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# Design and Implementation of IoT Based Waste Management System

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**Abstract:** The Collection of waste is a very much needed municipal service that requires huge expenditures and execution of this operation is high-priced. The high pricing is due to the various factors such as man power, navigation of vehicles, fuel, maintenances and environmental costs. The above factor necessitates the design, implementation and execution of the intelligent smart bin for proper management of waste. This paper focused on the implementation of an IoT based embedded system which integrates Radio Frequency Identification (RFID), Sensors, Arduino controller and GSM for solid waste bin and truck monitoring system with their performance measured in real time environment. Web based android applications were developed to interface with a web server to intimate the municipality regarding the cleaning process performed by the workers. This system provides a database of the information of bin status, amount of waste in the bin, time of the collection of waste are transmitted to monitor and efficiently manage the waste collection strategies. This data was processed by graph theory optimization algorithms to find the shortest path for the purpose of reaching the bin to reduce the cost.

**Key words:** Smart bin · Microcontroller · Sensors · RFID · GSM · IoT

## INTRODUCTION

Solid Waste Management (SWM) is one of the vital indispensable services provided by municipal authorities in the country to keep city clean. Nevertheless, the services rendered are very poor as the executions of this system are unscientific, old-fashioned and disorganized. The quantity of waste is littered all over leading to unhygienic living environment. The identification, monitoring and disposal of wastes are one of the major concerns of the present era.

The generation of waste is increasing by 1.3% per annum. The urban population which is increasing between 3 to 3.5% per annum generates waste around 5% annually. Thus 42.0 million tons of municipal solid wastes are produced annually; approximately 200 gm to 600 gm are generated per day. The collection of solid waste by the yardman varies from 50% to 90%. Urban Local Bodies spend Rs.500/- to Rs.1500/- per ton on solid waste management of which, 60 to 70% of the amount is on collection alone and 20% to 30% on transportation. The amount of fund that is spent on treatment and disposal of waste is minimal and hence crude dumping of this waste is practiced in most of the cities.

Reasons of Improper Management of Waste

- Inappropriate planning for the management of waste while scheduling the townships
- Lack of Integrated System for the efficient monitoring and disposal of waste.
- Lack of scientific and skilled manpower.
- Involvement and awareness of the public towards waste management is in a nominal level.
- Lack in the use of modern techniques and best practices
- Outdated Management Information Systems

The factors stated above in the management of waste collection necessitate the development of an integrated system to reduce the operational and environmental cost.

**Related Works:** In the traditional approach, a number of trucks from the municipal authority are sent to the waste bins to collect the Municipal waste (MW). The wastes are loaded in the truck and then transported and transferred to the pre-specified locality. However the group of the people involved in collecting and transporting the wastes are usually not responsible enough to make the job well

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done. Very often the wastes are not collected from each and every waste bin properly due to driver's attitude and lethargy [1].

An embedded system using sensors, ARM 7 controller and ZigBee technology for management of garbage or solid waste was implemented [2]. The sensors are placed in the garbage bins at the public places. When the pre-defined level of the garbage in the smart bin is reached, indication will be given by the controller to the driver of waste collection truck. This system creates immediate attention but did not focus on segregation of waste.

The above stated disadvantages were overcome by proposing an e-monitoring system that consists of RFID technology interfaced with PIC micro-controller and a web based computerized software [3]. This centralized GUI tool can be accessed from anywhere for the information to be viewed by different category of people. This facility also helps the public to lodge their complaints and comments. It has been explored in the laboratory environment as well as in the field environment. The test results show that the system functions properly and is working real time. Municipality can monitor the MW collecting status through the system and can produce different reports to improve the performance of their service.

To reduce the cost, integrated sensing system were designed using rule based decision procedure that is efficient and intelligent can be used to automate any solid waste bin management and monitoring system [4]. Pavithra *et al*. [5] developed a system to intimate the clearance of waste to the corporation office by positioning the sensor and microcontroller in thetrash bin. An alarm indication is also incorporated to confirm the clearance of waste. This set up helps the municipality for the immediate disposal of bin thus reducing the spread of disease.

The researcher introduced additional sensors, IR sensors, Humidity sensors and Toxic gas sensors to measure the status of bin [6]. The processor transmit the bin filling alert, Humidity alert and Toxic gas alert to the Municipal Corporation via SMS intimation with the help of GSM technology in order to reduce waste dumping. Further modifications were also performed in the category of processing and recycling of the waste. The separations of five types of plastic resinsusing NIR spectroscopy to produce biogas from the rest of biodegradable waste were introduced. The NIR reflectance spectroscopy scheme helps to distinguish and eliminate plastic item from MSW and provides all biodegradable substance that can be further used in biogas plant [7].

Implementation of the above smart bin can prevent lumping of the trash for a longer period of time thereby preventing the widespread of diseases to a great extent and promising a clean environment in the city [8].There is a decrease in the environmental and operational cost as a result of optimization of the resources and an effective usage of smart dustbins. It has indirectly reduced the traffic in city. In major cities the waste gathering vehicle visit the area's everyday twice or thrice depends on the population of the particular area and sometimes these dustbins may not be full. Informing the status of each and every dust bin in real time to the concerned authority can send the garbage collection vehicle only when the dustbin is full [9].

This work has focused on the implementation of smart waste management system using sensors, Arduino and GSM technology integrated with IoT. The status of the bin is continuously monitored at the control station to provide a user interaction with the system. The values stored in the database helps a user to have the updated status of the data in the bin as well as the previous values of the parameters of the bin. This collected data from the bin can be used in the optimization of routes for the collection trucks for efficient use of resources in the waste management system [10].

**System Implementation:** The proposed architecture of IoT based wastemanagement system shown in Fig. 1 is categorized into three modules.

- Smart Control and lid Sensing System – Ultrasonic Sensor, PIR Sensor, Servomotor, RFID Reader
- Transceiver Unit – GSM, Wi-Fi, ThingSpeak
- Smart Display Unit - LCD, Database, Monitor Section

The Fig. 2 shows the process flow of the implemented system. A PIR sensor is a motion detector sensor which detects the heat emitted naturally by human. Whenever a person is in the field of vision nearer to the garbage bin, the sensor is triggered and the servo motor automatically opens the smart bin for the disposal of waste. Lid Sensing system detects the overflow status of the garbage level in the dustbin using ultrasonic sensor. This Smart Trash Bin is interfaced with Arduino and whenever the lid sensing system is activated, a signal is transmitted through the GSM module to the server in the municipal office. After the disposal of waste, the above process is confirmed by the yardman using RFID Tag. RFID reader reads the tag and sends the status of cleaning to the server confirming the work done. The LCD screen is used to demonstration the status garbage collected in the bins. Wi-Fi module helps us to send the details of the smart bin at the receiver

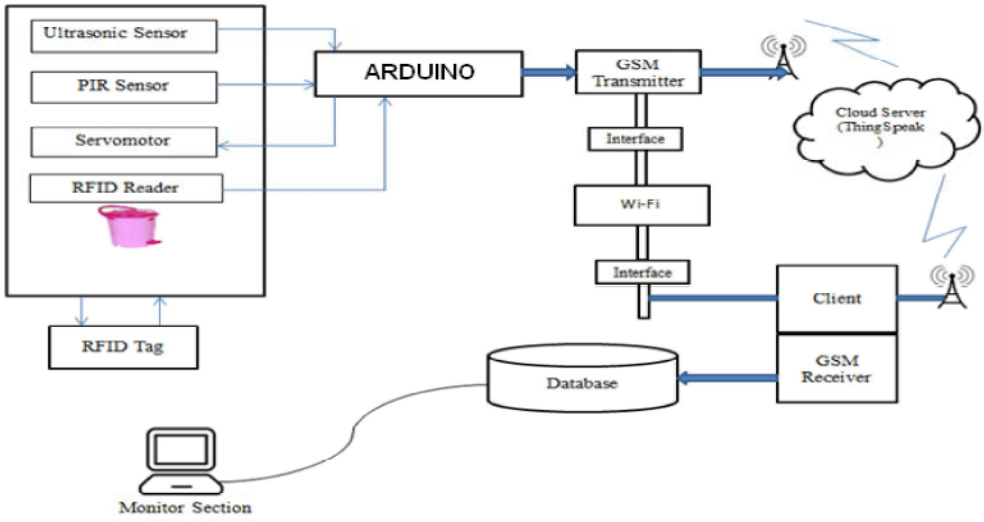


Fig. 1: Architecture of IoT Based Waste Management System

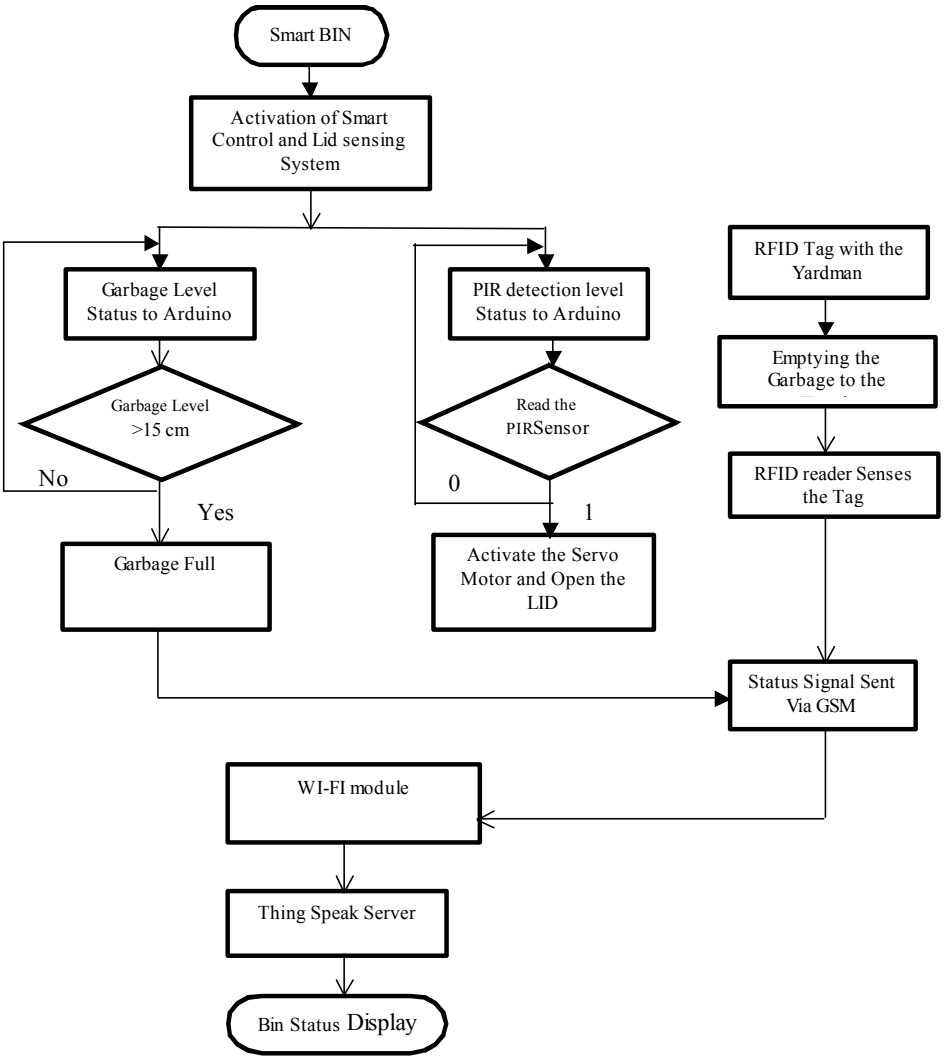


Fig. 2: Process Flow of the Implemented System

side. The graph theory optimization process is applied when considering the placement of multiple bins at different points in order to reduce the operational cost.

**Smart Control and Lid Sensing System**

**Ultrasonic Sensor:** The ultrasonic Sensor HC-SR04 is used to measure the level of garbage in waste bin. The range of the garbage measurement varies from 2cm – 400cm without non-contact. The module provides ultrasonic transmitters, receiver and control circuit.The length of theimplemented garbage bin is 20cm. A predefined threshold level is fixed at 15cm and programmed in the Arduino to predict the overflow status of the bin. The conditions for the activation of the lid based on the output of Ultrasonic sensor is listed below

- The garbage level in the bin is less than 15cm - Garbage Empty
- The garbage level in the bin is greater than 15cm - Garbage Full.

**PIR Sensor and Servo Motor:** HC-SR501 is a motion detector sensor which detects the heat emitted naturally by human. Whenever a person is in the field of vision nearer to the garbage bin, the sensor is triggered. SG-90MINI,a position controlled servomotoris programmed for theautomatic opening of the waste bin for the disposal of waste. It can easily control physical movement of objects due to its position controlled feature. Servo motor rotates in angle ranging from 0 to 180 degree and has many applications in robotics and industry for position based motion control system. Unlike other motors, servo motor is very easy to interface with Arduino or any other microcontroller due to its built-in controllers. The conditions programmed in Arduino board for the rotation of servo motor based on the output of PIR sensor is listed below.

- When the Output level of PIR sensor is equal to high - Motion detected, the servomotor rotates clockwise in an angle from 0° to 180° and automaticallyopens the waste bin. For closing the bin there will be an anti-clockwise rotation from $180^0$ to 0°.
- When the Output level of PIR sensor is equal to low - Motion not detected.

**RFID Detection:** EM-18 RFID reader is a device that will read data on tags and communicate to a computer system without any physical association. The RFID tag comprises of three parts: an antenna, a semiconductor chip attached to the antenna with encapsulation. The tag reader is liable for powering and sharing with a tag. The tag antenna captures energy and transfers the tag's ID.

**Transceiver Unit**

**WIFI Module:** The ESP8266 is a self-contained Single on Chip Wi-Fi Module with incorporated TCP/IP protocol stack that can provide microcontroller access to your Wi-Fi network. This component is comprised of 32 bit microcontrollerassociated with devices like ADC, UART, PLL and memories. It encompasses a self-calibrated RF permitting it to work under all working conditions and requires no external RF parts. The applications of ESP8266 are Smart power plugs, Home automation, Wi-Fi location-aware devices, Industrial wireless control and Security ID tags. Wi-Fi helps us to send details of smartbin at the receiver side.

**Mart Display Unit**

**Monitoring System:** ThingSpeak is IoT platform in which the user must create the channels by giving all the credential required, once the channel is created nearly 8 sensor values can be feed to the thingspeak channel and the data in channel can be accessed by anywhere in the world.The Smart control and Lid sensing system connected to Arduino and GSM will feed the sensed data to IoT -ThingSpeak applicationover the Internet. In the proposed system, ultrasonic sensor data are feed to the thingspeak channel.

The Fig. 3 (a) and Fig. 3 (b) shows the result of garbage monitoring system measured in real time environment. The sensed data from the ultrasonic sensor will be stored in the channel.The collected data of the different garbage level measured from 12.59 pm till 17.00 pm are represented in the form of a graph for monitoring purpose. In addition to the above, the location can also be viewed as shown in the Fig. 3(c) at Dr.G P Institute of Technology, Coimbatore, India. This test run were implemented at different places in diverse times with different level of garbage.

**Graph Theory Optimization Algorithm:** Optimization algorithms are applied to find the shortest distance between two points in the area for the yardman to follow for cleaning the smart bin. The routes are optimized to minimize driving time based on historical data or traffic blocking. This data processed by graph theory optimization algorithms can be used to dynamically and efficiently manage waste collection strategies. The following steps are used in a graph theory algorithm,

- Location of data collection
- Graph modelling for plotting data
- Graph Bi-Partioning for possible routes
- Applying algorithm on datasets
- Suitable path will be chosen for cleaning the smartbin.

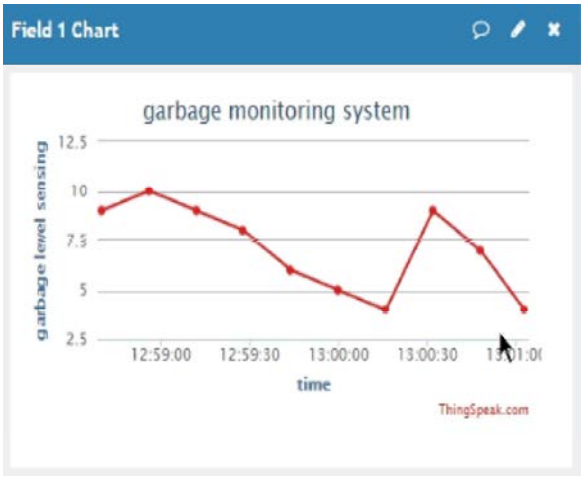


Fig. 3(a): Result of the Garbage Monitoring System implemented in real time

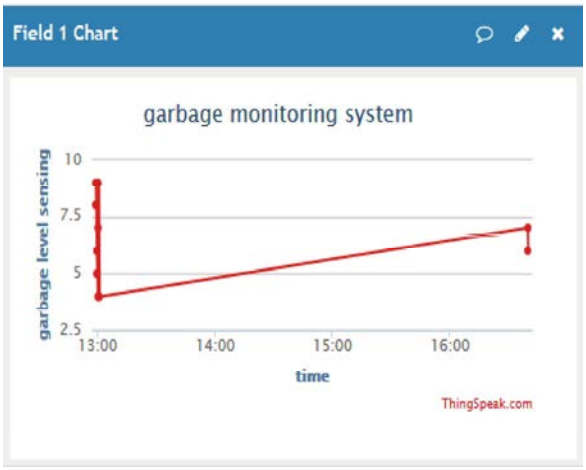


Fig. 3(b): Result of the Garbage Monitoring System implemented in real time

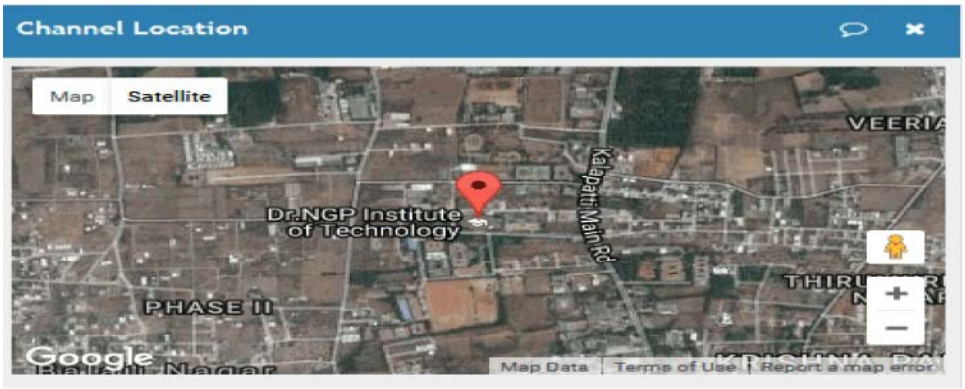


Fig. 3(c): Location of Smart Bin

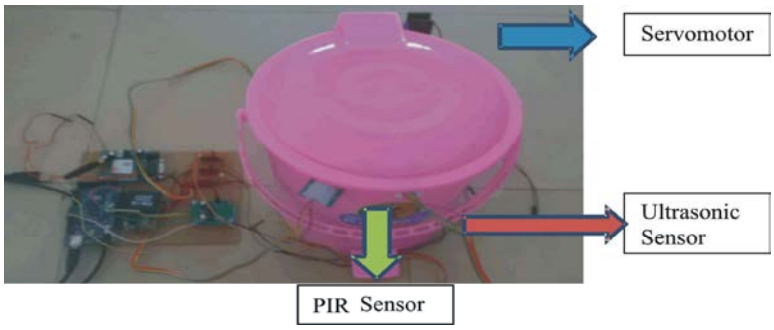


Fig. 4: Smart Bin for IoT Based waste management system

Table 1: Experimental data From Testing of the Prototype

| S.No | Output of the Ultrasonic Sensor | Time | Status of the PIR Sensor | Servo Motor Rotation | Action |
|---|---|---|---|---|---|
| 1. | 0cm | 12.58pm | NO | Anti-Clockwise | Bin is unloading |
| 2. | 4cm | 12.59pm | YES | Clockwise | Bin is loading |
| 3. | 5cm | 13.00pm | YES | Clockwise | Bin is loading |
| 4. | 5.5cm | 14.00pm | YES | Clockwise | Bin is loading |
| 5. | 6cm | 16.00pm | YES | Clockwise | Bin is loading |
| 6. | 7cm | 17.00pm | YES | Clockwise | Bin is loading |

## RESULTS AND DISCUSSION

The combinedresults of the prototype developed are shown as five fields in Table 1. The first two fields in the table corresponds to the output of ultrasonic sensor measured at various times. The third fieldshows the status of the PIR sensor.Theservo motor will respond based on the third field, it may rotate either in clockwise direction for opening the bin and anticlockwise for closing the bin. The final action that will take place is shown as the fifth field. The Fig. 4 shows the location of various sensors positioned in the Smartbinfor web based waste management System.

## CONCLUSION

The necessity for the web based waste management application is increasing day by day due to the population and less maintenance in the disposal of waste.The novelty of this proposed work is to develop an intelligent alerting systemintegrated with RFID and IoT for proper management of garbage. A municipal authority can use this type of system to monitor the waste collection status in real time environment and measure the performance of yardman, thereby reducing the manual process of monitoring and verification.

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