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Smart trash bin level monitoring system

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***Abstract*---**Solid waste management is still a big issue in cities, causing considerable health and environmental problems. Trash cans are strategically distributed across the city to handle solid waste. These containers have the potential to overflow, contaminating the environment and creating trouble for people. A real-time remote monitoring system that informs a waste management firm or the relevant authorities of the level of rubbish in trash bins is required. The proposed system describes the creation and validation of a self-powered, LoRaIoT-enabled Smart Trash Bin Level Monitoring System for effective solid waste management (IoT-STBLMS). Smart Trash Bin Level Measurement Unit (STBLMU) monitors the unfilled level and geographical position of a trash bin, then analyses and communicates the data to a cloud platform using the MQTT protocol. A dashboard allows users to examine and evaluate the status of each bin as well as its geo-location. The designed system's accuracy, average current consumption and life expectancy, battery charging time, and cost were investigated and published here.

***Keywords*---**STBLMU, ultrasonic sensor, IoT-STBLM server, solar panel, Lora transceiver.

Introduction

Municipal Solid Waste (MSW), sometimes referred to as trash or waste, is a major pollutant source. Though the World is becoming modernized, trash collection is one of the tedious processes. This process involves an enormous workforce and fuel. It is, nevertheless, an unavoidable outcome of human activity. According to a survey conducted by the World Bank's urban development and local government arm, around 1.3 billion tonnes of solid garbage are created in world cities each year. This figure is predicted to increase to 2.2 billion tonnes by 2025. According to the United Nations Population Division 2014, by 2050, 70% of the world's population will be living in cities. In India, According to the Ministry of Housing and Urban Affairs "SwachhataSandesh Newsletter," as of January 2020, 147,613 metric tonnes (MT) of solid garbage is created every day. Day by day generation of solid waste expeditiously increases. As the world's population migrates to cities, local governments throughout the world are investing increasing funds in infrastructure. Smart cities are defined as secure cities that have a sustainable economy, are well-organized, are satisfied, have renewable energy, competent mobility, are energy efficient, and are interactive.

IoT systems, sensor networks, cameras, data centers, and other smart city infrastructure may be created to allow municipal authorities to offer important services to clients in a timely way. Smart cities also employ technology to effectively manage transportation systems, provide enhanced healthcare services, and build powerful, dependable wireless communication networks that link all companies, people, and things. Solid waste management is one such critical function. If trash is collected every day, the bin may not always be full, resulting in workforce and fuel waste. If it is scheduled to collect once a week. The bins may be full ahead of schedule, causing odors to spread and cause serious health hazards for the humans and animals that live nearby. The amount of waste generated in each area may differ according to the population and standard of the people. As a result, there is a necessity for a smart trash bin level monitoring system that assists authorities in collecting waste on time and utilizing resources properly. Because the garbage can is regarded as the most important need for keeping the city clean, it is critical to clean all trash cans as soon as they get full. This method makes use of an ultrasonic sensor. The sensor is attached to the container's top and helps to alert the administrator when the waste level has reached its maximum capacity. The container must then be emptied as rapidly as practical.

The Internet of Things (IoT) is being employed, which will result in a better living environment for humans. In the city, unsanitary circumstances will no longer exist. With the aid of this technology, the city may employ the bare minimum of smart containers while still being significantly cleaner. This also helps with resource efficiency, and if the garbage bins are collected on time, the environment will stay safe and disease-free. Cities will be cleaner, and waste odors will be significantly reduced. Sensor design advancements, communication protocol advancements, and remote monitoring methods can all help give efficient solutions for the real-time monitoring of garbage bins in metropolitan settings. Garbage disposal in dump yards contributes to the unpredictability of flames. Unless the government intervenes, the situation will deteriorate. Various toxic

substances are discharged into the environment as a result. Significant respiratory difficulties emerge as a result of breathing these toxins from the air into the human body. As a result, a NodeMCU-based bin level indicator system with the route is suggested. This paper presents a waste management strategy that is both efficient and real-time. The suggested system combines sensor technologies that gather trash information in real-time from smart bins (things) and broadcast it to an online platform where residents may access it.

Literature survey

As the world's population grows at an unprecedented rate, more garbage waste is being generated daily, and waste management and proper collection from garbage bins are becoming more and more challenging and important [1]S.S.Navghane et al., [2] employ a dustbin that interfaces with a microcontroller-based system with IR wireless systems, as well as a central system that displays current rubbish status on a mobile web browser with an HTML page over Wi-Fi. As a result, the status of the HTML page will be changed. By using the Internet of Things (IoT) paradigm to design a smart bin level monitoring system, the constraints identified in the previous research may be solved. The Internet of Things (IoT) opens the way for pervasively linked infrastructures to enable novel services, as well as more flexibility and efficiency. These benefits are appealing not only for consumer uses but also for industrial applications [3]. Environmental monitoring [4], rodenticide depletion monitoring [5], and so on have all used IoT-based remote monitoring systems. [6] Describe a few ideas to integrate IoT into the design of garbage bin level monitoring systems. The bin level data was uploaded to a server using a Wi-Fi module on the system's end sensor nodes. In [7], an RFID tag was placed in a garbage can to track how full it was.

The data was uploaded to a server through an access point using an RFID reader and an ESP8266 module. To assess the unfilled level of garbage bins, an ultrasonic sensor was directly interfaced with an ESP8266 module in [8]. It is clear from inferences drawn from state-of-the-art research on smart garbage bins that IoT-based trash bin level monitoring systems outperform traditional systems in terms of resilience and cost-effectiveness. Nonetheless, it is falling behind in terms of power consumption and network coverage range. Wireless communication systems like Zigbee, SimpliciTI, and Wi-Fi, as seen in the table, have a short-range. It necessitates the use of repeaters to create long-range communication, which results in higher power consumption and a more complicated system architecture. This research focuses on IoT systems that use the Lo-RaWAN networking protocol. Long-range communication, low power consumption, and dispersed wireless sensor nodes are all advantages of LoRaWAN [9]. These capabilities of the LoRaWAN networking protocol can help existing IoT-based garbage bin level monitoring systems overcome their restrictions. [10]Recently introduced a LoRaWAN network-based trash management system in a university.

Dijkstra's algorithm is used to determine the shortest path for garbage collection in this system. This study claims a maximum transmission distance of 1619 meters. However, no experimental data on energy harvesting and visualization of data were presented.[11] Developed a temperature sensor that operates even

when there is a lot of smoke. When the temperature rises over the setpoint, an alert is sent to the administrator, who may then take appropriate action. It employs both a genetic and R-tree method. A smart waste collection system is described in [11]. This system includes temperature and humidity sensors to measure the temperature and humidity level within a trash bin, load cells to calculate the garbage bin's weight, an ultrasonic sensor to identify the unfilled level, and a GSM module as a communication link [12]. In [13] and [14], a real-time WSN-based bin level monitoring system is described to address the limitations of the aforementioned methods. The designed smart bin employs various sensors to monitor the trash bin's lid state, rubbish level, and weight. They created a smart bin, however, is not intended to link to a wireless network. In addition, the garbage bin's installation is costly (USD 560 per trash bin). Sensor nodes embedded in trash bins assess garbage levels and communicate data to an access point in these systems. A Universal Asynchronous Receiver Transmitter receives data from sensor nodes and transfers it to a central monitoring station through an access point (UART).

SimpliciTI, a low-power network protocol, was utilized for wireless communication. In addition, the graphical user interface displays an organizational view of all the bins in location order, allowing users to quickly determine the waste level and trash bin placement. However, sending data to a remote site costs money on a personal computer or a personal digital assistant. By using the Internet of Things (IoT) paradigm to design a smart bin level monitoring system, the constraints identified in the previous research may be solved. The sensor unit comprises an infrared sensor, ultrasonic sensor, or flame detection sensor that detects the presence of flame and recognizes waste levels in the dust bin. The main control unit is an Arduino, and the signal flows via it before reaching the user's cell phone through GSM. This indicates the bin's unfilled level.Later, Andrei Brozdukhin and colleagues presented a novel system with two working hands: a software component and a one-of-a-kind indication [15]. The dustbin walls are fitted with the one-of-a-kind indication device. It consists of two parts: a receiver-transmitter and a sensor. The sensor is coupled to a transmitter device that transmits a signal to the authorities stating, "Dustbin is full, please empty it."

Artificial Intelligence systems are now in charge of identifying the shortest path and closest truck driver to the required trashcan, as well as informing them of rubbish collection.Prakash and Prabu [16] designed IoT-based waste management for smart cities to address trash overflow, which results in unsanitary conditions and a foul odor in the area. This project is divided into two parts: a transmitter and a receiver. In the transmitter component, there was an 8051 microprocessor, an RF transmitter, and sensors that were mounted to the trashcan. The receiver part is comprised of an RF Receiver, Intel Galileo, and a Web Browser. This technology can detect the amount of garbage in the dustbin and prevent it from overflowing.There are several dustbins positioned around the city or campus; these dustbins are equipped with a low-cost embedded technology that aids in the tracking of waste bin levels, as well as a unique ID for each trashcan in the city, making it easier to recognize which rubbish bin is full. The gadget will broadcast the level together with the unique ID supplied when the level crosses the threshold limits. With the use of GSM, the concerned authorities may obtain

these facts from their location and take fast action to clean the dustbins[17].[18] Is made up of an ultrasonic sensor for measuring waste level, a GSM module for sending SMS, and an Arduino Uno for controlling the system. When the trash bin is full or about full, it is supposed to create and send SMS warning messages to the municipality so that the rubbish may be collected quickly.[19]

Features a smart waste clearing system that sends a warning signal to the municipal web server, allowing for immediate dustbin cleaning with correct verification according to the degree of rubbish loading. This operation is facilitated by an ultrasonic sensor that is connected to a PIC microcontroller and checks the level of waste in the dustbin before sending an alarm to the municipal web server. After cleaning the dustbin, the smart garbage alarm system provides automated recognition of rubbish in the dustbin and communicates the clean-up status to the server, indicating that the job is completed. The entire procedure is supported by an embedded module that is linked to a GSM module. [20] Describes a smart garbage collecting system using LoRaWAN nodes. Multiple sensors are used in this system, including temperature sensors to determine the temperature within a waste bin, load cells to determine the weight of the garbage bin, and an ultrasonic sensor to determine the level of unfilled rubbish. The usage of several sensors, on the other hand, uses more power, necessitating frequent battery changes. In addition, no actual data on the sensor node transmission range were reported. [21] Recently presented a university-based LoRaWAN network-based garbage management solution. The shortest path for garbage collection is determined by using Dijkstra's algorithm. This study mentions a maximum transmission distance of 1619 m. However, there were no experimental findings on data visualization and energy harvesting.

As a result, a versatile IoT system that allows for long-range data transmission, geolocation of trash bins, ease of scaling, cost-effectiveness, and accurate real-time information to the municipality or solid waste management firm is required. As a result, we designed an IoT system to satisfy the demands of the municipality or the solid waste management firm. The following are the primary aspects of our system:

- Long-range communication
- GPS module
- Notification system
- Route of the location
- GSM module
- LCD status indicator
- To view the unfilled level, and their location in real-time.

The following is how the rest of the paper is structured: Section III covers the network architecture, STBLMU design, power management unit design, and IoT-STBLM server design for the proposed IoT-STBLMS. The experimental findings are presented in Section IV, which includes a comparison of manual and IoT-STBLMU measurements, as well as a cost comparison. The paper comes to a close with Section V.

Methodology

Proposed IoT-STBLMS Network Architecture

STBLMU comprises of Lora transceiver, sensors, a power supply, an Arduino UNO board, and an LCD. AnSTBLMU monitors a trash bin's unfilled level, as well as its location, and transmits the data through a LoRa transmitter. The data from the STBLMU is then received by the LoRa receiver. Then the received data is stored in the cloud using NodeMcu. We use an open-source cloud platform known as thingspeak.A dashboard is been created using Wamp, an open-source software. PHP, script language is used to design the front end of the dashboard. Periodical updates is been done on the dashboard. Users can examine and evaluate the garbage bin's level, as well as their locations.

Smart Trash Bin Level Measurement Unit (STBLMU)

An ultrasonic sensor to measure the unfilled level of a garbagebin, a GPS module to gather geographical position, and other components make up anSTBLMU.Figure 1 shows the block diagram of STBLMU.

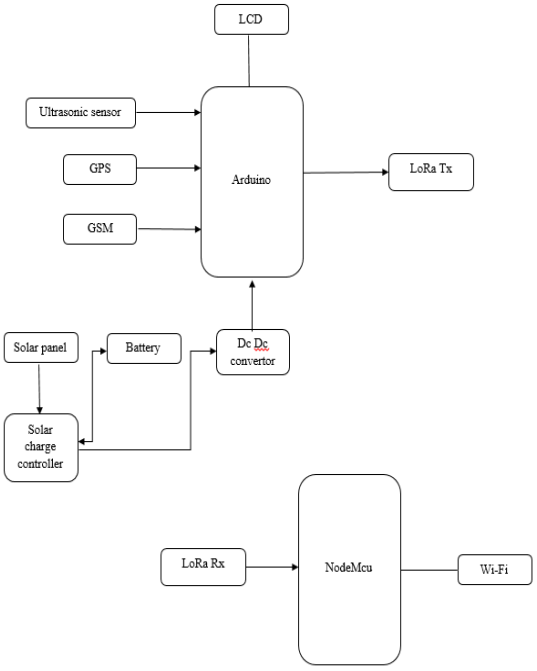


Figure 1. Block diagram of STBLMU

Ultrasonic Sensor

The STBLMU measures the unfilled level of bins using an ultrasonic sensor. The STBLMU's design hinges on the selection of an appropriate ultrasonic sensor. We chose the HCSR04 (Figure 2) to ensure efficient and dependable operation. It's a

low-cost, high-performance, stable-range detector with good beam characteristics. The sensor's operational voltage ranges from 2.5 to 5.5 V, with an average current consumption of 2 mA. Pulse-width and simultaneous output formats are provided for the sensor to communicate with the host microcontroller. The sensor was connected to the host microcontroller through a pulse width output format in the STBLMU architecture.

$$Distance = (speed * time)\ /2 \ldots (1)$$

Calculates the distance between the sensor and the object using the Ultrasonic sensor formula. Both the speed and the time values are known. The speed is the speed of sound, which is 340m/s, and the time is the length of time the Echo pin was HIGH. We still have one more step to do: divide the final value by 2. This is because we're measuring the time it takes for a sound wave to go to an item and bounce back.



Figure 2. Ultrasonic sensor

Host microcontroller

The ATmega328P is a high-performance AVR technology microcontroller with a lot of pins and functions. It has an RSIC CPU and an 8-bit CMOS processor, which enhances performance and power efficiency. It also includes auto naps and a temperature sensor built-in. Internal protections and a variety of programming methodologies are provided in the ATmega328P IC, allowing engineers to prioritize this controller for different scenarios. The ATmega328P microcontroller is getting more popular by the day since it offers a range of modern-era communication mechanisms for other modules and microcontrollers. Figure 3 shows the Arduino integrated with ATmega328P IC.

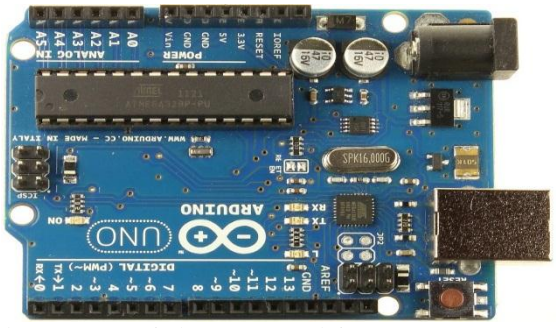


Figure 3. Arduino UNO with ATmega328P IC

GPS module

When dealing with solid waste across a vast area, a significant number of rubbish bins must be installed. The location data of each trash bin is necessary for the garbage truck to collect waste. Manually recording the geolocation data of a large number of garbage cans is time-consuming. Furthermore, the geo-location data aids in the identification of moving trash bins, stolen trash bins, and the central monitoring station, as well as determining the quickest and most effective route for garbage collection. The STBLMU features a GPS module that records the geo-location coordinates of each NEO6MV2 bin (Figure 4). The NEO6MV2 has an embedded antenna, a high sensitivity of -161dBm, and superior interference suppression to provide excellent performance even in challenging conditions.



Figure 4. GPS module

ESP8266 NodeMcu

The ESP8266 may host an application or offload all WiFi networking functionality to a separate application processor. Espressif Systems created the NodeMcu, an open-source Wi-Fi system on a chip. It's a built-in chip that enables complete internet access to the embedded circuit in which it's installed. It may be programmed using the Arduino IDE and a USB connection. It contains a total of 30 pins, nine of which are digital and one of which is analog. It is a tool that is used to connect Wi-Fi networks. It uses very little energy. It was chosen as the main microcontroller in this project because of its built-in Wi-Fi connectivity, which can be used to send real-time sensor data to web and mobile interfaces. Figure 5 shows NodeMcu with the ESP8266 module.

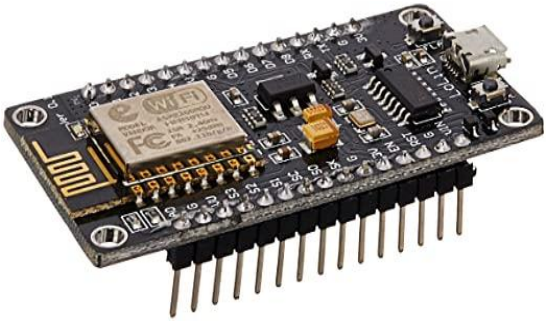


Figure 5. NodeMcu

DC to DC Buck convertor

A buck converter is a DC-to-DC power converter that reduces the voltage from the input to the output. It's a type of switched-mode power supply using at least two semiconductors and at least one energy storage device, such as a capacitor, inductor, or a combination of the two. Filters consisting of capacitors are usually added to the output and input of such a converter to eliminate voltage ripple. Because the voltage across the inductor "bucks" or opposes the supply voltage, it's called a buck converter. Figure 6 shows the LM2596 DC to DC buck converter.



Figure 6. DC to DC convertor

Solar panel and solar charge controller

The most popular form of the solar system accessible today is a 12v solar panel (Figure 7). It generates 12 volts, which is used to po12-volt batteries and gadgets. It contains 36 solar cells that produce 0.5 volts apiece. A charge controller (Figure 8), also known as a charge regulator, is a voltage and/or current regulator that prevents batteries from becoming overcharged. It controls the voltage and current going to the battery from the solar panels.



Figure 7. Solar panel



Figure 8. Solar charge controller

Power management unit

Figure 8 depicts the power management unit's entire circuit. The power management unit comprises a solar panel, a solar charge controller board, a battery, and a DC to DC buck converter.

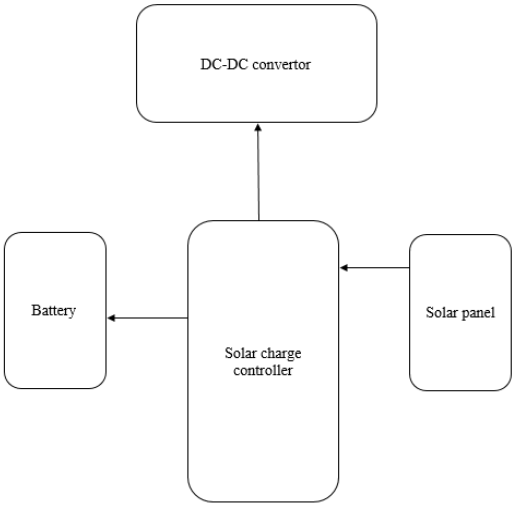


Figure 8. Block diagram for power management unit

Connecting wires

The jumper wire (Figure 9) is used to connect the Ultrasonic sensor to the Arduino microcontroller.

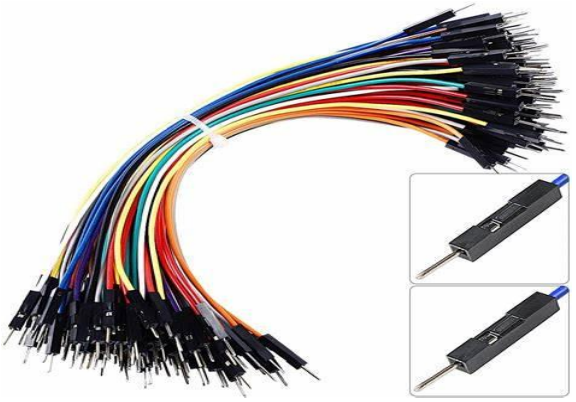


Figure 9.Jumper wires

GSM module

GSM Module is a communication standard that connects a terminal to another GSM system. The GSM system handles all signal transmission and reception from the controller to other devices and from other devices to the controller. Figure 10 shows the GSM module. The SIM800L is a small cellular module that can send and receive GPRS data, send and receive SMS, and make and receive voice calls. This module's low cost, small footprint, and quad-band frequency capabilities make it an ideal choice for any project requiring long-range communication.



Figure 10. GSM module

IoT-STBLM Server

The IoT-STBLM server program was installed on a personal computer with a windows 10 operating system. The software for Arduino is called Arduino IDE (Integrated Development Environment). It's a text editor with a variety of capabilities, similar to a notepad. It's used to write code, compile it to see if there are any issues, then upload the code to the Arduino. The sensors in the garbage bin are activated using the Arduino IDE. The data will be captured and then broadcast through the LoRa transmitter and received by the LoRa receiver. The data received will be stored in NodeMcu. ThingSpeak is an Internet of Things (IoT) cloud platform that allows you to transfer sensor data to the cloud. Your data may also be analyzed and visualized. Giving an API to both devices and social network websites makes data access, retrieval, and logging easier. We use

Thingspeak for the visualization of data. The data is processed and sent to the Wamp program. Wamp is a free and open-source platform for developing web applications. Here, W stands for Windows/Linux. A stands for Apache webserver. MySQL is a database management system. P stands for PHP. Figure 11 shows the overall network architecture diagram of the IoT STBLM server.

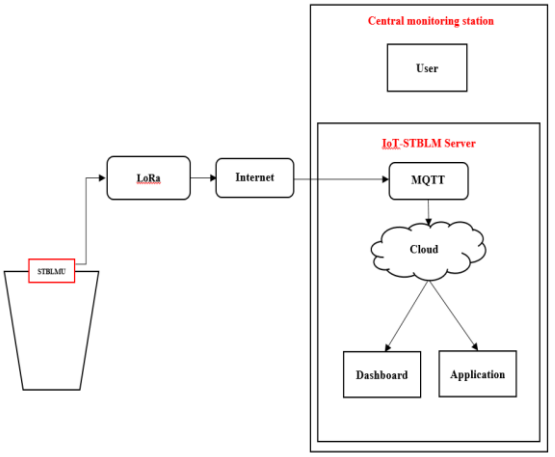


Figure 11. Block diagram of IoT – STBLM Server

Wamp is an excellent tool for setting up a local webserver. It's simple to set up and use. PHP runs on its computer system, disconnected from the internet. Practicing server-side scripting in a local web development environment is an excellent method to improve your skills. The front end is PHP. The block diagram is given in figure 11.

Experimental setup

Testing of the Developed IoT-TBLMS

A comparative study was conducted between the IoT-TBLMS measurements and manual measurements to assess the accuracy of the generated IoT-TBLMS. As a result, a garbage can (Bin 1) was lightly stuffed with rubbish (clothes). The data from the IoT-TBLMS was saved on the IoT-TBLM server, while manual data was measured with a line gauge. Similarly, for different levels of waste (clothes, bottles, shoes, and card boxes), the unfilled level was measured and shown in Figure 12. The data from the IoT-TBLMS and the manual data are close to each other, as shown in the figure. Due to the surface level of waste present in the trash bin, there is a difference between 0 and 0.9 cm.

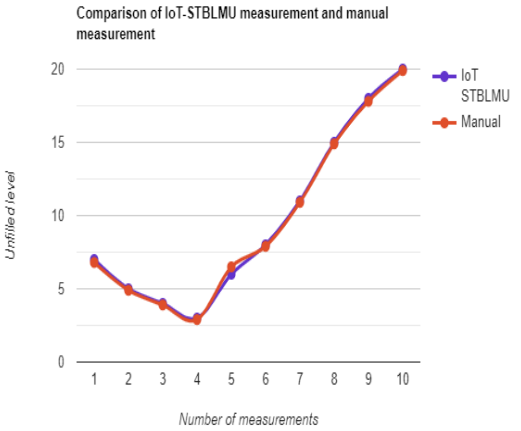


Figure 12. Comparison of IoT-STBLMU measurement and manual measurement

Sensor Mounting Position and Trash Bin Shape

The sensor mounting position and trash bin shape are important factors in reducing reflection errors. As a result, the below diagram depicts the appropriate sensor installation position as well as the design of the garbage bins. The sensor will range to the first depression in the garbage bin in red bins. The indentation generates a huge observable reflection, but the green color bin usually functions correctly. It is advised that the sensor be positioned in a garbage bin as indicated below diagram to either avoid or severely limit secondary reflections that may return to the sensor owing to the surface level of waste present in the trash bin (Green color). Figure 13 shows the results.

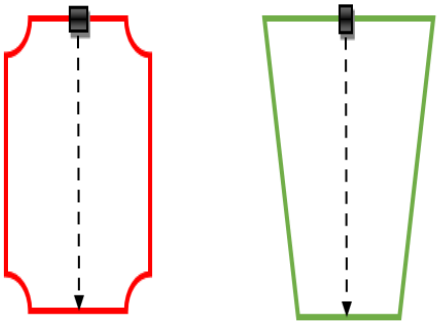


Figure 13. Sensor position and the design of the container. Recommended: Green bin. Not recommended: Red bin.

Multiple Sensors for Large Bins

The garbage bins used in our experiment were 46 cm x 46 cm (top) and 33 cm x 33 cm (bottom). The sensor is less likely to detect undesirable items and noise as the garbage bin capacity grows. On the other hand, larger garbage cans

necessitate the use of many sensors. There must be interference (cross-talk) between sensors when multiple sensors are interfacing in a single STBLMU. Therefore, the employed sensor presents a concept called chaining, and the connection of many sensors into a single STBLMU is shown below. To command a range, cycle of N sensors, set the Rx pin of the host microcontroller to high for 20 to 48 milliseconds, then return it to the ground. The sensor chaining process will be started as a result of this. Sensor 1 detects the unfilled level first, then activates sensor2 to measure, and so on. Figure 14shows the connection of multiple sensors for large bins.

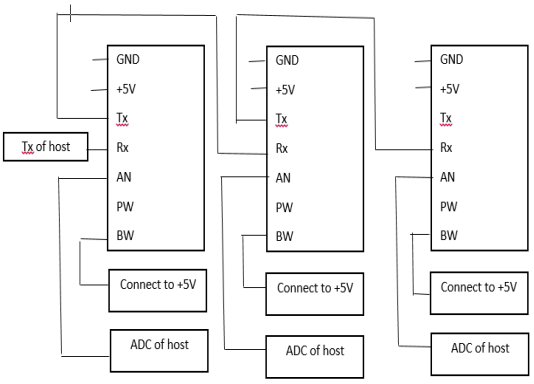


Figure 14. Connection of multiple sensors

Average current consumption

The current contribution of the STBLMU in active mode,

$$Q^{a}_{STBLMU} = ([I^{q}_{DC-DC} + I^{a}_{HM}] \times T^{a}_{HM}) + (I^{a}_{GPS} \times T^{a}_{GPS}) + (I^{a}_{LM} \times T^{a}_{LM}) + (I^{a}_{sensor} \times T^{a}_{sensor}) \quad (2)$$

$$= 0.42 \text{ A} \times \text{s}$$

The buck converter's quiescent current is - I^{q}_{DC-DC} . The host microcontroller's current consumption in active mode is -I^{a}_{HM}. In active mode, the duration of the host microcontroller –T^{a}_{HM} . The GPS module uses a lot of electricity while it's on - I^{a}_{GPS}. The GPS module's active time is measured in seconds - T^{a}_{GPS}. I^{a}_{LM} – In active mode, the LoRa module consumes the following amount of energy: The LoRa module's active time is measured in seconds - T^{a}_{LM}. I^{a}_{sensor}– In active mode, the ultrasonic sensor consumes a significant amount of electricity. In active mode, the ultrasonic sensor lasts for a certain length of time - T^{a}_{sensor}. The greater the contribution of the sleep current to the total average current transmute, the less frequently STBLMU measures the garbage bin level. The STBLMU's current contribution in sleep mode,

$$Q^{s}_{STBLMU} = (I^{q}_{DC-DC} + I^{s}_{HM} + I^{s}_{LM}) \times (T - T^{a}_{HM}) \quad (3)$$

$$= 0.13 \text{ A} \times \text{s}$$

Where I^s_{HM}- the host microcontroller's current consumption in sleep mode, I^s_{HM} - the LoRa module's current consumption in sleep mode, T^a_{HM} - the active period of the host microcontroller (300 s) - duration of garbage bin level measurement. STBLMU's average current usage,

$$I_{STBLMU} = \frac{Q^a_{STBLMU} + Q^s_{STBLMU}}{T} \quad (4)$$

$$= 1.83 \text{ mA}$$

The STBLMU's Life Expectancy

The STBLMU's life expectancy was calculated using a hypothetical scenario in which the energy source's voltage is optimal until its capacity is depleted. The STBLMU's life expectancy is expected to be as follows:

$$O_d = {Q_B}/{I_{STBLMU}} \quad (5)$$

$$\approx 15 \text{ days } 5 \text{ hours},$$

Where $O_d$is the total number of days the STBLMU has been operational, and Q_B is the battery's capacity. The projected life length of the STBLMU for different periods of garbage bin level measurement. Notably, the trash bin level may be tracked down to the minute, allowing the municipality or solid waste management business to efficiently manage municipal solid waste.

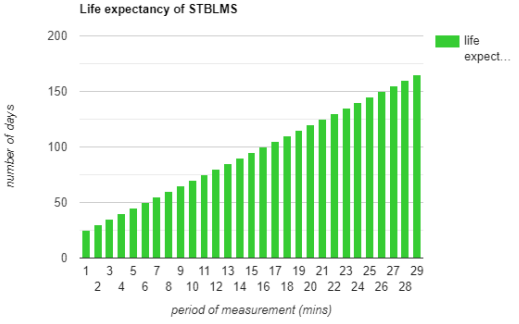


Figure 15. STBLMU's life Expectancy

Battery Charging Time Estimation

Another crucial experiment was conducted to predict the charging time of the battery. In this experiment, a Lead-acid battery with a capacity of 1300 mAh was employed. In this experiment, the battery charging time is defined as the time it takes to charge the battery from 1.5 V (under-voltage threshold) to 3.0 V (over-voltage threshold) using solar radiation. The load and the battery shared the energy that was gathered by the solar panel. In conclusion, if the battery is fully charged, it can endure approximately 15 days and 5 hours. As a result, even on rainy or overcast days, the status of the garbage bins may be watched without interruption.

Output



Figure 16. Hardware integration



Figure 17. Longitude graph



Figure 18. Latitude graph

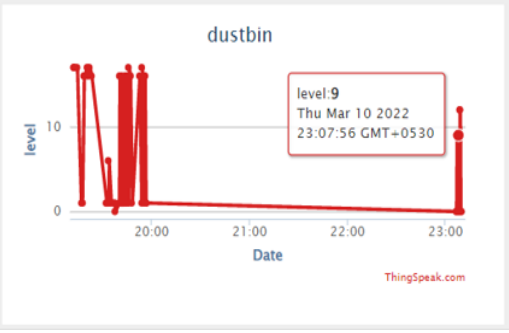


Figure 19. Level graph

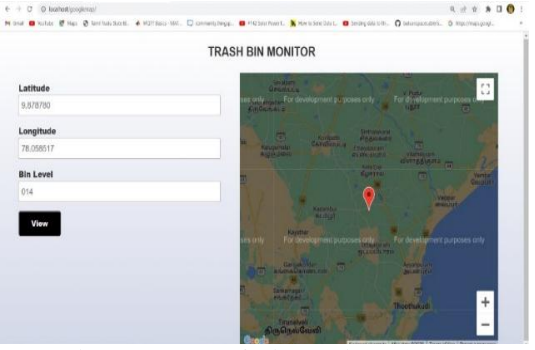


Figure 20. Website using wamp



Figure 21. Application using android studio

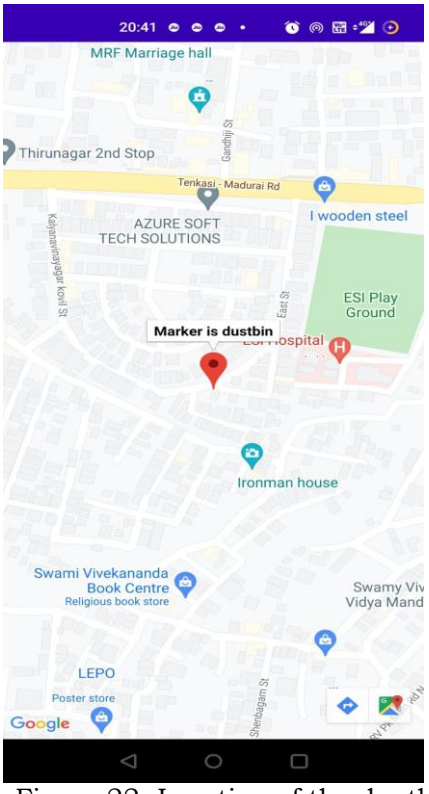


Figure 22. Location of the dustbin

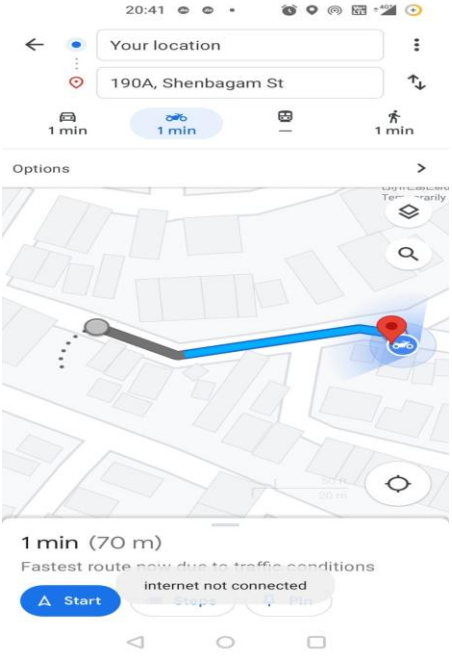


Figure 23. Route for the bin's location

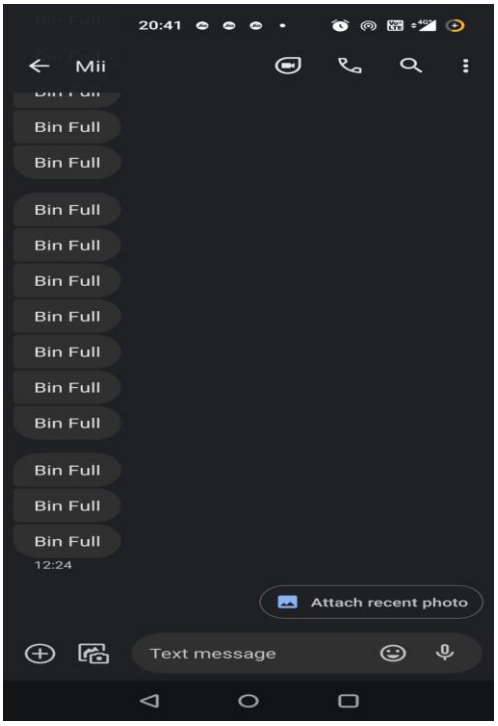


Figure 24. Notification

Figure 16 shows the circuit system design and how required components are connected. The garbage fullness level is detected using an ultrasonic ranging module sensor. Figure 20 is the website designed for the authorities to know about the bin's current status. Figure 21 is designed for the driver to know about the bin's status and take appropriate action. In figure 22 and figure 23, through the application, the driver can mark the location and find the route. A message will be sent to the driver to intimate that the bin is filled as shown in figure 24.

Cost

A garbage bin with a TBLMU and a personal computer are included in the pricing of an IoT-STBLMS. Table I summarises the cost of purchasing a garbage bin with a TBLMU. However, if commercially manufactured by acquiring a large number of pieces, the created IoT-STBLMS might be cost-effective.

Table 1
Parts cost of a trash bin withSTBLMU

ITEMS	COST (INR)
Arduino UNO with ATmega328P	550
Ultrasonic sensor (HCSR04)	278
Solar panel	405
NodeMcu	375
Solar charge controller	375
GPS module (NEO6MV2)	513

LCD 16*2	219
LoRa transceiver	1200
Battery	525
Trash bin	47
DC DC Buck converor	60
GSM module	240
TOTAL COST	4787

Comparison of results

Table II summarises our experimental findings, which are compared to current LoRaWAN-based garbage bin level measuring systems described in [20] and [21]. In a real-time environment, these systems were installed and tested. The wireless range and current consumption are, nonetheless, critical parameters of the LoRaWAN networking technology. The wireless range is not confirmed in [20], and the suggested system's wireless range at a transmission strength of 10 dBm is 50% greater than the system described in [21]. Furthermore, the suggested system's current consumption is significantly lower than [20] and [21]. For example, the ultrasonic sensor used in [20] and [21] consumes 15 mA in active mode, but the ultrasonic sensor used in the proposed system consumes just 2 mA. Furthermore, in the suggested system, factors such as life expectancy, battery charging time, solar panel performance, and cost were evaluated and published, whereas these variables were not provided in [20] and [21].

Table 2
Summary of results

EXPERIMENT	RESULTS
Testing	The unfilled level on the dashboard and application was observed when garbage
Battery	While giving power to the STBLMU, an 11.5 × 9 cm solar panel was able to fully charge the on-board battery in eight hours.
Cost	The total cost is 4787 INR
Current consumption	The STBLMU's average current usage is 1.83 mA. The on-board lead acid battery can power an STBLMU for 15 days and 5 hours at this pace.

Despite this, [20] and [21] provide a route optimization technique. The proposed LoRaWAN-based system outperforms existing LoRaWAN-based systems in providing reliable garbage bin-level information in real-time.

Conclusion and future work

According to UN predictions, approximately 70% of the world's population will live in cities by 2050. Cities do not always expand sustainably, so this rapid increase in the number of people living in them has been a source of concern. Smart city design is being researched and debated all around the world to address this

issue. Citizens are at the heart of an IoT-based, real-time waste management strategy aimed at enhancing city living conditions. The suggested system collects and disseminates trash data from smart bins in real-time using sensor and communication technologies. Waste monitoring systems are a new concept in which ultrasonic sensors detect garbage levels and the GSM module provides notification to the user, as well as updates the condition of the bin. When the waste can is full, an LCD displays the information and a notification is sent to the appropriate authorities. In the future, we want to develop software that will provide efficient trash collection routes for drivers depending on priority. We'll also impose a mechanism that allows users to send notifications to authorities by pushing a button on the unit. Future work efficiency will be improved by including these two extra processes.

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