Palestine Polytechnic University

College of Information Technology and

Computer Engineering

DISTRIBUTED IOT BASED SMART WASTE MANAGEMENT SYSTEM

Team:

Sally Ra'ed Manasrah (161018)

Aseel Iyad Ikhlayel (161016)

Supervisor:

Dr. Amal Dweik

Jan 11 , 2021

Acknowledgment

First and foremost, we would like to thank Allah Almighty for giving us the ability and opportunity to undertake this project.

Our heartiest thanks are due to our parents for their love and kind support which helped us in the project. We know the thanks are not enough and there are not enough words to describe how thankful we are to them.

We take this opportunity to express our regards and sincere thanks to our supervisor. Dr. Amal Dweik for her constant encouragement.

We would like to thank Eng. Wa’el Altakrori for his response and cooperation. Also, we would like to express gratitude to our families, friends and classmates for the unceasing encouragement, support and attention.

Abstract

In the present days, the garbage bins or trash cans which are placed at public places in the cities are getting overflow due to increase in the waste every day. It creates bad health conditions for people by spreading some deadly diseases . To avoid such situations , planning to design smart bins means that the particular authorities can receive messages about the bins’ status . So, our system serves particularly municipal employees , saves their time and reduces cost also . It provides smart waste management solutions for cities and businesses to cost effectively manage the waste , improve the environment and wellbeing of people . The system aims to improve the waste collection process and its operation efficiency, manage, understand and separate the waste type (either liquid or solid), thus knowing the possibility of recycling the waste .This is done through involving unique ultrasonic smart sensors that monitor waste in real-time using IoT. Thus provides cities and businesses with data-driven decision making, and optimization of waste collection routes.As trash increases , the distance between the ultrasonic and the trash decreases, this data will be sent to our micro-controller. Microcontroller then processes the data and sends messages to the android app which alerts the responsible staff. After that, the collected data is analyzed ,then the instructions and the schedules are updated accordingly.

Keywords : IOT, Internet of things, Waste management, RTOS, Raspberry PI, 3G SIM Module.

Table of contents:

List of Figures:

List of Tables:

List of charts:

Chapter 1

Introduction

1.1 Overview of the project:

Today, big cities around the world are facing a common problem, managing the city waste effectively. Today's waste management systems involve a large number of employees being appointed to attend a certain number of dumpsters which is done every day periodically. This leads to a very inefficient and unclean system in which some dumpsters will be overflowing, some dumpsters might not be even half full. Here a waste management system is introduced in which each dumpster is embedded in a monitoring system that will notify the corresponding authority if the dumpster is full and it is also
separate wet and dry waste. Our system provides an effective solution to the waste management problem.

1.2 Motivation

By 2100, they estimate, the growing global urban population will be producing three times as much waste as it does today [1]. That level of waste carries serious consequences – physical and fiscal – for cities around the world. One of the main concerns with our environment is waste management which impacts the health and environment of our society. The detection, monitoring and management of wastes are one of the primary problems of the present era. The traditional way of manually monitoring the wastes in waste bins is a cumbersome process and utilizes more human effort, time and cost which can easily be avoided with our present technology.

1.3 Importance

In summary, the system will:

1. Make reduction in collection costs: when smart dumpsters transmit their real-time fill level information to waste collectors. This leads to a pickup process which doesn't consider
empty trash bins, saving fuel as well as manpower.

2. Assure that there are no missed pickups: unlike traditional collection methods, the smart waste management process eliminates the overflowing of trash bins. When a trash bin is about to get full, the authorities are immediately notified. And collection trucks can be scheduled for a pickup even before the pre-scheduled time.

3. Generate waste analysis: smart waste management is not just about route optimization. The real value of IoT lies in data analysis. Such capabilities can help waste management companies, municipalities predict future waste generation.

4. Reduce CO2 emission: telling the drivers the exact location of full bins lead to less fuel consumption, which ultimately reduces the carbon footprint, making the waste management process eco-friendlier.

1.4 Objectives

The main aims that we are looking to achieve in our project are:

1- The system will be able to control the Wastage of fuel. In order to achieve that aim, it has to achieve these objectives:

A. Ability to identify the status and location of each waste bin .

B. Ability to update and send notifications in order to collect waste as-needed, thus reducing labor hours .

2- The system will be able to optimize waste collection logistics. In order to achieve that aim, these should be gained :

A. Ability to separate the waste depends on their type (either liquid or solid) .

B. Help the process of recycling the waste.

3-The system will be able to support safety conditions, in order to achieve that aim, these are the objectives:

A. Ability to detect the fire immediately

B. Sending notification of Short Message Service (SMS) to a Fire and Ambulance car.

4- The system will improve the environment and wellbeing of people , in order to achieve that aim, these are the objectives :

A. Ability to tell the citizens the location of nearest empty trash, thus minimizing the contamination of containers surrounding, no bad smells and no rodents.

B. Ability to give the exact location of fully trashes which led to decrease the amount of fuel required to collect the waste, thus eliminating the excess emissions.

5-The system will be automatically updated according to the data collected after analysis , the required data for analysis includes :

A-Bin status data(full or not) .

B-Fire detection data .

C-Waste type detection data .

6-The system will guarantee that the responsible authority can only schedule and make changes which can be done by:

A-The responsible authority will be informed about the system updates and then these updates either confirmed or rejected .

B- The drivers can only view the needed information to do their work and they don't have access to any further data.

1.5 Description of the project

In this research, the proposed system will design and implement an effective smart waste management system based on IoT. The system gives a real time indicator of the garbage level in a trash can at any given time. Using this data we can then optimize waste collection routes and ultimately reduce fuel consumption, by just telling the driver the locations of full trash cans. It allows trash collectors to plan their hourly/daily pick up schedule. The solution is composed of remote monitoring of the amount of waste inside containers via ultrasonic sensors which are able to monitor(in real-time) any type of waste in containers of different types and sizes. The system provides a mobile application which allows configuring, monitoring and managing waste. It provides an advanced analytics tool that enables to truly understand waste, so the driver can wisely plan capacity, ratio and location of his containers based on real requirements. In case the trash can is full before the round of the truck, our system will send a notification message to the responsible authority, and close the can, so it prevents the citizens from putting their trash; otherwise it will redirect them to the nearest trash can.

The solution can best benefit the municipalities and local authorities, waste management companies and large businesses, factories, industrial parks, campuses, universities, and hospitals.

1.6 Problem statement

The traditional method of waste collection is based on hygiene personnel (especially municipalities), and check out the trash bins distributed in different geographical regions. Therefore, it is necessary to go to all these areas, and typically a specific day is assigned to each region. The problems with this method are clear, most notably that the trash may not always be full and doesn’t need to be emptied compared to other trashes that may need to be emptied as soon as possible, consequently, this issue results in the loss of time, effort and money, to check empty trashes . In addition, a very important point is that in some cases waste is burning whether intentionally by people or inadvertently to empty the trash.

1.7 List of requirements

The system requirement can be summarized as:

1. The system should give a real time indicator of the garbage level in trash (container) at any given time.

2. The system should have the ability of analyzing system data that have been sent to the microcontroller and to the cloud.

3. The system should have the ability to give continuous feedback to the drivers and responsible.

4. The system should open a suitable section of the trash can depending on waste type.

5. The system should support and provide safety conditions.

6. The system should provide the citizens with the closer empty trash.

To meet these requirements:

1. The system should sense the waste and identify waste level continuously.
2. The waste detection unit must be able to identify waste type.
3. The system must be able to detect fires and refresh its data continuously, then update mobile application and SMS notifications.
4. An LCD must be able to display the location of the nearest empty trash.
5. The system must update ,schedule ,and give instructions according to the results after analyzing the data .

1.8 Expected results

1.Provide municipalities with the needed information about trash status using mobile apps, thus optimize the waste collection process .

2.Sending notification of Short Message Service (SMS) to a Fire car and to detect the fire location accurately using the SIM808 GSM/GPRS/GPS module**.**

3.Help citizens by telling them the location of the nearest empty trash on an LCD, in case the current one is full.

4.Reduce waiting time to empty fully trashes, thus reducing pollution and save the environment.

5.Contribute in the recycling process by separating the waste depending on its type.

1.9 Overview of the rest of report

The outline of the report is as follows:

Next chapter, “background”, contains the theoretical background and Literature review, options (design options for hardware components and design options for software components) and design constraints.

Third chapter “design”, includes a detailed conceptual description of the system (HW and SW), detailed design, schematic diagrams, block diagrams, structural diagrams, and any necessary information about the design.

Fourth chapter “System Implementation and Validation”, includes a description of the implementation, implementation issues, implementation challenges and description of the method used to validate the system, validation results.

Fifth chapter “System Analysis and Discussion ”, includes analysis and discussion about the results.

Sixth chapter “Conclusion”, includes summary, challenges , future directions, recommendations, and future work.

Chapter 2

Background

2 .1 Overview

This chapter introduces the theoretical background of our project, short description of design options that will be used in the system, design specifications, constraints and some additional information about the system.

2.2 Theoretical background

Waste management is a process that includes the activities and actions required to manage waste from its inception to its final disposal. This includes the collection, transport, treatment and disposal of waste, together with monitoring and regulation of the waste management process.

Waste can be solid, liquid, or gas and each type has different methods of disposal and management. Waste management deals with all types of waste, including industrial, biological and household. In some cases, waste can pose a threat to human health. Waste is produced by human activity, for example, the extraction and processing of raw materials. Waste management is intended to reduce adverse effects of waste on human health, the environment or aesthetics.

Waste management practices are not uniform among countries (developed and developing nations); regions (urban and rural areas), and residential and industrial sectors can all take different approaches.

A large portion of waste management practices deal with municipal solid waste (MSW) which is the bulk of the waste that is created by household, industrial, and commercial activity.

Our project focuses on optimizing the waste collection process using IoT technology. Here the problem of unorganized and non-systematic waste collection is solved by designing an embedded IoT system that will monitor each dumpster individually for the amount of waste deposited. An automated system is provided for segregating wet and dry waste. A mechanical setup can be used for separating the wet and dry waste into separate containers inside the same trash container. For detecting the presence of any waste wet or dry we will use an IR sensor, in the next step for detecting wet waste a moisture sensor can be used. In this process, if only IR is detected, the motor will rotate in the direction of the dry waste container if both the sensor detects the waste then it will go to the wet container. Both these containers are embedded with ultrasonic sensors at the top; the ultrasonic sensor is used for measuring distance. This makes it possible to measure the amount of waste in the containers if one of the containers is full then an alert message will be sent to the corresponding authority.

2.3 Related Work

Considering the advantages of IoT technologies, many researchers have investigated and developed new applications for smart cities, especially for waste management. There are different projects that are used to manage waste collection process, these are some of them:

1. "IOT based waste management system", which is being developed by Reem Ghayadah , Rawand Taha ,Palestine. The system proposed a solution to manage the waste collection process. They assumed that waste was collected in two trash cans, the first is a trash can that is used for personal use in homes. The second part is a trash can for people to share it, which would also be emptied by the municipality. For the personal use trash can, there is an ultrasonic used to detect when something is placed in the trash bin door, that would trigger the moisture sensor to measure the moisture level of what is placed. Which would trigger a motor to move the trash either to the dry container, or the wet container. For the large trash can, the trash cans would measure the waste inside them with an ultrasonic sensor. Using the distance measured with the sensor, it determines whether the trash can is full or empty. The city would have an application that would help them monitor the status of the trash cans[2].

2. "Design of a Monitoring System for Waste Management Using IoT", which is developed by Aravindaraman and P. Ranjana, April, 2019. The proposed system finds the solution for the garbage disposal by designing a smart trash can by managing the garbage. The garbage is collected, and the garbage collector sent from the control room. The smart trash can sends the message to the control room through the sensors attached to it. The trash can is attached with the ultrasonic sensor, infrared sensor for detecting the level of the waste and anonymous gases which is connected to a Raspberry Pi microcontroller where it is programmed to send message to the control room if the garbage is full and also if the garbage is not disposed for a long time[3].

3. "Internet Of Things (IOT) Based Waste Management System" which was developed by Tuton Mallick on Oct 01, 2018. In this proposed System, multiple trash cans in different locations all over the city have been provided with a low cost embedded device which sends data to the internet cloud after reaching a certain threshold level of the trash can in order to perform the cleaning as early possible. Moreover, the device will transmit the level along with the unique ID provided via SMS to the closest authorized cleaner. The total system is clearly visible with proper authentication to the highest authority of the waste management system. And also the system is able to notify the authority if any cleaner avoids the SMS[4].

In the following table ,the comparison of our system and other existing systems are shown.

Table 2.1 Existing work comparison

Feature	Proposed system	IOT based waste management system	Design of a Monitoring System for Waste Management Using IoT	Internet Of Things (IOT) Based Waste Management System
Microcontroller	Raspberry PI	ArduinoMega2560	Raspberry Pi	Raspberry Pi
Sensors	Smoke sensor, ultrasonic sensor, Moisture sensor	Ultrasonic sensor, Moisture sensor	Ultrasonic sensor, Gas sensor	Ultrasonic sensor
Information about the collecting time and location	✓	✓	✓	✓
Quick response to urgent cases like fire	✓	✓	✘	✘
Managing Application	✓	✓	✘	✓
Segregating wet and dry waste	✓	✓	✘	✘
Distributed System	✓	✘	✘	✘
Data analysis	✓	✓	✘	✘
Feedback	✓	✘	✘	✘

Reviewing the weaknesses of the above frameworks, we are proposing an "IOT based smart waste management system" where a distributed system contains multiple trash bins that are physically separate but linked together using the internet . All the trash bins in this system communicate with each other and handle processes in tandem .

the distributed feature that is added to our system have the advantages of :

1- All the trash bins in the distributed system are connected to each other. So trash bins can easily share data with other trash bins since they are connected with a unified IBM database.

2- More trash bins can easily be added to the distributed system i.e. it can be scaled as required.

3- Failure of one trash bin does not lead to the failure of the entire distributed system. Other trash bins can still communicate with each other.

In our system we analyze data on raspberry pi then send the result to an android application through Node-RED (IBM cloud service) . We have feedback in our system like when the trash can is opened we send a notification to the application ,also when the system went offline for any purpose , a notification will be sent .

Our system also uses an IBM cloud data analysis service which enables us to collect all the system data in a unified “cloudant database”(IBM service) so we can then understand problems facing the system , and to explore data in meaningful ways. Data in itself is merely facts and figures. Data analysis organizes, interprets, structures and presents the data into useful information that provides context for the data.

So our system is an automated system that is provided for optimizing the collection process, segregating wet and dry waste and supporting safety conditions. This system provides an effective solution to the waste management problem.

2.4 Design options

Our system consists of sensors that monitor waste in real-time using IOT. Sensors data will be sent through the internet to our microcontroller. Microcontroller then processes the data and sends messages to the application which alert the responsible staff. Also the system can detect emergency situations then send an alert to the responsible staff .

In the following sections, we will discuss the different options for the needed components and the reasons why we chose them .

2.4.1 Hardware components

1. Microcontrollers: There are different options of the microcontrollers that can be used in our project.

- First Design Option: Arduino UNO

  Arduino microcontroller: is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on a computer.

Figure 2.1 : Arduino-UNO

- Second Design Option: Raspberry pi :

  Raspberry Is a small ,single-board computer ,has a 64-bit quad-core ARMv8 processor and uses a Raspbian distribution of Linux for its default operating system (OS), the Raspberry Pi computer is essentially a wireless Internet capable system-on-a-chip (SoC) with 1 GB RAM, connection ports, a Micro SD card slot, camera and display interfaces and an audio/video jack.

Figure 2.2 : Raspberry Pi

Table 2.2 summarizes the main features that may affect our choice.

Table 2.2 Microcontrollers comparison

Feature	**Arduino UNO**	**Raspberry Pi**
1- Programming	Easy	Easy
2- Size(mm)	68.6 × 53.3	85 x 56
3- Power consumption(W)	0.25	1.3
4- Memory size	32 KB	1 GB
5- Open source	Yes	Yes
6-Number of ports	14	depends on the model
7-Cost	Low cost	Expensive

Chosen Design Option:

We will choose Raspberry PI microcontroller, because it has a RTOS which we need in our event driven system.

2. Ultrasonic sensors

Ultrasonic sensor can measure the distance to an object using ultrasonic sound waves. An ultrasonic sensor uses a transducer to send and receive ultrasonic pulses that relay back information about an object's proximity.

- First Design Option: HC-SR04

  +5 V DC Operating voltage, 2 cm to 80 cm practical measuring distance ,3 mm accuracy,$0.55/10 Pieces.

Figure 2.3 : HC-SR04

- Second Design Option: US-100

  +5 V DC operating voltage, 2 cm to <=80 cm practical measuring distance, 1 mm accuracy, 9600 baud serial communication, Temperature Compensation Available in Serial Data Mode , $2.49 /Piece.

Figure 2.4 : US-100

Table 2.3 summarizes the main features that may affect our choice

Table 2.3 Ultrasonic sensor comparison

Feature	HC-SR04	US-100
1- Accuracy (mm)	Up to 3	UP to 1
2- Size (mm)	45 x 20 x 15	44 x 26 x 14
3-Current Consumption (mA)	15	2
4-Cost ($)	3.95	9.45

Chosen Design Option

We will use HC-SR04 Ultrasonic Sensor. It is cheaper ; also we had used it before so we know how it works .

3. SIM card modules :

It is used to accurately detect the location of the bin. When the system detects a fire, it will send a notification from the SMS service to the fire and ambulance vehicle and accurately detect the location of the fire

- First design option: SIM900A GSM /GPRS/GPS Module

  The SIM900A GPS/GPRS/GSM Module is a GSM and GPS two-in-one function module. It is based on the latest GSM/GPS module SIM900A from SIMCOM, supports GSM/GPRS Quad Band network and combines GPS technology for satellites. It has high GPS receiving sensitivity with 22 tracking and 66 acquisition receiver channels .The module is controlled by AT command via UART and supports 3.3 V and 5 V logic levels.

Figure 2.5 : SIM900A GSM /GPRS/GPS Module

- Second design option: SIM5320E

  Simcom Wireless's SIM5320E is a 3G Module. SIM5320E supports GSM, GPRS, UMTS, EDGE, HSDPA technologies and a maximum download speed of 3.6 Mbps.

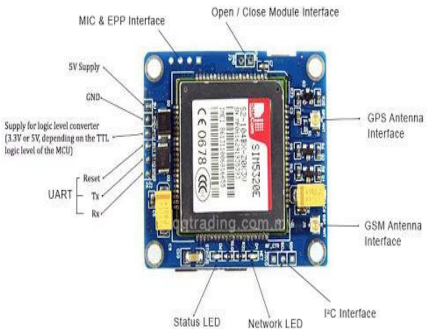


Figure 2.6 : SIM5320E Module

Table 2.4 summarizes the main features that may affect our SIM card choice

Table 2.4 SIM cards comparison

Feature	**SIM5320E**	**SIM900A GSM /GPRS/GPS Module**
1-Size(mm)	30 * 30 * 2.9	24 * 24 * 3
2-Easy to use	Easy	Easy
3-Cost($)	20.39	20$

Chosen Design option:

We choose SIM900A module instead of SIM5320E GSM /GPRS/GPS Module since it contains these technologies 3G module (Which needed for sending data through the internet) ,GSM, GPRS ,it is also easy to use and smaller .

4. Motors: it used for segregating wet and dry waste:

- First Design Option: DC motor

  Is a two wire continuous rotation motor and the two wires are power and ground. When the supply is applied, a DC motor will start rotating until that power is detached.

  Advantages:

  1. Simple, cheap drive design.

  2. Easy to control via computer with relays or electronic switches.

  Disadvantages:

  1. Requires gear reduction to provide torques needed for most robotic applications.

  2. Poor standards in sizing and mounting arrangements.

Figure 2.7 : DC motor

- Second design options: Servo motor

  Generally, the servo motor is an association of four things, namely a DC motor, a control circuit, a gearing set, and also a potentiometer, usually a position sensor.

  Advantages:

  1. Least expensive non-surplus source for gear motors.

  2. Can be used for precise angular control, or for continuous rotation

  Disadvantages:

  1. Requires modification for continuous rotation.

  2. Requires special driving circuit.

Figure 2.8 : Servo motor

Table 2.5 summarizes the main features that may affect the motor choice

Table 2.5 Motors comparison

Feature	**(DC motor)**	**(Servo motor)**
Operating speed (rpm)	Up to 9000	Up to 6.000
Angle of rotation (Degree)	Can be used for precise angular control, or for continuous rotation	180
Weight(grams)	17	17
Voltage supply	Low	High
Cost ($)	39.99	30.00

Chosen Design Option

We have chosen the DC motor to segregate wet and dry waste, because it is simple and cheap motor, it is easy to control the speed and direction, and DC motor responses quickly to control signals and servo motors do not rotate freely like a standard DC motor and angle of rotation is limited to 180 Degrees.

5. Motor driver

- First design option : L298N

The L298N is a dual H-Bridge motor driver which allows speed and direction control of two DC motors at the same time. The module can drive DC motors that have voltages between 5 and 35V, with a peak current up to 2A.

Figure 2.9 : L298N

- Second design option:L293D

The employed motor driver module circuit known as L293D motor driver controller consists of 4 inputs and 4 outputs to control two DC motors. One of the main facilities of L293D is to provide up to 600mA current at voltage variation from4.5 V to 36V . The direction of rotation of a DC motor in forward and reverse can be controlled through combining different input logics.

Figure 2.10 : L293D Motor Driver

Table 2.6 summarizes the main features that may affect the motor driver choice

Table 2.6 Drivers comparison

Feature	L298N	L293D
Easy to control	Easy	Easy
Current supply per channel (A)	0.6	2
Size (mm)	43 x 43 x 26	48 x 34 x 14
Weight(gms)	15	30
Price($)	2.99	3.89

Chosen design option

We have chosen the L298N Driver, because it is simple and cheap motor driver, easy to use it, and The module can drive DC motors that have voltages between 5 and 35V, with a peak current up to 2A.

6. Smoke detection sensor:

The fire smoke consists of CO (carbon monoxide), CO2 (carbon dioxide), S (sulfur), NO (nitrogen oxide) and water vapor. Therefore, smoke detection task can be carried out by detecting one of these gases

- First design option: Pololu MQ-4

  His semiconductor gas sensor detects the presence of methane (CNG) gas at concentrations from 300 ppm to 10,000 ppm, a range suitable for detecting gas leaks. The sensor's simple analog voltage interface requires only one analog input pin from the microcontroller.

Figure 2.11 : MQ-4

- Second design option: Pololu MQ-9 model

  It is a semiconductor gas sensor that can detect the presence of carbon monoxide at concentrations from 10 to 1,000 ppm (parts per million). The sensor can operate at temperatures from -10 ˚C to 50 ˚C.

Figure 2.12 : MQ-9

Table 2.7 summarizes the main features that may affect the smoke sensor choice.

Table 2.7 Smoke sensors comparison

Feature	**Pololu MQ-4**	**Pololu MQ-9**
Gases that can sense	Natural gas/ Methane	Methane,Propane, Combustible gas .and CO
Concentration (PPM)	300-10000 (Natural gas / Methane)	10-1000 CO 100-10000 combustible gas
Sensitivity	Low	High
Heater consumption (mW)	≤900	≤350
Price ($)	4.95	5.95

Chosen design option

We have chosen MQ-4 Sensor because it has high sensitivity, less heater consumption, it can make detection of the method of high and low Dc Motor 16 temperature. Sensor detects CO when heated by 1.5V (with low temperature) and detects combustible gases such as methane, propane when heated by 5V (with high temperature).we will use this sensor to discover the smoke when the fire starts immediately and help to detect the fire.

7. Moisture Sensor: used for separating wet and dry waste

Soil moisture sensors measure the water content in soil. A soil moisture probe is made up of multiple soil moisture sensors.

- First Design Option: Capacitance sensor

  Advantages: very accurate, no calibration required multiple output options.

  Disadvantages: expensive, can be affected by the environment, limited detection range.

Figure 2.13 : Capacitance sensor

- Second Design Option: Moisture Sensor

  Advantages: Simple method of measurement , It delivers the results immediately, Offers accurate results, and very low in cost.

  Disadvantages: It requires initial evaluation of site specific conditions before selection of appropriate moisture sensor , It requires probe to be inserted in the soil. It requires labor to collect the data and maintain the measurement processes.

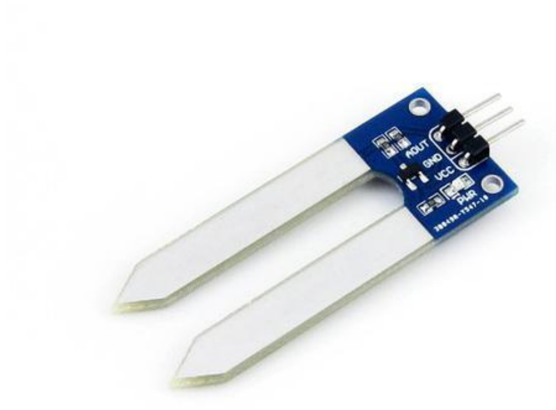


Figure 2.14: Moisture sensor

Table 2.8 summarizes the main features that may affect the moisture sensor choice.

Table 2.8 Moisture sensors comparison

Feature	**Capacitance sensor**	**Moisture sensor**
Accuracy	Accurate	Very accurate
Calibration	May require	Not required
Power hungry	High	Low
Price	Expensive	Inexpensive

Chosen Design Option

We will choose moisture sensor because they are simpler, so are potentially smaller, less expensive and less power-hungry.

8. Buzzer

Is an audio signaling device, which may be mechanical, electromechanical, or piezoelectric Typical uses of buzzers and include alarm devices, timers. When the system detects the fire, a warning will be issued.

- First design option: Active Buzzer

  This buzzer is an active buzzer, which basically means that it will buzz at a predefined frequency (2300 ±300 Hz) on its own even when you just apply steady DC power.

Figure 2.15 : Active buzzer

- Second design option: passive Buzzer

  It is like an electromagnetic speaker, where a changing input signal produces the sound, rather than producing a tone automatically.

Figure 2.16 : Passive buzzer

Table 2.9 summarizes the main features that may affect the buzzer choice.

Table 2.9 Buzzers comparison

Feature	**Active buzzer**	**Passive buzzer**
Size	Small	Small
Voltage	DC voltage	AC Voltage

Chosen design option

We will choose an active buzzer because it just needs to be supplied a DC power and it does the rest to provide a tone, whereas a passive buzzer needs to be provided a changing voltage, such as a square wave, to produce sound .

11.Screen

- First design option: LCD

  Is a type of flat panel display which uses liquid crystals in its primary form of operation

Figure 2.17 : LCD

- Second design option: TFT:

  Is a type of LCD with a thin film transistor attached to each pixel. Cost is now very good; power consumption is fairly good but dominated by the backlight.

Figure 2.18 : TFT

Table 2.10 summarizes the main features that may affect the screen choice.

Table 2.10 Screens comparison

Feature	**(LCD)**	**(TFT)**
Word spaces	Less	More
Easy to use	Easy	Easy

Chosen design option

We have chosen LCD because it's more practical, cheaper , easier to read and can accommodate a larger number of words.

12. IR Sensor: used for separating wet and dry waste

This device emits and/or detects infrared radiation to sense a particular phase in the environment. Generally, thermal radiation is emitted by all the objects in the infrared spectrum. The infrared sensor detects this type of radiation which is not visible to human eye. An infrared detector is a detector that reacts to infrared (IR)radiation. The two main types of detectors are thermal and Photonic (photo detectors).

- First design option: IR module :

The IR sensor module consists mainly of the IR Transmitter and Receiver, Opamp,
Variable Resistor (Trimmer pot), output LED in brief. IR LED Transmitter. IR LED emits light, in the range of Infrared frequency. IR light is invisible to us as its wavelength
(700nm – 1mm) is much higher than the visible light range .

Figure 2.19 :IR module

- Second design option: Thermal IR Sensor:

The thermal infrared is a sensor measures the temperature of objects without touching them, by measuring the infrared radiation coming off. Infrared sensors are used in everything from night-vision to medical diagnostics.

Figure 2.20 : Thermal IR

Table 2.11 summarizes the main features that may affect the IR choice.

Table 2.11 IR sensors comparison

Feature	IR module	(Thermal)
Performance	High	Low
Speed	Fast	Slow

Chosen design option

We will choose IR module infrared detectors because it offers higher detection performance and are faster than thermal type infrared detectors.

2.4.2 Software options:

1. The software that can be used in the project is Arduino software or python.

A. The Arduino integrated development environment (IDE) or Arduino software: is a cross platform that is written in the programming language Java. It is used to write and upload programs to the Arduino board. It's flexible and easy to use.

B. Python: The best programming language for Raspberry pi, Python is a wonderful and powerful programming language that's easy to use (easy to read and write). Python syntax is very clean, with an emphasis on readability and uses Standard English keywords.

Chosen Design Option:

The software we will use in our project is Python according to the hardware we were chosen and it's flexible and easy to use.

2. For application development, we will use these technologies:

A. Blynk Server:

A Blynk server is a program that uses Hypertext Transfer Protocol to serve the files that form Web pages to users, in response to their requests, which are forwarded by their computers' HTTP clients. Dedicated computers and appliances may be referred to as Blynk servers as well.

B. Blynk application :

Is a new platform that allows us to quickly build interfaces for controlling and monitoring hardware projects from iOS and Android device. After downloading the Blynk app, we can create a project dashboard and arrange buttons, sliders, graphs, and other widgets onto the screen. Using the widgets, we can turn pins on and off or display data from sensors.

We use these languages for Front and Backend development, because we know how to program using these technologies.

2.5 Specification:

The most important specifications of the system design may be:

1. It is employed to browse, collect, transfer information over the net.

2. Data freshness is required.

3. Good detection of the waste type is required.

4. Analyzing sensor data by the microcontroller in order to send the result to the android application is required.

5. Accepting data by the microcontroller from an android application through the internet and analyzing these data is required.

2.6 Design constraints:

1. Bad internet connection in some areas, our system will predict the bins' status in these areas according to data analysis which is done weekly.

2. The battery should be fully charged at all times in case of any emergencies, so we will monitor the battery status and assure that before it ends the system will send a notification to the authority.

3. The need for [system hardware] at each point of work, so we will just consider two operating points as a prototype.

4. Different truck drivers may accept the same notification at the same time, so we will permit one of them to accept the notification and directly prevent the other one. One of the choices is to choose the nearest and or the one which is not work overloaded.

5. If the assigned work is not completed within a certain amount of time , the work will be raised again to be re-assigned.

6.In case of internet disconnection , the system will depends on the data analysis to predict and assign instructions.

Chapter 3

System Design

3 .1 Overview

This chapter discusses the conceptual design of the system, it shows the system requirement analysis, a block diagram of the system, structural diagram, flow chart, detailed design, schematic diagrams.

3.2 Detailed system description

The system will utilize ultrasonic sensor to continuously monitor and measure the amount of waste. Then sensed data will be sent to the microcontroller to analyze it, in order to know when the trash can is nearly going to be full. In order to send this data through internet to the cloud, this data will be stored in a cloud , analyzed and give some suggestions and recommendations to the responsible .The responsible can take actions and update duties ,schedule and instruct the system and drivers. The system always guarantees that the trash trucks will be directed only to trash that only has a specific level of waste in the trash can. The IR and moisture sensor will detect waste type by sending the data to the microcontroller to identify the waste type and therefore instruct the motor to segregate it in the suitable can. The system will utilize smoke sensors to detect smoke to implement the fire detection unit. When fire accidents occur, the smoke rises. The smoke sensor will continuously monitor all-around of its range to detect any sudden rise of smoke. If the sensor detects any abnormal parameters, the data will be delivered instantly to the microcontroller, when fire is detected it will trigger the buzzer to make a sound. The system will also be able to call the fire station to send them with the exact coordinates of the location using SIM808 GSM/GPRS/GPS module. The system will also display the location of the nearest trash can on the screen to the citizens in case the current one is full.

Furthermore, our system is an event driven system. So depending on the collected and analyzed data ,the system may be programmed to trigger some events, based either on some predefined conditions or a feedback.

The functional block diagram of the proposed system is illustrated in Figure 3.1

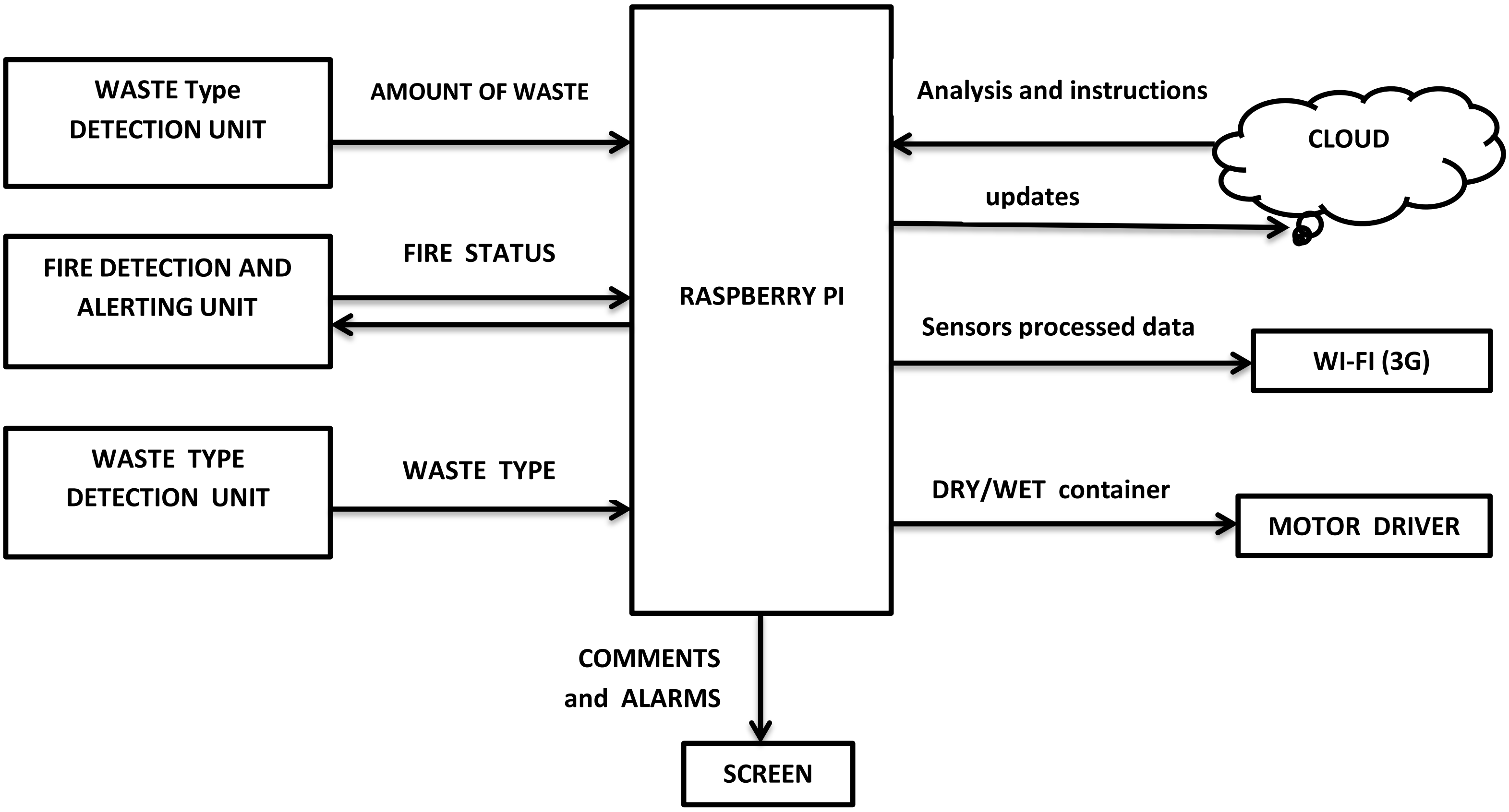


Figure 3.1 Functional Block diagram

3.3 Schematic diagrams

Hardware system design

1. DC Motor with Driver Controller:

As we mentioned in chapter 2, The L298N motor driver module is powered through 3-pin 3.5mm-pitch screw terminals. It consists of pins for motor power supply (Vs), ground and 5 V logic power supply (Vss). As shown in the detail design in figure 3.2 .

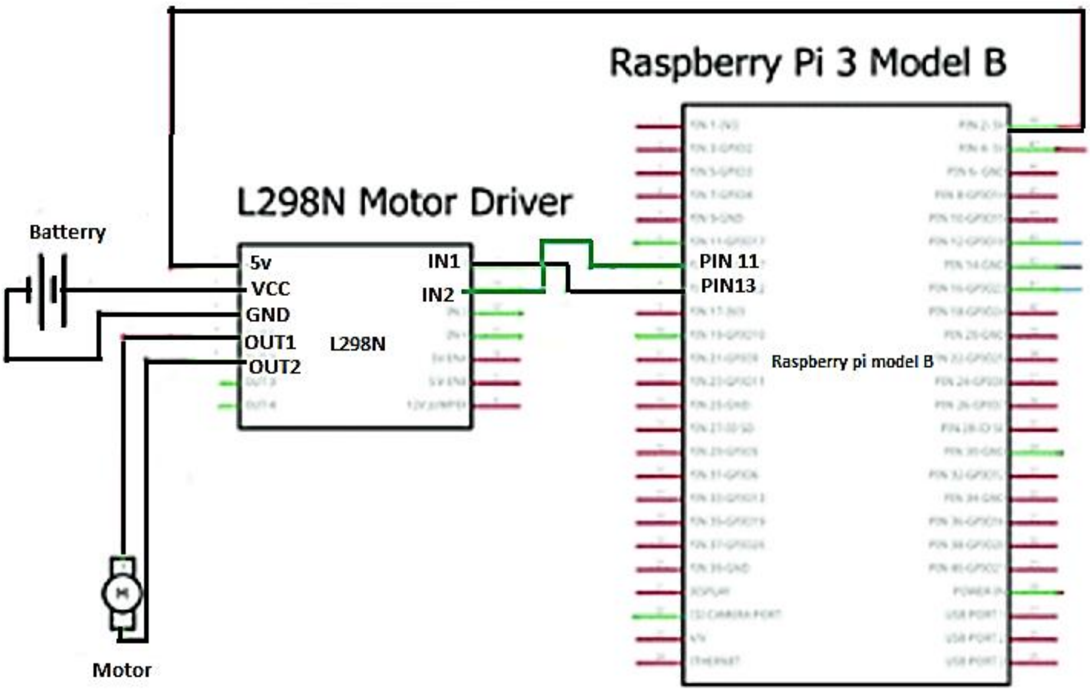


Figure 3.2:Schematic diagram of DC motor

2. Smoke detection with Raspberry PI :

The MQ-9 has the ability of detection smoke using the method of making the temperature cycle high and low.Figure 3.3 shown the detail design with Arduino. This module has 4 pins. Connect Vcc to 5V and GND to GND. The AO pin returns an analog value based on the concentration of the gas. The DO pin returns HIGH if the concentration of gas is higher than a certain value. This value can be set by the potentiometer on the board.

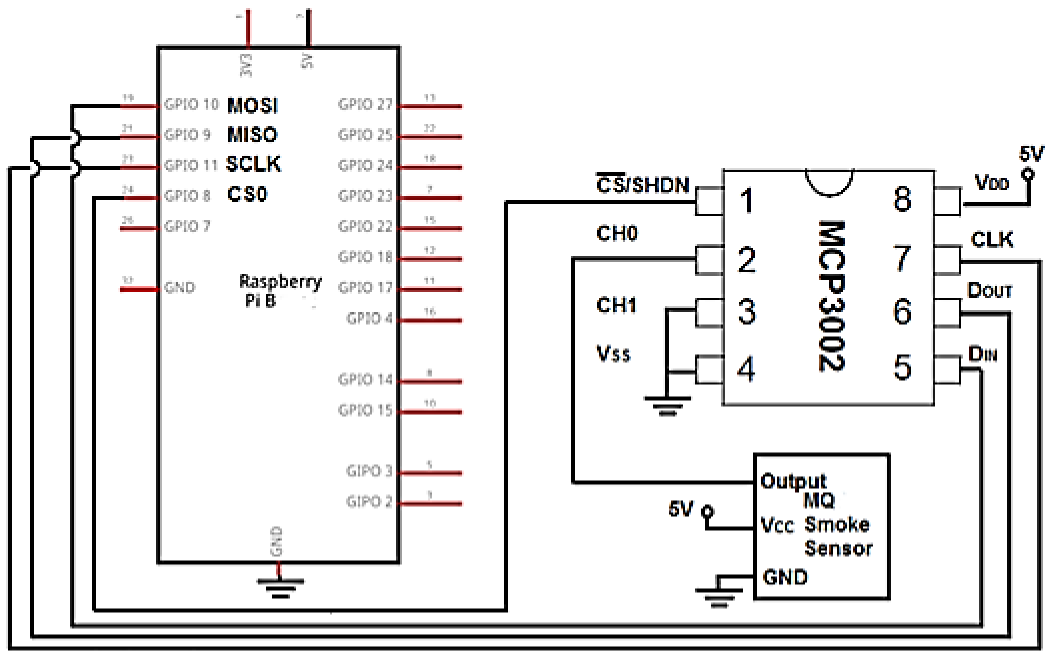


Figure 3.3:Schematic diagram of Smoke sensor

3. Ultrasonic sensor:

The HC-SR04 Provide fast response time, which allows the system to respond quickly to the changing environments around it, and information about the distance will be sent to the microcontroller .Figure 3.4 shows the detail design for the ultrasonic sensor.

VCC pin is connected to the 5 V power supply, GND pins are connected to the GND and the Trig and Echo pins are connected to the digital I/O pins as shown in Figure 3.4

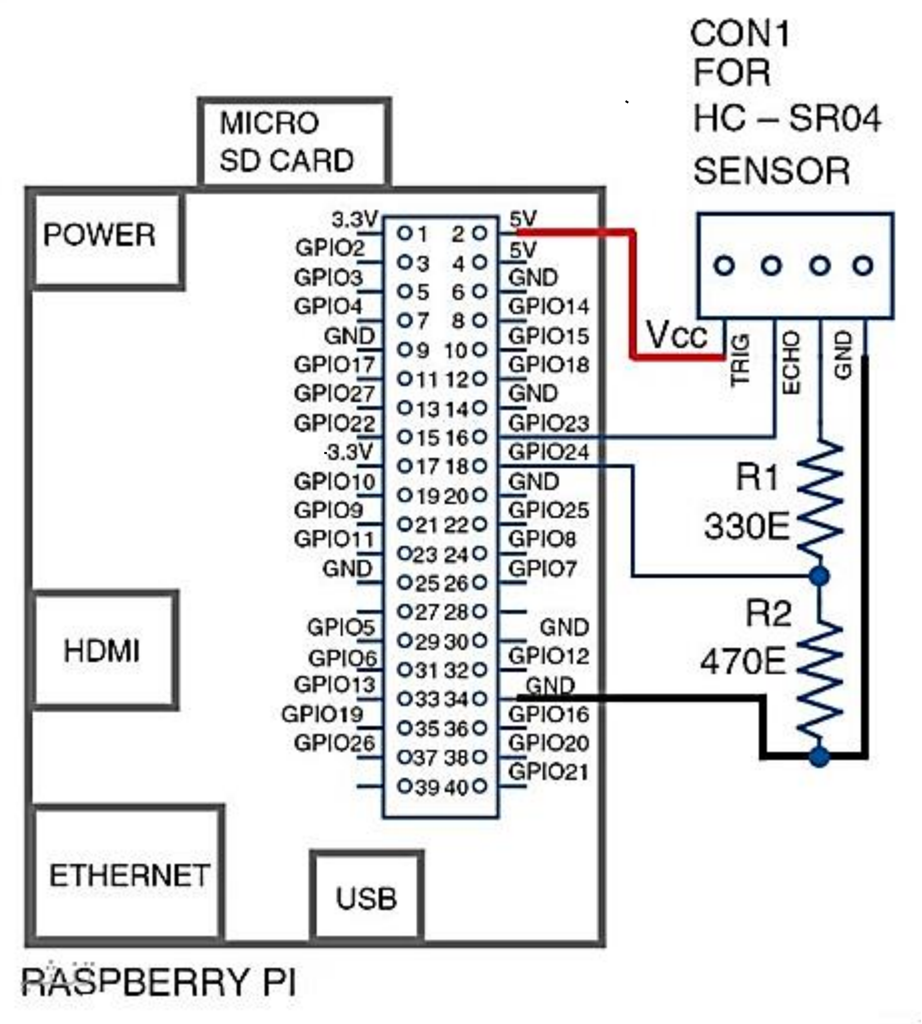


Figure 3.4:Schematic diagram of HC-SR04

4. Buzzer with Raspberry PI

Used when the system approaches the fire, a warning will be issued .Figure 3.5 shows the detailed design for the buzzer. The buzzer has 2 pins, one pin connects to the input pin of the Raspberry and another pin connects to GND of Raspberry PI as shown in the schematic diagram in Figure 3.5

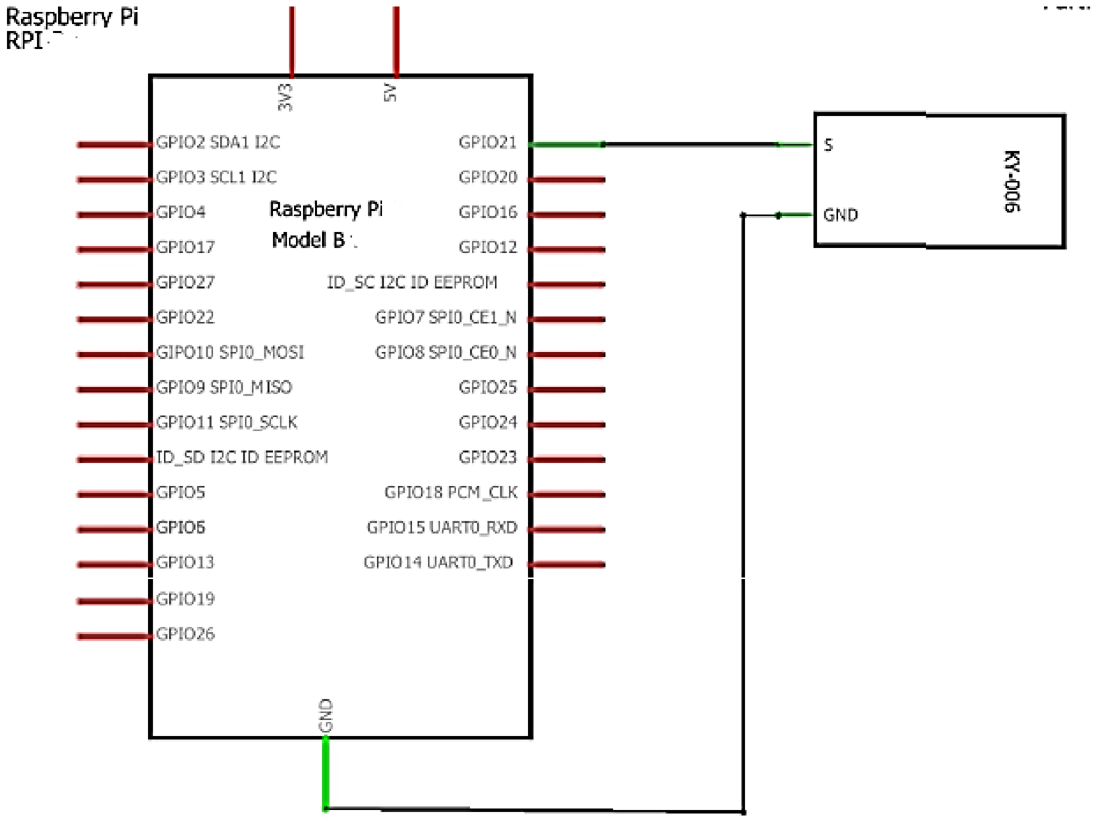


Figure 3.5: Schematic diagram of Buzzer

5. Moisture Sensor with Raspberry PI :

Used in our project for segregate waste depending on their type (either wet or dry),Connect the VCC pin to 3.3 V of Raspberry PI and GND to GND. Similarly, connect the Analog output pin to the A0 pin of the raspberry. As shown in figure 3.6

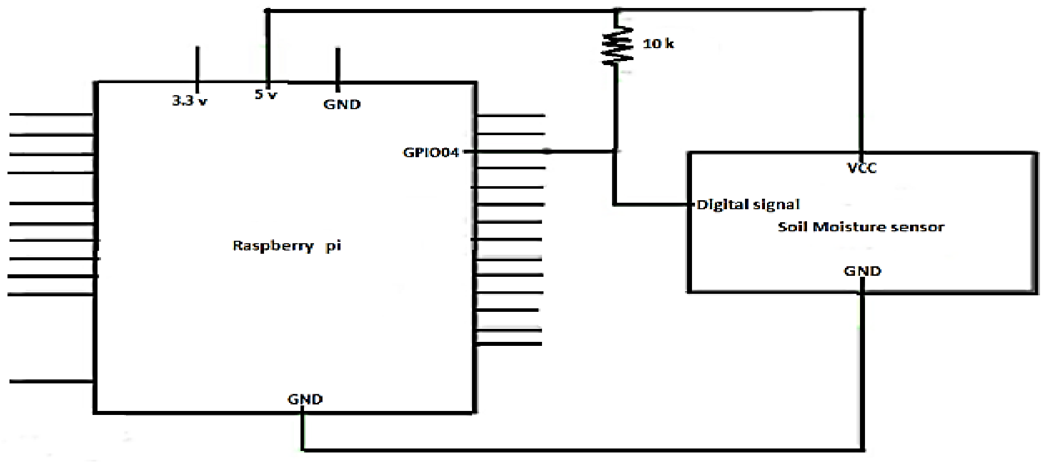


Figure 3.6: Schematic diagram of Moisture sensor

6. LCD with Raspberry Pi :

We used LCD in order to display the location of the nearest trash can in case the current one is full. The interfacing between the Raspberry PI and LCD is shown in figure 3.7 .By connecting VDD of the LCD with the 5 V of the Raspberry PI , Connect the two ends of potentiometer to GND ,D4 with GPIO13 , D5 with GPIO6, and VSS with the GND of the Raspberry Pi .

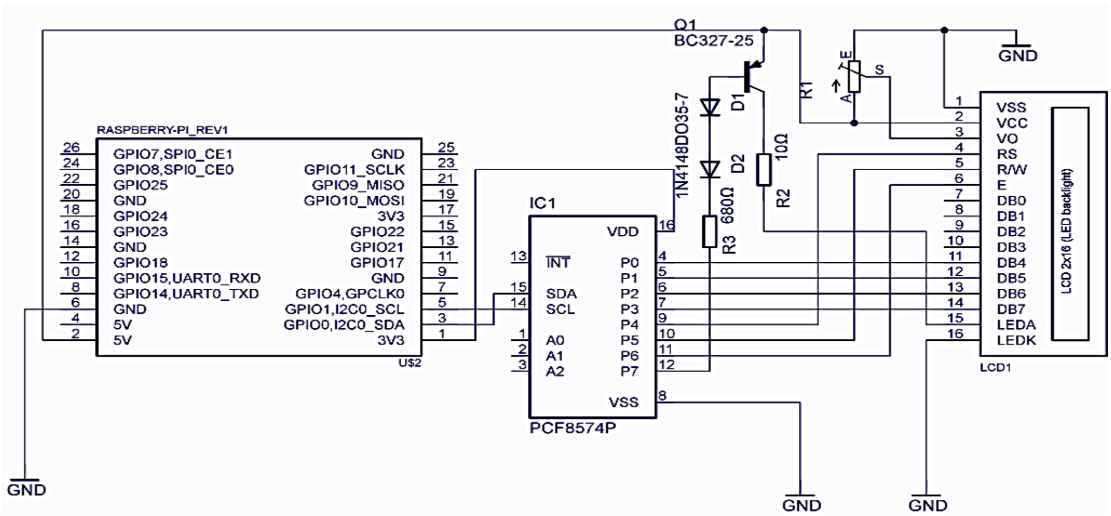


Figure 3.7 : Schematic diagram of LCD screen.

7. 3G SIM with Raspberry Pi :

We use the SIM5320E module, for identifying trash can location and to connect the system to the internet in order to send data and save the data on the server to be used later in the web application. The SIM module has an UART (TX) which connected to D1(TX) of the Raspberry PI and UART (RX) which connected with D0(RX) of the Raspberry PI as shown in figure below.

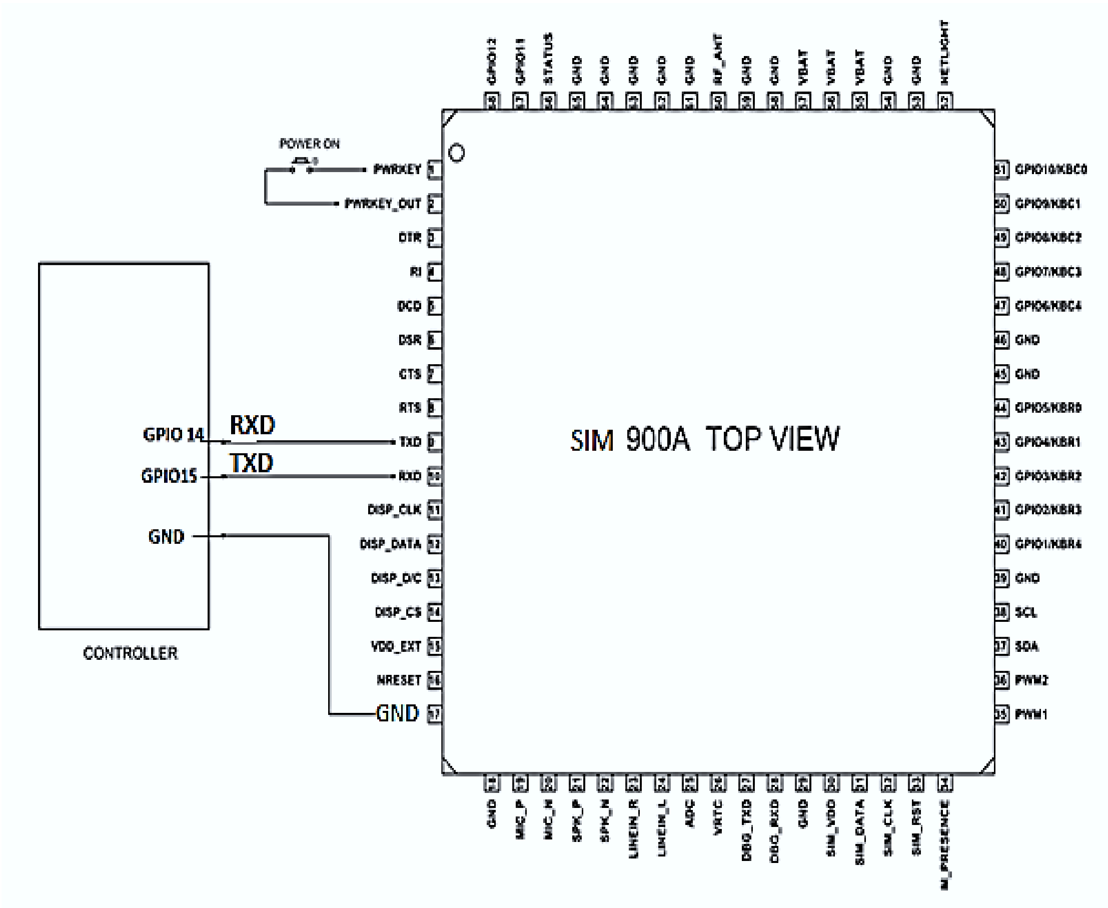


Figure 3.8 : Schematic diagram of SIM module.

Software design:

Our waste management system will be associated with web applications. This application will receive all system data which contains trash can status, locations of trash cans, locations of drivers, and extra information needed to be saved .The application functionality is to send notifications and requests to the drivers in case there is a need to empty the trash cans. Also, one of the main functionalities is to send notifications and alarm to the firefighting authority in case a fire accident happened. The application can display a map of all driver locations in real time. The application provides each driver with his own account which contains all of his information including name, efficiency and the amount of work that is assigned to him. All the drivers' data will be available on the admin account which represents the authority account. In case the driver does not do the required work, the application will send a notification to the admin account associated with the name of the driver to make a proper load balancing when assigning jobs.

3.4 Flow chart: Figure 3.9 represents the flow chart of system activity

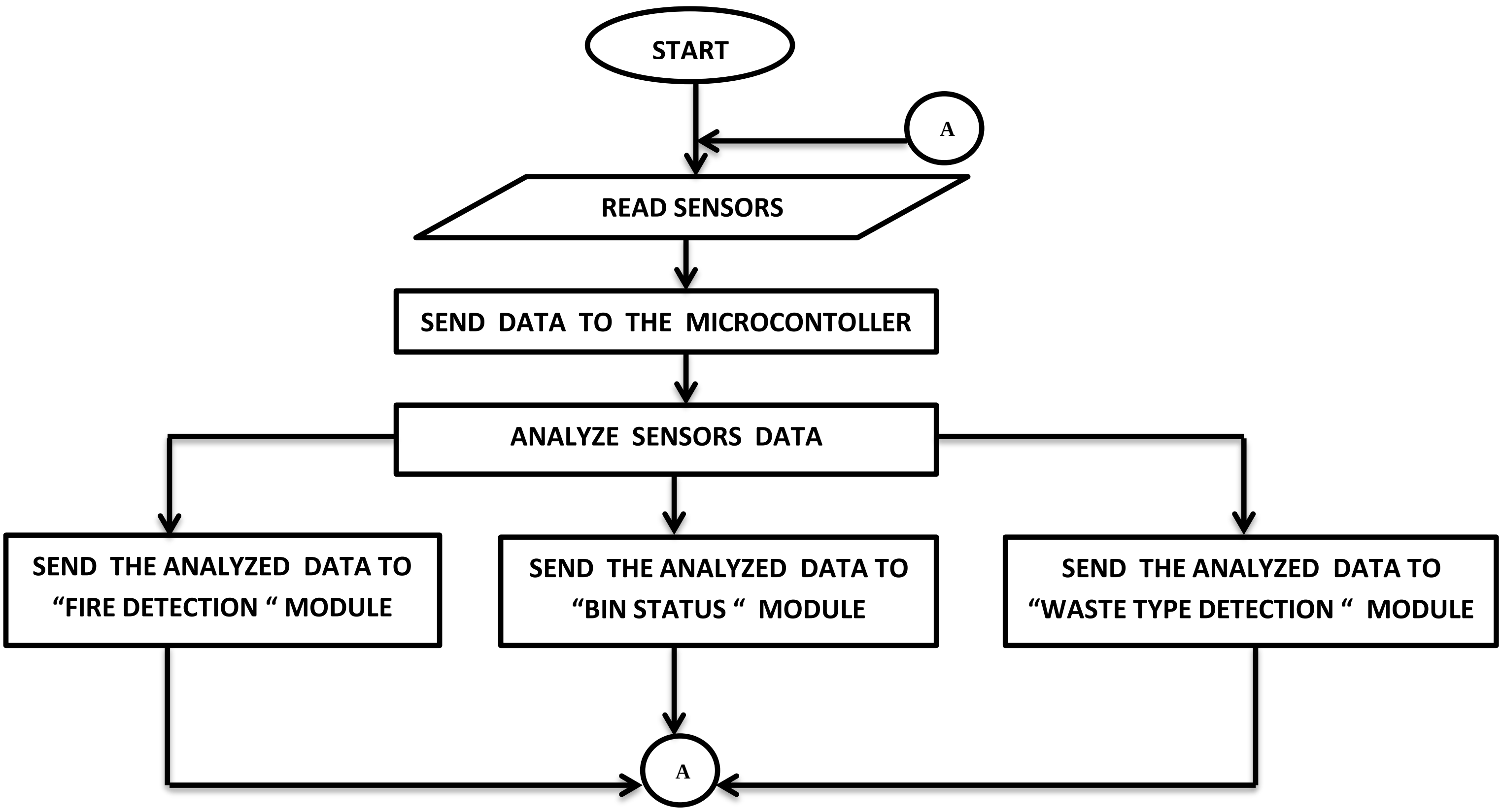


Figure 3.9 system activity flow chart

Figure 3.10 represents the flow chart of the “bin status” module

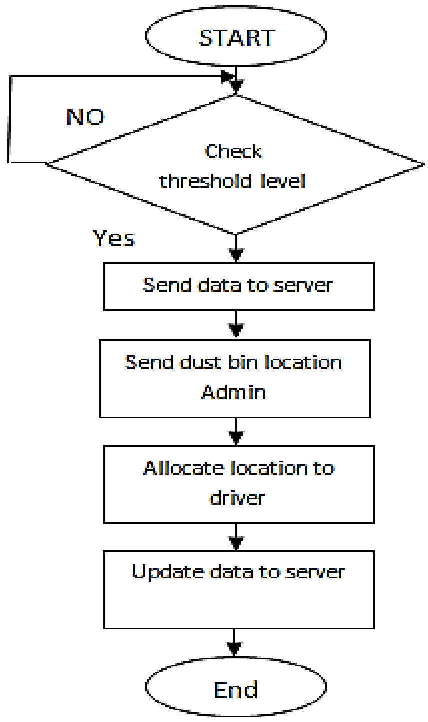


Figure 3.10 ‘bin status’ module flow chart

Figure 3.11 represents the flow chart of the “fire detection” module .

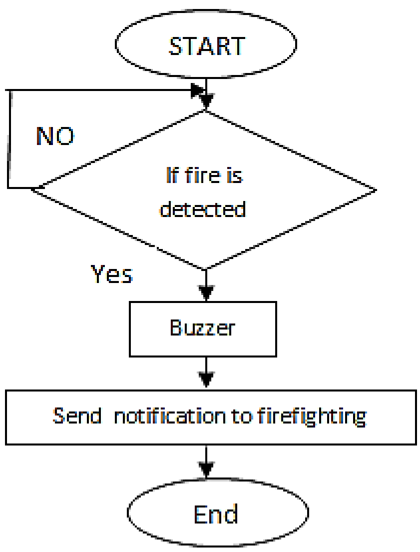


Figure 3.11 ‘fire detection’ module flow chart

Figure 3.12 represents the flow chart of the "waste type detection" module.

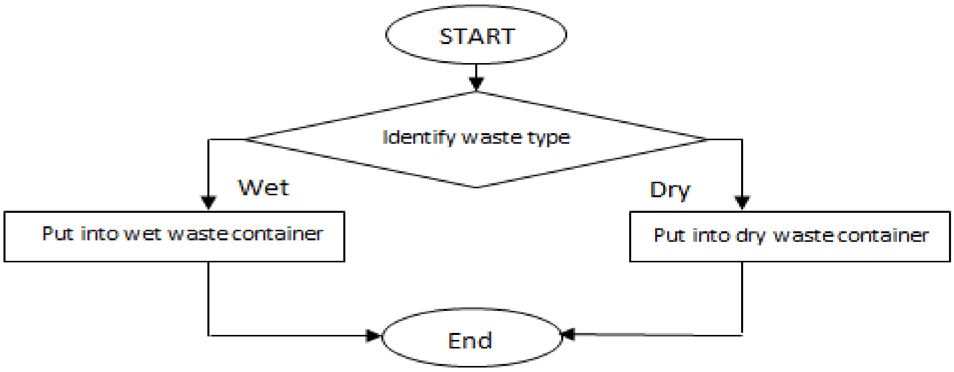


Figure 3.12 'waste type detection' module flowchart

3.5 Sequence diagrams

The sequence diagram describe event driven system workflow. A sequence diagram shows, as parallel vertical lines (lifelines), different processes or objects that live simultaneously, and, as horizontal arrows, the messages exchanged .Sequence Diagrams are time focus and they show the order of the interaction visually using the vertical axis of the diagram to represent time what messages are sent and when.

Figure 3.13 represents "System activity Sequence diagram".

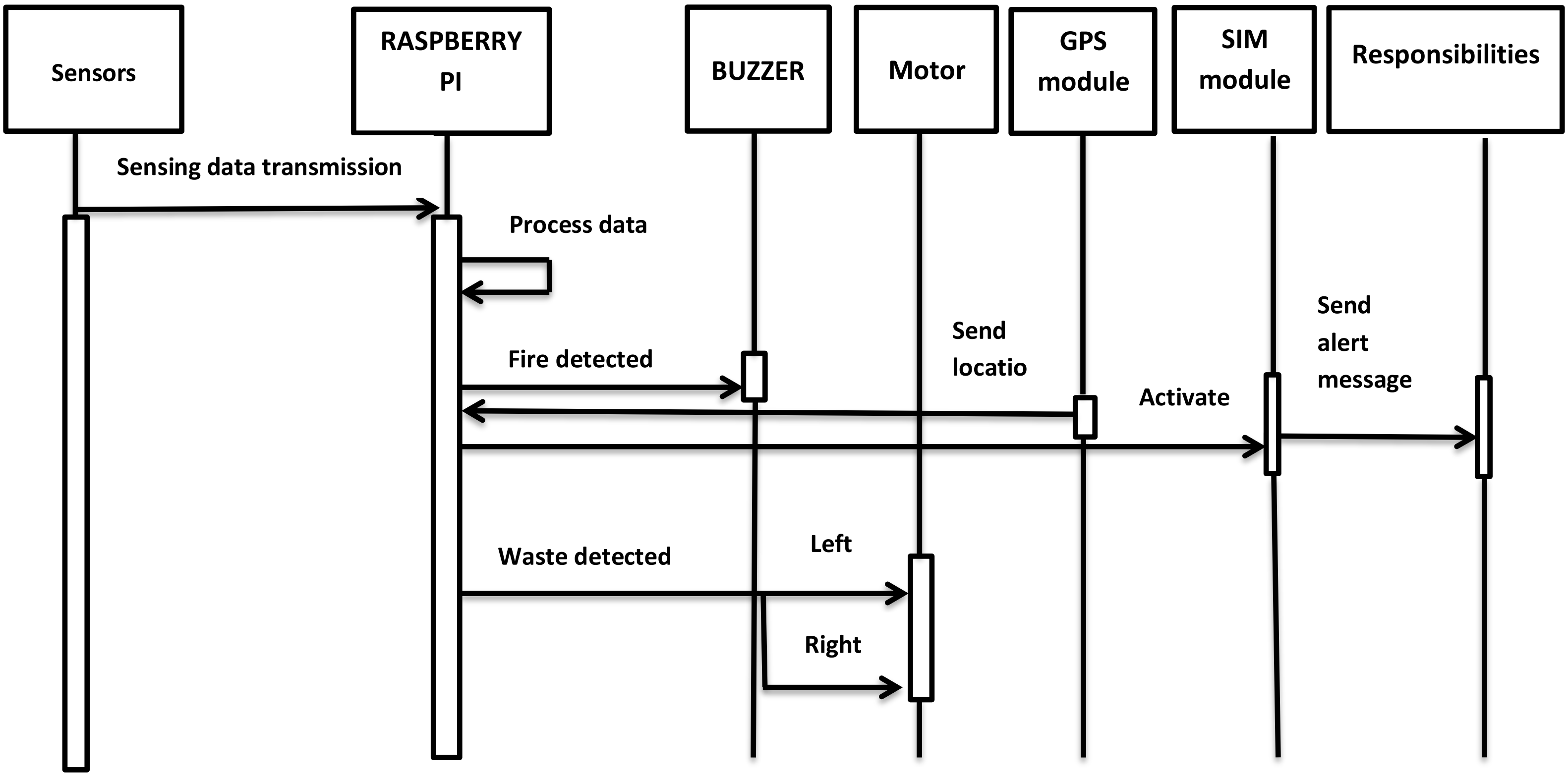


Figure 3.13 'System activity' Sequence diagram

Figure 3.14 represents "System workflow Sequence diagram ".

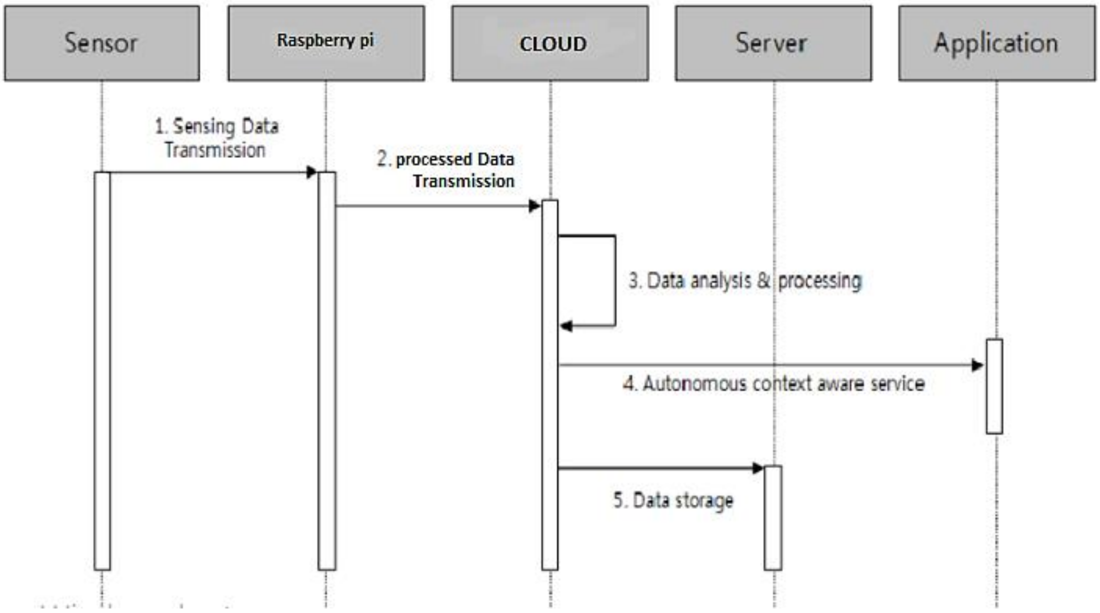


Figure 3.14 'System workflow' Sequence diagram

Figure 3.15 represents "Admin activity Sequence diagram".

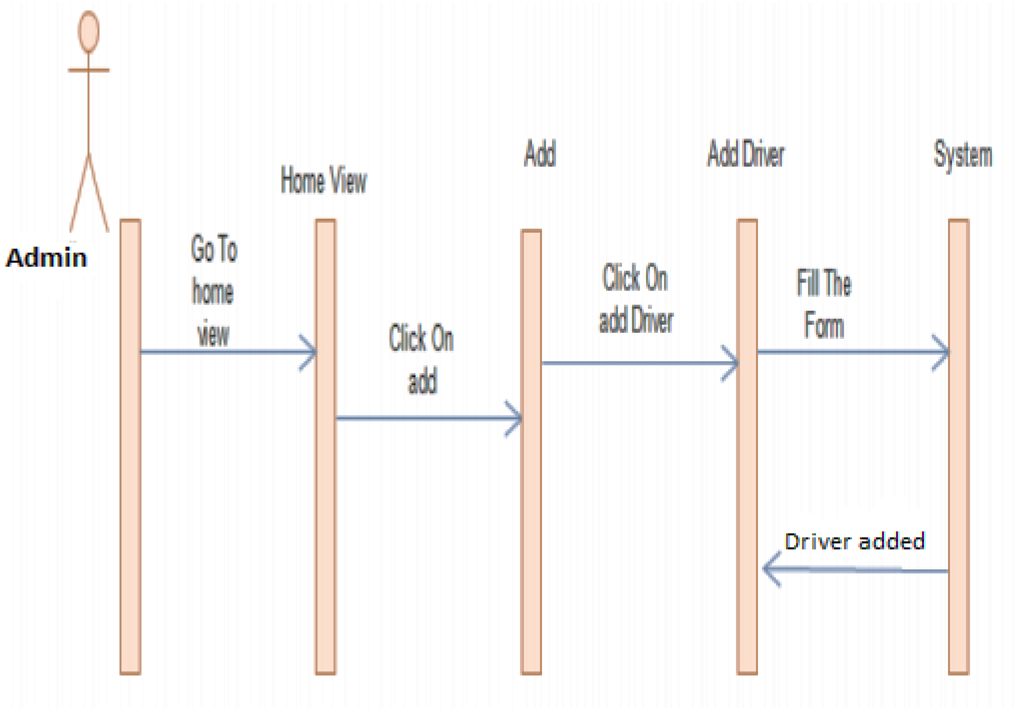


Figure 3.15 'Admin activity' Sequence diagram

Chapter 4

System Implementation and Testing

4.1 Overview

This chapter introduces the description of the implementation, implementation issues, and implementation challenges and description of the methods used to validate the system and validation results .

4.2 System implementation

This section will provide some information about the hardware and software implementations done through our project:

4.2.1 Software implementation

Raspberry Pi (Python IDE):

We used thony python ide for code implementations using python language. The code of all hardware components and sensors and their interfaces are written through the use of many python functions and libraries. We needed to download LCD I2C,pynmea2 libraries for LCD and GPS respectively .

Platforms:

Windows, Android, Raspbian.

Front End : Blynk, Node red.

Back End : Blynk Local Server, Javascript, Python, Node red.

- Blynk :- It is a hardware-agnostic IoT platform with customizable mobile apps, private cloud, rules engine, and device management analytics dashboard.

- Blynk Server :- is an Open-Source Netty based Java server, responsible for forwarding messages between Blynk mobile application and various microcontroller boards and SBCs (i.e. Arduino, Raspberry Pi. etc.).

- Node-RED :- is a flow-based development tool for visual programming developed originally by IBM for wiring together hardware devices, APIs and online services as part of the Internet of Things. Node-RED provides a web browser-based flow editor, which can be used to create JavaScript functions.

Flow of software process

We received our data from all sensors then processed these data through Node-RED to identify the exact event that must be triggered .Then a suitable python script executed. After that, the result is sent to the server(raspberry(local server)) through Node-RED. Our Blynk application sends requests to the server to get updated results. Finally the application views these results in the widgets.

The software flow is shown in figure 4.1

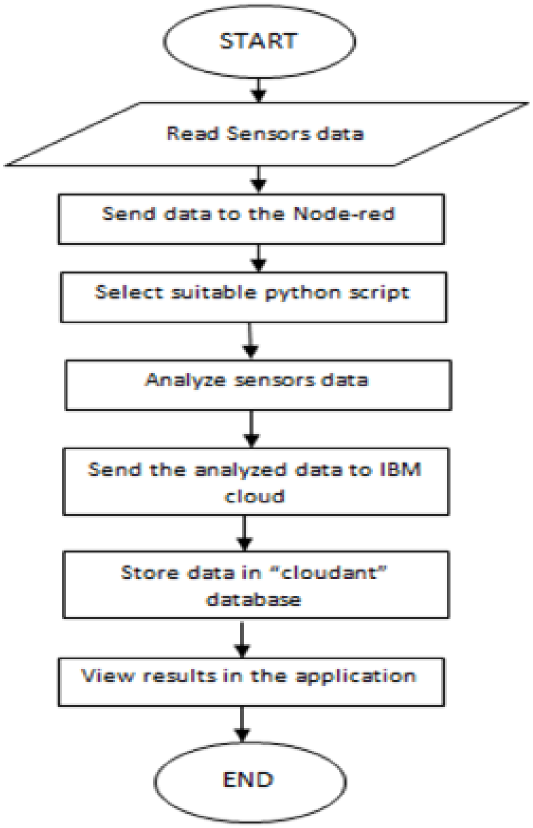


Figure 4.1 Software flow

4.2.2 Hardware implementation

Starting with Raspberry Pi, we successively connect the other system components as follows:

1. We connect Raspberry Pi with three ultrasonic sensors, compute distances. The first one is used as feedback to detect if the trash bin is opened or closed by calculating the distance between the top of the bin and its cover. The second ultrasonic sensor is used to detect if the wet trash bin is full or not and the third one is used to detect if the dry bin is full or not.

   Result:

   The three ultrasonic sensors enable us to identify the trash bin status if it is full or empty for both parts dry and wet, also if it is opened or closed .

2. We connect the raspberry pi with the moisture sensor in order to detect the waste type (dry or wet) by comparing the reading value with the threshold one ,then waste type is sent to the microcontroller in order to identify motor direction.

   Result :

   The moisture sensor identifies waste type then the value is sent to the microcontroller

3. We connect Raspberry Pi with motor driver L298N, in order to control motor speed and direction. We connected the input pins of the motor driver using the digital pins in the raspberry pi microcontroller, then we connected the output pins with the DC motor.

   Result:

   The L298N motor driver control the DC motor, which allows the motor to move left or right .

4. We connect Raspberry Pi with smoke detection MQ, to detect the smoke fire. The sensor simple digital voltage interface requires only one digital input pin from the microcontroller.

   Result:

   The smoke detection MQ succeeded to detect the smoke fire by taking the concentration readings of the smoke and compare it with the threshold value. Then if the reading value is greater than or equal the threshold one the buzzer start and notification will be sent.

5. We connect Raspberry Pi with buzzer , issuing an alarm.

Result:
The buzzer produced a warning sound , when the fire detected

6. We connect Raspberry Pi with sim900A GSM/GPRS module, in order to connect the raspberry with 2G internet and to send messages and notifications .

Result:
The sim900A GSM/GPRS enables the bin to be connected to the internet and send messages .

7. We connect Raspberry Pi with GPS module, in order to identify the bin location.

Result:
The location of the bin is being identified using the GPS module by giving the latitude and longitude values.

8.We connect Raspberry Pi with LCD to display the nearest location of the bin.

Result :
The LCD display the nearest location when the current one is full.

4.3 Implementation Issues and challenges

4.3.1 Hardware Issues and challenges

During the course of the project implementation, we faced many obstacles and had to take several issues to reach to the most suitable design of the system and reach the best properties. Related to the project's aims. We summarize these issues and results as follows:

1.When we started with the raspberry pi it was hard to work with it since it needs a monitor, keyboard and mouse in order to view the desktop screen and start work with it, that means that we can't work from home so we need to work in the university all the time.

Solution : We connected the raspberry with laptop through Ethernet cable then using SSH and VNC server to control the raspberry remotely from laptop through VNC viewer.

2 .We faced many issues with most of the components that we use in the system since it is not fully compatible with raspberry pi .

Solution:

We use other helpful components which made the raspberry support these components.

3. We faced trouble while testing the Dc motor movement. The DC motor was not working correctly. At first, we thought that there was a problem with the DC motor, and we must change it to a stepper or servo motor to get the exact speed and angle of movement .

Solution:

We tried changing the delay and PWM . After several time of trying we got the suitable angle and speed.

4.3.2 Software Issues and challenges

Many issues were faced during system implementation, such as:

1. Firstly we intend to build a flutter framework in order to build an android application, but after a long time of coding we realize that it needs much more time to build an application from scratch.

Solution : while we were searching for a way to build an IoT application in a short time we figured that we can use blynk application with node red IBM cloud which is event driven service which is really compatible with the needs of our system.

2.When we decided to download the blynk application we figured that that application is not available in our country , and we can’t download it.

Solution: We download a VPN application which allows us to change our location to the United states .Then Google play made the blynk application available to be downloaded.

3.We faced a very big problem with blynk server which is that the blynk server gives limited free storage and we need to pay in order to get more space .

Solution : After searching how to get more free space in blynk server we found that we can use our raspberry as a local server with enough storage space and more features like getting an admin panel , adding more users which mean we can add more drivers , authorities and stay control of all of their data.

4.4 System Testing and Validation

4.4.1 Hardware Testing

1**. Motor test :**

Firstly, we tested the motor with L298N motor driver and connected it directly with Raspberry Pi .The motor moved right or left in order to put wet waste to the wet bin or to the dry bin .As shown in figure 4.2 and result shown in figure 4.3.

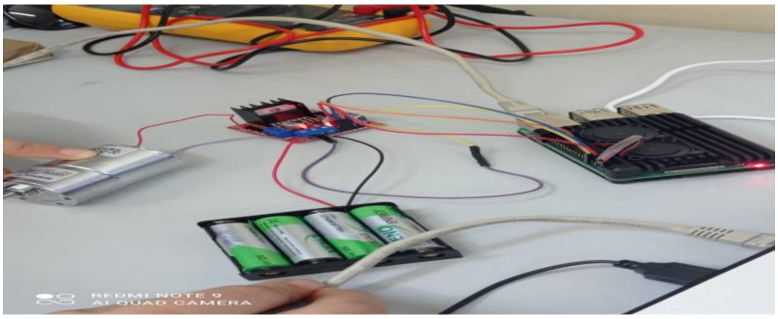


Figure 4. 2 : Test Motor with L298N driver

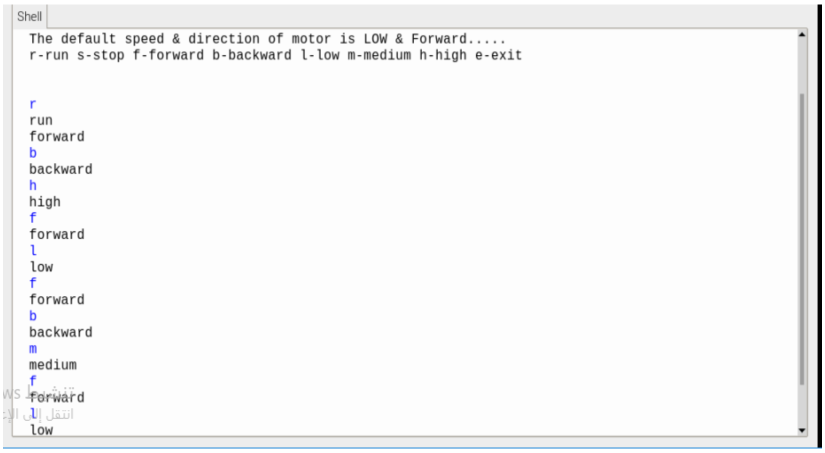


Figure 4. 3 : Result of Motor with L298N driver in Shell

2. **Smoke sensor testing:**

To test the response of MQ Smoke Sensor, we connect it with Raspberry Pi as shown in Figure 4.4, 4.5 . Result of MQ print on the shell in Figure 4.6, and Figure 4.7 .

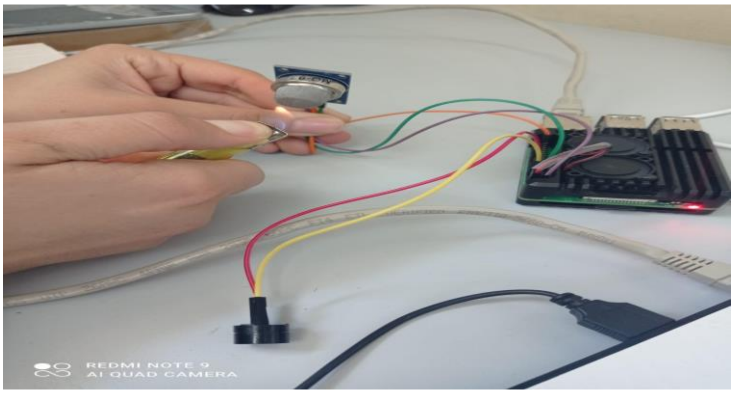


Figure 4. 4 : Test smoke sensor

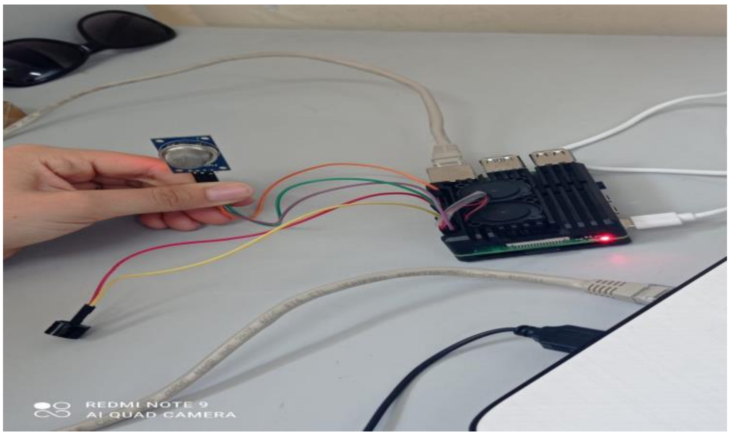


Figure 4. 5 : Test smoke sensor

```
Shell
>>> %Run gas_sensor.py

 gas exist
 buzzer turned on

>>>
```

Figure 4.6 : Result of smoke sensor in shell

```
Shell

>>> %Run gas_sensor.py

 gas doesn't exist!
 buzzer turned off
```

Figure 4.7 : Result of smoke sensor in shell

3.Ultrasonic sensor Testing:

To test the distance that Ultrasonic sensor measures , we connect it with Raspberry Pi as shown in Figure 4.8, 4.9, 4.10 and 4.11 .We connect it with four LEDs in order to detect the response where the red one indicates very small distances(bin is full) , the yellow one indicates the small distances(bin is nearly full),the green one for medium distances (bin status is medium) and the yellow one for large distances(bin is empty).The distances of Ultrasonic sensors print on the shell as shown in Figure 4.12.

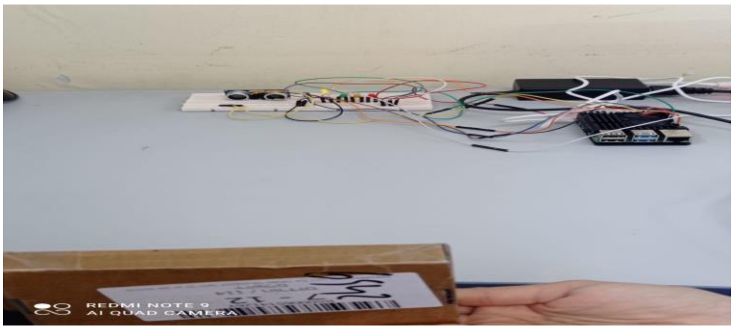


Figure 4.8 : Test Ultrasonic sensor

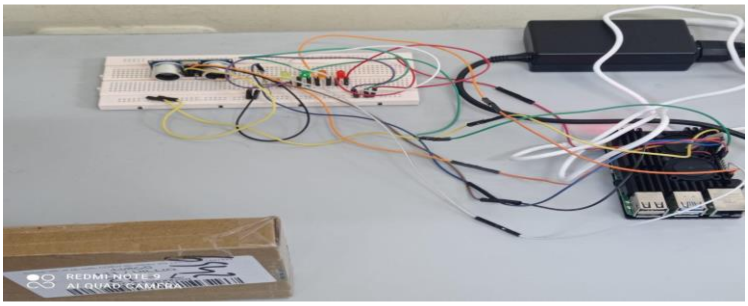


Figure 4.9 : Test Ultrasonic sensor

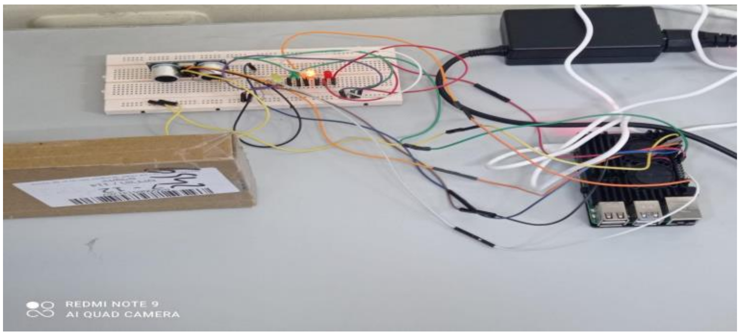


Figure 4. 10 : Test Ultrasonic sensor

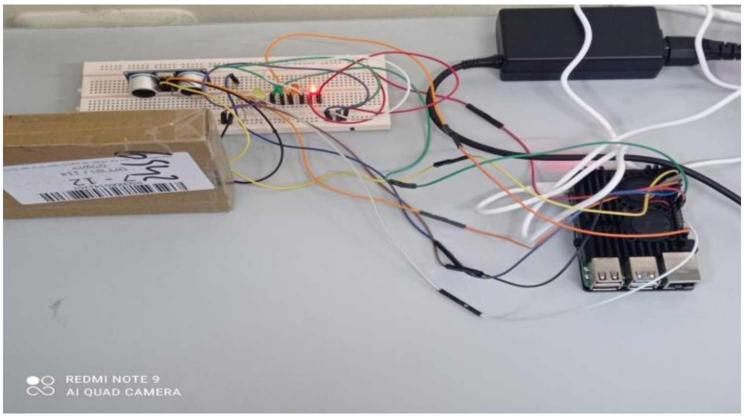


Figure 4. 11 : Test Ultrasonic sensor

Figure 4. 12 : Result of ultrasonic distance in shell

4. LCD Testing :

To display the location and bin status , we connect the LCD with Raspberry Pi as shown in Figure 4.13 and Figure 4.14 .

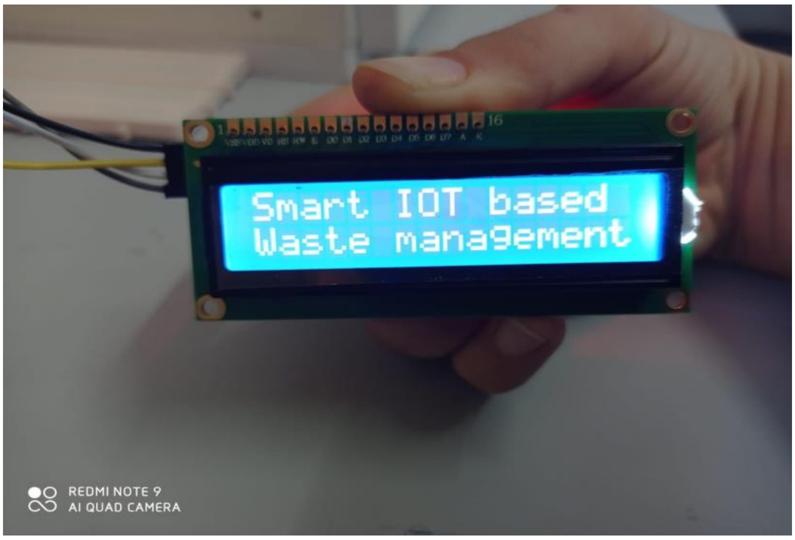


Figure 4. 13 : Test LCD

Figure 4. 14 : Test LCD

5. Moisture Sensor Testing :

To measure the volumetric water content which mean the waste is wet . We connect it with Raspberry Pi as shown in Figure 4.15 and Figure 4.16 . And the result of the moisture sensor is shown in Figure 4.17 .

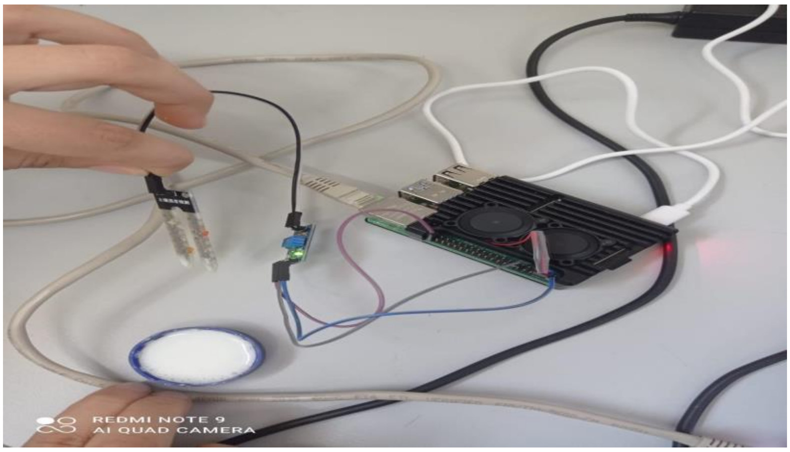


Figure 4. 15 : Test Moisture Sensor

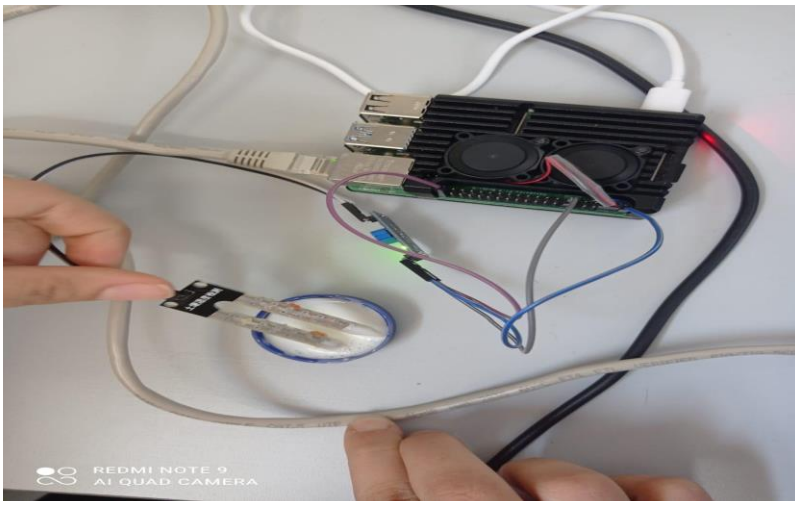


Figure 4. 16 : Test Moisture Sensor

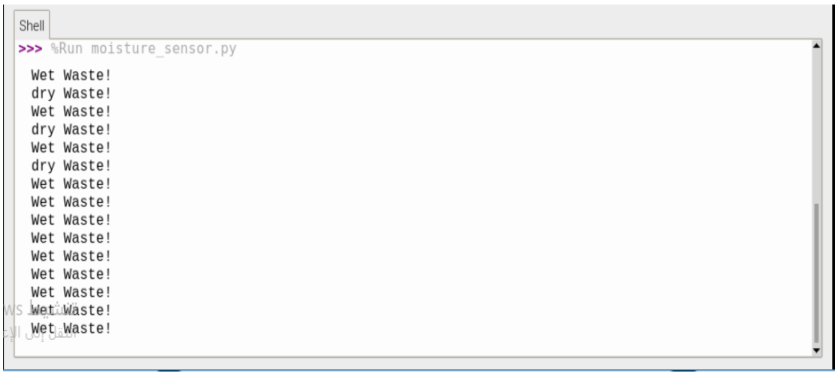


Figure 4.17 : Result of moisture sensor

6. Touch Sensor :

The connection between it and Raspberry Pi is shown in Figure 4.18 and Figure 4.19 . The result is shown in Figure 4.20 .

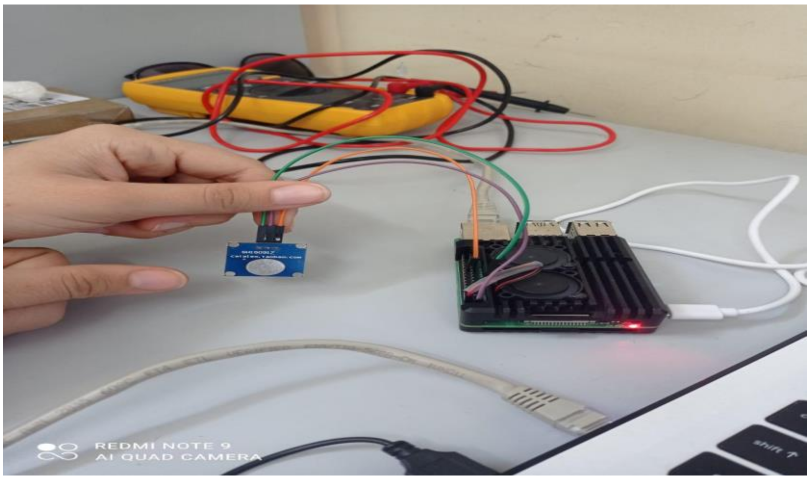


Figure 4. 18 : Test Touch Sensor

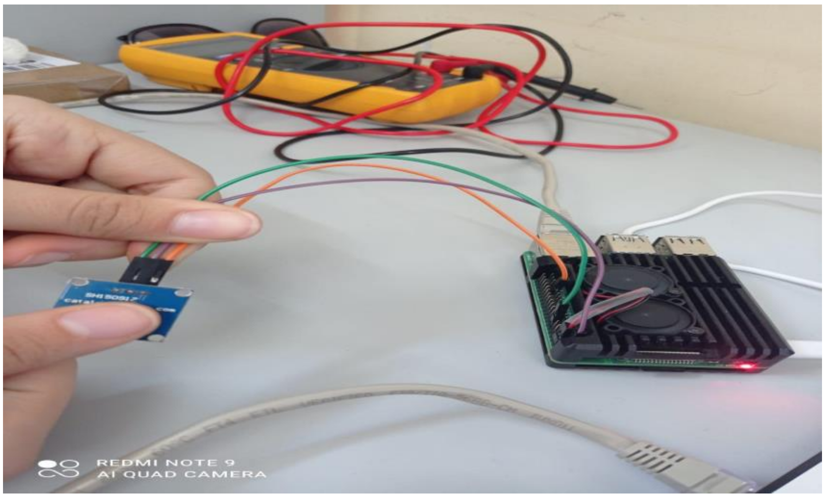


Figure 4. 19 : Test Touch Sensor

```
Shell
No Waste
No Waste
No Waste
No Waste
No Waste
No Waste
No Waste
Dry Waste
Dry Waste
Dry Waste
Dry Waste
Dry Waste
Dry Waste
Dry Waste
Dry Waste
Dry Waste
Dry Waste
No Waste
```

Figure 4. 20 : Result of Touch Sensor in shell

7. GPS Module :

We interface the GPS module with the raspberry pi by connecting the transmit pin of the GPS with the receive pin of the raspberry as shown in figure 4.21. The GPS module takes nearly an hour to fix the satellite position . The result of latitude and longitude values is shown in figure 4.22.

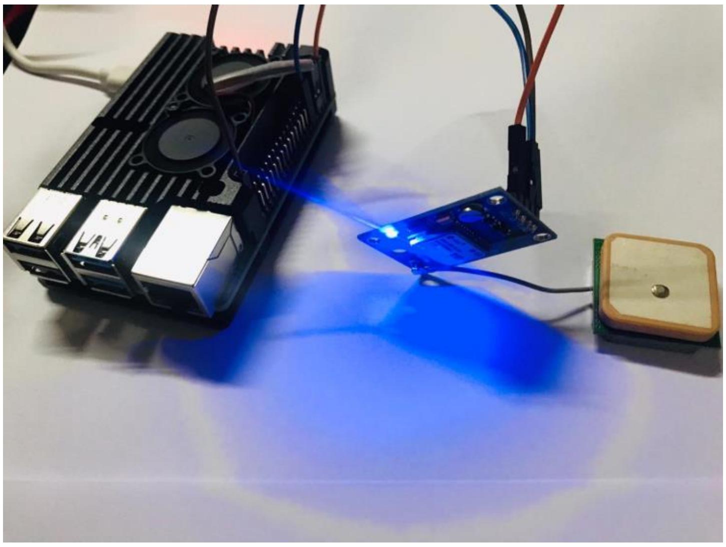
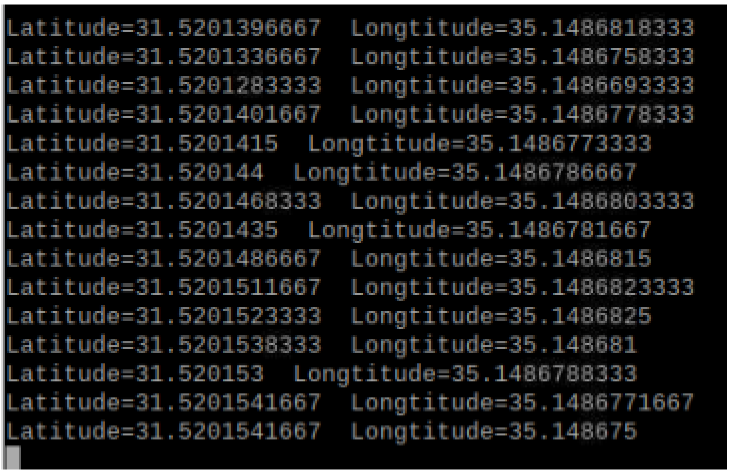


Figure 4. 21 : Test GPS module



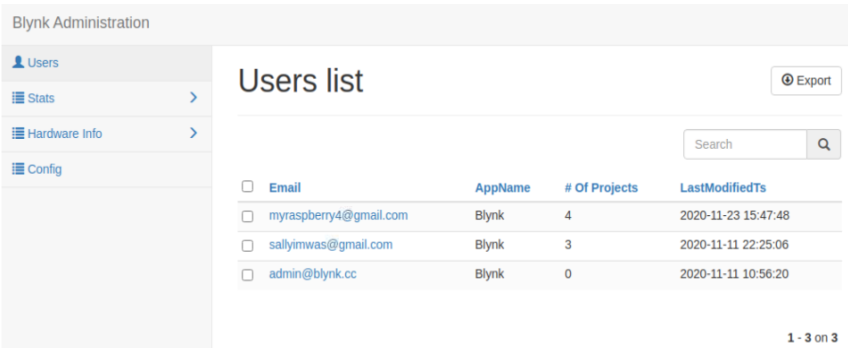
```
Latitude=31.5201396667  Longtitude=35.1486818333
Latitude=31.5201336667  Longtitude=35.1486758333
Latitude=31.5201283333  Longtitude=35.1486693333
Latitude=31.5201401667  Longtitude=35.1486778333
Latitude=31.5201415  Longtitude=35.1486773333
Latitude=31.520144  Longtitude=35.1486786667
Latitude=31.5201468333  Longtitude=35.1486803333
Latitude=31.5201435  Longtitude=35.1486781667
Latitude=31.5201486667  Longtitude=35.1486815
Latitude=31.5201511667  Longtitude=35.1486823333
Latitude=31.5201523333  Longtitude=35.1486825
Latitude=31.5201538333  Longtitude=35.148681
Latitude=31.520153  Longtitude=35.1486788333
Latitude=31.5201541667  Longtitude=35.1486771667
Latitude=31.5201541667  Longtitude=35.148675
```

Figure 4. 22 : Result of GPS module

4.4.2 Software testing:

Our system is primarily an event driven system , for this reason we used Node-RED for wiring together hardware devices, APIs and online services .

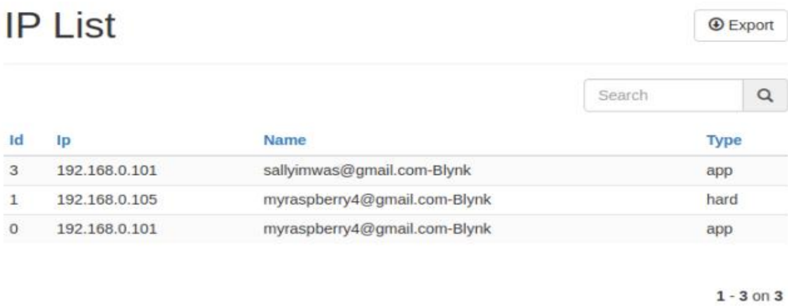
Using the Blynk control panel we can give multiple users the access for the raspberry server(blynk local server) . Which means in our system we can add multiple drivers and give them the access for the bins data and status as shown in figure 4.23.



Email	AppName	# Of Projects	LastModifiedTs
myraspberry4@gmail.com	Blynk	4	2020-11-23 15:47:48
sallyimwas@gmail.com	Blynk	3	2020-11-11 22:25:06
admin@blynk.cc	Blynk	0	2020-11-11 10:56:20

Figure 4. 23 : Blynk control panel

Using the blynk server we can also know the IP that the raspberry pi have and who the users are having access to its data .



Id	Ip	Name	Type
3	192.168.0.101	sallyimwas@gmail.com-Blynk	app
1	192.168.0.105	myraspberry4@gmail.com-Blynk	hard
0	192.168.0.101	myraspberry4@gmail.com-Blynk	app

Figure 4. 24 : Blynk control panel

We created the system flow on Node-RED .Where each event triggers a specific node to execute a suitable python script.

The wet bin work flow is shown in figure 4.25.

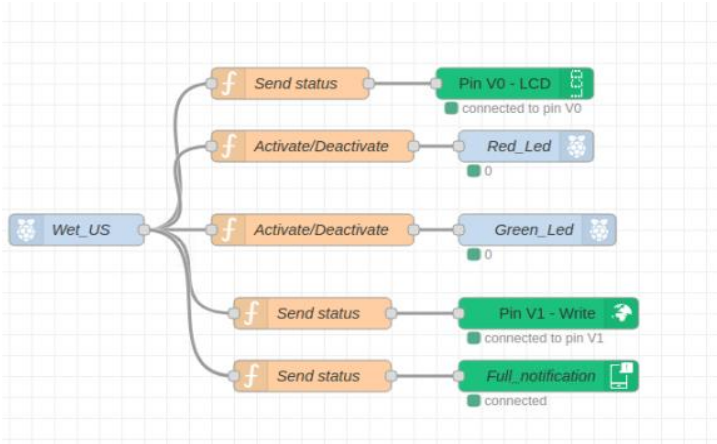


Figure 4. 25 : Wet Bin workflow

The dry bin workflow is shown in figure 4.26.

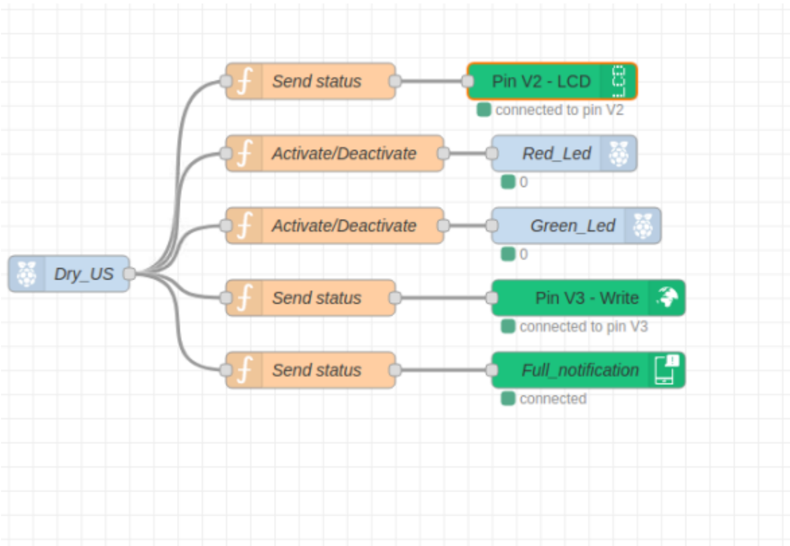


Figure 4. 26 : Dry bin workflow

When the bin is opened ,the system starts detecting waste type and motor starts ,so the bin status (closed/opened) , the DC-motor , moisture sensor and touch sensor workflow is shown in figure 4.27.

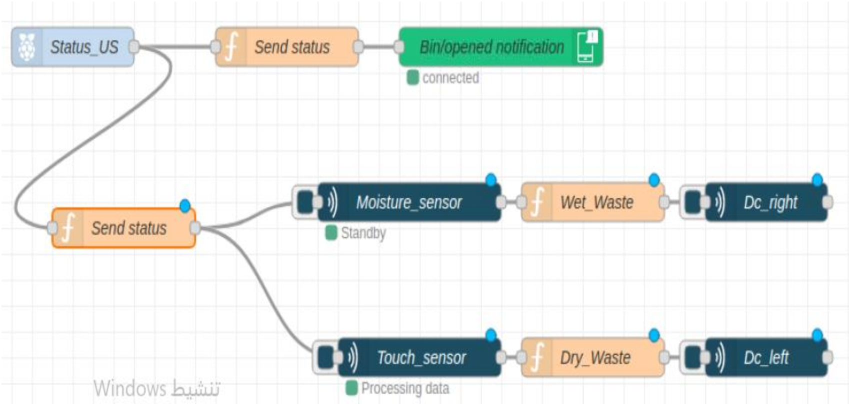


Figure 4. 27 :Bin status and waste detection workflow

The gas sensor -buzzer work flow is shown in figure 4. 28

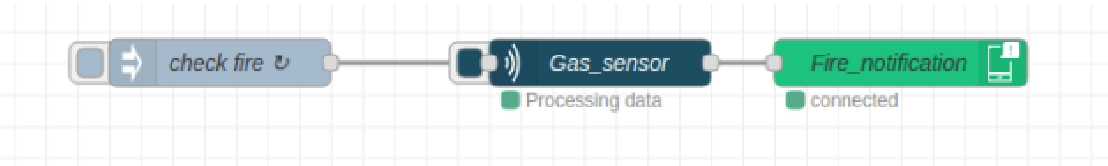


Figure 4. 28 : Fire detection workflow

The GPS workflow shown in figure 4. 29

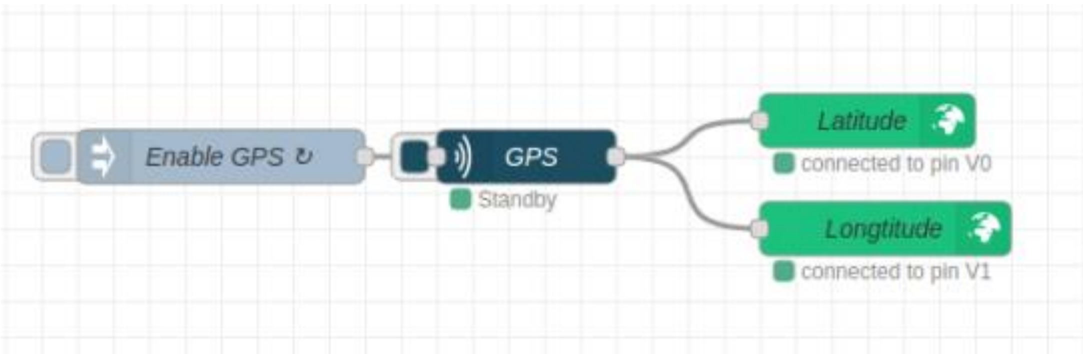


Figure 4. 29 : GPS workflow

In order to test the workflow of our system ,we should see what result it gives and how the communication process is being done between the microcontroller , Node-RED ,server ,sensors, and blynk app .

We first designed a widget for each bin ,also a GPS and notifications widgets in order to test the final results .

The widgets are shown in figure 4.30.

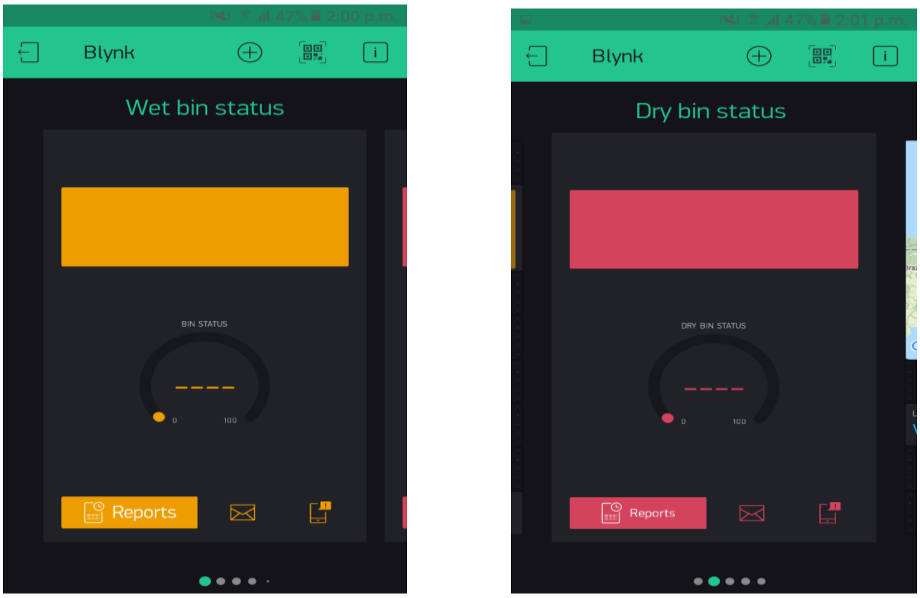


Figure 4. 30 : Wet /Dry bin widgets

1-We tested the three ultrasonic sensors-Node-RED-Server-Blynk app communication.

The result of the wet bin ultrasonic sensor is shown in figure 4.31.

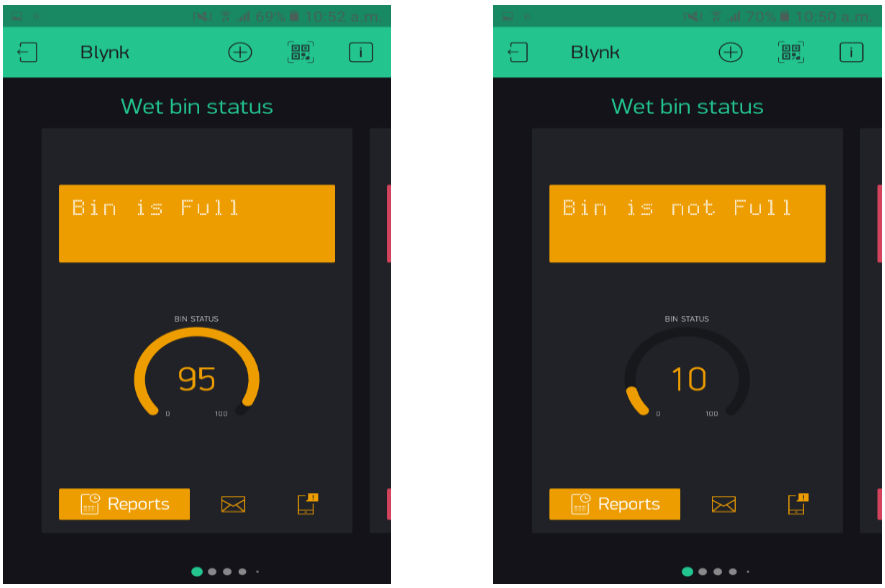


Figure 4. 31 : Wet /Dry bin widgets

The result of the dry bin ultrasonic sensor is shown in figure 4.32.

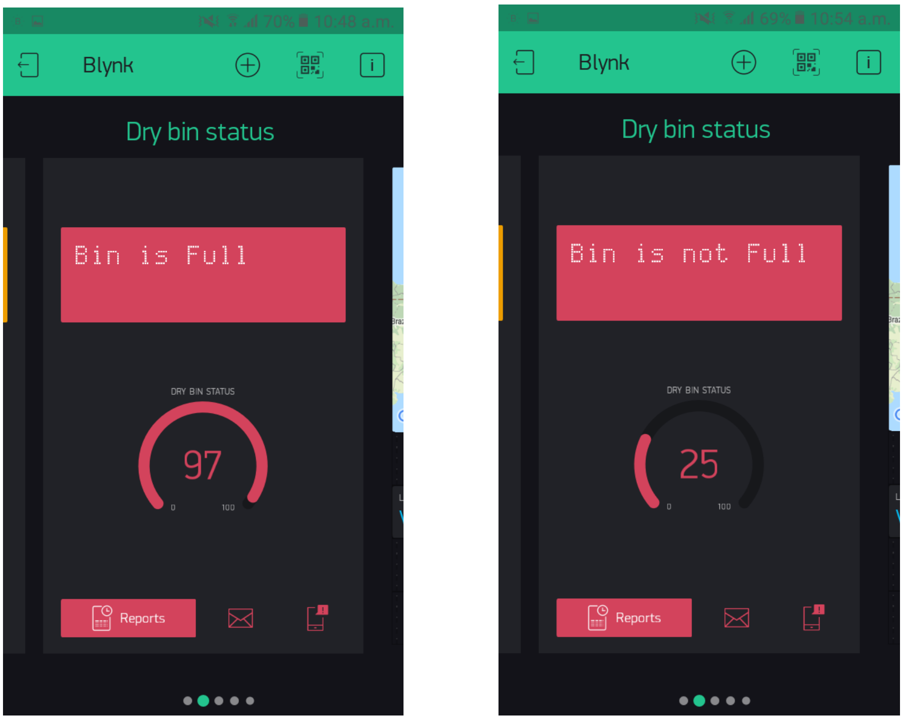


Figure 4. 32 : Wet /Dry bin widgets

The result of Bin status(opened/closed) feedback notifications is shown in figure 4.33

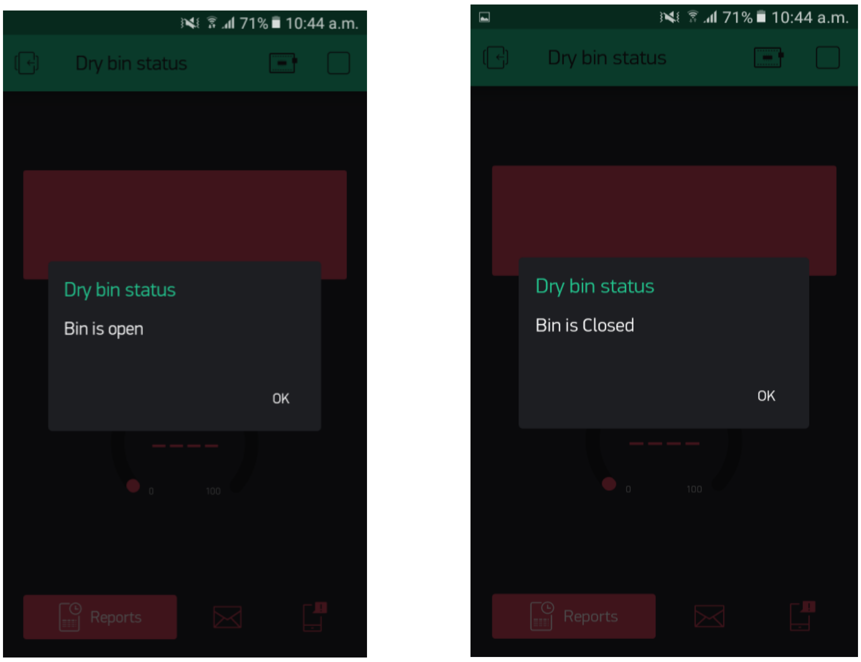


Figure 4. 33 : Feedback notifications

2-We tested the gas sensor-Node-RED-Server-Blynk app communication.

The result of gas sensor for fire notification is shown in figure 4.34

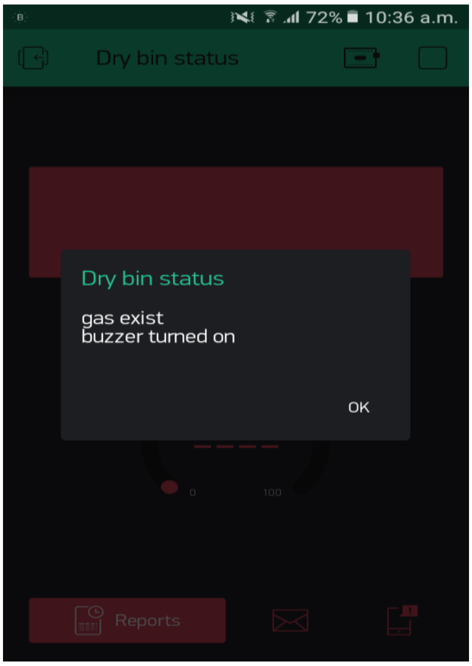


Figure 4. 34 : Fire notifications

3-We tested the system offline notification .

The result of system went offline notification is shown in figure 4.35

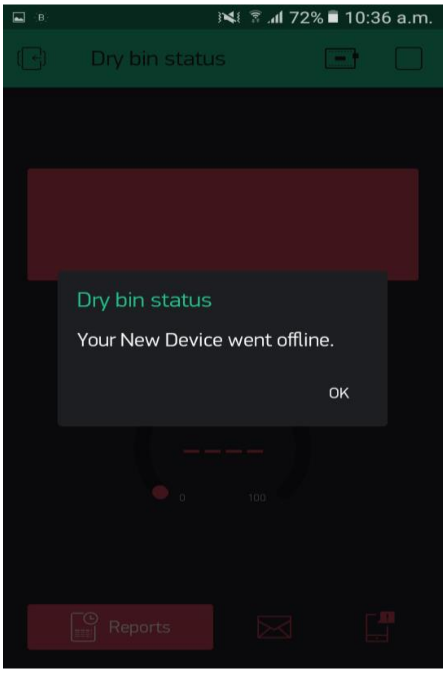


Figure 4. 35 : System status notifications

4-We tested the GPS-latitude -longitude values widget as shown in figure 4.36.

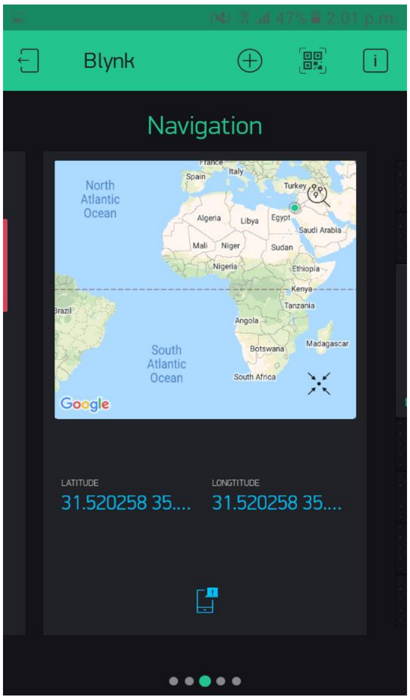


Figure 4. 36 : GPS result widget

4.4.3System Testing

We have three modules which need to be tested **:**

A. Bin status module Test:

Measuring bin level tested using two ultrasonic sensors. One sensor for each bin (dry /wet), two LEDs for each bin (red/green) and a suitable widgets on the blynk application which view the status as a user friendly interfaces.

Results:
The ultrasonic measure the waste level. Depends on the level it activate either the red LED or the green one. The microcontroller updates the sensor data on the cloud and the blynk application accordingly.

B. Fire detection module Test:

The fire detection capability of the system was tested using MQ sensor and buzzer , also the SIM and GPS module.

Results:
The MQ sense the fire immediately and then activate the buzzer , sending a notification with location information through the SIM module to the responsible authority.

C. Waste type detection module Test:

The Detection of waste type tested through an IR sensor and moisture sensor fixed on a robust carrier which hold the waste on the motor arm.

Results:
The placed waste was detected by the IR sensor, then the moisture measure its humidity to identify its type either wet or dry .Finally, the motor move the waste to the suitable place.

4.5 Implementation Results

By the end of the implementation process ,we combined all the components with each other to get the final IOT based waste management system. We connected the Battery, LCD, SIM900A, the gas sensor, raspberry pi, Ultrasonic,L298N motor Driver and the DC motor. The final connection of the system is shown in Figure 4.37, 4.38.

Figure 4. 37 : Implementation result

Figure 4. 38 : Implementation result

Chapter 5

System analysis and Discussion

5.1 Overview

This chapter introduces system functionality ,the added features which distinguish our IoT smart bin from other systems .

5.2 System functionality

This section will provide some information about the workflow of our smart bin .

5.2.1 Bin Design

Our smart bin is designed to recognize different types of waste. A smart system positioned inside the container uses sensors to segregate waste depending on their type either to the wet bin or to the dry one .It consist of IoT enabled sensors, which work as real- time indicators to determine if the bin is full or not , and help to customize the waste collection schedule accordingly. It has a SIM/GPRS module which allow the system to send data and receive instructions through the 3G internet. Also the system is supported with a GPS module which help on the fire detection procedure by identifying the exact location of the bin.

5.2.2 Bin Work principle

First, the waste is placed into the container, then the IR sensor detect if an object is placed ,when the object is detected the moisture sensor is enabled to measure the placed waste humidity , if it has a humidity greater than the threshold value , then the waste is identified as wet , if it is less than the threshold it's identified as dry. After identifying waste type, the microcontroller will instruct the motor to move either right to the wet bin or left to the dry one. The ultrasonic sensor will measure the bin level ,then the microcontroller will update bin status in the cloud accordingly.

5.3 Added features

This section will introduce the features that distinguish our IoT based waste management system.

1. Real time operating system

In our system, the tasks need to appear to be executing at the same time or concurrently, the use of a Real Time Operating System makes sense. A Real Time Operating System can have multiple tasks simultaneously in memory and can switch between them based on events and priorities.

We Used Raspberry pi as a RTOS in our IoT based system where the status and data changes from second to second depending on different events , where almost more than one event may occur simultaneously. Therefore a RTOS that rapidly switches between individual programming threads, giving the user the impression that there are multiple programs being executed simultaneously on a Central Processing Unit (CPU), as a CPU can only execute one task at any one time .

2. Distributed system

The trash bins are distributed in the cities , for nearly one bin for each street , every bin has its own data (location , status). Some of these bins are getting full quickly and others may stay empty for days, depending on population density and other factors. Some of these regions have a good internet connection ,but others may not. So the need for a distributed system appear as a good solution in this case ,where each street has its own smart bin with its own data and events which needed immediate instruction when it is happened ,So in the distributed system there is no need to wait for your turn to get the instructions and the internet connection problems will not obstruct the system operation since the system get the instructions immediately from its own microcontroller

On the other hand ,the event driven system produce data continuously , so there will be a huge amount of data , and these data need to be processed in order to identify the suitable action and trigger the suitable component immediately, if we send all the bins data to the same microcontroller through the internet , a clear problems will appear , the first one is the internet connection which in not stable all the time ,the second one is the huge load on the main microcontroller to process all the requests in a small time.

Finally, the efficiency problem since the disposal time takes just one second from the citizen, if the previous disposal is still not processed this will definitely cause a problem.

The distributed system gives the possibility of adding more bins easily when needed. These bins are connected with a unified database which allow them to communicate and share data with each other. Any failure of any trash bin does not affect the system ,other trash bins can still communicate with each other in distributed manner..

3. Data analysis

IoT and data remain intrinsically linked together. Data consumed and produced keeps growing at an ever expanding rate. The data generated from IoT devices turns out to be of value only if it gets subjected to analysis. By using data analysis we can examine big and small data sets with varying data properties to extract meaningful conclusions and actionable insights. These conclusions are usually in the form of trends, patterns, and statistics that help in proactively engaging with data to implement effective decision-making processes.

Our IoT based waste management system is an event driven system. Every new event produces new data .These data need to be managed ,processed , analyzed and stored in order to optimize operations at all levels, and improve decision making .

As we already use Node-Red as our event processing platform , we need a compatible platform with Node-Red in order to receive the data to be analyzed later , for this reason we use IBM cloud IoT which provides a set of IBM Cloud services as a single IBM-managed SaaS offering that enables us to collect ,process and analyze system data.

We used multiple IBM cloud services which includes :

1- IBM Watson IoT platform

From chip to app to cloud , is a fully managed, cloud-hosted service that makes it simple to derive value from Internet of Things (IoT) devices. We can simply register and connect raspberry pi as a device to Watson IoT Platform and start sending data securely up to the cloud using the open lightweight MQTT messaging protocol. We can set up and manage our device using an online dashboard or secure APIs, so that we can access and use our live and historical data.

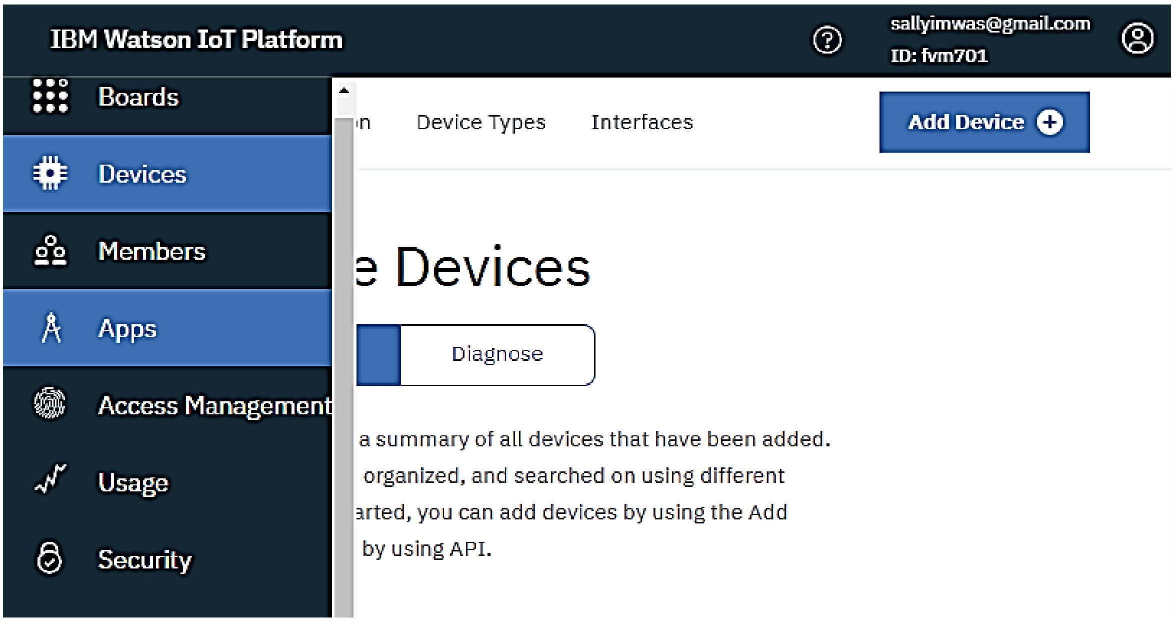


Figure 5.1- IBM Watson IoT platform

2-IBM cloudant database

IBM Cloudant is a fully managed JSON document database that offers independent server less scaling of throughput capacity and storage. It is a distributed database that is optimized for handling heavy workloads that are typical of large, fast-growing web and mobile apps. Available as an SLA-backed, fully managed IBM Cloud service, Cloudant elastically scales throughput and storage independently.

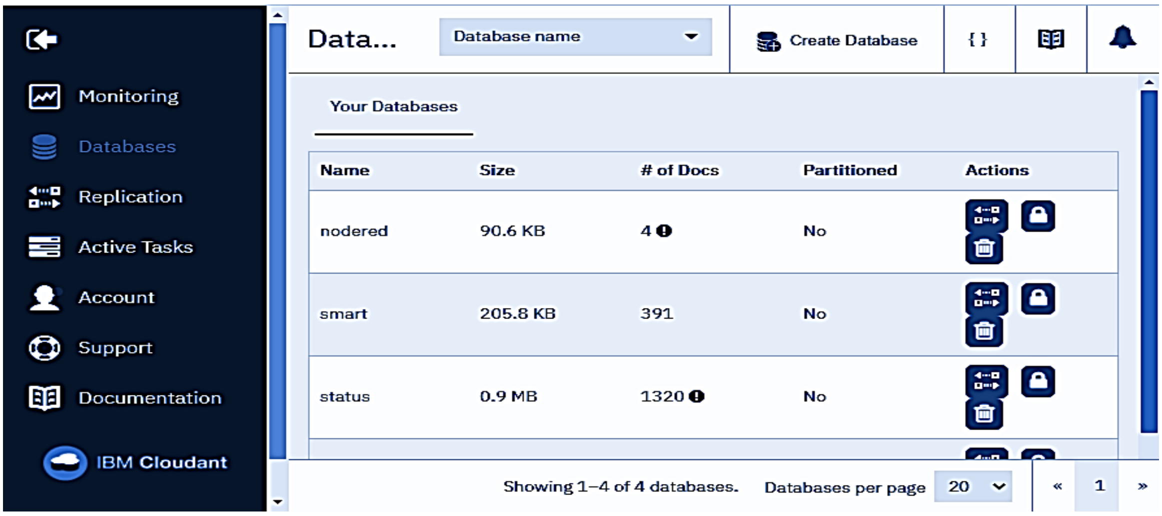


Figure 5.2- IBM cloudant database

3-IBM Watson studio

IBM's integrated hybrid environment that provides flexible data science tools to build , prepare ,analyze and visualize data.

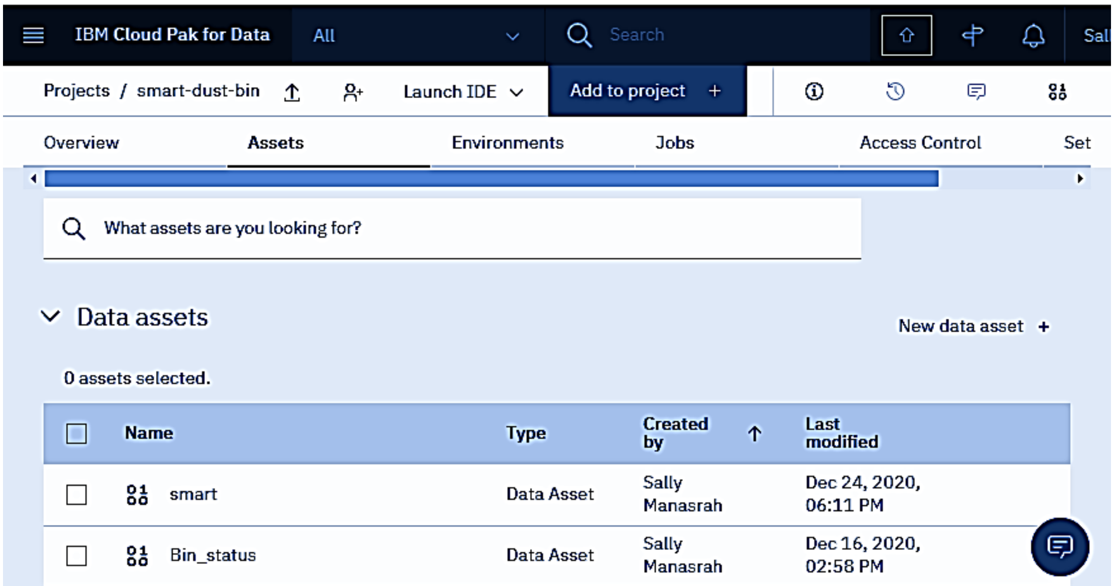


Figure 5.3: IBM Watson studio

Every event driven system need a real time data presentation which provide a good view about system correctness . IBM IoT platform provide us with a real time boards which presents the system workflow as a charts shown in figure and 5.

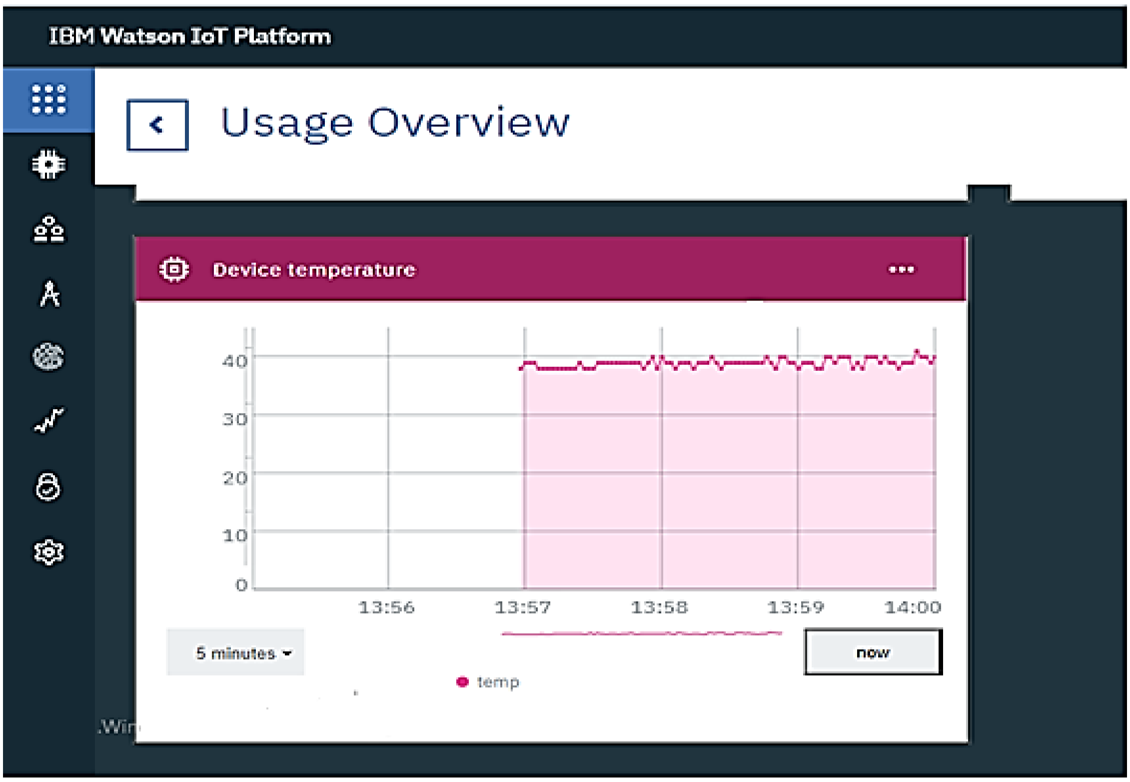
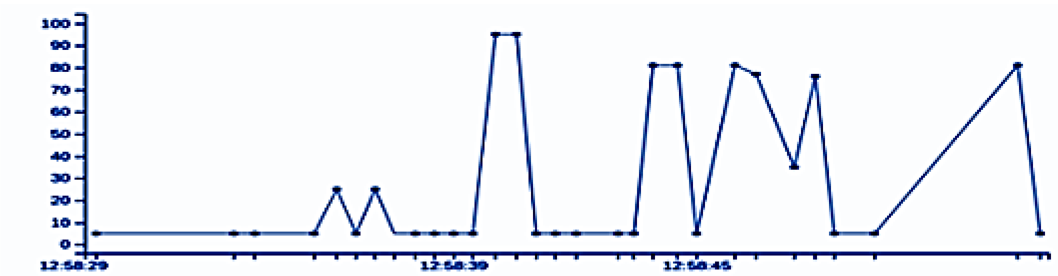


chart 5.1: Real time chart for CPU temperature



Event	Datapoint	Value
event	date	2020/12/7
event	time	12:58:53 PM
event	location	Wad alhariya
event	binStatus	empty
event	binType	Dry
event	level	5

chart 5.2: Real time chart for Bin status in 'Wad al hariya'

Historical data enables the tracking of improvement over time which gives key insights. These insights are essential for driving a system. For this reason we use the IBM cloudant database in order to record all the system data to be analyzed later .

Figure 5.4 : cloudant database records

We had created several tests to see how the system act . Then we analyzed the data :

Test 1 :

Sending CPU temperature from raspberry pi continuously to the 'IBM Watson IoT platform' , and check if the temperatures are stored in the 'cloudant ' database .

Result : as shown in chart 5.3, the data has been stored in the 'cloudant database' ,and we can view the historical data as a descriptive chart .

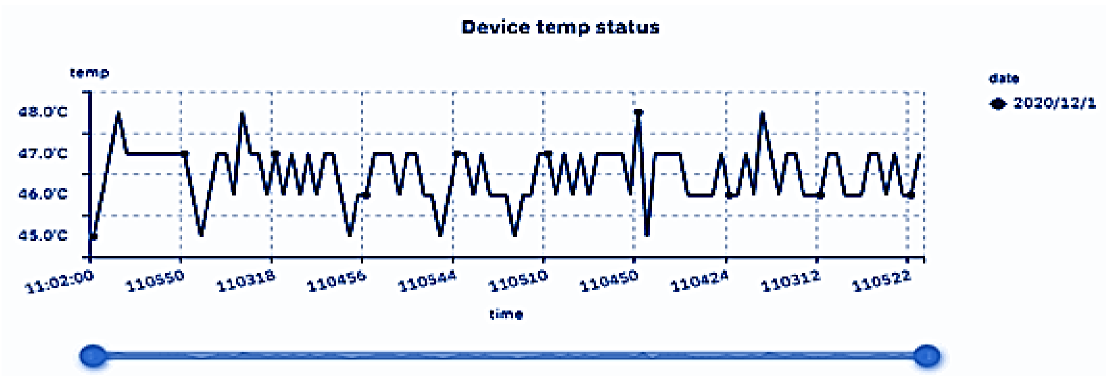


chart 5.3: Raspberry pi CPU temperature

Test 2 :

We suppose that the system located at 'Al Manara' square' , and we test the system behavior for a week starting from 1/12/2020 at 12PM-12AM.

As shown in chart 5.4 ,the wet bin of 'Al Manara' square' needed nearly three days to be full .As chart show , the bin status changed from empty to full in 3/12/2020, the same for 6/12/2020.

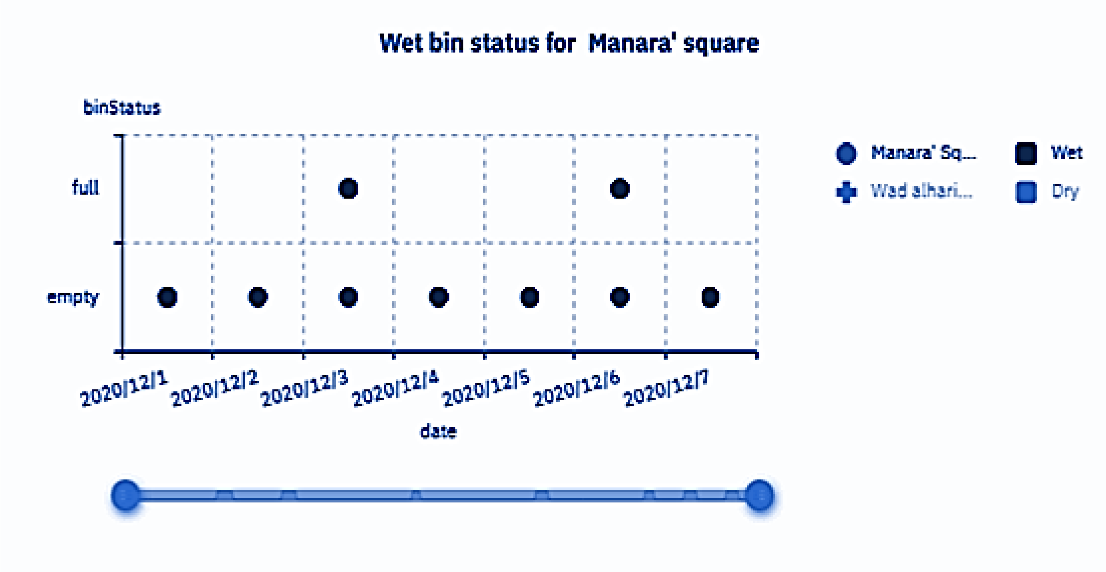


chart 5.4 : Wet bin status for 'Al Manara' square'

To take a deep view of what happened we have a chart which describe the bin level for each day. As shown in chart 5.5, the wet bin level reaches nearly 40% of its capacitance in the first day , 80% in the second day , and get full on the third day.

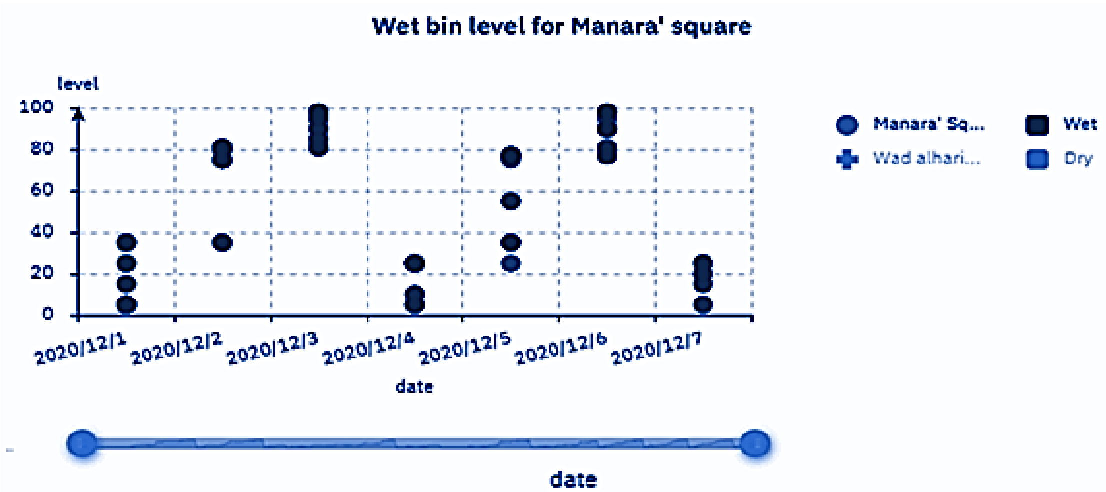


chart 5.5 : Wet bin level for 'Al Manara' square'

The bin status for ‘Al Manara’ square’ in the first day , and how the level changes hourly, is shown in chart 5.6 ,

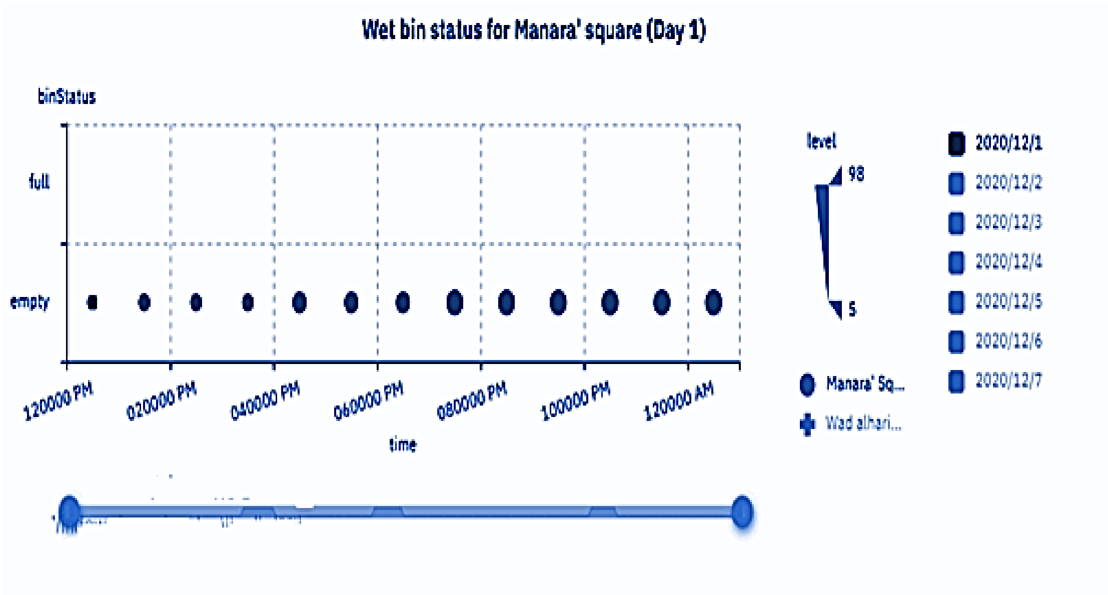


chart 5.6: Wet bin status Day 1

The bin status for ‘Al Manara’ square ‘ in the second day , and how the level changes hourly, is shown in chart 5.6

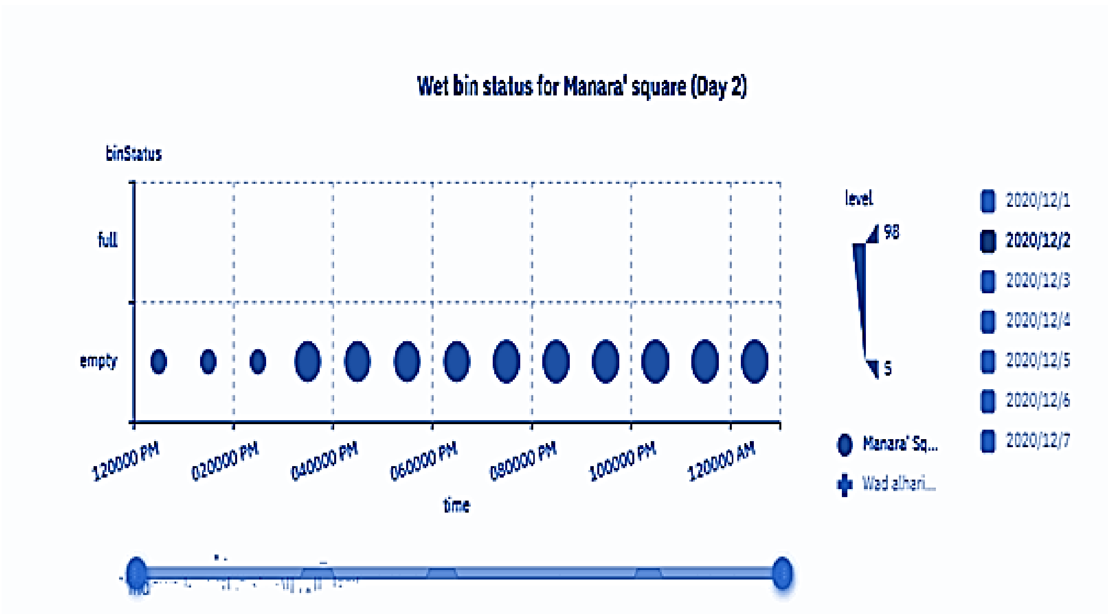


chart 5.7: Wet bin status Day 2

The bin status for 'Al Manara' square' in the third day , and how the level changes hourly, , is shown in chart 5.8. Also we can see that it got full at 4:00PM

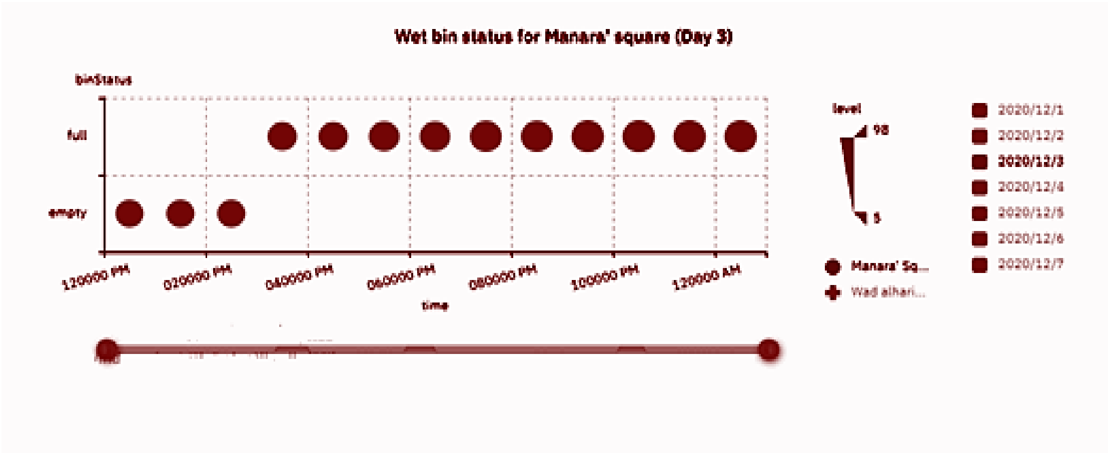


chart 5.8: Wet bin status Day 3

In the chart below , we have the level per-day for wet bin in 'Al Manara' square' . As shown, the level in the first, fourth , and seventh day the bin level is about 39%, where the bin level in the second and fifth day it is nearly about 80%, and in the third and sixth day it got full at 4:00-8:00PM.

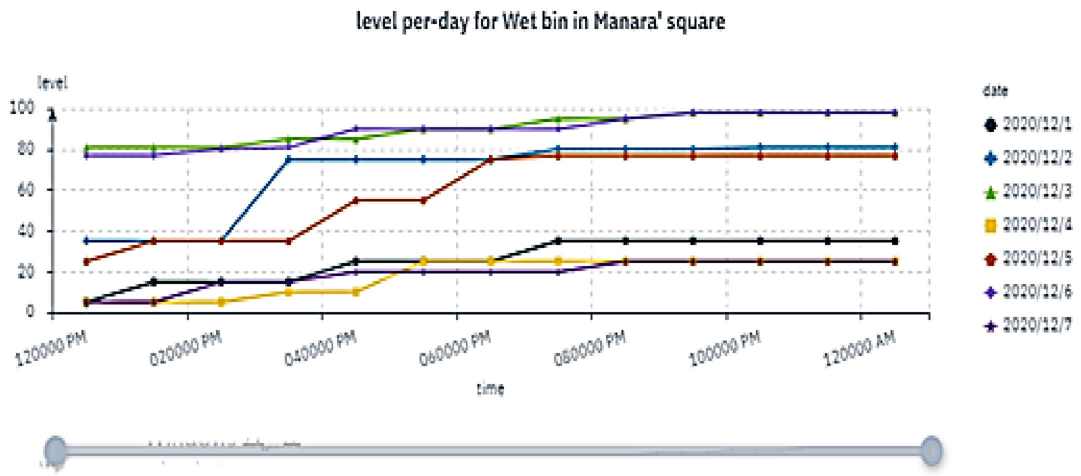


chart 5.9: level per-day for wet bin in 'Al Manara' square'

The second part of 'Al Manara' square ' bin is the dry bin , we do the same procedure which had been done for the wet bin and we got the result shown in chart below. Which showed that the dry bin needed nearly five days to be full.

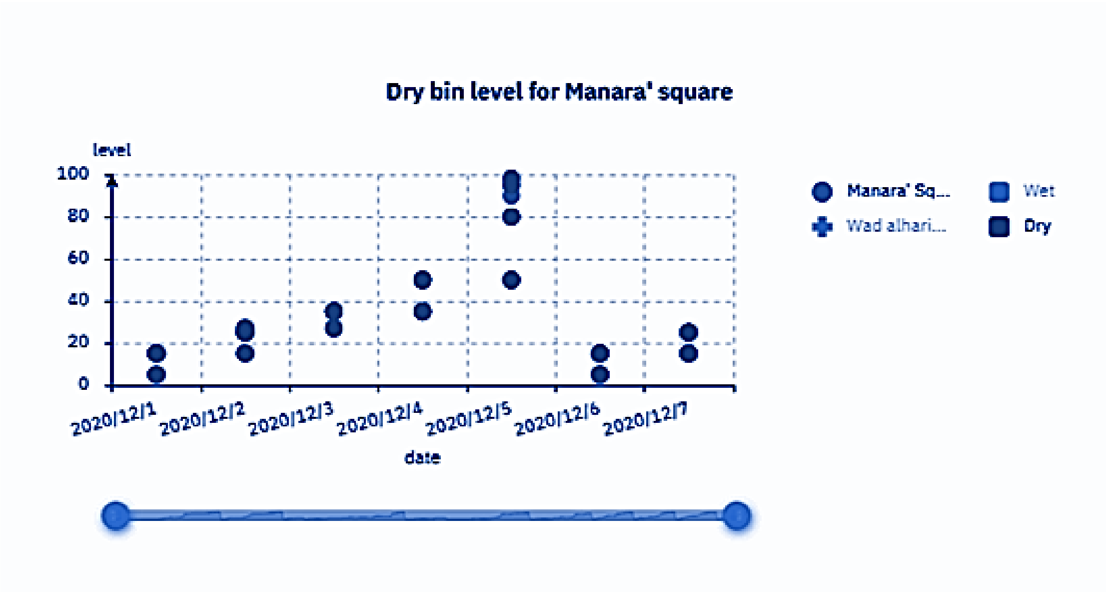


chart 5.10: Dry bin level for 'Al Manara' square'

In the chart below , we have the level per-day for dry bin in 'Al Manara' square' , and we see that the level in the first, second , third , sixth and sevnth day is about 40%, where the bin level in the fourth day is nearly about 55%, and in the fifth day it got full at 8:00-12:00 AM.

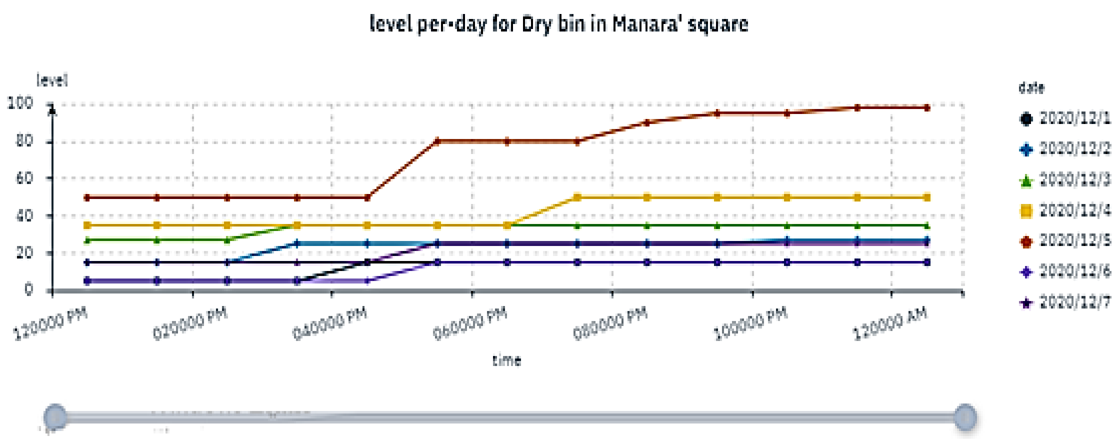


chart 5.11: level per-day for dry bin in 'Al Manara' square'

Test 3:

We suppose that the system is located at 'Wad al hariya' , and we test the system behavior for a week starting from 1/12/2020 from 12PM-12AM .

As shown in chart 5.12 , the bin status changed from empty to full in 4/12/2020,so the wet bin of 'Wad al hariya' needed four days to be full .

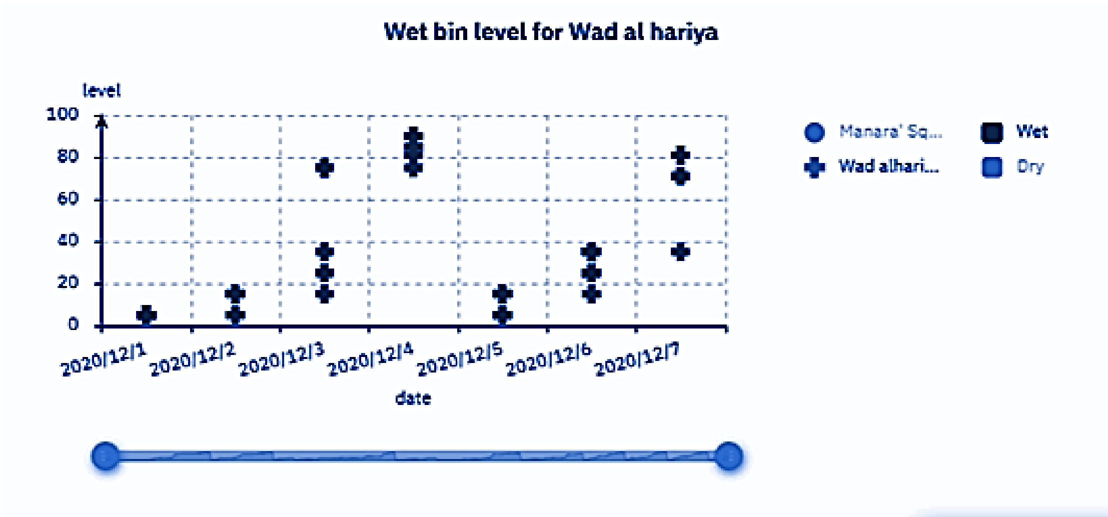


chart 5.12: Wet bin level in ' Wad al hariya'

In chart 5.13 , we have the level per-day for wet bin in 'Wad al hariya' , and we see that the level in the first, second is about 20%, where the bin level in the third day is nearly about 80%, and in the fourth day it got full at 10:00-12:00 AM.

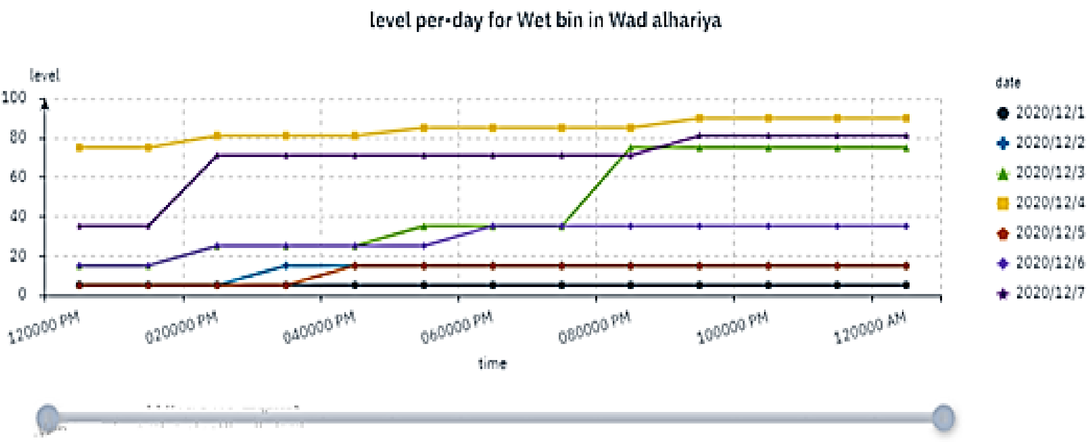


chart 5.13: level per-day for wet bin in ' Wad al hariya'

The second part of ‘Wad al hariya’ bin is the dry bin , we do the same procedure which had been done for the wet bin and we got the result below which shown that the dry bin needed nearly two days to be full.

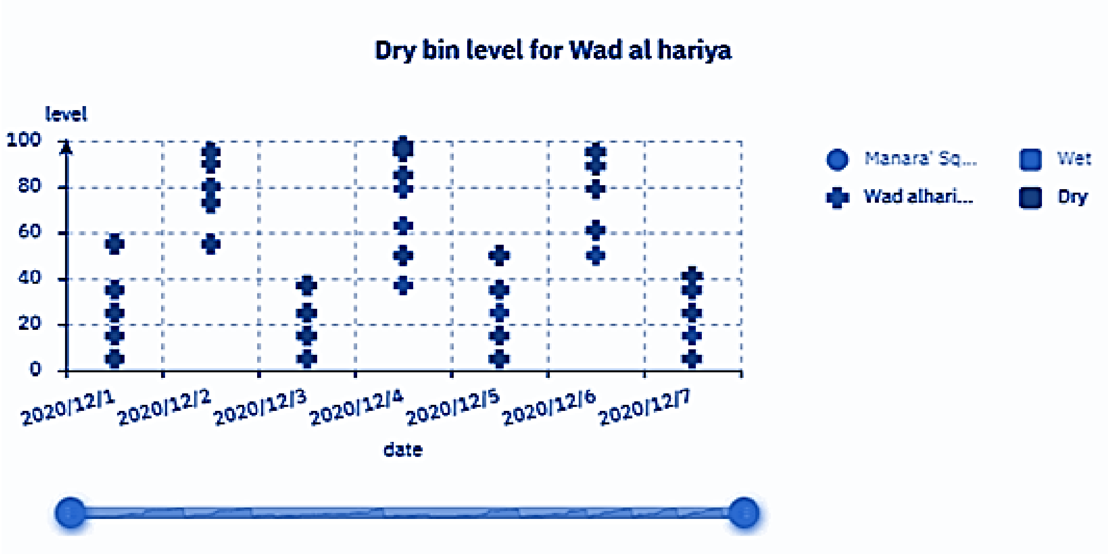


chart 5.14: Dry bin level in ’ Wad al hariya’

In chart 5.15 , we have the level per-day for dry bin in ‘Wad al hariya’ ,and we see that the level in the first day is about 60%, and in the second day it got full at 9:00-12:00 AM.

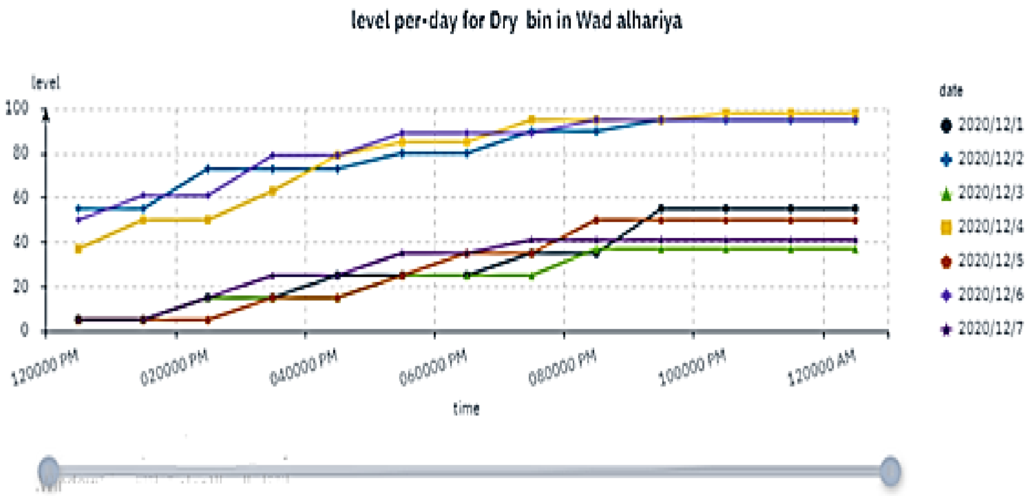


Chart 5.15: level per-day for dry bin in ’ Wad al hariya’

Test 4:

In our system there is a two disposal ways either automatically or manually .So we test the system for two days to know which is the disposal method used mostly by the citizen.

The chart below shows that the automatic way is used mostly in the two days in “Al Manara’square’ where there is nearly 2-4 manually disposals among the total of 13 disposals.

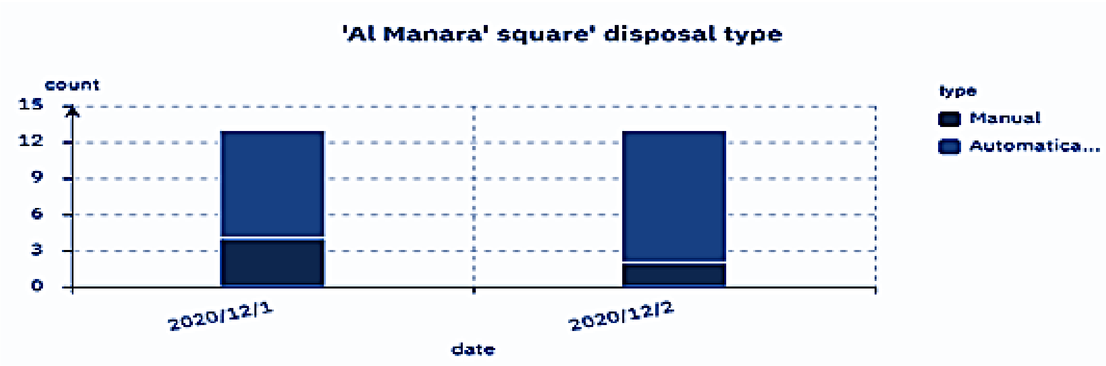


Chart 5.16: ‘Al Manara square’ disposal type

For ‘Wad al hariya ‘ , the chart below shows that the automatic way is used mostly in the two days , where there is only 1-2 manually disposals among the total of 13 disposals.

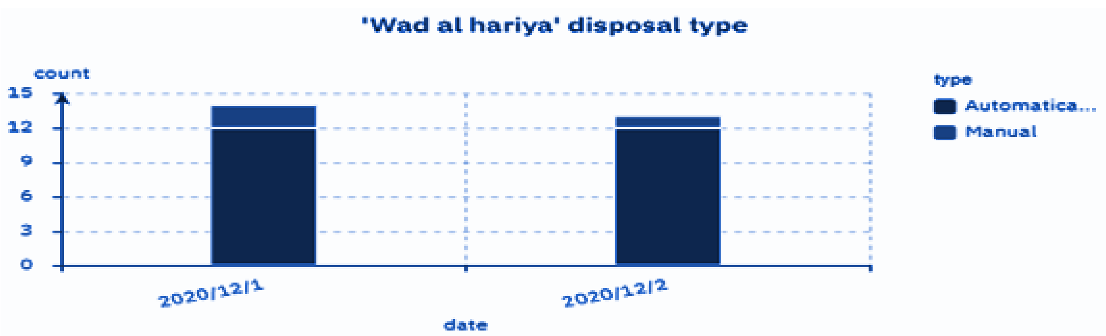


Chart 5.17 : ’ Wad al hariya’ disposal type

4. Feedbacks

The system have a lot of hardware components , hardware problems are all too common. Sometimes when a PC or disk gets old, it might start acting erratically and damage some data before it totally dies. Unfortunately, hardware errors frequently damage data on even young PCs and disks. Effective feedback, is very helpful. Feedback tell us how the system work and give us a good view of system workflow. So, Feedback is a valuable help to make important decisions.

In our IoT based waste management system , the need for an effective feedback is essential. For this reason we supported the system with feedbacks which tell the responsibilities , citizens about the system correctness

These feedbacks include:

1.Motor movement feedback

The DC motor move either right or left in order to throw the waste , then the motor need to get back to its origin point. In some cases the motor may face a difficulty in getting back to its origin, the arm may get stuck in one side , so we need to know if that case happened ,in order to provide the motor with the suitable speed and direction. We used a piece of tin fixed in the barrier between two bins , and uncovered copper wire fixed with the arm which move right or left .If the motor do not get back to origin and get stuck in any of the bin sides, the wire will not touch the tin so we know that the arm get stuck. This technique help us to know if the motor movement is correct or not.

Figure 5.5 : Motor movement feedback

2.Bin door status feedback

The system interact with the citizen who do the disposals . The citizen may forget to close the bin door, so the bin may still open for the next disposal and that may take a long time .

We need a way to remember the citizen to close the bin door . For this case we used two limit switch for each bin door (wet and dry). When the bin is opened the limit switch will tell the microcontroller about that , the microcontroller will wait two second before starting the buzzer and displaying a suitable message in the LCD.

Figure 5.6 : Bin door status

3.System availability feedback

The system may suddenly go down or the internet connection may loosed ,or the microcontroller may become off for different reasons .It's important to know when that happened .

In our system , the blynk server will send a notification to the blynk application when the system go off for any reason.

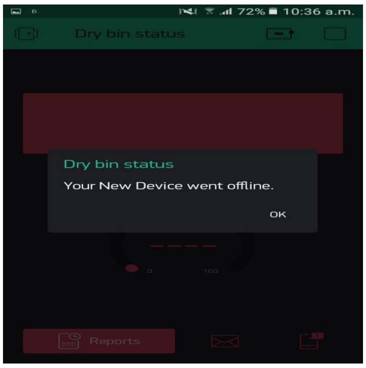


Figure 5.7 : System availability

4.CPU temperature feedback

As a general rule, computers do not like being hot — and when they heat up, bad things can happen. That's why it's so crucial to monitor CPU temperature to ensure that it doesn't overheat .

Node-Red has an 'exec' node supported with 'vcgencmd measure_temp' command, which measure the CPU temperature , then this temperature will be send to the IBM cloud to the admin panel who can take actions when the temperature exceeds its normal value.

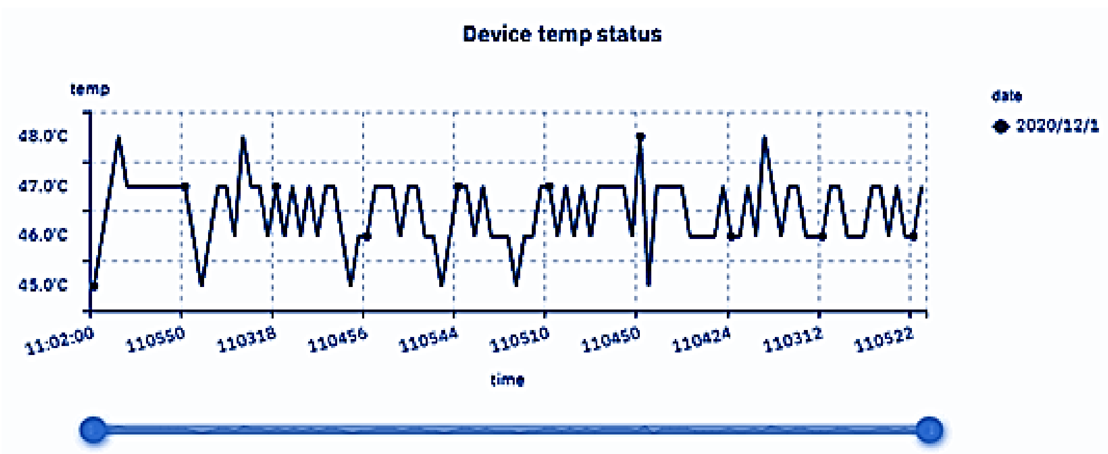


Figure 5.8 : CPU temperature

5.Displosal way feedback

Nowadays, people become more aware of the importance of preserving the environment and that waste damages the environment, so people have become aware that the process of separating waste into dry and wet has an obvious impact on reducing waste burning and the possibility of recycling.

We provided our system with a useful technique to know what is the way of citizen disposal either manually or automatically by using a touch sensor fixed on the back bin door , when the user open the back door that's mean it's a manual disposal but when the up door is open, the limit switch will tell the microcontroller that it's an automatic disposal.

Figure 5.9 : Disposal type

Chapter 6

Conclusion

6.1 Summary

IoT communication paradigm have provided the capability for devices to communicate and share information in long range distances while utilizing less power. In this project we have conducted and presented analysis of distributed smart waste collection system using IoT technology. Taking into account the creation of a real prototype of the smart container and the implementation of a new waste management mobile application and corresponding cloud based data analyses , and based on the case study experiments, it was concluded that the proposed system can efficiently improve the way people deal with their garbage and optimize economic and material resources.

.

At this level, hardware components, software tools and design are explained functions of the smart bin are tested , analysis and results are discussed. Despite the implementation issues, the smart bin passed the function tests successfully. It passed the segregating waste depending on their type , send bin status to the responsible ,analyses the system data and give reports, give good feedbacks about the system workflow ,send a message to fire station with a fixed location.

6.2 Challenges

The first challenge faced us was the mechanical constraints and how to build the model to be reliable and safe. The second challenge faced was the component constraints, the quality of some components such as LCD and motor driver which is damaged quickly and the quality of wires was bad. The third challenge is the environments constraints because the GPS module need to be outdoor to get the exact latitude and longitude.

6.3 Recommendations and future work

By further developments and improvements, the smart bin will have more functions and produce more reliable waste collection and management .

To improve the smart bin functions some additions and changes can be done:

The waste type detection technique can be improved to detect all the waste types and to detect the wet waste which do not has the required humidity value which can be detected by the moisture sensor.

In future work, the application developed for this solution can be evolved by adding new facilities that can bring to the end user more significant interactions with the management system besides integration with a platform, to calculate the best path in collection routes, seeking efficiency with a lower cost of operating the of trucks. In addition, the investment and operation costs of this solution will be a very interesting study and can be performed as future work.

References

[1] The World Bank: "https://www.worldbank.org/en/news/feature/2013/10/30/global-waste-on-pace-to-triple". [Online; accessed 16-Dec 2020].

[2] Google Drive:" https://drive.google.com/file/d/19teIQOX2v36oJvFuudJuWXBZV8qBNJbd/view?usp=sharing". [Online; accessed 16-Dec 2020].

[3] ResearchGate:"https://www.researchgate.net/publication/333922358_Design_Of_A_Monitoring_System_For_Waste_Management_Using_IoT" [Online; accessed 16-Dec 2020].

[4] ResearchGate:"https://www.researchgate.net/publication/328007139_Internet_Of_Things_IOT_Based_Waste_Management_System"[Online; accessed 16-Dec 2020].

[5] Digikey, URL: "https://www.digikey.com/en/blog/types-of-temperature-" [Online; accessed 16-Dec 2020].

[6] Arduino, URL: "https://www.arduino.cc/en/Main/OldSoftwareReleases",[Online ;accessed 16- Dec 2020].

[7] Raspberry Pi, URL: "https://www.raspberrypi.org" , [Online ;accessed 16-Dec 2020].

[8] Maxbotix ,URL:"https://www.maxbotix.com/articles/ultrasonic-or-infrared-sensors.html ",[Online; accessed 16-Dec 2020]

[9] EEWorld, URL: " https://www.ecnmag.com ", [Online ; accessed 16-Dec 2020].

[10] Fritzing, URL "https://fritzing.org/home/",[Online ; accessed 16-Dec 2020].

[11] ResearchGate"https://www.researchgate.net/publication/328007139_Internet_Of_Things_IOT_Based_Waste_Management_System", [Online; accessed 16-Dec 2020].