Thesis Report On

WASTE MANAGEMENT SYSTEM USING RFID AND ULTRASONIC SENSOR

By

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A thesis submitted to the Department of Computer Science and Engineering in partial fulfilment of the requirements for the degree of
Bachelor of Science in Computer Science and Engineering

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Declaration

It is hereby declared that

1. The thesis submitted is my/our own original work while completing degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I/We have acknowledged all main sources of help.

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Abstract

Bangladesh is a developing country, developing many different sectors of our country and countrymen although waste management quality is not very appreciable right now. We are introducing a smart waste management system. It is such a process which can be used to accelerate present waste management system. We are proposing a cost efficient or a low-cost device using Arduino UNO, Ultrasonic sensor, GSM module, RFID and LEDs. We are developing a smart bin based on RFID system where the RFID reader is attached to the bins and the reader will read the tags containing the information of each employee collecting the waste. With the help of the device, it will be possible to track the status of the garbage bin if it is full or not. The device will use ultrasonic sensor to measure the waste level of the container. According to the waste level the device will take necessary actions. When the garbage level of the bin is full the device will turn on LED signal to show that it is full. Besides, it will immediately send SMS to the assigned waste collector and to the server of the authority using GSM module. As the device uses the GSM technology, so there will be no need of any internet connection. So, it is not necessary that the waste collectors will need smartphones which will be cost efficient for both sides of the authority. The device will have RFID reader or scanner which will track the waste collector who is cleaning the container by RFID readable ID card or tag. This process will help to keep track of the employees if they are working properly or not. Finally, all this information will be sent to the server by SMS in JSON format. The server side must be able to retrieve JSON data and store in the database. In this rapidly growing country, Bangladesh waste is getting produced vigorously and it is really hard to dispose all of them at once. RFID based waste management system will surely be able to extract the wastes of our growing cities, keep our society and environment clean, hygienic and reduce air pollution spread by waste.

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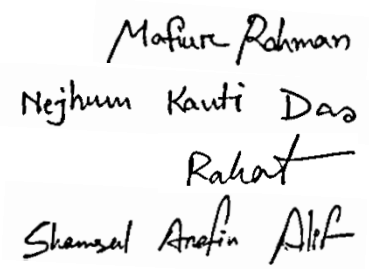
Signature of Students



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Introduction

Generally, waste management system means gathered waste transferring for treating to recycle and disposing the waste which is of no use. The procedures for waste management consists of treating both solid and liquid waste and often different types of gaseous waste. Throughout the whole process of waste management, it offers a variety of solutions too. For example, items that can be recycled and reform many items that are not categorized as trash or waste.

Waste collection and management methods vary widely among different countries and regions of the world. In Bangladesh, waste management sector is developing alongside many sectors of the country but it is still lagging behind from the perception of other countries waste management system. In the capital city Dhaka, people experience exhausted waste collection services, inadequately managed and uncontrolled dumpsites and the problems are worsening gradually. Air is getting polluted day by day and people of the city are often suffering from publicly open and uncontrolled dumpsites. Sometimes, it is seen that waste is burned by the roadside or by canal side which can spread water diseases and pollute drinking water.

Waste collection method in such countries is an on-going challenge and many struggles due to weak rules and regulations. People who are attached with waste management and waste controlling are not taking or doing their job seriously as a result, the city is not able to dispose the amount of waste it produces every day. Rapid urbanization is another reason for this rapid increase of wastes. Now-a-days, mills, factories, and other production and commercial sites produce wastes more than humankind has ever seen.

Curbside collection is the most familiar method of waste disposal in most countries, in such case waste is collected at certain regular intervals by specialized trucks. Then, the collected waste is transferred by specialized trucks to such areas where the trash can be disposed. For the waste of Dhaka, we have north and south city corporations and local authorities to work with waste management although their work is not that much satisfactory.

There is so much importance of waste management as the majority of the world population lives in cities; waste disposal is a big issue for these cities. To prevent environment pollution, we also need to manage the waste in such manner where the waste cannot pollute water or air or any other natural elements. The more we improve our waste management system, the more we reduce pollution and by recycling the waste material, we create more green energy for our developed world. In addition, processing and extracting raw or virgin materials can cause the environment pollution in many harsh ways which can be prevented by recycling. Recycling also prevents the emissions of so many different types of greenhouse gases and water pollutants, and saves energy.

Our sensor-based smart bin can judge the level of waste in it and using its sensor it can identify how much it can contain more. Whenever the smart bin becomes full, it will send a message to City Corporation directly notifying that it has become full and specialized trucks must be sent to collect the wastes. The ultrasonic sensor helps to find out about the garbage levels in the smart bins. Because of this, the system will know when and from where the garbages' of the bins need to be collected. These collected wastes will be turned into many recyclable goods, composite fertilizers and so on. Doing so, we will create more green energy and recycling prevents environment pollution. However, our system will know every important information about the smart bin, also about the collectors through the RFID tags. As a result, mistakenly empty bin collection would be rare case this time, which is both time and money consuming.

1.2. Problem Statements

In city areas, management of solid wastes is a far-reaching challenge now-a-day. In a typical waste management system, the garbage collection authority is unaware of the quantity of garbage in the dustbin; if the dust bins become full of garbage, it overflows and spills out, resulting in unsanitary conditions in cities. People put debris into the already overflowing trash can. When garbage bins are not kept clean, hazardous and unsanitary gases are released, contributing to air pollution and the spread of infectious diseases. The use of a traditional system results in a system that is

inefficient and wastes time and money. By 2030, more than 70 percent people of the whole world population will be living in the cities all across the globe. This reality necessitates the development of sustainable urban solutions, as waste management is a major health concern. In developed countries, effective waste management is critical. Although waste management might consume up to fifty percent of a city's budget, it only serves a small portion of the population. Up to 60% of garbage is not collected, and it is frequently burned by the side of the road which results in contamination of drinking water and spreading disease to those who live close. By minimizing industrial and residential wastes of hazardous and dangerous nature, waste management system protects human health and environment both from contamination. Improved waste management reduces pollution, recycles useful materials, and generates more renewable energy.

1.3. Research Objective

By improving waste management system properly, more waste can be pulled out of our cities, that can provide more recyclable materials and so, it will produce more and more renewable energy. This smart waste management system will be more efficient than traditional system in terms of cleanliness, safety, time and money.
Here, the overall objectives of the waste management assessment are summarized below:

1. Keeping a close eye on waste management is essential.
2. Providing trash management technology that is automated.
3. Avoiding the use of humans.
4. Reducing the amount of time and effort required by humans.
5. Keep a proper note of the collectors' information.

1.4. Literature Review

We have read many research papers and out of that 6 Research papers had a lot of similarities with our topic which are reviewed below:

In the first paper we reviewed "IOT Based Smart Garbage alert system using Arduino UNO. By Dr. N. SATHISH KUMAR, B. VIJAYALAKSHMI, R. JENNIFER PRARTHANA, A SHANKAR" which was published in 2016. This paper proposes a smart alert system for garbage clearance by giving an alert signal to the municipal web server for instant cleaning of dustbin. This research proposes a model which will be built with ultrasonic sensor, GSM module and RFID. The system will be able to detect the different types of garbage. It will also show the real time level of the garbage to the server station of the authority.

In the second paper we reviewed "Automated Waste Management System with RFID and Ultrasonic Sensors by M. V. Amritkar" which was published in 2017. This paper proposed the idea of an automated waste management system to do auto-management of waste with less human interaction in order to maintain a clean environment. This research is proposing an algorithm which will sort the different types of garbage using RFID. Also, it is using GPS and GSM module to show the location of the garbage bin which is full.

In the third paper we reviewed "A Cloud integrated wireless garbage management system for Smart Cities by Mohd. Talha Amar Upadhyay, Raaziyah Shamim, M. Salim Beg' 'which was published in 2017. The paper proposed a system that with the help of wireless sensing nodes centrally monitors the temperature, humidity, flammable gases concentrations (or smoke), fire detection and garbage fill volume in waste bins. These sensing nodes are placed at different remote locations of the whole city and they are in communication with the central station using TCP/ IP protocol via GPRS infrastructure.

In the fourth paper we reviewed "IOT-oriented Waste Management System based on new RFID-Sensing Devices and Cloud Technologies by Luca Catarinucci, Riccardo Colella, Stefano Irno Consalvo, Luigi Patrono, Alfredo Salvatore, and Ilaria Sergi" which was published in 2019. In this paper a waste management system is based on the use of an innovative RFID tag that is equipped with low-cost sensors that will pass their readings to the tag and there is a cloud-based software that is able to collect, manage and extract information form the collected data from the tag.

In the fifth paper we reviewed "IOT based Waste Collection Management System for Smart Cities by Megha. S. Chaudhari, Bharti Patil, Vaishali Raut" which was published in 2019. In this paper, smart bin is built on a microcontroller-based platform Raspberry pi UNO board. This is interfaced with GSM modem and Ultrasonic sensor and also the weight sensor, which is used for calculating the weight of the dustbins. Using ultrasonic and weight sensor whenever the threshold weight and height reaches, the GSM modem with notify the waste collectors and the waste collector will be sending messages to separate administrator and the collected waste will be eliminated later by a robotic equipment.

1.5. Existing System and Disadvantages

- "Route optimization" projects are done for increasing the efficiency of waste management, but still the waste collectors must physically go to the dustbin to check waste levels. Because of this, trucks often visit containers that do not need emptying, which wastes both time and fuel.
- This is quite normal that, more than about 60% of waste of the cities of Bangladesh is not collected, and it is frequently burned on the side of the road. In Dhaka the waste collection rate is only 37%. It can contaminate drinking water and spread disease to those who live nearby.
- In 2016, the DNCC and DSCC built approximately 6,000 garbage containers throughout the Dhaka city. However, due to the lack of citizen awareness, the project failed within a year.

Smart waste management prevents harm to human health and the environment by reducing the volume and hazardous character of residential and industrial waste. Improving proper waste management will reduce pollution, especially in the densely populated cities. This will also possible to recycle useful materials and create more green energy.

1.6. Proposed System and Advantages

- Less time and fuel consumption will be possible as the waste collection trucks go only to the filled containers.
- The system will be able to decrease noise, traffic flow and air pollution as a result of less trucks on the roads.
- Our smart operating system allows for two-way communication between the city's dustbins and the service provider. As a result, the focus is solely on the collection according to route-based container fill levels.
- The sensors installed in the containers provide real time information on the fill level. This information will help to set the priority for waste collection in places.
- In this way both service providers and citizens will benefit from an optimized system which results in major cost savings and less urban pollution.
- This system can reduce the infrastructure (trucks, containers), operating (fuel) and maintenance costs of the service by up to 30%.
- Applying this technology to the city optimizes management, resources and costs, and makes it a “SMART CITY” or “DIGITAL TOWN”.
- Historical information on collections helps adapt the deployment of containers to the actual needs of the city, therefore reducing the number of containers that clutter up the road and increasing public parking spaces.
- It will keep the surroundings clean and green, free from bad odor of wastes, emphasize on healthy environment and keep cities more beautiful.
- Even this is possible that the system will be able to reduce manpower required to handle the garbage collection.

1.7. Limitations

The system has some limitations as well. Such as:

- **Maintenance:** There is skepticism that an automatic dispenser is high maintenance. As the sanitizer dispenses automatically, it gets clogged in places, which requires timely cleaning. This also makes the place dirty and unhygienic. The project will need mechanical persons at the time of system failure.

- **Price Factor:** These machines will have fully automatic system and quite understandably, these are more expensive than the current analog ones. Also, it will primarily require more manpower for electrical and mechanical maintenance of the device.
- Right now, the system doesn't have a "Route optimization" feature with android device. When that is possible the smart bin will be more efficient to use with android software specially for the workers.
- Currently, the system does not have any sustainable power source except Li-ion batteries. These batteries are quite high maintenance. These require to be charged manually and they also have a smaller life cycle. Also, these are large in size with respect to their capacity. So changing them on a weekly basis is quite a hassle.

Chapter 2

System Architecture

2.1. Architecture

In this stage, the system detects the garbage level inside the bin with sensor. The Ultrasonic sensor uses a set of frequency wavelength into the garbage. The frequency of the sensor is around 40 kHz, that doesn't go through garbage and bounces back form the top surface of garbage level. The echoed wave registers into the sensor as distance by which it measures less the distance more the

garbage is filled. HC-SR04 analogue ultrasonic sensor will be used in this system. The central system will be controlled by Arduino microcontroller which will be equipped with GSM module. The groundand the VCC pin need to be connected to the module, and the 5 volts pin into the Arduinoboard respectively. There will be an LED display to interact with the system and GSM module will notify through SMS both the client and garbage collector about the level of garbage inside the bin.

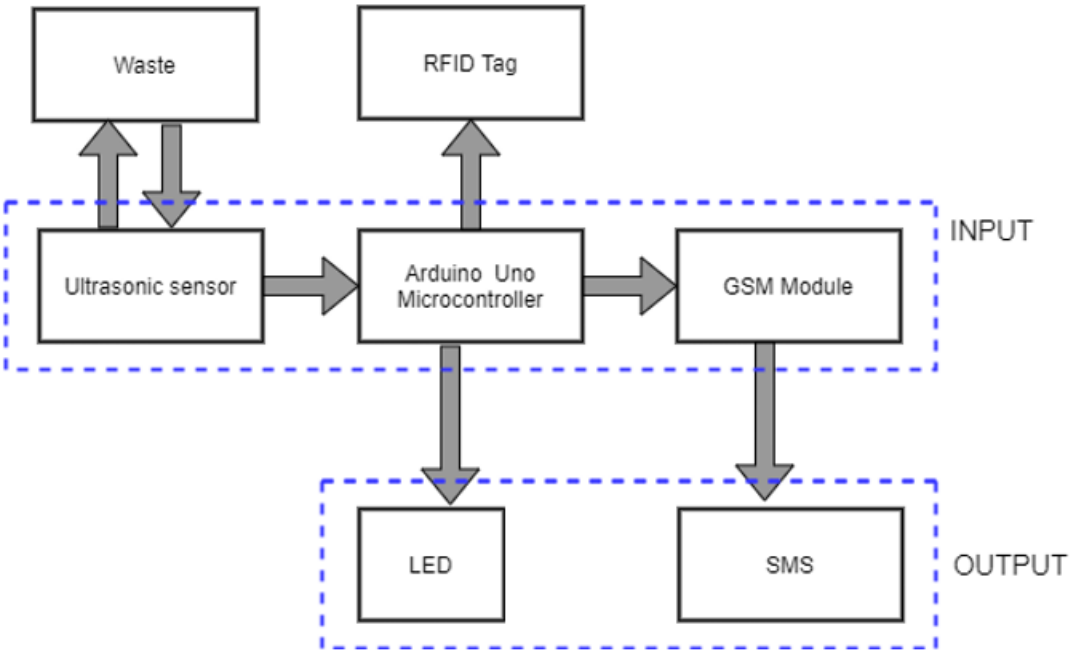


Fig.- A system design of the proposed smart bin

Next phase is about data collection and notification procedure. The information of garbage collector is stored into the database and upon RFID tag scan, it sends data to cloud database. When the RFID reader (of collector) is placed on the RFID tag. The system sends information to the GSM module, which retrieves it from the cloud database and displays it on the end user's phone or web page displaying the current state of the garbage as well as the collection date and time.

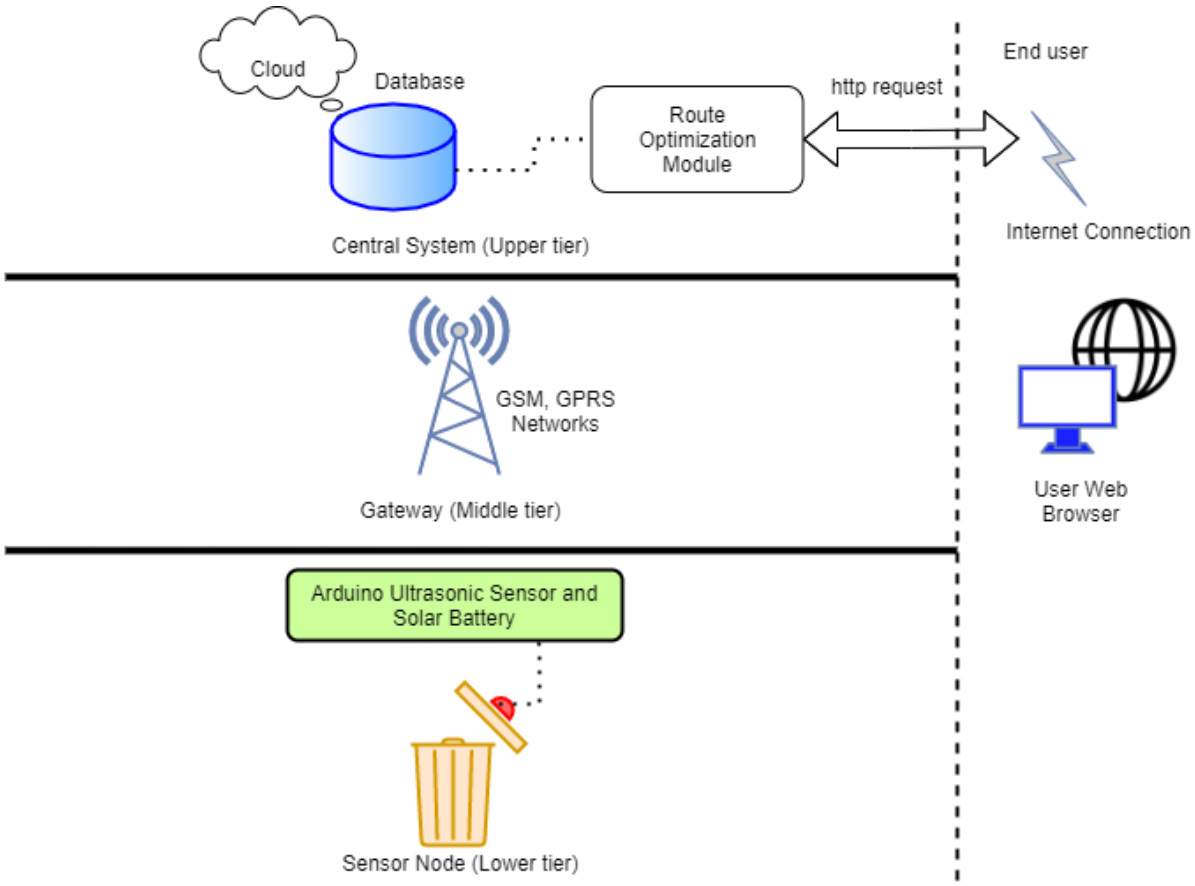


Fig.- Operational system design

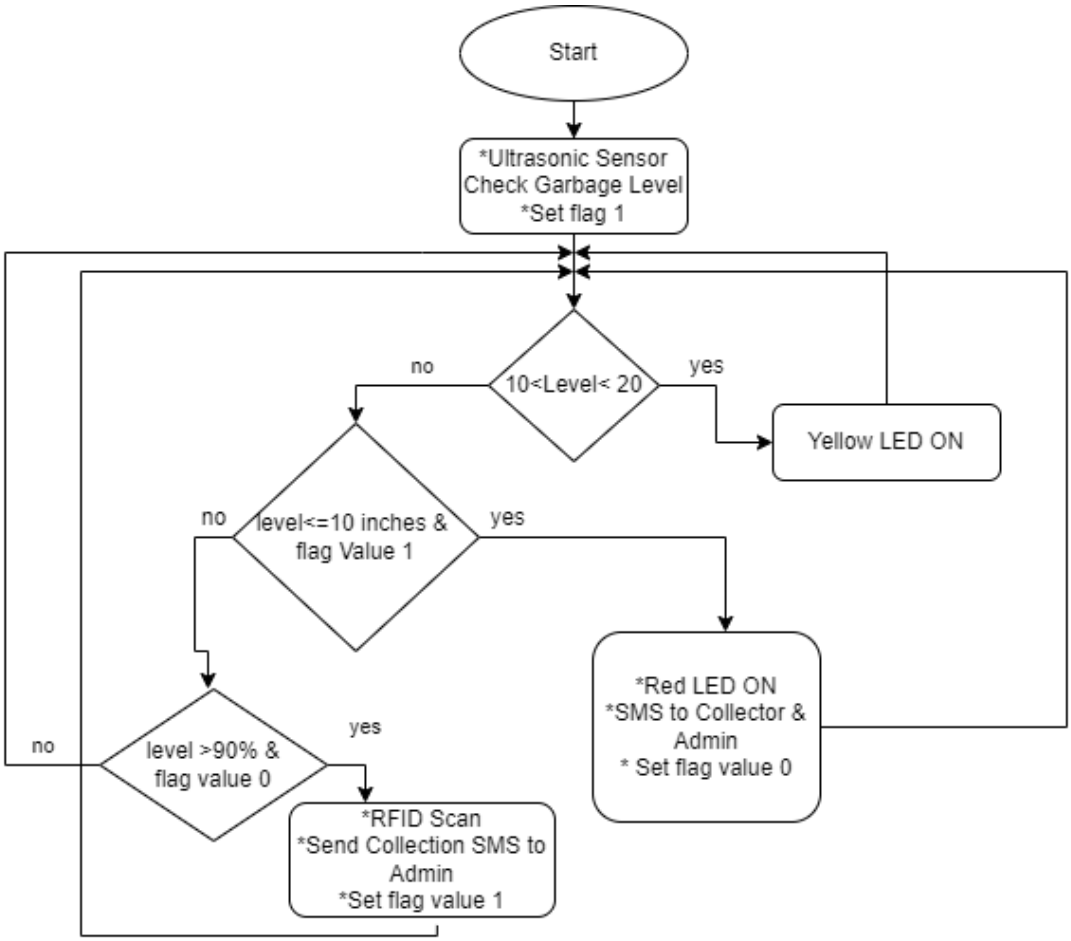
2.2. Methodology:

In our proposed system, we'll use two different types of approaches to make the existing system autonomous and smart. Firstly, an ultrasonic sensor and RFID reader will be installed in the garbage container. The sensor will detect the level of waste that has been dumped into the container, and if it exceeds a specific level, it will send a notification to the appointed garbage collectors. The garbage collector appointed for the particular bin/ zone has to come with his Tag which had already been given to him, where the details about the person are stored. Whenever a Tag comes into contact with the Reader, the garbage collector's information will be available. The information will be sent from the reader to the database of the authority. The notification will be

sent in JSON format from the RFID reader using the GSM module and the server will receive the notification in JSON format and retrieve and collect the waste collector's data.

We are implementing algorithms in the proposed system to make it smart and automatic. We are using the reading of ultrasonic sensor to measure how much the garbage bin is filled up. Whenever the garbage bin is filled, an alert will be sent in JSON object format to the authority's database using the GSM module. Then, when the garbage collector arrives to collect the waste, he scans his RFID tag and the scanner gets the data of the collector and again sends it through GSM module to the database of the authority. The system helps in saving a lot of time and manpower due to this automated alert from the bins and all the waste collectors have to do is collect the waste from the bins only that are full.

Work Flow Diagram:



2.3. Hardware and Software Requirements:

1. Hardware kits:

1. RFID Tag and Receiver
2. Arduino Board
3. GSM Module
4. Bread Board
5. Jump Wires
6. Ultrasonic sensor
7. Bin

2. Software:

1. IDE (Arduino Integrated Development Environment)
2. Proteus
3. Waste Management System Web Application (will be required on the user side of the system)

3. Programming Languages:

1. C/C++

2.4. Functional and Non-Functional Requirements:

Functional Requirements:

Functional requirements are the requirements that the end user specifically demands as basic facilities that the system should offer which tell us how the system should react to particular inputs and how discreetly it performs. Such as: -

i. Garbage detection: It detects the level of the garbage filled within the bin.
ii. Notification: It gives us a notification through the GSM module to not to drop any the garbage if bin is full. And it sends a message when it needs to be emptied.
iii. Bin Information: It displays the information of garbage location and collector's information.
iv. Data Processing: It is able to send SMS through the connection of GUI, Arduino and GSM.

Non-functional Requirements:

Non-functional requirements are basically the quality constraints that the system must satisfy according to the project contract. The priority of these factors that are implemented varies from one project to other. Here, this system works only when there is a network connection between garbage bin location and control room to inform the municipal authorities.

Web Application: For the user end, our system will require a web application to obtain real-time information regarding the status of trash in a specific area. It will be especially designed from the admin perceptive. Here, an admin allocates the regions to the specific sanitary worker who is responsible for collecting the garbage within time and also can overview the monthly reports that shows the overall statistics of waste collection garbage of that specific area. He can also view the

bin status, bin locations, and worker's locations and their assigned bin at any moment. Again, the admin can deal with user's complaints and feedback in a separate section. This web application can be implemented with REACT JS. As the GSM module sends SMS in JASON object format. So, the JavaScript code will need to retrieve information from the object and show the real time data on Website.

Chapter 3

Hardware Tools

3.1. Hardware Tool Description

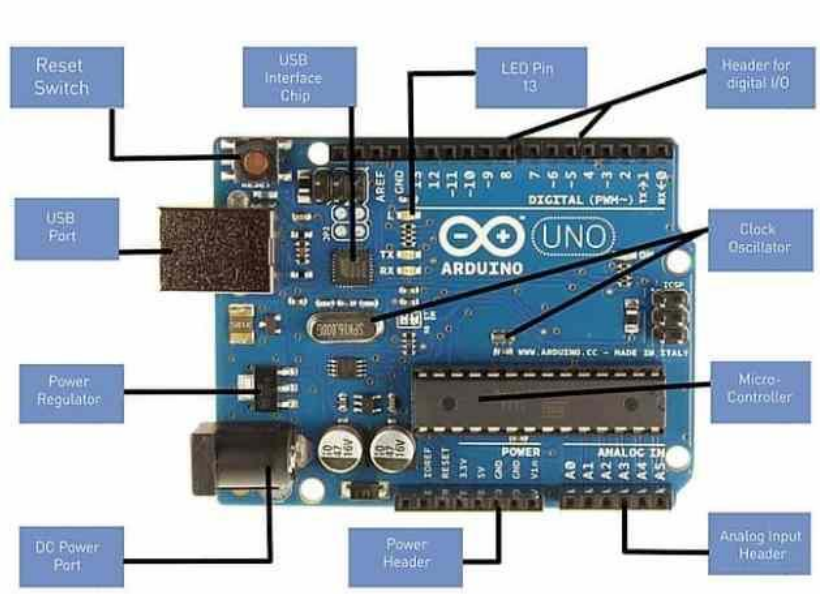
1. RFID Tag and Receiver:

A radio transponder, a radio receiver, and a transmitter are all part of an RFID system. The tag transmits digital data, often an identifying inventory number, back to the reader when activated by an electromagnetic interrogation pulse from a nearby RFID reader device. This number is useful for keeping track of inventories. The radio frequency gets transmitted by the reader when powered ON. When the RFID tag is in close proximity to the reader, the antenna within the tag collects the radio frequency solely. The received radio frequency will be transformed into electrical power, which will allow the tag to send data back to the RFID reader. In addition, the reader will use serial connection to send the tag ID to the external device. A large number of reader modules are now

accessible. For instance, EM-18 is the most widely used and simple to use reader. The RFID passive tag is read by this module, which then sends the tag ID to the Arduino microcontroller.

2. Arduino Board:

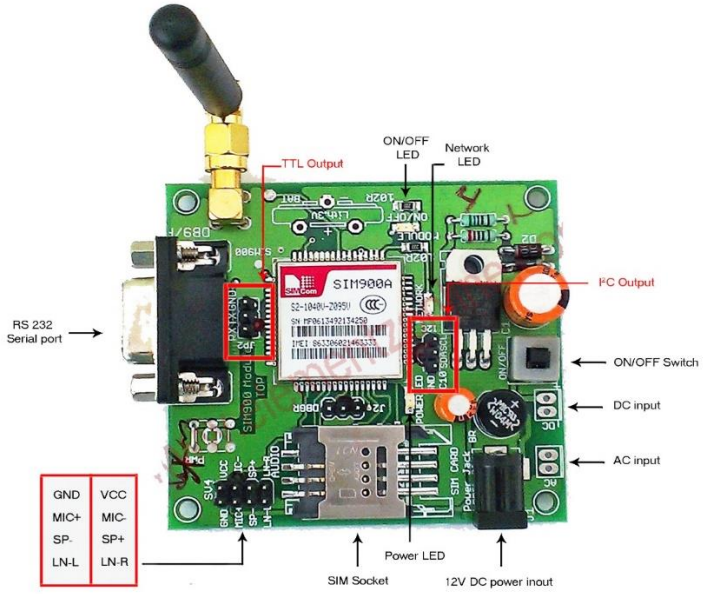
Arduino is an open-source platform that may be used to create electrical creations. Arduino is made up of a hardware programmable circuit board (also known as a microcontroller) and software, known as an IDE (Integrated Development Environment) that runs on your computer and is used to create and upload computer code to the physical board. The Arduino platform has grown in popularity among those who are just getting started with electronics, and for good cause. Unlike most prior programmable circuit boards, the Arduino does not require a separate piece of hardware (known as a programmer) to load new code into the board; instead, a USB cable is all that is required. Furthermore, the Arduino IDE makes programming easier by using a simplified form of C++. Finally, Arduino offers a standard form factor that separates the microcontroller's operations into a more manageable container.



The Arduino Uno is a wonderful choice for beginners and one of the most popular boards in the Arduino series.

3. GSM Module:

GSM (Global System for Mobile Communications, originally Groupe Spécial Mobile), is a standard developed by the European Telecommunications Standards Institute (ETSI). It was designed to specify the protocols for mobile phones' second-generation (2G) digital cellular networks, and it is currently the worldwide standard for mobile communications, with over 90% market share and operations in 219 countries and territories.

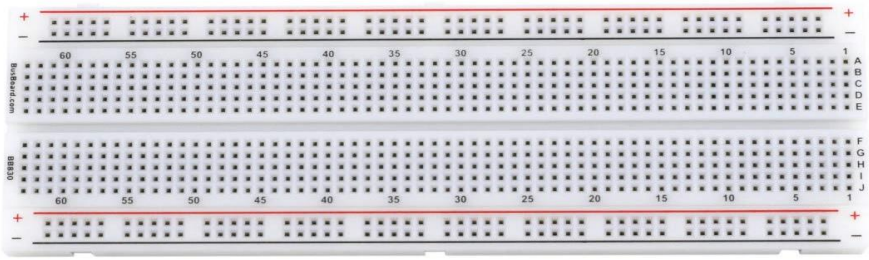


Most 2G GSM networks run in the 900 MHz or 1800 MHz bands, with GSM frequency ranges for 2G and UMTS frequency bands for 3G. Instead, the 850 MHz and 1900 MHz bands were utilised when these channels were previously assigned (for example in Canada and the United States). In rare circumstances, certain nations allocate the 400 and 450 MHz frequency bands since they were previously utilized for first-generation systems.

4. Bread Board:

A breadboard is a rectangular piece of wood with a lot of mounting holes on it. They're used to link electronic components to single-board computers and microcontrollers like the Arduino and Raspberry Pi. The connections aren't permanent and may be deleted and reinstalled at any time. We use a breadboard to quickly connect components such as resistors, LEDs, and capacitors so

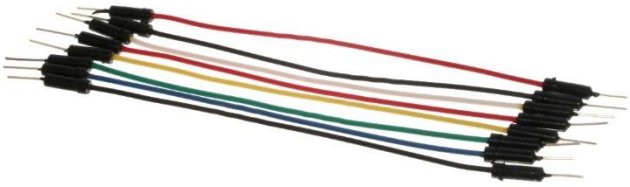
that you can test your circuit before permanently soldering it together. Breadboards feature a lot of tiny sockets, and some of them are electrically linked to one another.



5. Jump Wires:

A jump wire is an electrical wire, or a set of electrical wires in a cable, with a connector or pin at either end that is typically used to connect the components of a breadboard or other prototype or test circuit, internally or with other equipment or components, without soldering.

For uniformity, different colored cables and color-coding discipline are frequently used. The number of possible colors, on the other hand, is generally far smaller than the number of signal kinds or routes. Typically, a few wire colors are designated for supply voltages and ground (e.g., red, blue, black), whereas others are utilized for primary signals.



6. Ultrasonic sensor:

The ultrasonic proximity sensors use a unique sonic transducer that permits sound waves to be sent and received alternately. The transducer's sonic waves are reflected and returned to the transducer by an item. The ultrasonic sensor will switch to receiving mode when it has released the sound waves. The time it takes for an item to emit and receive information is related to its distance from the sensor.

Ultrasonic sensors produce high-frequency sound waves and assess the echo that is returned to the sensor, determining the distance to an item by measuring the time delay between delivering the signal and getting the echo.

7. Garbage Container:

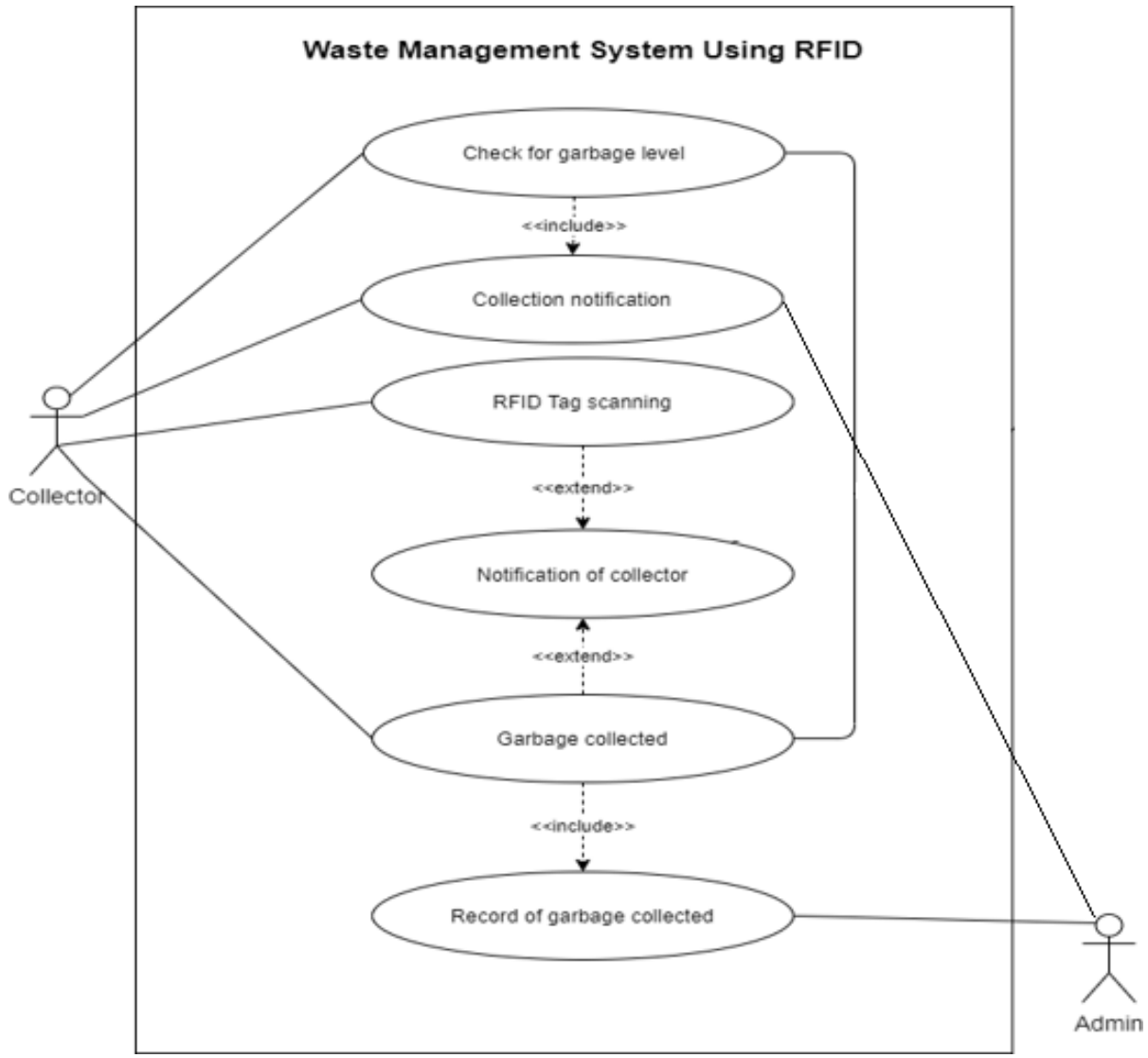
A garbage container is a container that is used to store waste temporarily and is generally constructed of metal or plastic. Trash cans (metal or plastic receptacles), dumpsters (huge receptacles comparable to skips), and wheelie bins are the three most common forms of roadside dustbins (light, usually plastic bins that are mobile). Collectors will empty all of them and load the contents into a garbage truck, which will then be driven to a landfill, incinerator, or consuming crush plant to be disposed of.

Chapter 4

Implementation

4.1. Use case diagram

This type of UML diagram should provide an overall overview of the relationship between actors and systems, making it a great tool for explaining the system to non-technical audiences.



Use case name: Waste management System using RFID

Actors: Collector, User & Admin

Description: The diagram shows how the workflows are occurring in this system. The box represents the main system; ovals are the main use cases and the 3 actors are represented in stick figures. From the diagram, we can see nearby garbage collector gets notification when garbage container is full and after clearing container and scanning RFID tag client/user gets notification as well. After that admin/server gets detailed the data of collection.

Trigger: i) Ultrasonic sensor detects max level garbage
ii) Collector scans RFID

4.2. Data flow diagram

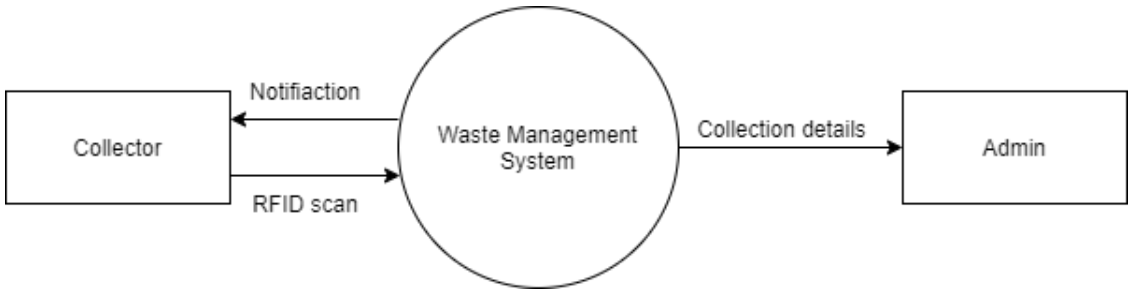
1. DFD or Data Flow Diagram is the representation of the data flowing throughout the system.
2. DFD includes data inputs and outputs, data stores, and the various sub-processes the data movement. DFDs are represented using standardized symbols and notation to describe various entities and their relationships.
3. DFD are categorized by many different levels. Most basic level is level 0. The diagram get gradually complex and elaborated as the level increases. Level 0 is called as context diagram. It provides broad to be easily understandable.
4. There are essentially two different types of notations for data flow diagrams. (Yourdon & Coad or Gane & Sarson) defining different visual representations for processes, data stores, data flow and external entities.

Process Notations: A process transforms incoming data flow into outgoing data flow.

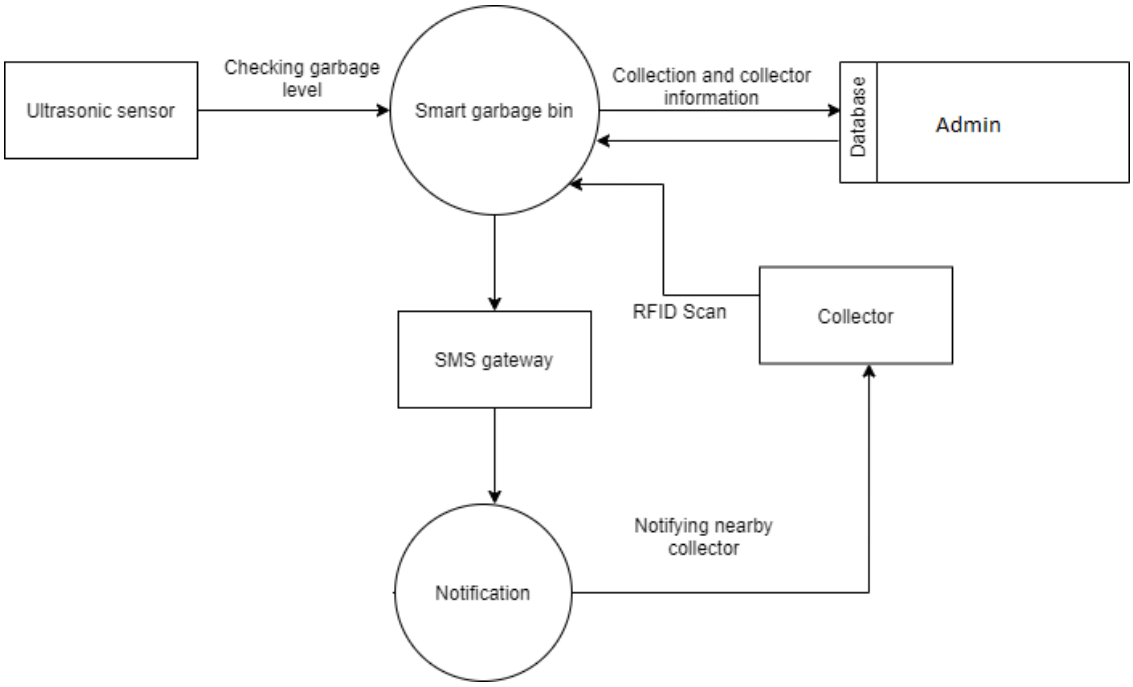
Data store Notations: Data stores are repositories of data in the system. They are sometimes also referred to as files.

Dataflow Notations: Dataflow are pipelines through which packets of information flow. Label the arrows with the name of the data that moves through it.

Level 0:



Level 1:

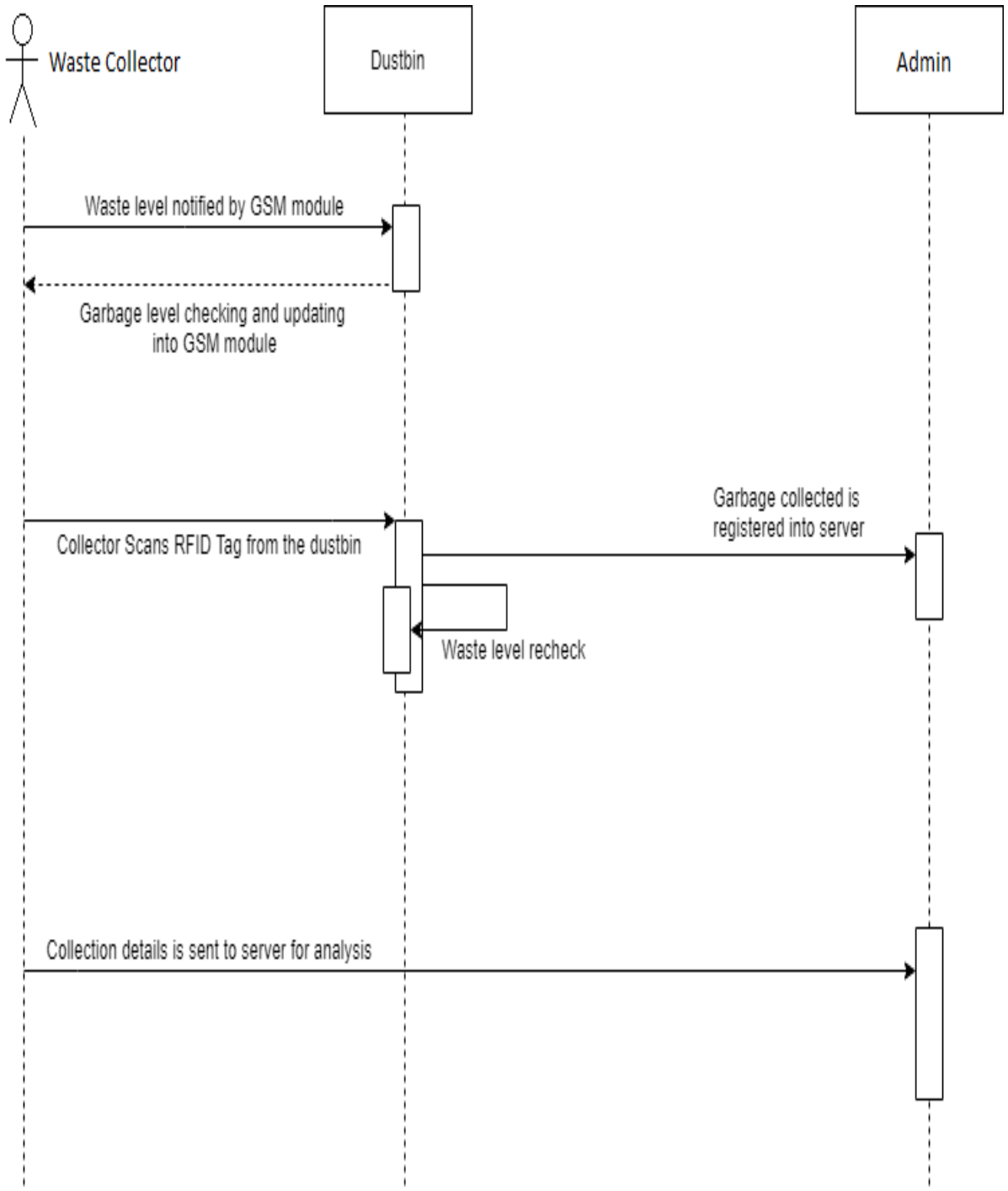


4.3. Sequence diagram

A sequence diagram, also known as an event diagram or an event scenario, represents the order in which objects interact. One can visually represent simple runtime in this manner.

The GSM module informs the collector of the level of garbage, and an ultrasonic sensor checks the waste level. When the collector arrives, he scans the tag, which is attached with the

garbage container. The RFID reader tells the system to send SMS notification to the user and the server when collector arrives and is collected.



4.4. Algorithms used

For communicating with the controller of the bin, we used the algorithm to go accurately with our system. The ultrasonic sensor will sense the density of a certain bin and after reaching the targeted level, the GSM module will send a notification to the municipality or the control station. So, the algorithm we need is based on the simple instruction flow from the GSM module of the smart bin.

Algorithm is written below:

a. Start.
b. Initialize setup.
c. Calculate depth(X) of the bin, set flag= 1
d. Check real time level i.e. fulfilment of garbage in bin and flag status.
e. If depth(X) < 20 Inches, turn on Yellow LED showing that the garbage bin is about to full.
f. If depth(X) < 10 Inches & flag =1, turn on RED Led showing that the bin is full and send SMS to collector and control station.
g. Set flag = 0
h. If depth(X)> 90% & flag = 0, Start RFID
i. Scan Tag.
j. Send SMS to Authority, set flag =1.
k. Else go to step d.

Through this algorithm, we are sending notifications to the control center several times for informing them about the fulfillment of the smart bins.

Code:

```
#include <SoftwareSerial.h>
#include <SPI.h>
#include <MFRC522.h>

#define SS_PIN 10 //RX slave select RFID
```

```
#define RST_PIN 9 // RST pin for RFID

MFRC522 mfrc522(SS_PIN, RST_PIN); // Create MFRC522 instance for RFID.

byte card_ID[4]; //card UID size 4byte
byte Name1[4]={0xC7,0x5B,0x7A,0x7B};//first UID card
byte Name2[4]={0xF3,0xE7,0xDB,0x0A};//second UID card
String Name;//user name
long Number;//user ID
int n ;//The number of card you want to detect



SoftwareSerial sim800l(0, 1); // RX,TX for Arduino and for the GSM module it's TXD RXD, they should be inverted


const int redLed = 8;
const int yellowLed= 6;

const int echoPin = 2; // Echo Pin of Ultrasonic Sensor
const int pingPin = 3; // Trigger Pin of Ultrasonic Sensor

char smsCollector= "Container ID: Mohakhali-Wireless-02, Status: FULL ";
char smsAuthorityFull= "\'{\"dustbinName\":\"Mohakhali-Wireless-02\", \"status\": \"full\"}\'";

char smsCollectorInfo1= "\'{\"dustbinName\":\"Mohakhali-Wireless-02\",\"status\": \"cleaned\", \"empName\":\"Shakhawat Ali\", \"empID\":1234}\'";
```

```
char smsCollectorInfo2= "\'{\"dustbinName\":\"Mohakhali-Wireless-02\",\"status\":\"cleaned\", \"empName\":\"Anwar Parvez\", \"empID\":5678}\'";

bool flag=1;

void setup()
 {
    Serial.begin(9600); // Starting Serial Communication GSM
    sim800l.begin(9600);

    pinMode(pingPin, OUTPUT); // initialising pin 3 as output Ultrasonic
    pinMode(echoPin, INPUT); // initialising pin 2 as input Ultrasonic

    pinMode(redLed, OUTPUT); // installing pin 8 as red led output**
    pinMode(yellowLed, OUTPUT); // installing pin 6 as yellow led output**

   // RFID Setup
    SPI.begin();  // Init SPI bus
    mfrc522.PCD_Init(); // Init MFRC522 card
 }

void loop()
 {
        long duration, inches, cm;

        digitalWrite(pingPin, LOW);
        delayMicroseconds(2);

        digitalWrite(pingPin, HIGH);
```

```
        delayMicroseconds(10);

        digitalWrite(pingPin, LOW);
        duration = pulseIn(echoPin, HIGH); // using pulsin function to determine total time
        inches = microsecondsToInches(duration); // calling method
        cm = microsecondsToCentimeters(duration); // calling method

        Serial.print(inches);
        Serial.print("in, ");
        Serial.print(cm);
        Serial.print("cm");
        Serial.println();

        delay(100);


// led logic codes.....................................................

          if(inches>10 && inches<20) {
                digitalWrite(yellowLed, HIGH);
                delay (100);
           }
            else{
                digitalWrite(yellowLed, LOW);
            }

          if(inches <= 10){
                digitalWrite(redLed, HIGH);
                delay (100);
```

```
            }
            else{
                digitalWrite(redLed, LOW);

             }

 //Waste Collection logic codes.....


  // RFID working logics & Device Activation:

  if(inches > 30 && flag==1){

    //RFID look for new card :

       if ( ! mfrc522.PICC_IsNewCardPresent()) {
            return;//got to start of loop if there is no card present
           }

        // Select one of the cards
       if ( ! mfrc522.PICC_ReadCardSerial()) {
            return;//if read card serial(0) returns 1, the uid struct contians the ID of the read
card.
           }
        // Checking & Matching User ID with scanned tags
            for (byte i = 0; i < mfrc522.uid.size; i++) {
               card_ID[i]=mfrc522.uid.uidByte[i];

                if(card_ID[i]==Name1[i]){
```

```
                Name="Shakhawat Ali";//user name
                Number=1234;//user id
                  }
                else if(card_ID[i]==Name2[i]){
                Name="Anwar Ali";//user name
                Number=5678;//user id
                 }
                  else{ }
               }


  //.....sending Activation / Waste Collection confirmation SMS to Authority....
             if (Number == 1234){
               SendSMS(smsCollectorInfo1);
               }
               else if(Number == 5678){
               SendSMS(smsCollectorInfo2);
                }
                else{}
          flag=0 ;
  }
  else{}


  // GSM sms sending logics :
    if (inches<=10 && flag==0){
          if  (sim800l.available()){                    //Displays on the serial monitor if there's a
communication from the module
           Serial.write(sim800l.read());
```

```
            }
            else{ flag=1;}

     SendSMS(smsCollector);
     SendSMS(smsAuthorityFull);
     flag=1;
      }
 }

long microsecondsToInches(long microseconds) // method to covert microsec to inches
              {
               return microseconds / 74 / 2;
              }
long microsecondsToCentimeters(long microseconds) // method to covert microsec to
centimeters
              {
                return microseconds / 29 / 2;
              }



void SendSMS(char msg)
       {
         Serial.println("Sending SMS.............");            //Show this message on serial monitor
         sim800l.println("AT+CMGF=1\r");               //Set the module to SMS mode
         delay(100);
    sim800l.print("AT+CMGS=\"+8801791693954 \"\r"); //Phone number with country code
         delay(500);
    sim800l.print(msg);       //This is the text to send to the phone number
```

```
delay(500);
sim800l.print((char)26);// (required according to the datasheet)
delay(500);
sim800l.println();
Serial.println(msg);
delay(500);

}
```

Chapter 5

Development

5.1. System Development

Primarily, we came up with this idea of cleaning our nasty city in a smart way. The people of the city are producing more and more trash than they can even think. The extraction of all of these wastes don't go cheap. The government is spending every year lots of money but all in vain. It is failing to manage all of the city's waste properly. So, to keep our city clean and based on the idea, we started our project of waste management using IOT. We used a "Smart Bin" and RFID system for our waste management system.

First of all, we started with the diagrams. The diagrams that are needed to understand how the system should work. The use case diagram that models the behavior of the system and shows the details of system's users and their interactions with the system. Then comes the Data Flow

diagram, which helps to visually represent the whole system and it is easy to design the whole setup using the data flow diagram. Then, there is also Sequence diagram needed for expressing the interactions of the external elements with the system. After going with some such diagrams, the algorithms, the codes should come before. The algorithm is the whole process that the system should follow.

Following the algorithm, we started writing the code for the system. The code that was needed for the system, for the sensors to work properly. Finishing up the code, we implemented the software system of our project.

The designed module containing the ultrasonic sensor, Arduino, RFID reader, GSM module etc. is installed into the smart garbage bin.
An ultrasonic sensor is used to measure distance. The sensor uses ultrasonic sound wave and it counts the time for the reflected waves to come back to the sensor from the targeted object. We set the distance sensor at the top of our smart bin and faced down. That's how it is going to measure the distance and calculate how much full the bin is. The ultrasonic sensor will check the level of the garbage and send the data to the Arduino. When the ultrasonic sensor's reading matches with the pre-determined reading of bin being full in the code, the Arduino will send the update to the server as well as the cleaner via GSM module and red LED will turn on showing that the bin is full.

In the project we are using two (red and yellow) LEDs. The yellow LED will turn on when the bin is about to full or the garbage level distance from the sensor is less than 25 inches. Then, we have set the state of turning on red LED at 10 inches distance of garbage level from the top.

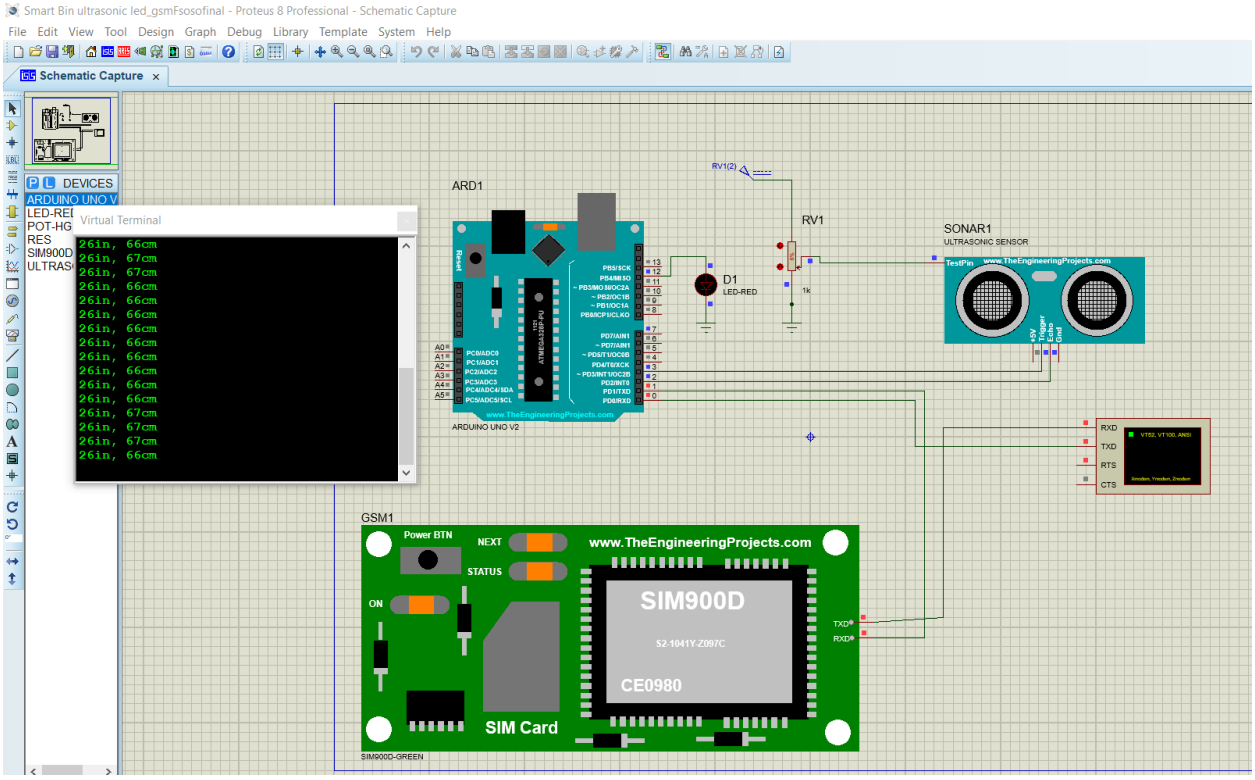


Image: Ultrasonic sensor reading data.

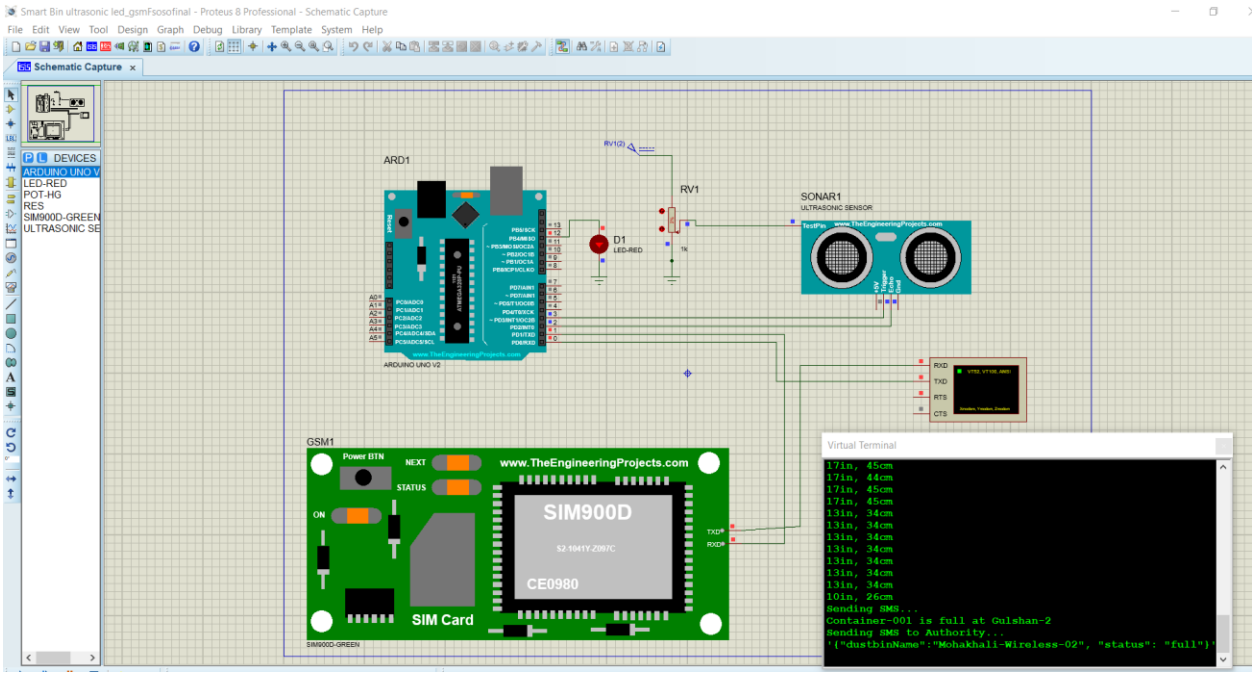


Image: The red LED and GSM module turns on when the distance from the top is 10 inches.

When the red led turns on, the GSM module turns on as well. The GSM module will then send the predetermined unique dustbin code along with the location to the cleaner and the server. Here to mention that, in the server site the SMS will be a JavaScript JSON object. The dustbins and the manpower for unloading the dustbin must be distributed in a regional way. For example, Dhaka north city corporation can divide Mohakhali area in several zones. One zone is Mohakhali Wireless area. Suppose there are 3 dustbins in this place. So, the dustbins can be named in this manner (Region-Zone-Bin Number). For example: “Mohakhali-Wireless-01”, “Mohakhali-Wireless-02”, “Mohakhali-Wireless-03”. When the appointed cleaners get the message of dustbin is loaded, they will go to the spot and clean the bin. In case of server the SMS will be like this: '{"dustbinName": "Mohakhali-Wireless-02", "status": "full"}'.

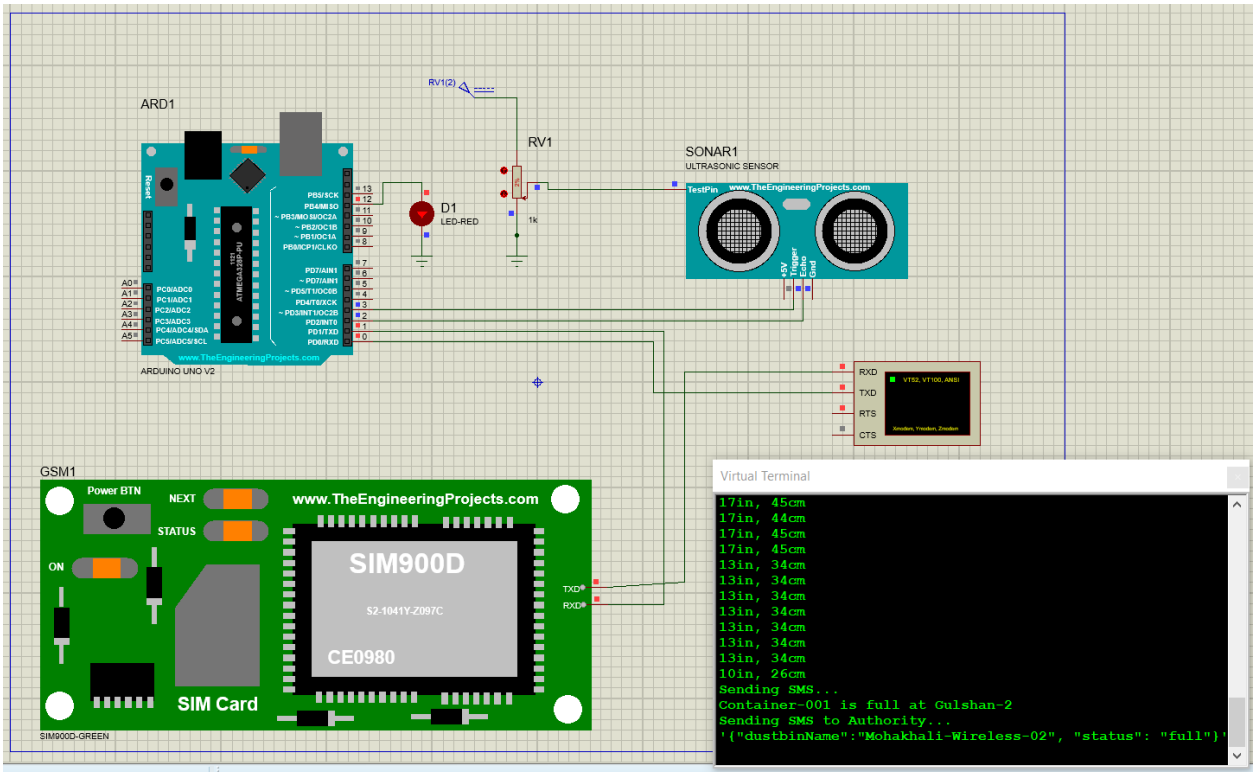


Image: SMS with dustbin name and location is sent to the cleaner using GSM module

After unloading the bin, the cleaner will scan his RFID tag or RFID ID card. Then these data will also be sent to the server via SMS in JSON object format. For example: '{"dustbinName":"Mohakhali-Wireless-02","status": "cleaned", "empName":"Shakhawat Ali",

"empID":1234}'. This SMS data will be directly caught by a JavaScript variable as an object. This whole process will be able to keep a clean city time to time, also this will keep track of the employees of the city corporation or municipality if they are doing their jobs properly or not. In the perspective of Bangladesh this is the most efficient way to build a smart city at a minimum cost.

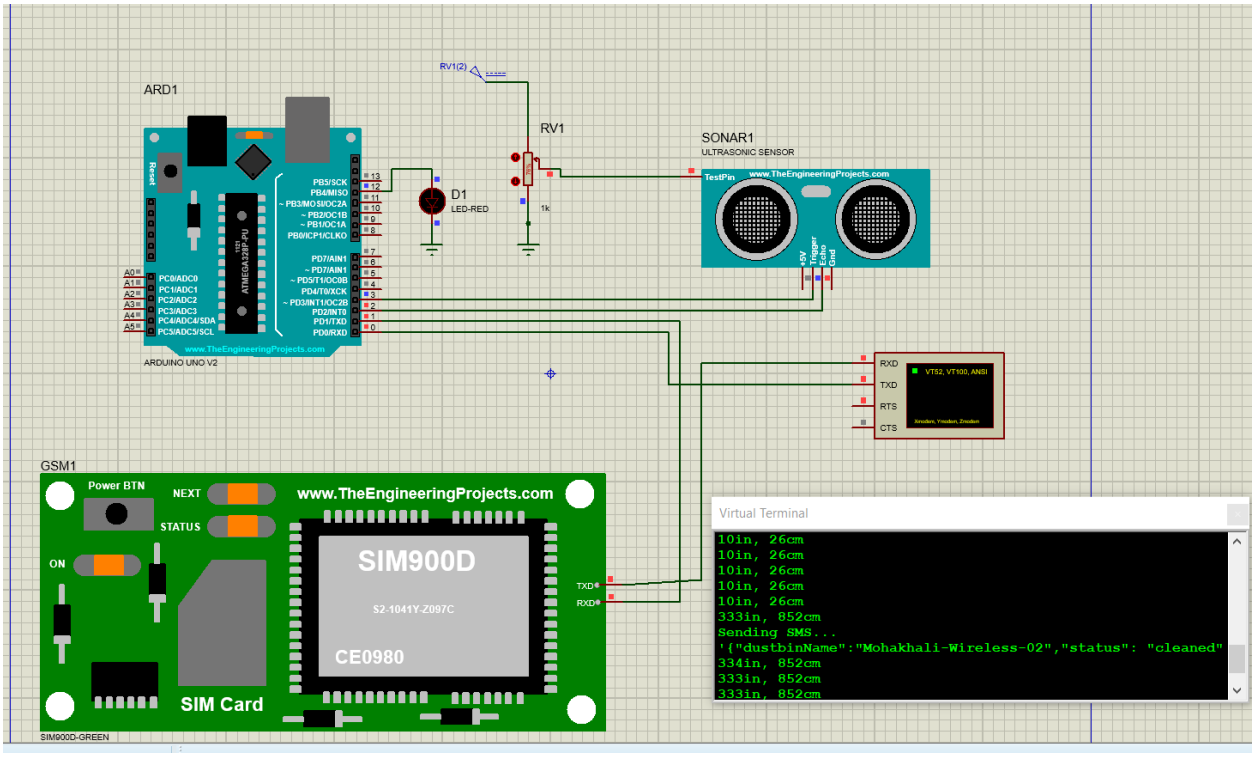


Image: The cleaning's information sent to the server

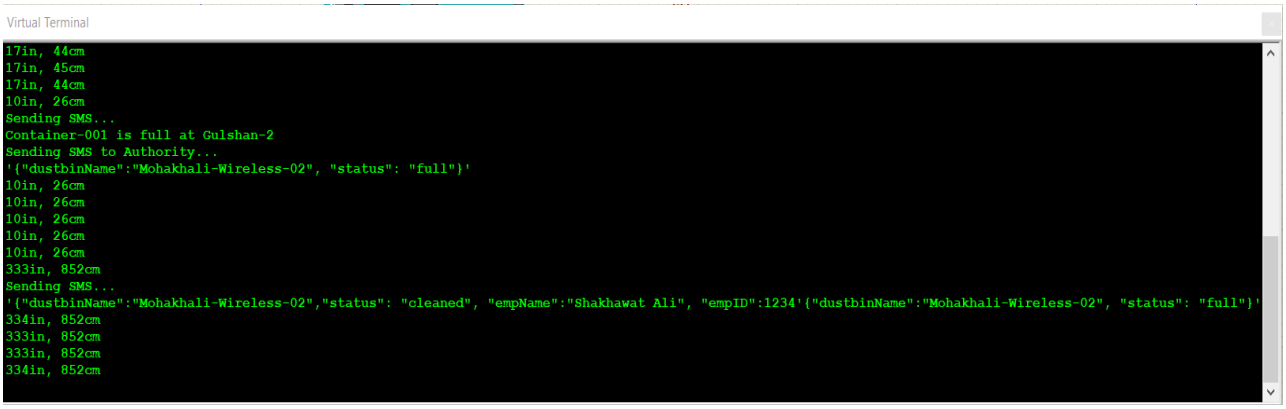


Image: Whole working procedure of the system

5.1.1. Development Cost:

Serial	Product Name	Unit	Price
1.	Arduino Uno R3 SMD	01 Pc	539
2.	Ultrasonic Sensor	01 Pc	100
3.	5 mm Red LED	03 Pcs	5
4.	5 mm Yellow LED	03 Pcs	5
5.	SIM800L Mini GPRS GSM Module	01 Pc	450
6.	RC522 RFID Card Reader Module	01 Pc	185
7.	Breadboard	01 Pc	65
8.	Jump Wires (Male, Female)	20 Pcs	60
	Total		1409 BDT

This cost is estimated for building one device using the local market price. When massive production is done the cost will be at most 1000 BDT for each. This can be the lowest cost for this multifunctional smart bin.

5.2. System Development Analysis

In our system we focused on reducing the development cost. We used cheaper sensors like Ultrasonic Sensor for the detection of the garbage level of our smart bin. Here we could use other sensors like the IR sensor to make it more cost efficient. But in terms of reliability, the ultrasonic sensors are much more reliable than the IR sensor. As our smart bin will have a top door, so if the door is open at the daytime the IR sensors will not be able to work properly as IR sensors can't work at sunlight. But the ultrasonic sensors use soundwaves for measuring distance at the place of IR light. From this perspective the Ultrasonic sensor is more efficient than the IR sensor.

5.2.1. Accuracy Analysis of sensors:

List of Materials	Ultrasonic Sensor		IR Sensor		(US – IR)
	Std. Dev	Correlation (r)	Std. Dev	Correlation (r)	Correlation (r)
Cardboard	9.3	0.9879	10.6	0.91089	0.88424
Paper Sheet	37	0.2611	20.2	0.97866	0.20663
Sponge	5.8	0.9868	21.6	0.78774	0.72976
Wood	10	0.9999	36.5	-0.32911	-0.32852
Plastic	4.3	0.9995	25.1	0.78681	0.78767
Rubber	4.6	0.9988	58.3	0.90998	0.92163
Tile	11	0.9952	23.8	0.73032	0.73085

Table: Statistical analysis of sensor data against different objects/ barriers

For the analysis, the correlation coefficient (r) between measured and actual distance measurements, as well as IR-US sensor data, was calculated. To assess the consistency of the sensor measurement for a certain type of obstacle, the standard deviation parameter (for individual sensor data set) was also considered. There is a standard benchmarking for the readings of sensors that is stated below:

0.9 and above	Very High Correlation
0.7 - 0.9	High Correlation
0.5 - 0.7	
0.3 - 0.5	Low Correlation
0.3 and lesser	Very Low/ Negligible Correlation

So, according to the benchmark we can see that the ultrasonic sensor gives us the most efficient result than the IR sensor in most obstructions.

There are smart bins projects with load sensors or weight sensors. The load sensor smart bins use the weight of the garbage to determine it is filled or not. But we found that less efficient. Because the weight of the garbage can be different in different times. If a bin is filled with heavy garbage like metal, the sensor might detect the bin is filled and give notification to the control center. Then the garbage collector will find the bin not filled. The vice-versa can happen if there is light weight waste. So, ultrasonic sensor is more efficient than the load sensor.

Also, our dustbin will have air tight body with a top door or cover. This air tight feature will prevent the air pollution. Along with this, our smart bin will be able to handle any garbage no matter what they are solid or liquid. So, there will be no need for using separate bins for solid or liquid garbage. The dustbins can be metal or plastic according to the type of garbage. Plastic Bins can be used in residential areas and metal bins can be used in industrial areas as the industrial areas can produce chemical waste which can be harmful for the plastic bins.

During our research we found that LoRa is an effective option for tracking down the areas where the bins are densely filled or not. But in our project without using LoRa we are focusing on data collection from the GSM module activity. When the GSM module get activated, it will send SMS to the garbage collector and the user. Our system can be used for collecting those active GSMs location data. The data can be stored in a database and using that database it can be identified that which area has the larger number of filled bins and which areas have lower number of filled bins. According to that information, more or less manpower can be deployed to required regions.

5.2.2. Data Transmission Module Analysis:

During our research we used the GSM module instead of any other data transfer modules. In this section, a thorough explanation is given.

Firstly, GPS modules could be used here instead of GSM. GPS module is a modern device which uses satellite for navigation. This is also a low-cost device and shows the pathway to any certain location. This facility can certainly help our system to be more user friendly. But there is other side. Such as, The GPS chip is very notorious for battery draining. It consumes a lot power than any other modules. Except that, GPS signals are occasionally inaccurate due to signal obstructions. Buildings, big trees and extreme atmospheric events can provide inappropriate navigation to the user. Besides, we are planning to raise a extremely low cost waste monitoring device. GPS module is more costly than the GSM. Also, our targeted users of the device are people with any kind of mobile phone. The users won't need to have smartphones or internet connections. Also, it is rarely seen that the people involved with works in dirty environment, use smartphones at least at the time of their work. So, GSM can give him the location more frequently than the GPS.

Secondly, Wi-Fi modules could be used but the problem is again in terms of internet connection. Non-smart mobile phones sometimes don't have the internet connection. So, data transmission would be problem for that. Also, it will cost the user to keep data in their phone to get the notifications.

In maximum cases, for user end data transmission internet is required, but in the present perspective of Bangladesh internet is not that much economic. Network issue is also a major problem in terms of using internet. Even in big cities like Dhaka or Chattogram network issue is often detected. For example, many areas only support 2G network coverage which is not good for internet connection.

5.2.3. Identification Module Analysis:

Doing the analysis of the identification module, we can see that among all the identification modules, RFID is the one who gives much accuracy according to its price. There are some technologies alongside RFID such as NFC, Barcode, QR code, Bluetooth Low Energy (BLE) etc. Firstly, talking about NFC, which is Near Field Communication is cheap just like RFID, but it supports a low range whereas in terms of scanning range, RFID is better than NFC because it has

a better range than NFC. Moreover, thinking about the Barcode or the QR code scanning system that will require quite a cleanliness of the picture of the code attached on the bin to scan the code perfectly. It is though quite impossible to keep the picture of QR code on the bin clean. So, in terms of rapid processing power, there is no module better than RFID. However, the Bluetooth Low Energy (BLE) is a Bluetooth compatible module which works in Bluetooth communication can be used in such condition. It is also quite accurate and reads assets quickly though it has a low covering range than RFID. However, researching the market, we came to know that the pricing of BLE module is quite high in our country which is 1441 BDT whereas, RFID reader is only 189 BDT along with some usable tags. One more advantage using the RFID module is the tags that are reusable because they are covered in plastic.

Furthermore, fingerprint reader could be used for the data collection module of the waste collectors in the smart bin. However, it is quite understandable that the waste collectors would be wearing gloves whenever collecting the waste, it would be a hassle for them to work with the fingerprint scanner and scan their fingerprint. Moreover, in terms of pricing, the fingerprint scanner is more expensive than the RFID. Though fingerprint scanner would give the best result as it scans fingerprint that everyone has a unique one, it is difficult for the workers to work out with it and also it is very expensive.

Talking about another module which is the Wi-Fi RTLS that works in communication with Wi-Fi. In such case, the Wi-Fi module gives more accuracy than the RFID but it requires Wi-Fi enabled device or tag to all those assigned workers which is a bit difficult to execute. In terms to RFID tags, the Wi-Fi tags costs 50-60 dollar more. During our research, we find these types of many modules and among all those, RFID is the best suitable module that gives more accuracy in cheap price and are very user-friendly that the workers will be comfortable to work with.

5.2.4. Development Cost Analysis:

Our System Development Cost (Ordered minimum required pieces) *from local shop			Mass Production Cost (Ordered over 10000 pieces) *from Alibaba.com	
Product Name	Unit (piece)	Price (BDT)	Unit (piece)	Price (BDT)
Arduino uno r3	1	539	1	495
Ultrasonic Sensor	1	100	1	60
5mm red and yellow LED	3	10	10	3
SIM800L Mini GPRS GSM Module	1	450	1	190
RC522 RFID Card Reader Module	1	185	1	80
Breadboard	1	65	1	20
Jump Wires (Male, Female)	20	60	20	40
	1409 BDT		888 BDT (approx. excluding shipping cost)	

The table shows the estimated production costs for a single system developed locally and also the cost for mass production. If this system is under mass production the cost will be cut down almost by half. In addition, traditional waste management system will cost almost 20-30% less if we equip the existing system with this system.

Annually, almost 261 million BDT money is spent after the existing system regarding fuel cost for operations(47million), equipment depreciation cost(100million), labor cost(14million) and maintenance cost(100million) [5]. Which means waste management cost will come down to 209-183 million BDT per year. Moreover, the papers we reviewed earlier related to this work, have more system development cost than this system. So, we can assume our system is much more cost effective than others in the context of Bangladesh. All these calculations are roughly estimated since we have no authority to implement our system over existing system right now.

5.3. Testing & Results:

We have implemented the software and hardware design of our project and we tested the codes, the algorithms, the sensors and we tested the RFID system of getting the information from the tag. After hardware implementation, we are attaching some hardware snaps below showing the testing results.

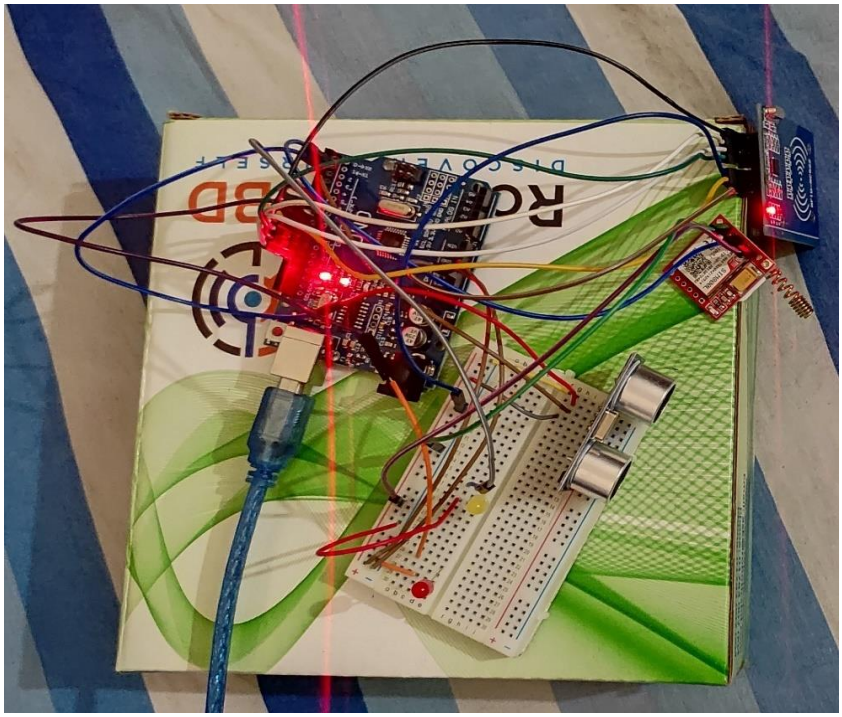


Image: Hardware Setup (i)

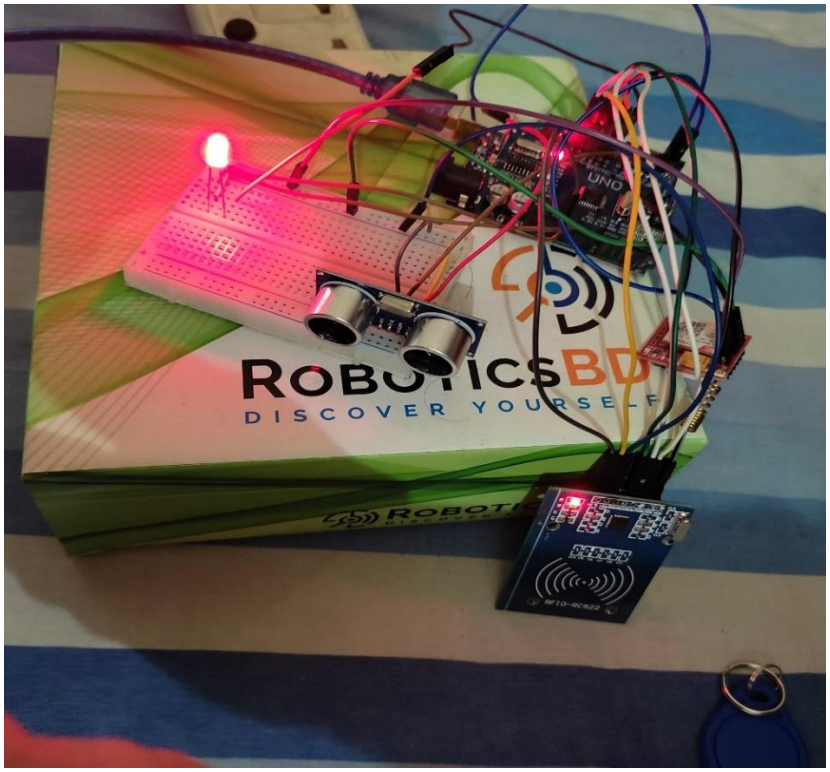


Image: Hardware Setup (ii)

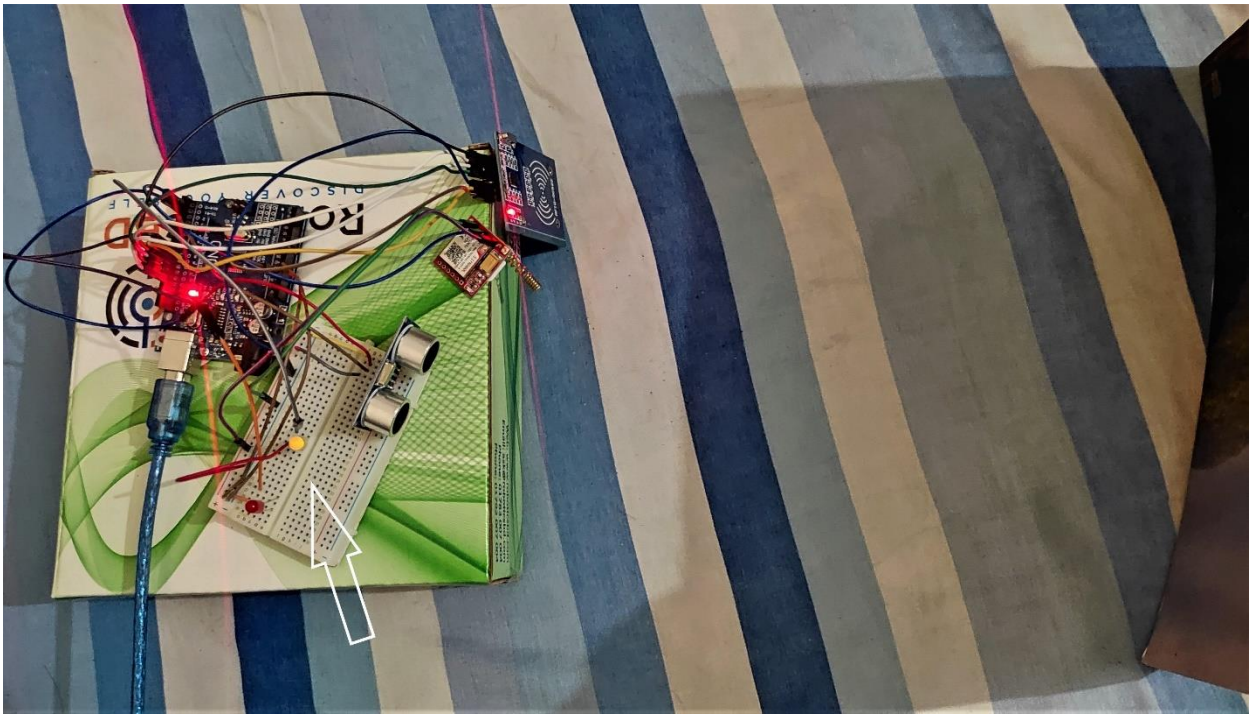


Image: When the distance from the sensor is 20 cm the Yellow LED turns on

Image: When the distance from the sensor is 10 cm or below the Red LED turns on

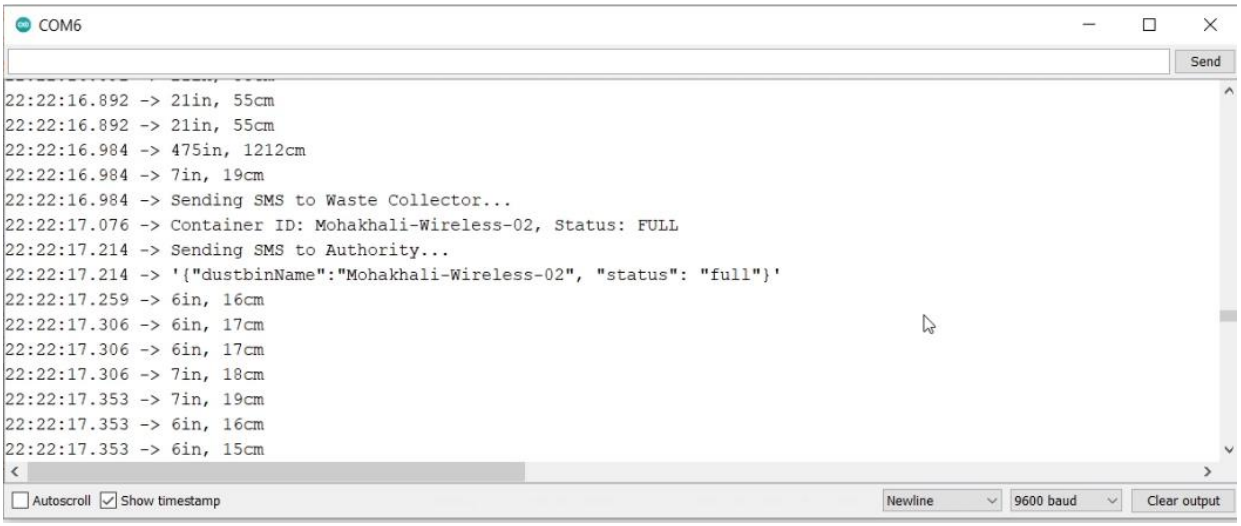
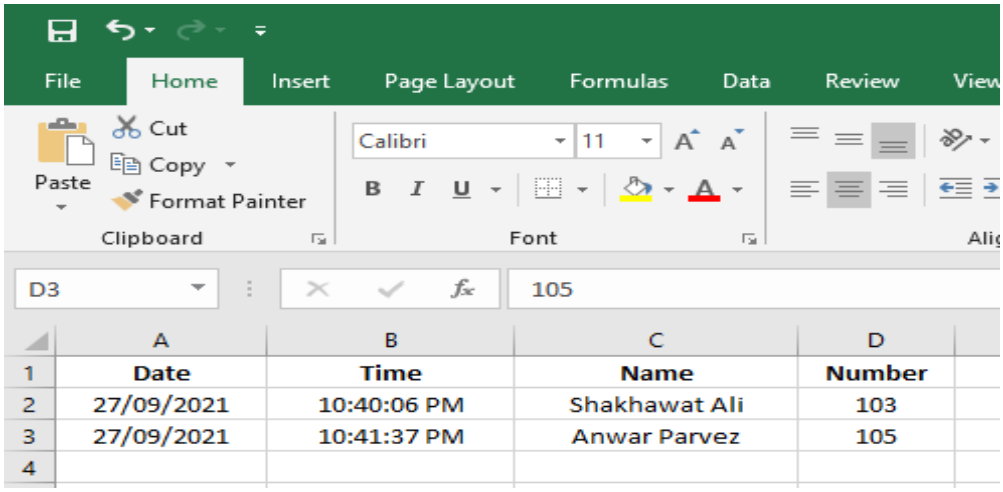


Image: SMS sending after the bin is full

Image: RFID tag is scanned with RFID reader



	A	B	C	D
1	Date	Time	Name	Number
2	27/09/2021	10:40:06 PM	Shakhawat Ali	103
3	27/09/2021	10:41:37 PM	Anwar Parvez	105
4				

Image: Excel sheet result of tags

This is a excel sheet where the basic information collected from the tags (name, id) is listed which is showing of certain sanitary workers are working for certain smart bins in specific areas.

Conclusion & Future Scope

In the final analysis, Bangladesh, a third world, developing country, produces a massive amount of rubbish every day, and it is quite difficult to handle it all at once. With our current waste management system, it takes a lot of time and labor to process all the garbage only in planned cities let alone other areas. Since our country is rapidly developing, RFID-based waste

management systems will undoubtedly be able to help garbage management in our expanding cities, maintain our society and environment clean and sanitary, and minimize waste-related pollution. This system will also be like an invitation and motivation to all the sincere citizens of the country to manage and recycle waste properly and instead of throwing rubbish here and there, they should put it in the dustbin for a more pollution-free and healthy environment. In this age of IoT, this system can make a game-changing difference between this and the regular, old and inefficient waste management system.

Considering the limitations and perspective of our country's city terrains, we have built a very cost-efficient device for mass production. Since no research is free of limitations, we can overcome ours with a lot of future scopes. When this system will be out live and properly funded by the government or private companies, we can upgrade the system to be more accurate with less maintenance cost. This system has great potential for future improvement in the field of portability, maintainability, and power management. It can be upgraded with a GPS tracker to find different locations of the smart dustbin nearby. Also adding a solar panel to the system can make the system automated, sustainable and smaller so that it does not require an additional power supply. In addition, there is another amazing idea with AI integration for future improvement, where the system reads the database of garbage collection and predicts the garbage ammount and notifies nearest collector. The AI will analyze the date, collection time and area, and it will give a time and date when to collect garbage from where, so that the system can become fully automated and there will be less human require to maintain the system.

References:

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