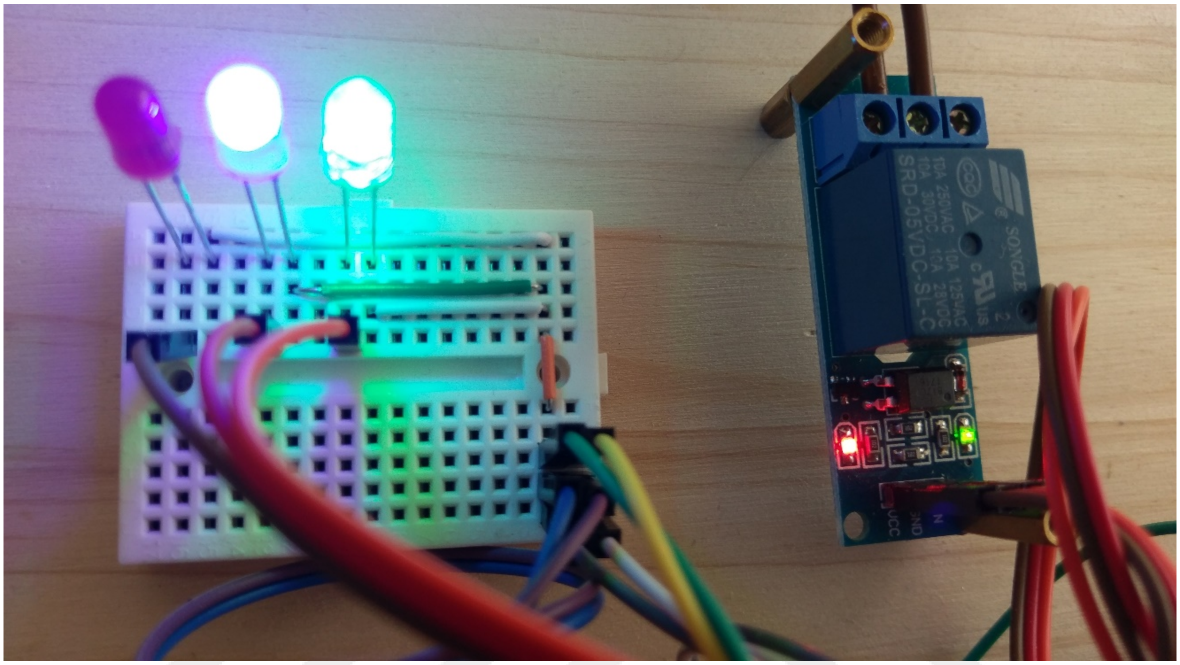

Figure 3.13: Node 2 relay on.

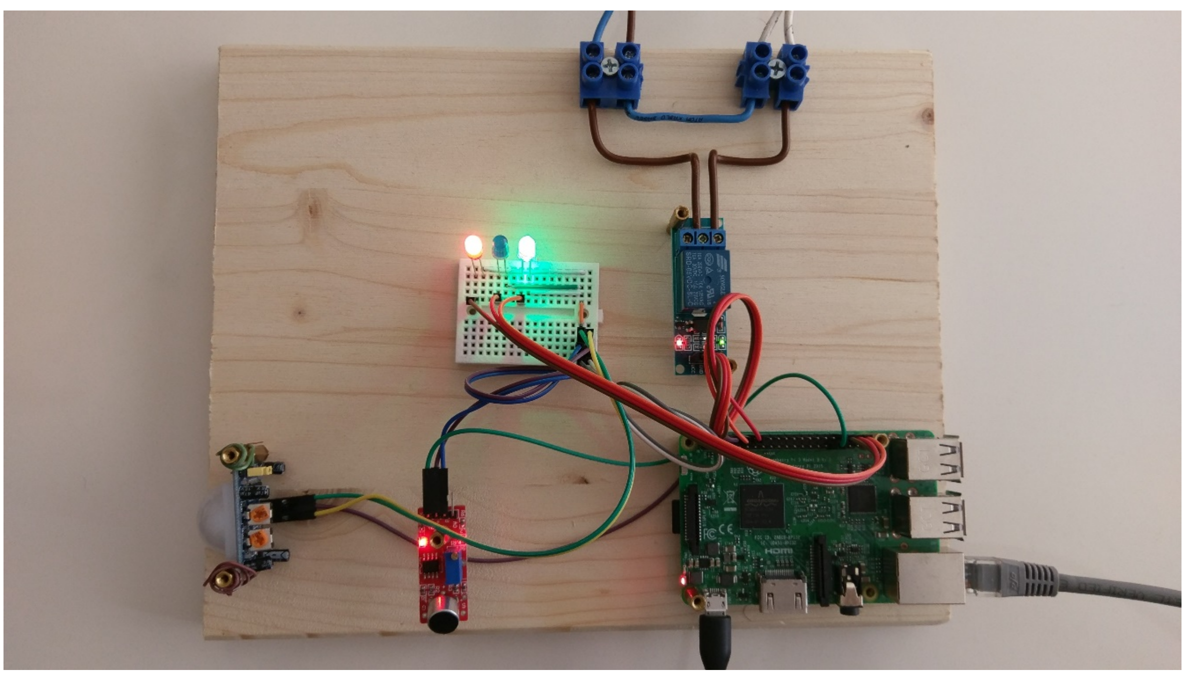

Figure 3.14: Node 2 sound detected.

The two nodes are shown below in the figure, both nodes are connected to the server through the EoP adapters

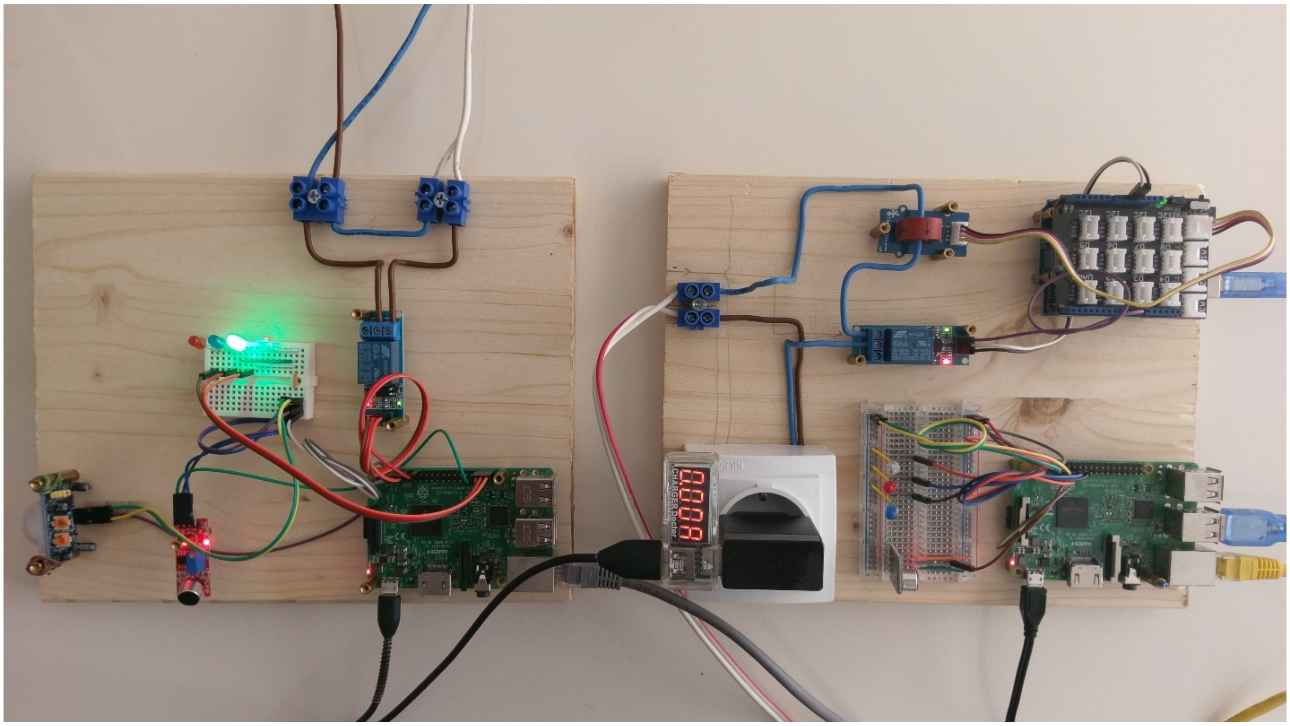

Figure 3.15: Node 1 and node 2.

The server is a Virtual Machine that simulates the dedicated device at home or cloud VPS. The VM uses the PC Ethernet jack to connect to the EoP Adapter to create the network between the server and the node. After the connection is established the system monitors and manages the node depending on the received information from the Raspberry Pi module in the node.

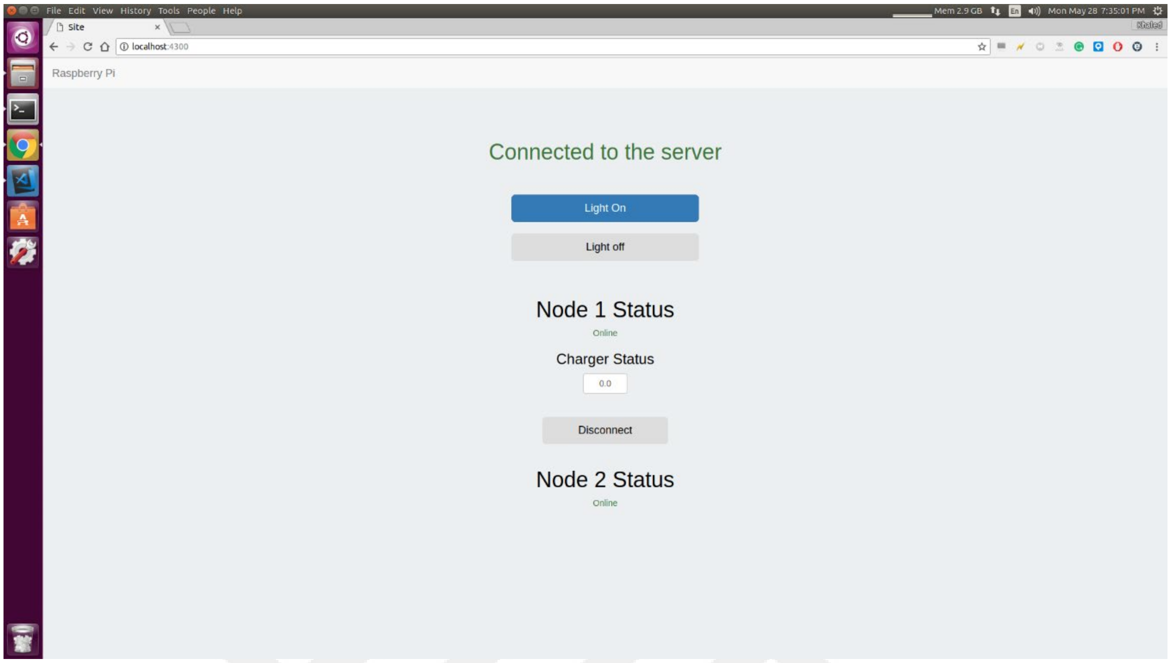

Figure 3.16: User interface (charging).

The developed algorithm in the server analyzes the received data from the current sensor and the sound sensor, to determine when to send information to the relay to cut the power off. Figure 2.14 shows the workflow of the algorithm.

Another part of the software manages the connection between all nodes, and each node has its own script to send direct information to the GUI System. The script will start sending the data whenever a user opens the GUI through the web. And the other part of the software will act as a router between the nodes to avoid the delay of sending information from the node to the user; this will also help to monitor the nodes without accessing the server.

As a result of building this system, we are providing a way to prevent damage to lithium batteries which are built into smart devices.

4. DISCUSSION

As described in the previous section the system keeps monitoring the power line to detect if a charger is plugged in or not. When the system cuts the power, a problem accrues when trying to turn on the power again, because we cannot measure the current when there is no current flow in the line. To avoid this problem, the system reconnects the power after a while (3sec) to check if a charger still connected or not, the system will override this procedure and do not disconnect the power if a sound detected in the room. The sound means that there is someone in the room and no need to disconnect the power. However, if no sound means there is no one around the device that is being charged and will keep monitoring the power line until there is no current withdraw, then the system will cut the power and go back to the regular procedure. Another problem we should consider is that: the relay makes a sound in the switching stage, and that will affect the sound sensor and prevent the standard procedure. We solve this issue by ignoring the sound when the relay is switching off. Also, this issue can be solved by an algorithm to determine if the sound is human sound or not, or by learning the algorithm that this sound is the relay switching sound.

The second node acts as an individual power source by cutting the power from the connected devices also helps in making the decision in the first node for cutting the power or not. This procedure is done by monitoring the environment for any motion and send feedback to the system for any detected motions. If the motion is detected in the same room the power in the first node will keep charging the phone. When the first node does not detect any sound or current draw from the power, it will check the status of the second node if there is a motion or not. Depending on this information the system will decide what happens next by cutting the power in these nodes or keep it running.

5. CONCLUSION AND RECOMMENDATIONS

This thesis discusses the smart home systems in general and focuses on one type of smart home application, which uses the power line communication and monitors the power line to prevent damage to batteries that are getting charged from the same line. Also, it detects the sound in the surrounded environment to determine whether to disconnect the power or keep the power on and feed the charger. All of these procedures done by using the Internet of Things technologies to provide a smart home system and Home Automation System.

The faster connection speed, security, and reliability make the power line communication the best candidate to use. Using the Wi-Fi technology has many disadvantages that compromise the smart home system (Wi-Fi attacks, distortion, noise, data loss). All of these problems can be avoided using the power line communication. Power Line Communications (PLC) are developing each day to ensure reliable connection without losing data while transferring through power lines and it has much more speeds that Wi-Fi technology has, it can reach 1Gb and up to 100 meters without any problems.

An algorithm that is running on the server communicates with the other algorithms that are running on the distributed nodes to keep monitoring the environment and the power lines. As shown in Figure 2.14 the algorithm analyzes the data that is coming from the sound and current sensors.

Sensors feedback can be seen directly from the GUI System, so the user can monitor each node and control them to override the default behavior of the algorithm. The Relay also can be controlled from the GUI System and receive information whether to cut the power or keep it on.

The system can be upgraded to use more sensors to determine when to cut the power off or to reconnect the power again. Also, modify the algorithm to use sound detection to differentiate human sound from another sound and to use the sound command.

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