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Development of IoT based Garbage Management System using NodeMCU

Paleti Surya Teja, Motapothula Murali Krishna, Venkata Ratnam Kolluru

Abstract*: *In this paper, a smart system is developed for collecting the garbage without letting it overflow. This system collects the sensor data and delivers it to the cloud server using a gateway. An effective system with low cost and low power consumption can be achieved by using NodeMCU as a gateway. An ultrasonic sensor is used to observe the waste level inside the bin and the other ultrasonic is used for detecting the motion whether anybody is approaching the bin to dump the waste. A servo motor is used to automate the opening of bin. A weight sensor is being used in order to evaluate the heaviness of the bin along with its levels. Using a load cell also acts as an alternative to the failure of ultrasonic sensor. These sensor values are continuously uploaded to the cloud server(Thingspeak) for analysis and also for further reference. If the garbage level of bins reaches certain threshold value an alert mail can be sent to the concerned authority through an application. These levels and location of the filled dustbins can be seen in a mobile application given to the municipal authority, so that they can optimize their routes for collecting waste.

***Index Terms*: Cloud server, Garbage management, Smart city, Thingspeak, Ultrasonic sensor.**

I. INTRODUCTION

Internet of Things (IoT) can be defined as the devices(things) communicating with each other by using the internet [1,2]. IoT applications vary on a large scale. European Research Cluster on the Internet of Things (IERC) classifies major IoT applications as smart buildings, smart transportation, Smart energy, smart industry, smart health and smart city as major areas. IoT is a trend setting innovation where the data from sensors can be put in storage in the cloud which makes it easy to access. This innovation comprises of sensors and actuators for gathering the information and transferring across the internet. Cloud is used not only to store data, but also to analyze, collect and visualize the data. This evolving technology could be used in IoT applications, such as agriculture, health, smart home, etc.to make the already existing systems more efficient. The key characteristics of cloud include on-demand service provision, ubiquitous access, resource pooling and elasticity [3].

Waste management is perhaps the mechanism of collecting, transporting, storing, recycling and disposal of waste accumulated by humans and living organisms. If this waste is not collected on time, then there may be an overflowing of waste bins and can lead to many problems [4].

From the study of "Central Public Health and environmental engineering organization", states that every Indian generates approximately 1.3 Pounds of waste each day. It would be relatively less when contrasted with the waste generated in U.S which is almost 4.6 Pounds per person per day. But the U. S population is 30.7 crore in 2009 where as India's population is 120 crores which was nearly four times greater [4]. These numbers imply that India could be generating as much as 2.7 crore tons of waste more than the United states per year, though it has only one-third the land space suitable for final disposal. India's rapid growth in population makes this problem worse. The urban populace has developed at a percentage greater than 20 percent each year since 1980 and is anticipated to achieve a percentage of greater than 30 percent by 2015. Most claim that the nation's ill planned garbage management system will continue to result in severe health issues and irreversible damage to the environment.

The initial technical technology used in waste management employs Radio Frequency Identification (RFID) for real time waste management [5]. The disadvantages of using RFID is that the information of the RFID tags placed on liquid and metal surfaces are difficult to read by an RFID reader because these surfaces tend to reflect radio waves. The major activities of current IoT include sensing, data gathering, actuating, storing, and processing by connecting physical or virtual devices to the Internet. The initial methods use a load cell for the detection of bin's weight and empty those bins based on that single parameter. However, the load cell only gives the total weight of the bin and doesn't specify whether the bin is empty. Moreover, the relatively slow speed of response of load cell makes the system inefficient.

So, in the next methods load cells were replaced by infrared sensors (IR) to sense the distance between the garbage filled in the bin to the top of the bin. Since IR sensors work on the principle of reflected light waves, they can't be used in sunlight due to interference. Moreover, IR sensors can't work in dark environments and can't withstand to factors like dust, fog, smoke etc. It is difficult to use IR sensors in outdoor applications and dark indoor applications. Due to these limitations of Infrared sensors, the use of ultrasonic sensors can make the method more effective.

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In this paper the City Waste Management can be made smart by introducing smart garbage containers of self-describing nature i.e., bins that can detect the level of the waste in it on its own by incorporating some sensors. These garbage containers are made to transmit this data to the cloud and then from cloud to the mobile app. This mobile app automatically guides the waste collection trucks to the nearest garbage container which is full. This system will convert the traditional garbage collection system with an optimized system based on real time data which results in much better efficiency and predictability in the overall process.

The remaining part of the paper is structured as follows. Section-II discuss the Literature Review of the existing solutions and their demerits. The proposed methodology and Block diagram are explained in section-III. Section-IV gives the Results and Discussion of the proposed system. Finally, Section-V deals with the conclusions.

II. LITERATURE REVIEW

Abdulla Al Mamun [6] proposed an intelligent solid waste bin for efficient waste management. This system incorporates sensing and algorithm for the solid waste management process. The detection of bin condition was achieved through the integration of several sensing methods. To assess the functioning of the prototype system the author conducted several test runs and the author come to a conclusion that these results proved that the employed sensing system and the algorithm is efficient for any solid waste bin management system.

Theodoros Anagnostopoulos [7] talks about different technologies used in smart waste management and thorough survey of Information and Communication Technologies (ICT) enabled waste management models. The author also focuses on dynamic models that adopt sensors, Radio Frequency Identification (RFID), and actuators in contemporary waste collection. The paper provides a thorough report on the pros and cons of these numerous dynamic methods to reveal their characteristics. For example, Models that adopt Capacity, Temperature, Weight, Humidity and Chemical Sensors, a collection-monitoring method for timely recognition and examination of waste through sensors placed in bins, Models that adopt Capacity, Temperature, Weight, Pressure and Humidity sensors, Models that adopt RFIDs, Models that adopt wireless sensor networks (WSNs) which incorporates an effective dynamic scheduling, and routing model, Models that adopt Actuators and the author talks about the advantages and drawbacks of each model and the modifications that can be made to the make the model work efficiently. S. Vinoth Kumar [8] provided a method of waste management by detecting the level of waste inside the bin by using an ultrasonic sensor and a force sensor to measure the weight of the bin. Light emitting diodes (LEDs) are used to indicate these levels and a GSM system is used to communicate the location of the bin to the android device. By comparing the co-ordinates, the android device detects and updates the location in the web server.

Gopal Kirshna Shyam [9] proposed a smart method for garbage management with the help of sensors capable of detecting the waste levels in the bin. Sensor data is transferred via the Internet to a database server to store and process mechanisms. These data are used to observe the dust bins and to determine the optimized routes for waste collection. The most important feature of this system is the routes are decided not only on the basis of waste level but also expect the upcoming state with respect to factors like traffic congestion in the area where bins are placed, the rate at which the bins get filled. Once the waste bins have been identified, the shortest path for the collection of waste is achieved by using shortest path spanning tree algorithm.

Md Shafiqul Islam [10] proposed a system by using General Packet Radio Service (GPRS), Global Position System (GPS), Geographic Information System (GIS), Radio Frequency Identification (RFID) and Web camera. The RFID tag mounted on bin contains the bin information and all sorts of customer information. When the collection truck with built-in RFID reader passes near the bin it would retrieve this information and updates the center server spontaneously over GPRS communication system. The GPS and GIS map sever are used for location information and monitoring of collection truck respectively. This system presents the bin information, waste estimation and real-time image processing in the GUI of the monitoring system.

III. THE MATERIAL AND METHOD

In this proposed system the Smart bins are fixed with ultrasonic sensor modules, Load cell and a servo motor. The ultrasonic sensor placed to the lid of the bit continuously monitors the level of the waste. The other ultrasonic placed at the outside of the bin monitors the motion whether anybody are approaching the bin to dump the waste and automatically opens the door of the bin through the servo motor. The load cell placed below the bin senses the weight of the bin. These sensor values are continuously uploaded to the cloud (Thingspeak) for analysis and also for further use. These waste levels and location of the filled dustbins can be seen in an application given to the municipal authority, so that they can optimize their routes for collecting waste. The sensor data is transmitted to the Node MicroController Unit (NodeMCU) using wired or wireless connection. Wireless connection can be done with the ZigBee or Wi-Fi. The NodeMCU has inbuilt Wi-Fi module. So, by using the Wi-Fi, the data can be transmitted from ultrasonic, load cell. The NodeMCU data is pushed into cloud and there to android application. Here we are using Thingspeak cloud to save the data of bins and monitoring using graphs. An alert mail regarding the locations of the filled bins will also be sent to concerned authority to take action.

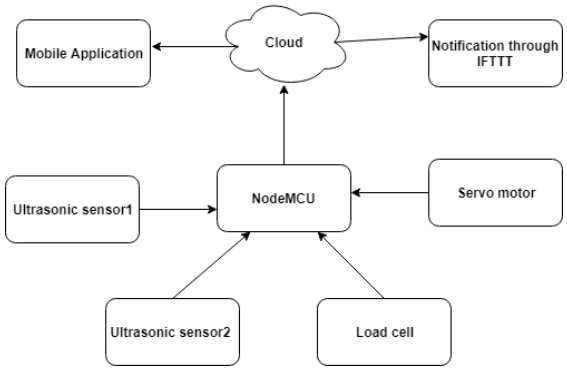

Fig. 1. Block Diagram of Proposed Waste Management

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Fig. 1 represents an overview of the proposed system; the components used are detailed as follows.

A. Selection of Sensors

The choice of sensing element in an application may be quite difficult because the performance of a system primarily depends on the liableness of a sensor and different elements of the application. To determine the correct sensor for any application, certain things ought to be taken into thought:

- Accuracy – closeness of the measured reading to a standard or known value.
- Resolution – A resolution is the lowest reading or change of readings that can be measured.
- Precision – The smallest reading that can be taken repeatedly and reliably.

Ultrasonic sensor: we are able to notice the garbage level by calculating the space from the top of the trash-bin to the waste by using a sensor. The sensor that is to be utilized in this model ought to give measurement from 2cm to 4m with 3mm accuracy, which is suitable for usual dust bins. The main reason behind selection of Ultrasonic sensor over Infrared sensor is Infrared sensors can't be used in the dark environments. The values of Infrared sensor vary with light and they are unable to use in sunlight due to interference. Moreover, Ultrasonic sensors are fully unaffected to factors like dust, light, smoke etc.

So, we are using an Ultrasonic Ranging Module (HC-SR04) which has 4 pins: V_{cc}, Trigger, Echo, and GND. The V_{cc} pin provide power to produce the ultrasonic pulses. The ground(GND) pin is coupled to the ground. The Trigger(Trig) pin is where the ultrasonic range finder drives the information to the controller about the time period taken by the ultrasonic pulse (i.e. we send a triggering pulse to the sensor).

Fig. 2. Picture of Ultrasonic sensor

By knowing the time taken, and the speed of sound, the controller calculates the distance to the body. The principle connecting the speed, distance, and time is as follows:

Speed(s) = distance(d)/time(t)

By rearranging the above formula, we get:

Distance(d) = speed(s)*time(t)

We know that the speed of sound in air fluctuates with temperature and humidness. Therefore, to precisely compute the distance, we must consider the ambient temperature and humidity. The formula for the speed of sound in air with temperature and humidity accounted for is:

$$C = k + (0.606 * T) + (0.0124 * H) \qquad (1)$$

C : Speed of sound in meters per second (m/s)

k : Speed of sound (in m/s) at 0 °C and 0% humidity i.e is 331.4 m/s

T : Temperature in °C

H : % Humidity (relative humidity)

From (1), it's clear that the speed of sound varies greatly with temperature and the effect of temperature is greater than that of the humidity.

Load cell: A Load cell is the heart of any weighing system. An electrical device which converts mechanical force into electrical signaling could be a load cell. Pneumatic, hydraulic, and strain gauge are the various types of load cells. In manufacturing and research, the most commonly used load cells are strain guage load cells. These load cells have a tendency of very long life cycles and are especially rigid, have very good resonance values. The functioning of the strain guage is that it deforms/stretches/contracts when the material of the load cells deforms appropriately. These measured values are very small and related to the stress and/or strain experienced at the time by the material load cell. Change in the strain gage element's resistance provides a measurable electrical value change. In a wheatstone bridge configuration, a load cell generally consists of 4 strain gages.

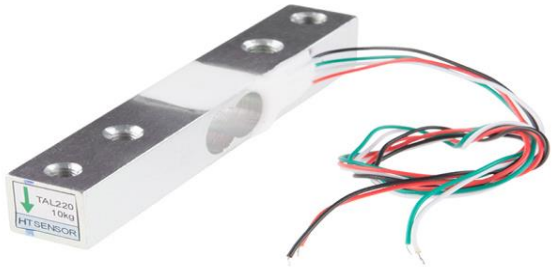

Fig. 3. Snapshot of Load cell sensor

The output of load cell is an electric signal normally in the order of some millivolts and may require amplification before it can be used. So, a HX711 load cell amplifier module is interfaced with the load cell. HX711 is a 24-bit high precision analog to-digital(A/D) converter that is typically designed for weighing scales. Load cells usually have 4 wires: red, black, green and white which are connected to HX711 board as following:

White wire to A+, Black wire to E-, Red wire to E+, Green wire to A-

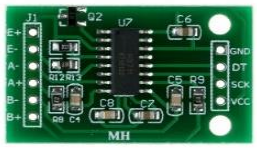

Fig. 4. Photo of load cell amplifier (HX711)

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B. NodeMCU

The Node MicroController Unit (NodeMCU) is used as a gateway. It has inbuilt Wi-Fi module which is used to drive the sensor data to cloud for storage and analysis. The main reason behind selecting NodeMCU is that the sensors used in our project uses only digital pins and no analog pins are required. Also, it consumes less power (3.3v) and is of low cost when compared to other micro controllers / processors like Arduino and Raspberry pi. NodeMCU is connected to both the ultrasonic sensors and load cell to receive their values and send the data to the cloud platform.

Fig. 5. Photo representing NodeMCU

The NodeMCU is an open source software and hardware development environment built around the ESP8266, a very low-cost system - on - a - chip (SoC). Espressif Systems designs and manufactures the ESP8266. NodeMCU contains all the key components of the modern computer: CPU, RAM, Wi - Fi networking, and even a modern operating system and SDK. The ESP8266 chip costs just $ 2 USD a piece when it is purchased in bulk. The features like establishing a Wi-Fi connection with just few lines of code, Plug and play mode, Programmable Wi-Fi module and Arduino like software and hardware I/O made NodeMCU an IoT Tool that is best suitable for various applications based on IoT. It has a deep sleep mode which consumes 60mA is useful for low power consumption of an application. Some more features of NodeMCU are:

- Voltage:3.3V.
- Wi-Fi Direct (P2P), soft-AP.
- Operating current Average: 80mA
- Flash memory attachable: 16MB max (512K normal).
- Integrated TCP/IP protocol stack.
- Processor: Tensilica L106 32-bit.
- Processor speed: 80~160MHz.
- RAM: 32K + 80K.
- Operating temperature range -40 ℃ ~ 125 ℃
- GPIOs: 17 (multiplexed with other functions).
- Analog to Digital: 1 input with 1024 step resolution.
- +19.5dBm output power in 802.11b mode
- 802.11 support: b/g/n.

C. Servo Motor

Usually, the servo motor is a simple DC motor controlled by additional servomechanism (a typical closed-loop feedback control system) for specific angular rotation. A DC motor, a Gear system, a position sensor and a control circuit are the basic parts of a servo motor. The position of servo motor is controlled by pulse width modulation technique. The angular position of the servo motor is determined by this pulse width. For example, an angular position of 0^{o} is caused by a pulse width of 1ms and a 180^{o} degree angular width is caused by 2 ms.

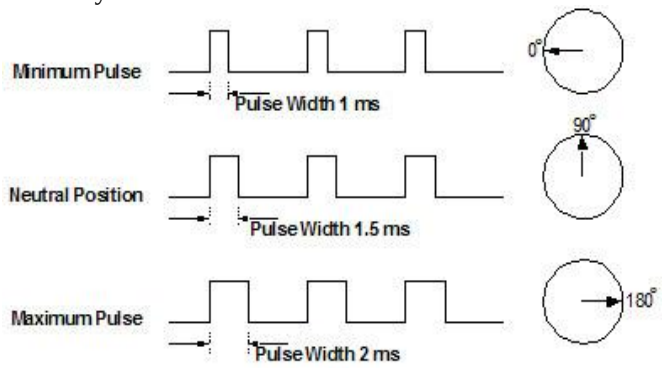

Fig. 6. Picture showing the Working of Servo Motor

The main intention of using a servo is to provide angular accuracy, i.e. it rotates as much as we are required and then stops and wait for further action to be taken on the next signal. The servo motor differs from a standard electric motor that starts to rotate as we apply power to it and continues to rotate until the power is switched off.

Fig. 7. Picture of servo motor

D. Cloud Platform

The cloud is a term that refers to accessing computer, information technology (IT), and software applications through a network connection, typically by accessing information centers by means of wide area networking (WAN) or Internet connectivity. Most IT resources are capable of living in the cloud: A software program or application, a service, or whole infrastructure. For instance, if a business desired to form an IT infrastructure, it would naturally set up the servers, software, and networking resources it required, on the other hand by going to third parties that offer them in the cloud, almost all of these services and resources are now accessible. The following are advantages of Cloud Over Database:

- Usability: Most cloud storage services provide their users the facility to drag and drop the concerned files between the local storages and cloud storages which improves the flexibility of usage.
- Bandwidth: Instead of sending files in a traditional way like emailing, one can send a web link to the involved recipients which greatly reduces the bandwidth usage.

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- Easy Accessibility: Through Internet one can be able to access the stored files from anywhere.
- Backup and Disaster Recovery: Cloud offers easier backup and recovery facilities when compared to the physical device. Even at the time of extreme disasters, cloud is capable of providing sound technology that helps to retrieve or access any kind of information.
- Low-cost: Organizations and individuals can minimize their annual net costs by using storage; cloud storage costs about 3 cents per gigabyte (Gb) for internally storing data. Users can see additional cost savings because the remote storage of data may not involve internal power.

The main reason behind selecting Thingspeak is that it creates a sense of community through the possibility of creating public channels. It is noted to be the only open data platform specifically designed for the IoT in 'the cloud'. Also, the collected data can be easily visualized by using spline charts and we can even download this data in the form of an excel sheet. Therefore, it is visually appealing and is much easier when examining collected data compared to other open source APIs. Another point in Thingspeak's favor is the fact that it uses Phusion Passenger Enterprise, a web and application server. Therefore, the API provides additional support for the programming languages Ruby, Python and Node.js. The API keys provided by Thingspeak are helpful in storing the information to the cloud. The write API key is pasted in the Arduino code to get the sensor data to cloud. The cloud platform is integrated with mobile application to get the sensor data. By integrating Thingspeak with IFTTT the municipal authorities will be able to get the email alerts regarding the filled dustbins along with their location.

Fig. 8. Thingspeak cloud platform

E) MIT Application

In this paper we have used MIT app inventor for the development of Android application. The main reasons behind using MIT App inventor are:

- It is simple and easy to use and intuitive.
- In order to build an App one need not to be expert in programming language.
- Designing of app is as easy as selecting and placing widgets in the smart phone screen.
- Coding is done with drag and drop puzzle blocks and can be leart easily with in few hours.

Fig. 9. MIT App Inventor

As Thingspeak contains sensor statistics, by means of the write API key of channel used in that session we can get the data into android app. The details of dustbins along with its location can be seen in this mobile app. The locations of the filled bins can be known by primarily pre-defined unique number assigned to the sensor along with their installed position. Since, this app will be given to municipality people the GPS in their mobile is used to show the distance between their location and the location of the dustbin which is filled. As this application is connected to google maps this will give the shortest path from the location of the truck to the targeted bin.

E) IFTTT

IFTTT (If This Then That) is both a website and a mobile app. By using IFTTT you can connect all your "services" together to complete the tasks automatically. IFTTT is connected to Thingspeak to receive an alert mail whenever the levels of the dustbins cross certain threshold value. Like sending an alert mail It can also provide many services like writing to your Twitter, Facebook Page, sending SMS etc.

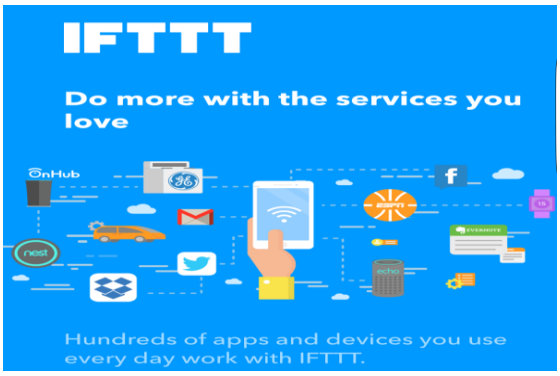

Fig. 10. IFTTT

IV. RESULTS AND DISCUSSIONS

The figure below represents the load cell and ultrasonic data uploaded to Thingspeak. The x-axis represents the date and time and y-axis represents the sensing parameter of the bin. Thingspeak provide us with feature of downloading this data in the form of an excel sheet. By using Thingspeak the data can also be presented in widgets as shown below:

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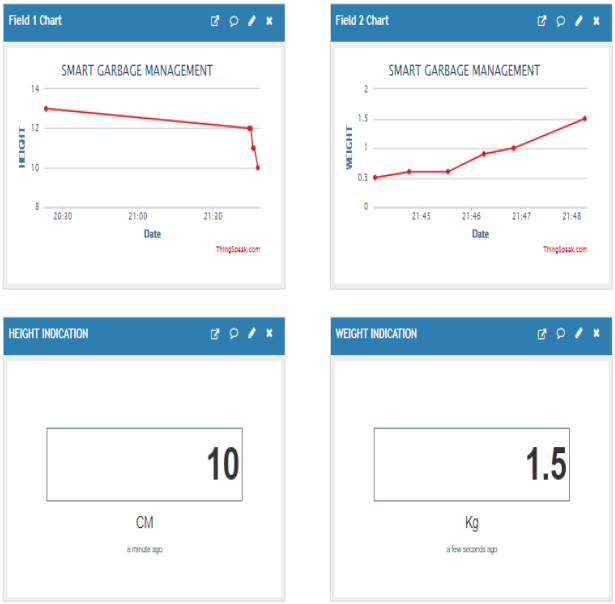


Fig. 11. Screen shots representing sensor data in Thingspeak

The below picture shows the design window of screen1. In screen1 we have displayed App name and we have a button named “get data” for entering screen2 and to know the status of the bin.

Fig. 12. Screen shot showing the screen-1 of mobile application

Screen2 has labels for displaying the text and text boxes for displaying the data from ThingSpeak. It also has a button named “next” for entering screen3 to get the route. When the screen-2 opens the locations field of the dustbins is made invisible automatically. These locations will be visible only if the dust bin is about to fill. When only 20% of bin is empty, then these labels are visible by showing the location of the respective bin.

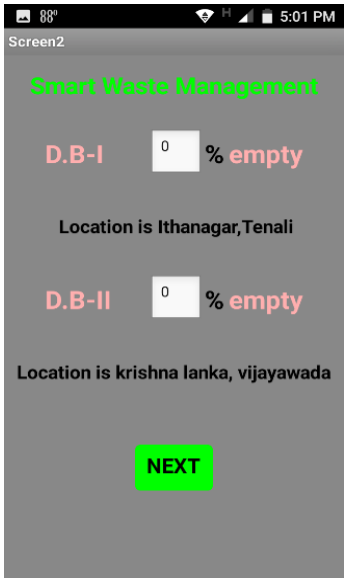


Fig. 13. Screen shot showing the screen-2 of mobile application

In screen3 we have divided the screen into 2 halves. 1st half is for performing operations and 2nd half is for displaying the Map with the route. In first half we have kept a button for adding the locations of the dustbins.

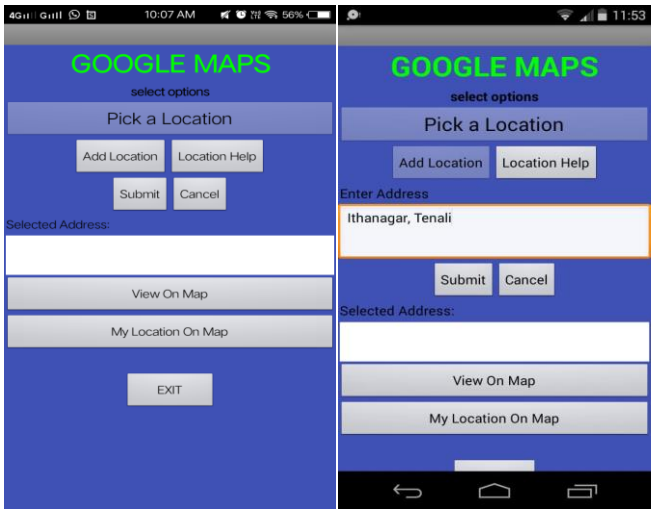


Fig. 14. Screen shots showing the screen-3 of mobile application

After adding a location, we have a button named as “Select Location” for selecting the required destination. The button “View On Map” is used to display the distance between the current location of the truck and filled bins.

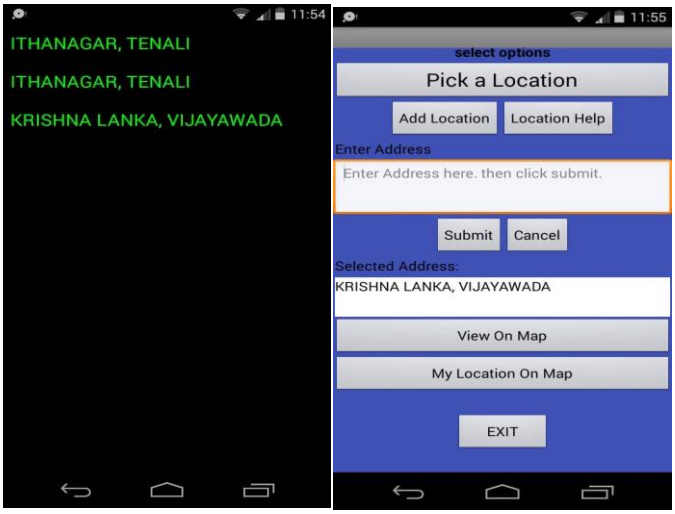


Fig. 15. Screen shots showing the selection of addresses of the filled bin

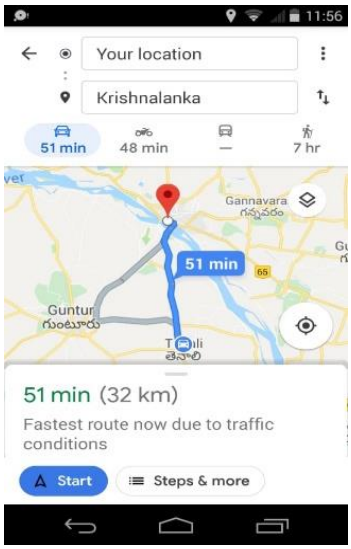
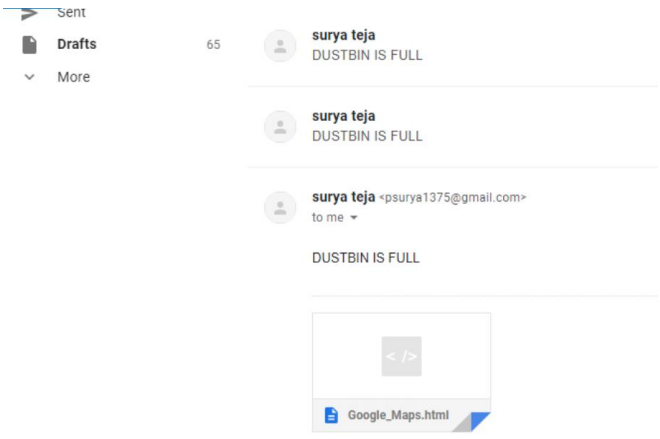


Fig. 16. Screen shots showing the distance between the dustbin and the location of truck

If the dustbin is full, then a notification is sent to your mail along with the location of the bin.



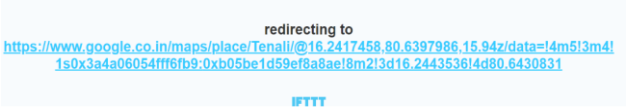


Fig. 17. Images showing the notifications to mail along with the location of the bins

V. CONCLUSIONS

Implementation of smart garbage collection management system using the ultrasonic sensor, NodeMCU, ThingSpeak cloud, android App gives a solution for unhygienic and unclean environmental conditions in a city. The chief goal is to preserve the cleanliness level in the city and create a better living environment. By utilizing this system, one can regularly check the garbage level in the dustbins that are placed in different parts of the city. If the maximum level of a specific dustbin has been reached, the employees can be informed and they can take certain actions immediately to empty it as soon as possible. Employees on their mobile phones can check the status of these bins at any time. Here the truck drivers and concerned authorities deployed in this area of waste management should be well guided about this system so that they can make best use of this system. If used properly, this may prove to be a very useful system. The price reduction, resource optimization, efficient use of smart dustbins can be done by implementing this proposed system. This system indirectly reduces the city's traffic.

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