Smart Waste Management System in Smart Cities Using IOT

Submitted in partial fulfilment of the requirements for the degree of

Bachelor of Technology

in

Computer Science and Engineering

by

16BCE2120 M. Sai Rishikesh

16BCE2291 Abhaya Shrestha

16BCE2295 Nitesh Dhital

Under the guidance of

Dr. MOHAN K

School of Computer Science and Engineering

VIT, Vellore.

Winter Semester 2019-2020

DECLARATION

We hereby declare that this thesis entitled "Smart Waste Management System in Smart Cities Using IOT" submitted by us, for the award of degree of *Bachelor of Technology in Computer Science and Engineering* at VIT is a record of bonafide work done by me under the supervision of Dr. Mohan K.

We further declare that this work reported in this thesis has not been submitted and will not be submitted, either in part or in full, for the award of any other degree in this institute or any other institute or university.

Place : Vellore

Date : **Signature of the Candidate**

CERTIFICATE

This is to certify that this thesis entitled "Smart Waste Management System in Smart Cities Using IOT" submitted by **M. Sai Rishikesh 16BCE2120 , Abhaya Shrestha 16BCE2291 , Nitesh Dhital 16BCE2295**, **SCOPE**, VIT, for the award of degree of *Bachelor of Technology in Computer Science*, is a record of bonafide work carried out by them under my supervision during the period, 01. 12. 2019 to 30.04.2020, as per the VIT code of academic and research ethics.

The contents of the report have not been submitted and will never be submitted either in full or in part, for the award of any other degree in this institute or any other university. This thesis fulfils the requirements and regulations of this University and in my opinion also meets the necessary standards for submission.

Place: Vellore

Date: **Signature of the Guide**

Internal Examiner **External Examiner**

Head of the Department

SCOPE

Acknowledgements

The project “Smart Waste Management System in Smart Cities Using IOT” was made possible because all the effort that was put into it. The success and final results of this project necessitated a lot of guidance and help from many people. We are very honoured to be able to do this throughout the completion of this project.

The involvement of our guide was immense and, Dr. Mohan K put in his best efforts to make this project see its light. It would have not been possible to get the project going without his support and cooperation. We would also like to thank all those who directly or indirectly directed us to write this task. Many people, particularly our classmates, have provided invaluable suggestions and advice for our projects, which gave us inspiration to improve the quality of the project. Everything that we have accomplished is solely due to this supervision and assistance, and we would definitely not forget to thank all of them.

The HOD Prof Shanti V also played an integral part in this project. She was not involved directly but her role could not simply be ignored. She helped us compiling this report and also helped us get a general template idea.

Since the completion of the project made us very happy, we would like to thank Dr. Mohan K again because of the good guidance that he provided us for the project in many consultations. We would like to wholeheartedly express our gratitude towards Dr. Mohan K for providing us with the opportunity to carry out this project, and provide us with all the support and guidance by imparting us with all the necessary information to develop a good system until the project work completion.

Finally, we would like to thank Vellore Institute of Technology, for giving us with all the essential instruments and supplies for carrying forth the project. Without the proper environment the project might have never seen its light

.

Executive Summary

The exponential growth of the population poses huge challenges to the waste management system and maintaining a clean environment. Due to improper garbage monitoring and management, many cities in the world are at risk. Our project here aims to get a solution by using smart dust bins that support GSM and WIFI. It uses "ultrasonic sensors" to prevent garbage from overflowing the trash. We have used Wifi module to send the data to the Cloud and use this cloud service to collect the data, store the data, analyze the data, visualize the data and act accordingly on the data we will receive from the sensors used here. Therefore, our project aims to prevent garbage from spilling out of the bin, and to control unhygienic conditions that are common near the bin. Therefore, our project discusses about the ways to establish an effective and efficient waste treatment system

Contents

List of Figures

List of Tables

List of Abbreviations

SWM	Solid waste management
RFID	Radio Frequency Identification
WSN	Wireless Sensor Network
IoT	Internet of Things
GSM	Global System for Mobile Communications
MHZ	Megahertz
USB	Universal Serial Bus
IDE	Integrated Development Environment
ICSP	In-Circuit Serial Programming
AC	Alternating Current
DC	Direct Current
TCP/IP	Transmission Control Protocol/Internet Protocol
SOC	System on a Chip
GPRS	General Packet Radio Service
QOS	Quality of service
HTTTP	Hypertext Transfer Protocol

1. INTRODUCTION

1.1 Objective

The most important reason for proper waste management is to protect the health and safety of the population and for the enhancement of a smart city vision, to reduce the quantity of all waste through the implementation of waste management system and recycling process, maintain a balanced SWM system which helps the community while following regulatory requirements. Other objectives include preventing the pollution, reducing and reusing of different types of waste, safe disposal of all types of waste, also maintaining the sustainable development and encourage waste to the development of energy.

1.2 Motivation

Waste management is the one of the biggest problems now a days faced, which causes different diseases and attract animals. So, to overcome this problem an automation system is needed which must inform the municipal cooperation to clean the bins to maintain the cleanliness of the city.

1.3 Theoretical Background

The total generation of waste in India is about 150 million tones in a day, it mainly includes the solid substances that are unwanted which can be classified according of its origin, potential hazards and the type of material. These solid wastes are laid in the public places as a trash which causes the unhygienic area in the surroundings and causes contagious diseases. Prior to the steps taken for the waste management in the area, trash monitoring and collection steps requires the trash collector tools and the sanitation engineer to visit the place continuously. This human labor and transportation are a tedious process Therefore, some durable and cost-effective means are important for efficient solid waste management. Solid waste becomes contaminated and hazardous when we do not treat on time. It causes big impact on the health, environment and surrounding if not treated before it becomes toxic. To solve the problems and also for sustainable management of wastes in India, Swacch Bharat Abhiyan mission has been organized.

Figure 1: Waste management System Cycle

In order to develop a smart city, use of various technologies such as RFID, WSN, IoT etc. has emerged as an effective smart solution so as to preserve the assets, resources and environmental surroundings. IoT enabled devices are widely been used for different processes like monitoring, collection, transportation and disposal of solid wastes.

2. LITERATURE SURVEY

2.1 Survey of Existing Models

(a) Intelligent Bin Management System for Smart City using Mobile Application

This research paper proposes an idea where an individual user manually sends details about the dustbin to the server through the use of an android application when the bin is filled.

After receiving the respective message, the server will send this information to authorized users. The filled bin can then get cleaned when an authorized user receives the notification from server.

(b) Smart Garbage Monitoring System using Internet of Things (IOT)

This research paper proposes a very innovative system that monitors the garbage bins using ultrasonic sensors and informs about the level of garbage collected in the garbage bins by providing us a graphical image of the bins via a web page. The web page is developed to show the status to the user who is monitoring it.

The web page is also capable of giving a graphical view of the bins and uses color and highlights to show the level of waste collected. Thus, the system is efficient in monitoring the waste whilst also reducing the effort required.

(c) IoT Based Solid Waste Management System Summary

An advanced embedded system is proposed that provides bin information for the corresponding locations by taking the requirements of complex design need with minimized essentials for analyzing different places for restorative needs.

This system checks different sensors to help oversee about the bin status and provides latitude and longitude values. In crisis the framework cautions the personal to oversee about the dangerous levels and conditions for further examination. The system is deemed better due to its use of existing identification processes followed by continuous streaming data using MQTT protocol.

(d) Smart Waste Bin with Real-Time Monitoring System

This research paper presents a framework that enables remote monitoring of solid waste bin in real-time via Wi-Fi connection along with developed subsystems namely solar power system, short messaging service [SMS] notification system and real-time monitoring system.

This system also contains a motion detector in the lid such the bin is aware when the bin is used and triggers the ultrasonic sensor after the lid is closed.

2.2 Summary of this Survey

From the survey it is found that IoT is being used as an effective approach for the management of garbage waste in public as well as private areas. The experimental research done till now is found to be progressive and useful. Although the waste management includes collection, monitoring, disposal, segregation measures etc. but the experiments are found to be more focused on monitoring and collection steps only. Thus, this survey concludes that identifying the initial steps is important and what other measures need to be considered should be addressed. In this regard, more experiments should be done with the help of advanced technologies to make the smart waste management system so as to develop a smart city. Following points are observed from the survey which are given below;

- In our Survey we tried to classify each model used in research papers. From the survey it is found that IoT is being adopted as an effective approach for the management of waste in public areas.

- The experimental research done till now is found to be useful and progressive. Although the waste management include monitoring, collection, disposal, segregation measures, the experiments are found to be more focused on monitoring and collection steps only.

- Thus, this survey concludes with identifying the initial steps and what other measures need to be considered. In this regard, more experiments should be done by using advanced technologies to avail the smart waste management system so as to develop a smart city.

3. PROJECT DESCRIPTION AND GOALS

Instead of using different types of bins in improper way around the city, we can have a smaller number of smart dustbins that can be placed making them more feasible and affordable. Therefore, our problem statement here is to design a model which will based on a microcontroller using required methodology for collecting many garbage from different areas where garbage bins are overflowing with prior concern. This technique is advanced when garbage management is automated. This system here makes use of microcontroller, RFID, Wifi and GSM Module for sending data into the cloud. Different types of sensors can be used to detect the level of dust collected in the bins, to detect the toxic substances around the bins and to segregate the garbage. Also, compression technique can be used to compress the solid waste inside the bins itself.

4. TECHNICAL SPECIFICATION

Materials & Methods

Arduino:

Arduino UNO is an open source microcontroller board that is manufactured by Arduino. The evaluation board is equipped with many input and output lines, which may be connected to different boards and circuits. This board has 14 digital input pins and output pins. There are 6 PWM output pins. 6 analogue inputs, 16 MHz, power supply point, ICSP connector and reset point, and is programmable with the Arduino IDE through a USB connection.

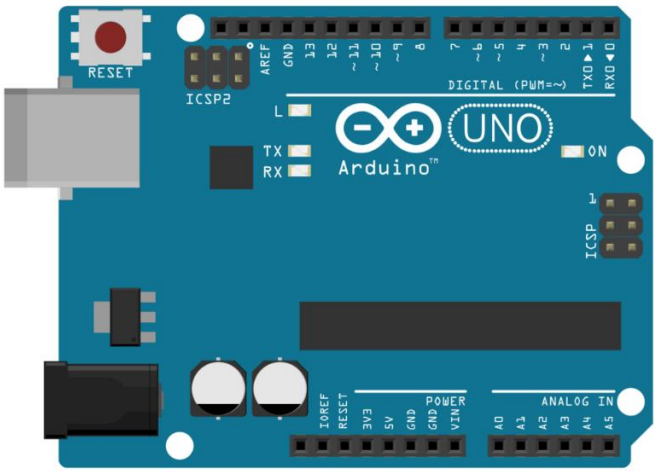

Figure 2: Arduino Uno microcontroller

Ultrasonic Sensor:

An ultrasonic sensor is a type of sensor which can emit high-frequency sound pulses and record the time it takes for the signal to reflect back. Because the measurement method of the ultrasonic sensor works reliably, it can solve even the most complex tasks, including object detection or level measurement in millimetres. The sensor surface can also clean itself by vibration, which is one of the reasons why the sensor is not sensitive to dust.

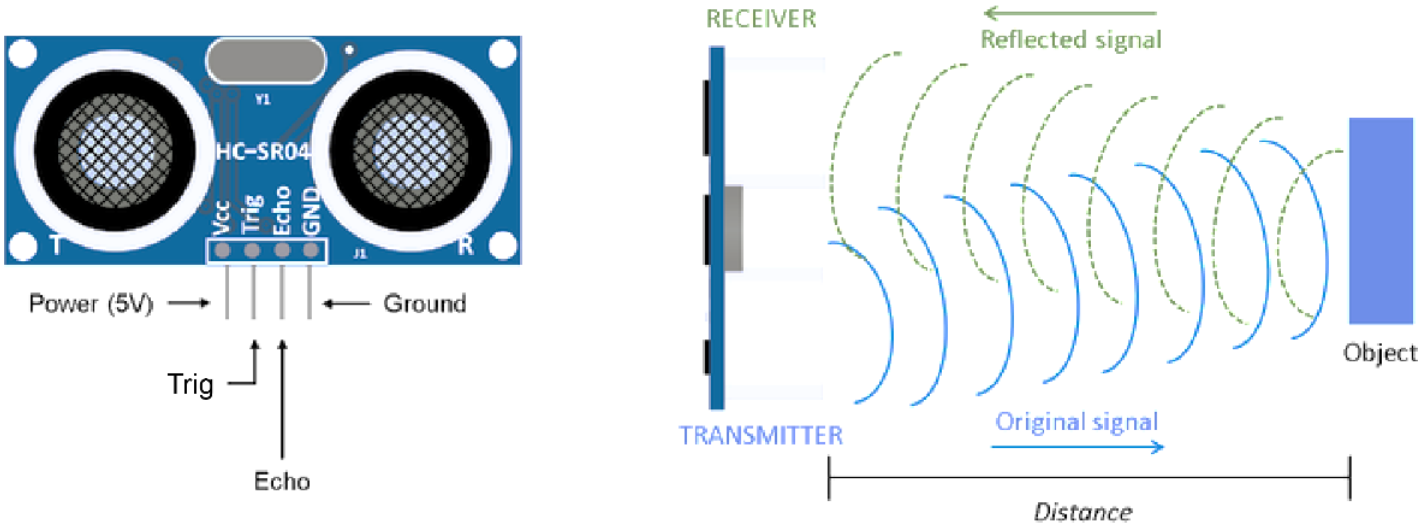

Figure 3: Ultrasonic Sensor

WIFI module:

ESP8266 is a less expensive Wi-Fi chip with a complete TCP / IP protocol and microcontroller functions. This module helps to send the data that will be received from the sensor to the cloud that we will be using. It acts as a communication device. It will be connected to Arduino board with the help of jumper wires.

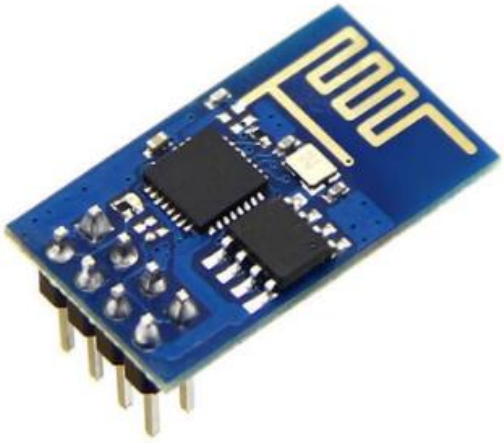

Figure 4: WIFI module

Jumper Wires:

A jumper can be defined as a cable or a group of cables with a connector or pin on each end of the cable, typically used internally or with other devices or internally interconnected breadboards or other prototype or test circuit components without soldering.

` *Figure 5: Jumper Wires*

GSM module (Sim900A):

GSM module can be defined as a type of circuit which can be used to establish communication between a mobile or compute device and a GSM system This will be used to send the information about the bins to the authorized user.

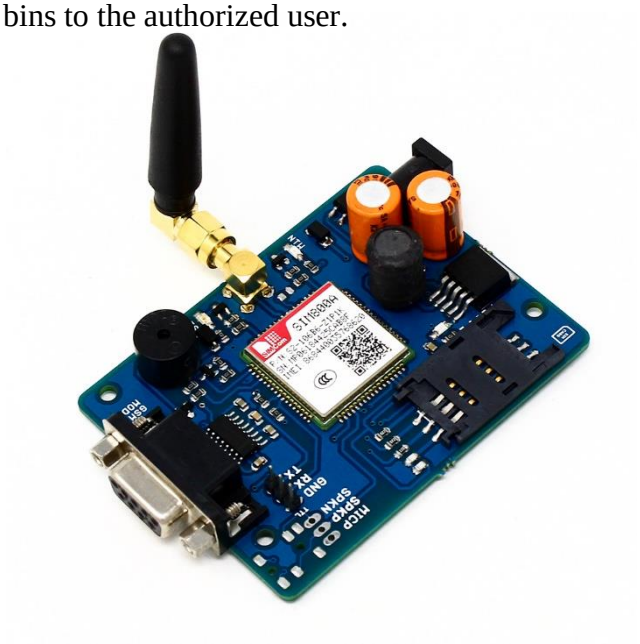

Figure 6: GSM Module

Cloud (Thingspeak):

Thingspeak is a cloud service that can handle and visualize multiple feeds of data. We will be using this cloud service to collect the data, store the data, analyse the data, visualize the data and act on the data we receive from the sensors used.

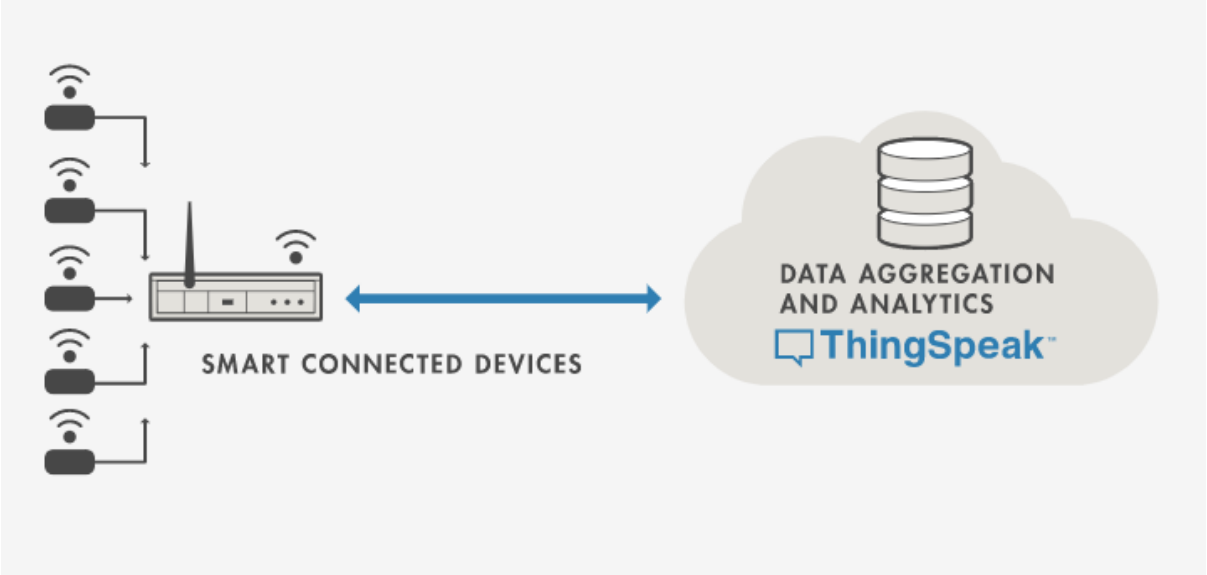

Figure 7: Thingspeak Cloud

5. DESIGN APPROACH AND DETAILS

5.1.Design Approach

This work has focused on the implementation of waste management in smart cities and also monitoring system using sensors, Arduino and WIFI module integrated with IoT. The status of the dustbin can be continuously monitored at the control station to provide an easy user interaction with the system. The values stored in the database of the system helps a user to have the updated status of the bin as well as the previous values of the parameters of the dustbin. This system helps to monitor and analyze the waste management properly in a real time environment.

Advantages:

- It doesn't take much time.
- Low cost of transportation.
- It reduces human efforts.
- It will help to enhance smart city vision.
- It reduces pollution
- It supports Swacch Bharat Abhiyan mission.

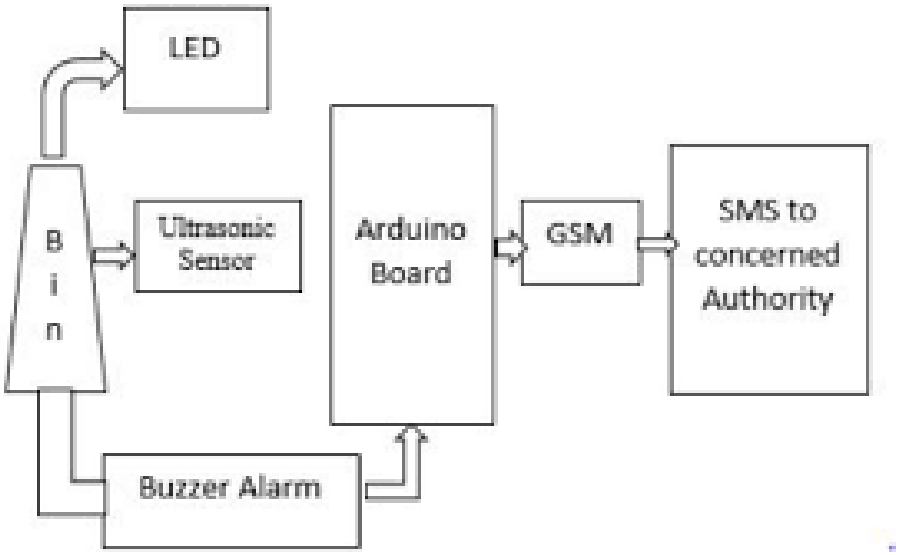

Figure 8: Process Flow Diagram

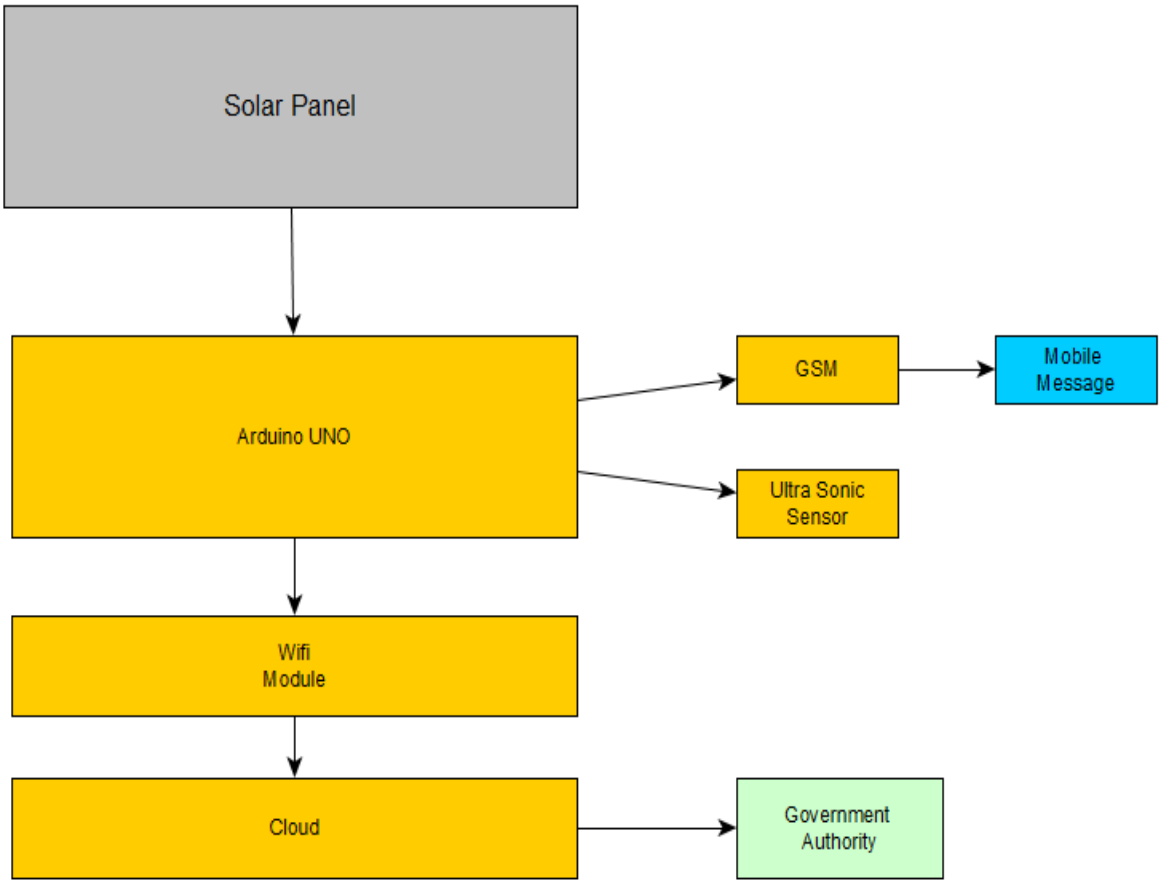

Figure 9: Block Diagram of Proposed System

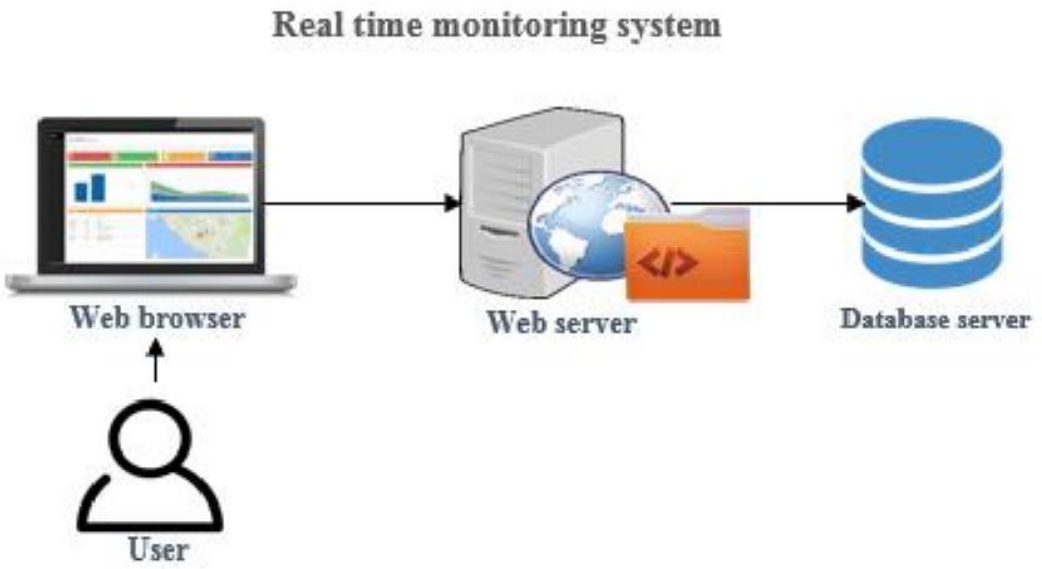

Figure 10: Architecture of Real time Monitoring

5.2 Module Description

(a) Sensing the data

The Ultrasonic sensor that we use will to detects the level of the waste present in the bin. This sensor will transmit the waves in the range of 100cm. The sensor transmits the waves from its head and receives the waves reflected from an obstacle. Ultrasonic sensor consists of four pins i.e. Echo, Trig, GND and Voltage which are connected with Arduino board.

(b)Analog to digital conversion

The data which we have been received from the sensor will be then stored in microcontroller. The ESP8266 runs on any device. We preferred using a 3.3-volt power source. The conversion consists of some steps such as sampling, quantizing and encoding. 230v is given as an input through power adaptor but the output will be in 9v.

The microcontroller used here is ESP 8266. This module is an IoT device that consist of a 32-bit ARM which supports WIFI. It also supports a built-in flash memory

(c) Data storing

The data that is stored in the microcontroller is then transferred to the Database. The WiFi is then utilized with the help of WIFI system in the microcontroller. The cloud server which is used in our project is Thing Speak. It is an open source API platform to retrieve and store data from different types of Iot devices by using HTTP protocol over an internet. It also helps to design a location tracking application, sensor logging system applications as well the social network of things by adding many status updates.

5.3 Codes and Standards

Where -

This system is designed to be suitable for both rural areas as well as urban areas aiming to convert into smart cities along with people with less accessibility to healthcare infrastructures and proper management of waste.

What -

This is an IOT based system that is capable of collecting data from various locations or defined points and relay the information to the selected delegate as well as transmitting the obtained data to the cloud for further analysis.

How –

The system is built using the Arduino UNO microcontroller, Arduino IDE and various sensors that are used for data collection along with a GSM module that establishes connection between the system and a mobile device. A WIFI module is also used to relay the collected data for further analysis using Thingspeak cloud service.

5.4 Constraints, Alternatives and Trade-offs

Constraints

One of the major constraints our system comprises in its current state is power management. Our system relies on data collection from the surrounding or selected locations for analysis. Since, the system will always be working despite the rather unpredictable nature of people and their waste management habit. The result can be an inefficient use of power. This problem can be tackled by the incorporation of machine learning in the system. Machine learning can help us detect a pattern through which we can place a variety of rules that govern the working time of the systems that will help us manage power and make the system more efficient.

Secondly, our system is kept out in the open. This can result in tampering and hence mess up the data obtained. Since, our system also heavily relies on software implementation. Hardware, along with software tampering can also breach our security and privacy.

Therefore, in order to meet challenges, a new architecture needs to be proposed, focusing on many key factors i.e data integrity, sustainability, reliability, and confidentiality.

Alternatives

Features	**Proposed Model**	**Alternative Model**
Operating system	WINDOWS 10	Any latest windows, Linux, Mac or ubuntu
Mobile device	Android	Any device
Language	Arduino	Any Latest Language
System Requirement	Ram 8 Gb, Graphics- NVIDIA Processor: - Intel i5	Ram 4Gb, Graphics: -NVIDIA Processor: - above i5
Software	Arduino	Based upon your project language
Hardware requirement	GSM, Arduino UNO, RFID, Ultrasonic sensor	Based upon your project and Requirement you can apply model on Hardware components.
Model Testing	Easily run and test in the Arduino IDE	It varies project to project
Suitable for Real time	Yes	It varies project to project

Table1: Alternatives of the proposed model

Trade-offs:

In this project we compared our innovation with other research which was done before in the field of waste management system. So, by implementing out innovative idea, government can easily do following 5 steps easily to properly manage the waste which are Monitoring, Collection, Transportation, Processing and Recycling**.** The main benefits of this innovation will be that many environmental problems like water pollution, land pollution, air pollution and outflow of greenhouse gases can be minimized to a great extent.

6. SCHEDULE, TASKS AND MILESTONES

Schedule

We started this project in December, initially we started by studying various research paper and made a comparative analysis (literature survey) for the project, then we started implementing the project.

Task	Time (in days)	Time (Starting day – ending day)
Problem Definition	7	1-7
Research	8	8-15
Prototype development	16	16-30
Finding best solution	6	30-35
Design	210	36-56
Hardware connection	14	57-70
Coding	16	70-85

Cloud computing	10	86-95
Final implementation	15	96-110
End result	6	110-115
Follow UP	11	115-125
Documentation	___	125- remaining days

Table 2: Schedule

Tasks

The whole framework of this project is divided into 3 main tasks where each task contains subtasks to function properly and to provide each deliverable.

The Three tasks module are given below:

Task-1: Problem Definition

i) Defining the Problem.
ii) Defining the Approach
iii) Action

Task -2: Innovation

i) Looking for insight for prototyping of the solution.
ii) Prototyping Potential Solution.
iii) Delineating the end results.

Task -3: End Results

i) Choosing the Best solution and then initiating it.
ii) Delivering the Results

After completing various tasks which are listed above, it converts into different milestone and all the major milestones are given below.

Milestones

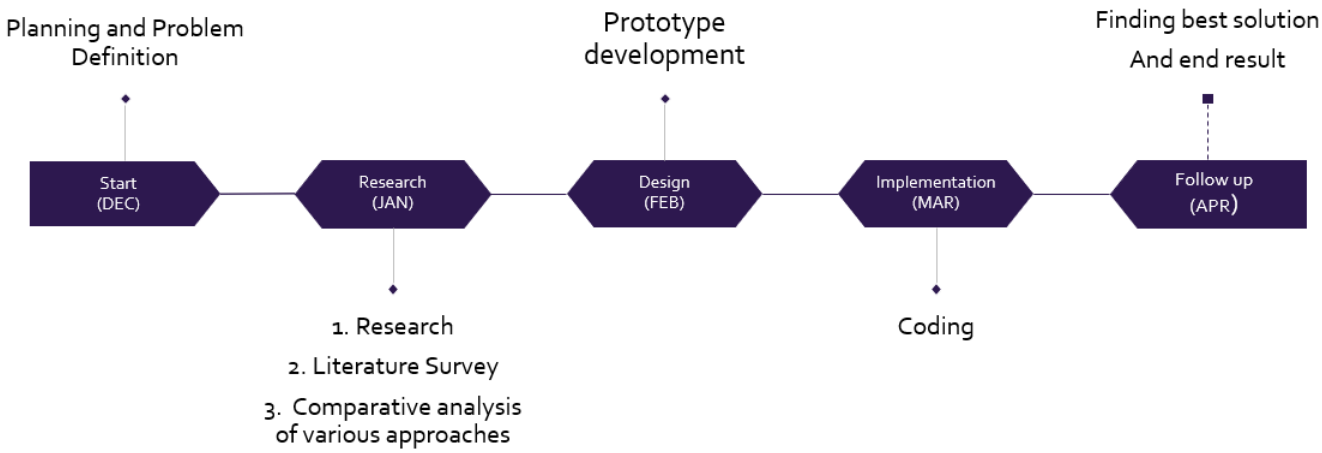

Figure 11: Milestones

7. PROJECT DEMONSTRATION

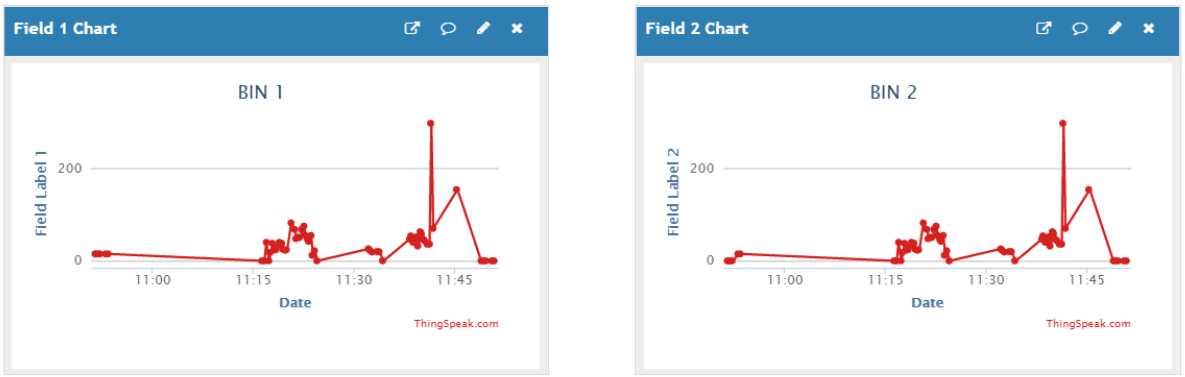

Figure 12: Bin waste Chart

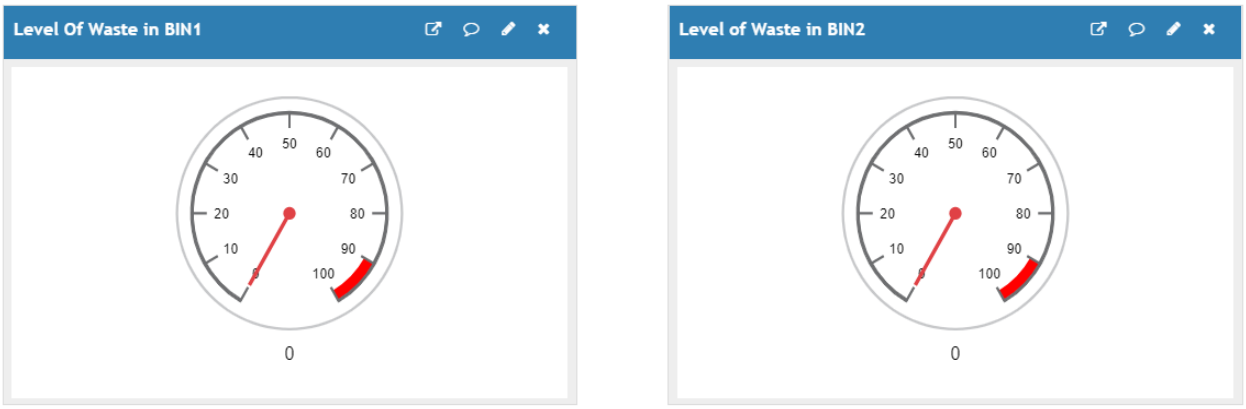

Figure 13: Level of waste Displayer

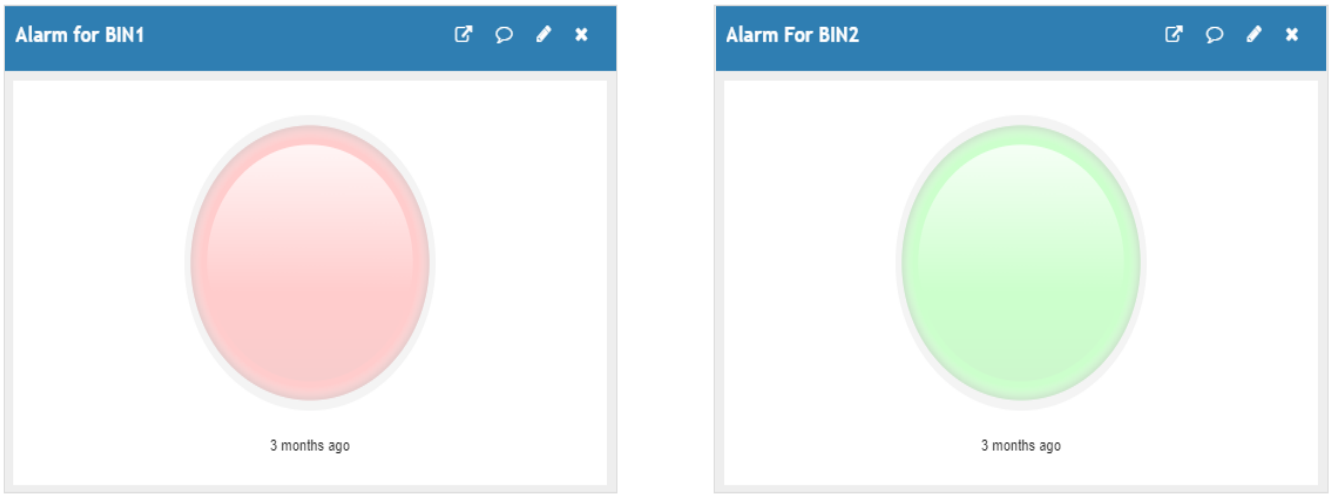

Figure 14: Alarm for Dustbins

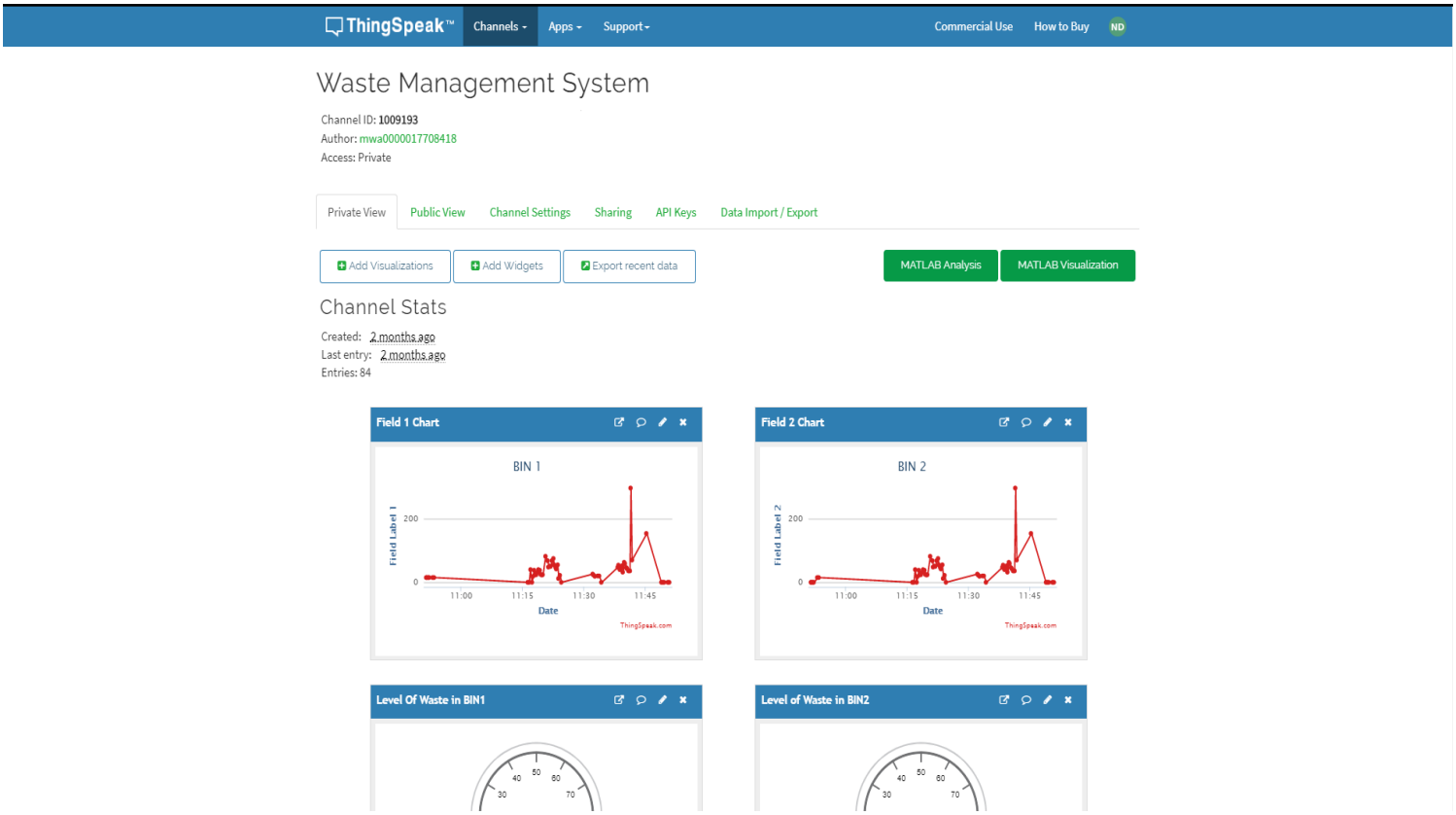

Figure 15: Cloud (Thingspeak)

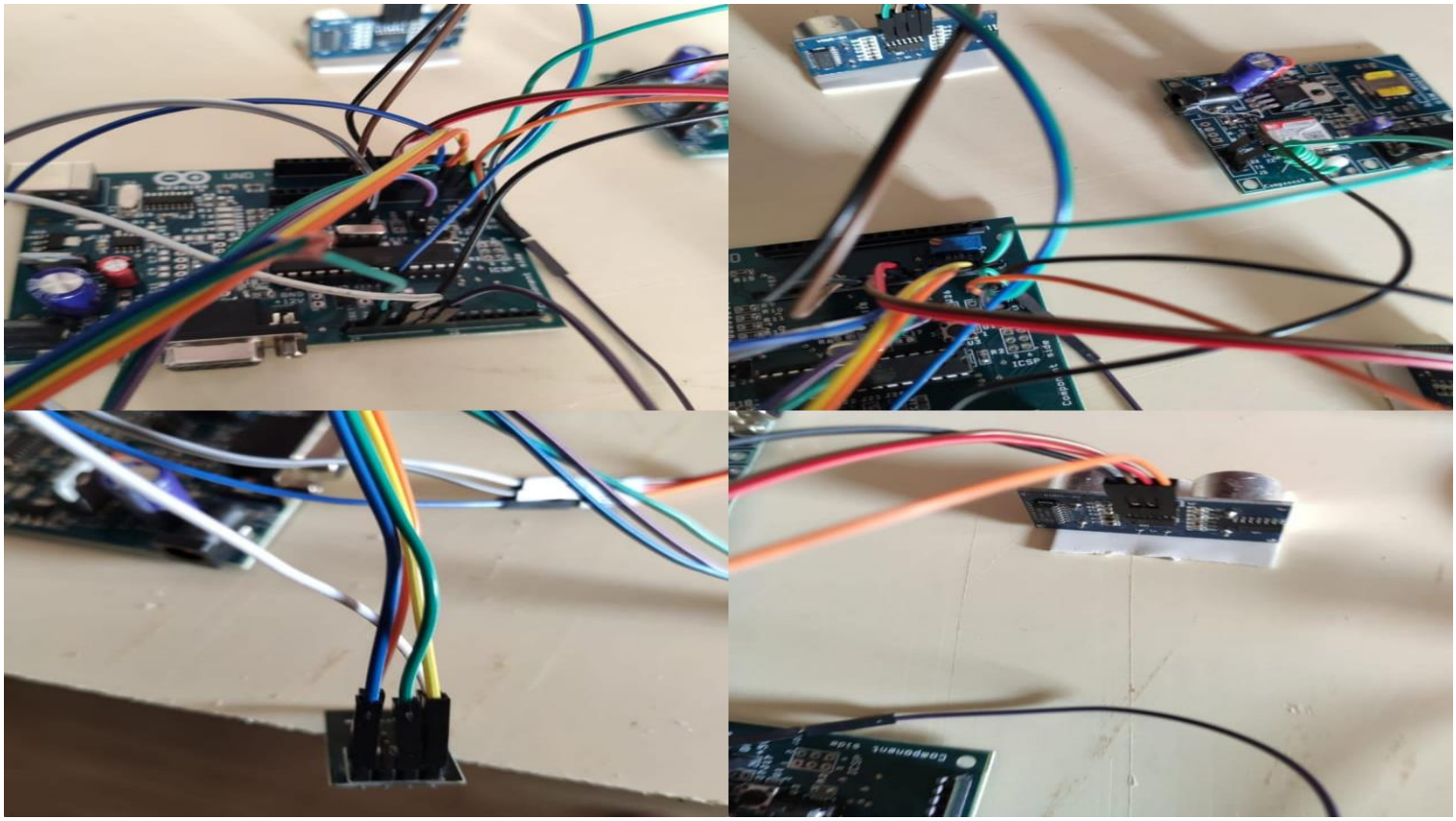

Figure 16: Hardware Components and Connection

Connection of following components:

1. Arduino Board
2. GSM Module
3. WIFI Module
4. Ultrasonic Sensor

8. COST ANALYSIS/RESULTS & DISCUSSION

According to the latest reports, PM Narendra Modi's cleanliness Plan, Swachh Bharat, has provided a 28% increase in the funds in 2020-21 as government has shifted its priority from building small toilets to the better waste management. But, India first general budged in new decade as given a hike of 28% which amounts to Rs 12,294 crore for the programme.

The total cost for the system proposed is INR 8k. But, mass production of the product even with new additions would not cross INR 10k at max. The testing should be started with a small area to further improve how the system is distributed and improve the overall cost. This way the government could benefit from reducing the budget for waste management. The analysis for the proposed system is as follows:

8.1.ORGANIZATIONAL REQUIREMENTS

Organizational Requirements can be defined as the organisation's goals and priorities that determines the course of its progress. Various components are necessary for achieving a quality system that is successful. The required components are as follows: -

1. **Leadership:**

   A required lead would be the one who keeps tabs on the tasks and ensures the successful integration of deployed units. The lead must also have the vision, motivational and good communicational skills to make the team determined towards the implementation of the system.

2. **Structure of the organization:**

   An important aspect of organizational requirement that defines the parameters and working of the organization. For our case, the structure would point to production and efficient implementation of the system.

3. **Process Planning:**

This is one of the most important skills required when organizing the structure of any product. For our system, the planning should look over the structure that defines a suitable time frame, accounts for human resources and financial resources.

4. **Deployment:**

   This is one of the latter stages which describe the implementation and deployment of the proposed system. The developed product must be addressed by the government, or a proper management team or organization that is assigned by the organization.

5. **Monitoring and Maintenance:**

   This is a necessary component as this ensures the proper working of the system and also checks whether the standards are being met. This also results in a longer lifetime for the system.

8.2.IMPLEMENTATION REQUIREMENTS

Implementation Plan consists of many steps that are listed below:

1. **Market Justification:**

   Prior to releasing any product, a study of the market is very necessary to determine whether a product like this is actually needed or not. And if something like this does exist, our goal is to bring any new idea that would improve the system.

   In our project, the product can be justified as it is aimed to reduce the health risks by proper management of waste and reduce the overall cost of the existing system.

2. **Vendor Selection:**

   After the process of justification is complete, a vendor is to be selected. For our project, the vendor would be either be the government itself or the organization selected by the government.

3. **Product Implementation:** With the selection of vendor complete, the next step is to initiate the project. This involves the selection and assignment of personnel to handle the implementation and deployment of the project.

4. **Research and Development:**

   This is the stage where understanding of the business process is crucial. The main team works with business process experts to start identifying where the perfect place for the deployment of the system.

5. **Initial Software Building**:

This is the stage where the technical team starts building the product after all the functional teams have completed their process and research.

6. **Testing and Refinement:**

   This is the stage where the testing of the product is commenced such that all the listed functions are working. Refinement is also done on this stage if the product is not up to the mark.

7. **Release:**

   The final stage of the implementation of the product where the proposed system is released and goes live for working.

8. **Support and Maintenance**:

   This is the aftermath after the system is released. This is very important to improve the age of the product and gradual improvement.

9. RESULTS & DISCUSSION

As mentioned in the report, the system is monitoring the garbage level, to sense whether the level of waste is increase in dustbin and not overflow outside the dustbin. The sensors used in project collects the respective information and send it to the microcontroller and the microcontroller execute the information. With the help of Wifi module, the information is now sent to the cloud system and then forwarded to the database and monitor by an authorized admin regularly.

We used two dustbins for the project which are connected through Arduino UNO microcontroller. So, one dustbin will be open and other one will be closed, so when the garbage level in one dustbin crosses the threshold limit that dustbin will close and other one will be open. When one dustbin closes an alert message will be sent to the authorities regarding the level of the dustbin. Because of this feature there can never be overflow of garbage waste, even if the vehicles are stuck in traffic jam or if there are some other problems then also garbage will never overflow. One more main feature that we used is compression technique. This is a technique which has never been used in dustbins proposed till now. So, by using this technique the garbage will be compressed to a certain level once it crosses the threshold limit. When the threshold limit of one dustbin is crossed it will close and compression technique will be applied to this dustbin and it will be remained closed until the other one gets filled. Once the other one gets filled the compression technique will be applied to that one and the other dustbin open. This process will be repeated for at least

two times so that the garbage will be compressed to the maximum point. The alert message will be sent after compression technique is applied at least once on both the dustbins. By using this technique more waste can be accumulated in a dustbin and also before if garbage collecting vehicles had to travel at least 4 times a day now can travel only 2 times a day to pick up the garbage. One more advantage is that during compression of garbage, plastic bottles that are present in the garbage will be crushed so that no one can use them again. We have also used solar panel as an energy source. Because of this the consumption of resources like batteries are reduced and also solar power is unlimited so it will be very useful. So, with these features our project will provide the best smart waste management system.

10. SUMMARY

Multi sensor-based waste management system in smart cities is proposed using IOT where we can easily monitor waste in a real time using smart dustbin to check if it is full or not. The project provides real time access of information about the bin. Literature survey reveals that manual data computation is time consuming and existing system are inefficient at providing accurate results because they do not provide long range communication but since our project uses cloud computing module, the data can be transmitted over a long range and the proposed system is also cost effective.

11. REFERENCES

[1] Sirisha Yerraboina, Nallapaneni Manoj Kumar, K. S. Parimala, N. Aruna Jyoth , MONITORING THE SMART GARBAGE BIN FILLING STATUS: AN IOT APPLICATION TOWARDS WASTE MANAGEMENT, International Journal of Civil Engineering and Technology (IJCIET), 2018.

[2] Kusum Lata, Shri S. K. Singh, IOT BASED SMART WASTE MANAGEMENT SYSTEM USING WIRELESS SENSOR NETWORK AND EMBEDDED LINUX BOARD, International Journal of Current Trends in Engineering & Research (IJCTER), 2016.

[3] B.Rajapandian, K.Madhanamohan, T.Tamilselvi, R.Prithiga, Smart Dustbin, International Journal of Engineering and Advanced Technology (IJEAT),2019.

[4] Vishesh Kumar Kurre, Smart Garbage Collection Bin Overflows Indicator using IOT, International Research Journal of Engineering and Technology (IRJET), 2016.

[5] Abhishek Dev, Maneesh Jasrotia, Muzammil Nadaf, Rushabh Shah, IoT Based Smart Garbage Detection System, International Research Journal of Engineering and Technology (IRJET), 2016.

[6] Kalpana, m., & jayachitra, j. (2017). Intelligent bin management system for smart city using mobile application.Asian journal of applied science and technology (ajast).

[7] Chaware p d s m, dighe s, joshi a, bajare n and korker (2017), smart garbage monitoring system using internet of things, international journal of innovative research in electrical, electronics, instrumentation and control engineering, volume 1, issue 5.

[8] Harish s v, arjun y k, vinay m n, mujamil m j and Praveen (2018), IOT based solid waste management system, international research journal of engineering and technology, volume 5, issue 5.

[9] Mohd Yusof, Norfadzlia & Zulkifli, mohd faizal & Mohd Yusof, Nur & Azman, Nur. (2018). Smart Waste Bin with Real-Time Monitoring System. International Journal of Engineering & Technology.

[10] Sureshkumar, A., Dixit, S. and Awate, P. (2017). IoT Based Intelligent Garbage Monitoring System, Journal of Emerging Technologies and Innovative Research, Volume 4, Issue 06.

[11] David Rutqvist, Denis Kleyko, and Fredrik Blomstedt(2019)An Automated Machine Learning Approach for Smart Waste Management Systems,IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS

[12] Theodoros Anagnostopoulos, Member, IEEE, Arkady Zaslavsky, Senior Member, IEEE, Kostas Kolomvatsos, Alexey Medvedev, Pouria Amirian, Jeremy Morley, and Stathes Hadjieftymiades,2017,Challenges and Opportunities of Waste Management in IoT-Enabled Smart Cities: A Survey,IEEE TRANSACTIONS ON SUSTAINABLE COMPUTING

[13] Kellow Pardini , Joel J. P. C. Rodrigues , Sergei A. Kozlov , Neeraj Kumar and Vasco Furtado (2018),IoT-Based Solid Waste Management Solutions: A Survey, Journal of Sensor and Actuator Networks

[14] Patric Marques, Diogo Manfroi, Eduardo Deitos, Jonatan Cegoni, Rodrigo Castilhos, Juergen Rochol, Edison Pignaton, Rafael Kunst, (2019) An IoT-based smart cities infrastructure architecture applied to a waste management scenario, Ad Hoc Networks

[15] Rajavizhi n, hamsaveni p, kavya p and priyadarshini k (2018), iot based waste management in smart city, international research journal of engineering and technology, volume 5, issue 2, pp 1984-1986.

[16] Chaware p d s m, dighe s, joshi a, bajare n and korker (2017), smart garbage monitoring system using internet of things, international journal of innovative research in electrical, electronics, instrumentation and control engineering, volume 1, issue 5, pp 74-77.

[17] Dewangan, s (2018), iot-enabled intelligent solid waste management system for smart city: a survey, international journal of advanced in management, technology and engineering sciences, volume 8, issue 3, pp 221-223.

[18] Deshmukh d, karme a, nagmote b, joshi m, dekate n and mishra p (2018), iot based garbage monitoring using location tracking system, ijariie, volume 4, issue 2, pp 215-220.

[19] Saranya l, rajeshwari p, priyadharshini m, kumar p s s and pradeep g (2018), garbage management system for smart city using iot, international journal of pure and applied mathematics, volume 118, no. 20, pp 597-601

[20] Norfadzlia Mohd Yusof1*, Mohd Faizal Zulkifli2, Nor Yusma Amira Mohd Yusof3, Azziana Afififie Azman4 (2018),Smart Waste Bin with Real-Time Monitoring System,International Journal of Engineering & Technology

[21] Shyamala S.C, Kunjan Sindhe, Vishwanth Muddy, Chitra C N,"Smart waste management system",International Journal of Scientific Development and Research (IJSDR), Volume 1, Issue 9 , September 2016.

[22] Nithya.L, Mahesh.M," A Smart Waste Management and Monitoring System using Automatic Unloading Robot", International Journal of Innovative Research in Computer and Communication Engineering, Vol. 4, Issue 12, December 2016.

[23] J. Kokila, K. Gayathri Devi, M. Dhivya and C. Haritha Jose." Design and Implementation of IoT Based Waste Management System", Middle-East Journal of Scientific Research 25 (5): 995-1000, 2017

APPENDIX A

1. Arduino code

Code:

```
#include < SoftwareSerial.h >
Software Serial espSerial(2, 3;
#define DEBUG true
String my SSID = "yolo";
String my PWD = "12345678";
String my API = "C9CQ01K2U9D3GKYS";
String my HOST = "api.thingspeak.com";
String my PORT = "80";
String my FIELD ;
#include <Servo.h>
Servo myservo;
Servo servo;
const int echoPin1 = 4;
const int trigPin1 = 6;
const int echoPin2 = 5;
const int trigPin2 = 3;
long duration;
int distance;
int range;
void setup()
{
   myservo.attach(4);
   servo.attach(5);
  pinMode (trigPin1, OUTPUT);
pinMode (echoPin1, INPUT);
pinMode (trigPin2, OUTPUT);
pinMode (echoPin2, INPUT);
  Serial.begin( 9600);
```

```
  espSerial.begin(115200);
  espData("AT+RST", 1000, DEBUG);
  espData("AT+CWMODE=1",1000, DEBUG
  espData("AT+CWJAP=\""+ mySSID +"\",\""+ myPWD +"\"", 1000, DEBUG);
  delay(1000);
}
void ultra(const int trigPin, const int echoPin)
{
  Digital Write(trig Pin, LOW);
delay Microseconds(3);
digital Write(trig Pin, HIGH);
delay Microseconds(15);
digital Write(trig Pin, LOW);
duration = pulseIn(echo Pin, HIGH);
distance= duration**0.034/2;
delay(1000);
}
  void loop()
  {
   ultra(trigPin1,echoPin1);
  Serial.println("LENGTH:");
  Serial.print(distance);
  if (distance > 10)
  {
     myservo.write(0);
     servo.write(180);
  }
  if(distance < 10)
  {
    myservo. write(180);
    Serial. print("AT");
         Serial. write(14);
         Serial.write(11);
                delay(110);
```

```
          Serial.print("AT+CMGF=1");
        Serial.write(14);
        Serial. write(11);
              delay(100);
              Serial.print("AT+CMGS=");
        Serial. write (34);
        Serial. print("9791333595");
        Serial .write (34);
        Serial. Write (14);
        Serial.write(11);
        Delay (2010);
       Serial.print("dustbin 1 filled");
          Serial.write(14);
        Serial. write(10);
   Serial.write(26);
     Delay (5000);
    ultra(trigPin2,echoPin2);
  Serial.println("DISTANCE:");
  Serial.print(distance);
  distance = range;
  if(range >10)
  {
   servo.write(180);
   myservo.write(0);
  }
  if(range >10)
  {
servo.write(180);
 if(distance < 10)
  {
   myservo. write(180);
   Serial. print("AT");
        Serial. write(14);
        Serial.write(11);
```

```
            delay(110);
          Serial.print("AT+CMGF=1");
        Serial.write(14);
        Serial. write(11);
            delay(100);
            Serial.print("AT+CMGS=");
        Serial. write (34);
        Serial. print("9791333595");
        Serial .write (34);
        Serial. Write (14);
        Serial.write(11);
        Delay (2010);
       Serial.print("dustbin 1 filled");
          Serial.write(14);
        Serial. write(10);
   Serial.write(26);
     Delay (5000);
    ultra(trigPin2,echoPin2);
  Serial.println("DISTANCE:");
  }
  }
   myFIELD += "&field1=";
myFIELD += String(distance);
myFIELD += "&field2=";
myFIELD += String(distance)
   String sendData = "GET /update?api_key="+ myAPI +"&"+ myFIELD ;
   espData("AT+CIPMUX=1", 1000, DEBUG);
   espData("AT+CIPSTART=0,\"TCP \",\""+ myHOST +"  \ ","+ my PORT, 1000,
DEBUG);
   espData("AT +CIPSEND=0," +String (send Data.length()+4),1000,DEBUG);
   espSerial. find( ">");
   espSerial. println(sendData);
   Serial.print("Value to be sent: ");
   Serial.println(myFIELD);
```

```
   espData("AT+ CIPCLOSE=0",2000,DEbug);
   delay(10000);

{
  Serial. print("AT Command ==> ");
  Serial.print(command);
  Serial .println("     ");
  String response = " ";
  espSerial .println(command);
  long int time = ();
  while ( (time + time) > millis())
  {
    while (espSerial. available())
    {
      char c = espSerial .read();
      response + = c;
    }
  }
  if (debug)

  }
  return responses;
}
```

2. Database

Dustbin 1

{"channel":{"id":1009193,"name":"Waste Management System","latitude":"0.0","longitude":"0.0","field1":"Field Label 1","field2":"Field Label 2","field3":"Field Label 3","field4":"Field Label 4","field5":"Field Label 5","field6":"Field Label 6","created_at":"2020-03-04T04:16:27Z","updated_at":"2020-03-04T04:16:27Z","last_entry_id":84},"feeds":[{"created_at":"2020-03-

Dustbin 2

{"channel":{"id":1009193,"name":"Waste Management System","latitude":"0.0","longitude":"0.0","field1":"Field Label 1","field2":"Field Label 2","field3":"Field Label 3","field4":"Field Label 4","field5":"Field Label 5","field6":"Field Label 6","created_at":"2020-03-04T04:16:27Z","updated_at":"2020-03-04T04:16:27Z","last_entry_id":84},"feeds":[{"created_at":"2020-03-

***