JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

REAL TIME SOLID WASTE MONITORING USING GSM AND SENSOR TECHNOLOGY

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Abstract: With urban centers growing denser and populations surging, the volume of waste generated daily is rising at an unprecedented rate. The traditional approach to waste collection marked by static schedules and manual oversight struggles to keep pace with modern demands. This outdated system often results in delayed pickups, overflowing bins, foul Odors, and public health risks, all while wasting operational resources due to unnecessary or mistimed collection trips. In response to these persistent inefficiencies, this project introduces a forward-thinking real-time waste monitoring framework. Central to this solution is the ESP32 microcontroller, which orchestrates data collection and decision-making by interfacing with a suite of embedded sensors. Among the sensor suite, an ultrasonic module continuously measures the vertical distance between the sensor and the waste pile, determining the fill level with precision. A moisture sensor flags the presence of damp or organic waste, enabling hygienic categorization, while a metal detection module identifies metallic content, facilitating source-level segregation and recycling. Upon detecting a full bin or specific waste characteristics, the system initiates dual alerts: a GSM module sends real-time SMS notifications to the relevant waste handling authority, and a buzzer sounds an alert locally for quicker on-site response. Simultaneously, the data captured by the sensors is relayed to a cloud-connected IoT dashboard, allowing remote visualization and real-time monitoring of waste bins distributed across various zones. This smart integration promotes dynamic route planning, reduces fuel consumption, and ensures bins are serviced precisely when needed neither too early nor too late.

IndexTerms: Solid Waste Management, Real-Time Monitoring Technology, Ultrasonic Sensors, Smart Waste Bin, IoT-Based Waste System, Dynamic Threshold, Waste Collection Optimization, Microcontroller, Remote Monitoring

I. INTRODUCTION

Urban waste accumulation is an escalating concern, especially in rapidly growing cities where traditional collection methods struggle to keep pace with the volume of refuse generated daily. Overflowing public bins, delayed pickups, and inefficient routes not only compromise urban cleanliness but also pose serious environmental and health risks. These challenges often stem from outdated waste management systems that rely on rigid collection schedules, ignoring the actual status of waste containers. To address these inefficiencies, this project proposes an intelligent, sensor-driven waste monitoring solution designed to enable dynamic and data-informed collection practices. The system leverages an ESP32 microcontroller as its core, interfacing with a network of sensors and a GSM module for communication. An ultrasonic sensor continuously measures the fill level of the bin by analyzing the time delay between emitted and reflected sound waves, providing accurate waste height data. Complementing this, a moisture sensor identifies the presence of wet or organic waste, facilitating better sorting and targeted disposal strategies. Additionally, a metal sensor detects recyclable metallic items, enhancing the segregation process at the source. Once the bin reaches a predefined threshold, the system automatically sends alerts via SMS to the waste management team using the GSM module, while simultaneously activating an audible buzzer for local awareness. All sensor readings are also streamed to an IoT-based dashboard, allowing real-time visualization of bin status and supporting smarter decision-making. This approach minimizes unnecessary vehicle deployment, reduces fuel usage, and ensures bins are serviced only when required, leading to a cleaner, more efficient urban environment.

II. Literature Review

Smart waste management systems now use the ESP32 to process data from sensors like ultrasonic, moisture, and metal detectors for efficient sorting. GSM modules enable real-time alerts via SMS, ensuring timely collection even without internet access. This approach reduces manual checks and avoids unnecessary bin collection trips. Future improvements can focus on power efficiency, faster communication, and better scalability for large networks.

In [1], B. Rubini, S. P. Kumar, and M. Suganiya developed a GSM-based remote monitoring system for waste bins using ultrasonic sensors to measure fill levels. The collected data was wirelessly transmitted to a central station, enabling timely waste collection and reducing fuel consumption.

In [2], Rahul Kumar Borah et al. developed a smart system using ultrasonic sensors and GSM modules to monitor bin status in real time. This enabled optimized waste collection routes, reducing manual effort and improving operational efficiency.

In [3], Prof. Balaji Chaugule and his team conducted a comparative study on GSM and GPRS-based smart bin technologies. Their review emphasized how integrating sensor networks with wireless modules enables urban areas to monitor waste more effectively and implement responsive collection strategies.

In [4], Dr. G. Kumaravel and Varadharamanujam Ilankumaran developed a sustainable smart bin system driven by solar energy. Their model included not only waste level detection via ultrasonic sensors but also power management features to ensure long-term operation in off-grid or remote regions.

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In [8], Thangavel Bhuvaneswari, J. Hossen, Nur Asyiqin bt. Amir Hamzah, P. Velrajkumar, and Oo Hong Jack implemented a networked smart waste solution featuring load and ultrasonic sensors, with data transmitted to a cloud platform via Wi-Fi. Their work demonstrated the benefits of integrating real-time analytics into waste management systems to avoid bin overflow.

In [9], S. N. Satbhai, P. R. Gavhane, and M. R. Dhavale developed a bin-level monitoring approach using ultrasonic sensing and GSM modules. Their design focused on reducing manual effort and automating bin surveillance to enhance the overall efficiency of municipal waste operations.

III. Existing Method

Conventional waste collection systems primarily operate on fixed schedules, regardless of the actual waste levels in bins. In such setups, municipal workers are assigned predefined routes and collection times, leading to inefficiencies such as collecting half-filled bins or overlooking overflowing ones. These methods typically lack any form of automation or remote monitoring capability. Although some systems have attempted basic monitoring through manual inspections or local alarms, they do not provide centralized data or real-time notifications. Communication between collection teams and control centers is often done verbally or through periodic reporting, which limits responsiveness. Additionally, most traditional methods do not integrate any form of waste-level detection, resulting in unnecessary trips, increased operational costs, and missed opportunities for timely waste disposal.

IV. Real-time solid waste monitoring using gsm and sensor technology

The growing volume of municipal waste in urban areas demands a shift from conventional collection methods to intelligent, responsive systems. This project presents a smart bin monitoring solution that utilizes ultrasonic sensing technology to detect waste levels in real time. The system is powered by a microcontroller and uses GSM communication to relay bin status to a centralized platform, enabling timely and efficient waste collection. By integrating affordable components and focusing on modular deployment, the proposed solution reduces unnecessary collection trips, saves fuel, and improves public hygiene. Unlike systems that rely on Wi-Fi or cloud-based IoT platforms, this design prioritizes GSM for its accessibility and coverage, making it ideal for both urban and rural settings. The system promotes sustainable waste management by ensuring that bins are only serviced when needed, reducing manpower costs and optimizing operational efficiency. The rapid escalation of solid waste production in densely populated urban zones has outpaced the capabilities of traditional collection approaches, which are often rigid, time-consuming, and resource-intensive. Fixed-schedule waste collection systems, though widely used, fail to adapt to real-time demand, leading to frequent scenarios where bins overflow or are emptied prematurely both of which result in inefficient use of public funds and human resources.

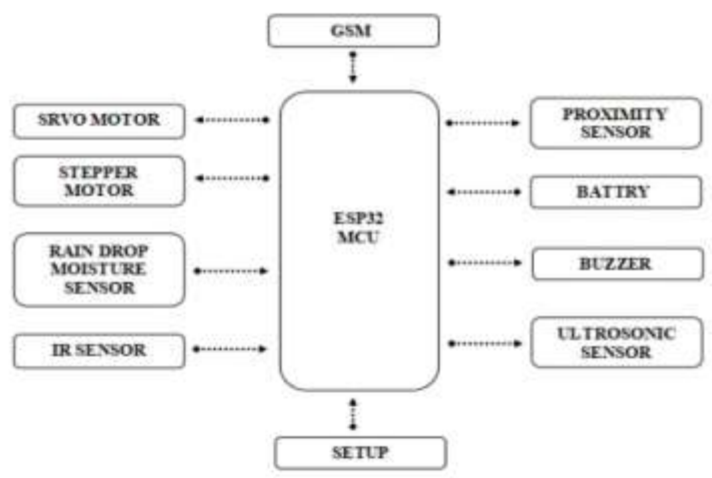

Fig 1: block diagram of real-time solid waste monitoring using gsm and sensor technology

The above block diagram shows the basic setup of the Real-Time Solid Waste Monitoring System. The system is built around an ESP32 microcontroller and includes an ultrasonic sensor to check how full the bin is, a moisture sensor to detect wet waste, and a metal sensor to find any metal items. A GSM module sends SMS alerts when the bin is full or specific types of waste are detected. A buzzer is used for local alerts, and everything is powered by a DC power supply, making the system simple and effective for real-time waste monitoring.

Working Principle

The real-time waste monitoring system utilizes an ESP32 microcontroller to process data from ultrasonic, IR, raindrop, and proximity sensors for efficient waste tracking. Based on the sensor inputs, the system controls actuators such as servo motors, stepper motors, and a buzzer to trigger immediate responses. Communication is facilitated by a GSM module, enabling SMS-based alerts even in remote areas. Powered by a rechargeable battery, this solution provides a scalable and autonomous approach to modern waste management.

Real-time solid waste monitoring system includes hardware and software components:

Hardware components

ESP32

ESP32 is a low-power, high-performance microcontroller with built-in Wi-Fi and Bluetooth capabilities, making it ideal for IoT applications. It features multiple GPIO pins, supports various sensors, and enables real-time data transmission. With its dual-core processor and low energy consumption, ESP32 ensures efficient processing for smart systems. In this project, it is used for waste monitoring, sensor integration, and GSM-based alerts.

Fig 2: esp-32

GSM

GSM (Global System for Mobile Communications) serves as a wireless backbone for transmitting SMS notifications and facilitating remote system oversight. It allows real-time data transmission over cellular networks, making it ideal for IoT-based applications. In this project, GSM is used to send notifications when the waste bin is full and needs collection. This enables prompt waste handling and real-time alerts to relevant authorities, ensuring proactive and streamlined management.

Fig 3: gsm

SERVO MOTOR

A servo motor is a specialized motor designed for precise control of rotational movement and positioning. It receives PWM (Pulse Width Modulation) signals to regulate its angle with high accuracy. In this system, the servo motor plays a critical role in automating the opening and closing of the bin lid based on sensor data. This automation enhances hygienic waste disposal and helps mitigate overflow, ensuring a cleaner and more efficient waste management process.

Fig 4: servo motor

IR SENSOR

An Infrared (IR) sensor operates by emitting a beam of infrared light and detecting the reflection from nearby objects. In this project, it plays a key role in monitoring the disposal of waste into the bin, enabling automated waste tracking and ensuring more effective waste management through real-time monitoring.

Fig 5: ir sensor

ULTRASONIC SENSOR

An ultrasonic sensor operates by emitting high-frequency sound pulses and measuring the time taken for the reflected signal to return. It consists of a transmitter and a receiver, which together enable non-contact detection of objects. In this project, the sensor is utilized to track the waste level within the bin, helping to prevent overflow and ensuring timely waste collection. This contributes to optimized waste management and improved resource allocation.

Fig 6: ultrasonic sensor

BUZZER

A buzzer is an electronic device that generates sound alerts when activated. It operates using electromagnetic or piezoelectric mechanisms to produce beeping sounds. In this project, the buzzer alerts users and authorities when the waste bin is full, ensuring timely waste collection. This helps in preventing overflow and maintaining hygiene in public areas.

Fig 7: buzzer

INDUCTIVE PROXIMITY SENSOR

An inductive proximity sensor identifies metal objects without direct contact by producing an electromagnetic field. When a metallic object enters the electromagnetic field, the sensor detects the disturbance and activates an output response. In this project, the sensor is employed to detect metallic waste, facilitating automated sorting of recyclable materials. This process enhances recycling efficiency and significantly reduces the need for manual sorting.

Fig 8: inductive proximity sensor

STEPPER MOTOR

A stepper motor operates with precise control, rotating in fixed increments in response to a series of input pulses. It provides accurate position control without the need for feedback, making it ideal for automated systems. In this project, a stepper motor can be used for opening and closing the waste bin lid or for sorting waste into different compartments. This enhances automation and efficiency in waste management.

Fig 9: stepper motor

SOFTWARE DESCRIPTION

ARDUINO SOFTWARE (IDE)

The Arduino IDE provides an intuitive interface featuring a script editor, notification area, output console, and a toolbar equipped with key functions for easy code development and execution. It enables seamless communication with Arduino or Genuino boards, allowing users to write, upload, and interact with programs on the hardware.

Fig 10: arduino software (ide)

V. Results and Discussions

The developed system effectively monitored waste levels using ultrasonic and IR sensors, while the GSM module ensured timely data transmission. Sensor readings accurately reflected the bin status, enabling real-time tracking and preventing overflow. Metal detection using an inductive sensor supported basic waste segregation. Data delays were minimal, and remote access to bin status improved collection efficiency. Some limitations included environmental sensitivity and the need for stable power, suggesting the benefit of solar-powered options. Overall, the system proved to be a practical and efficient tool for smart waste management.

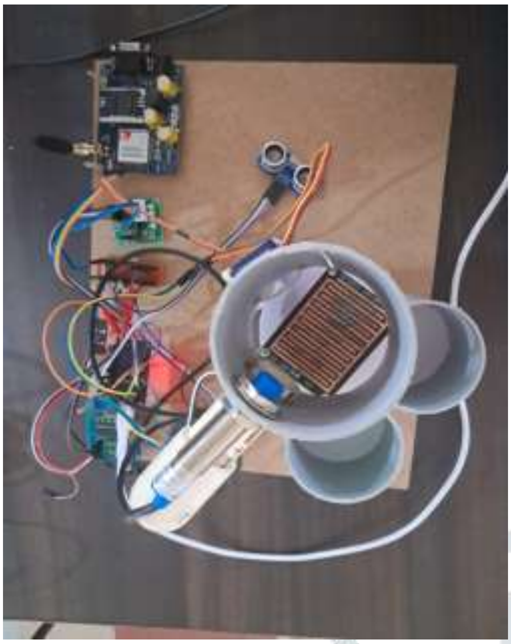

Fig 11: transmitter

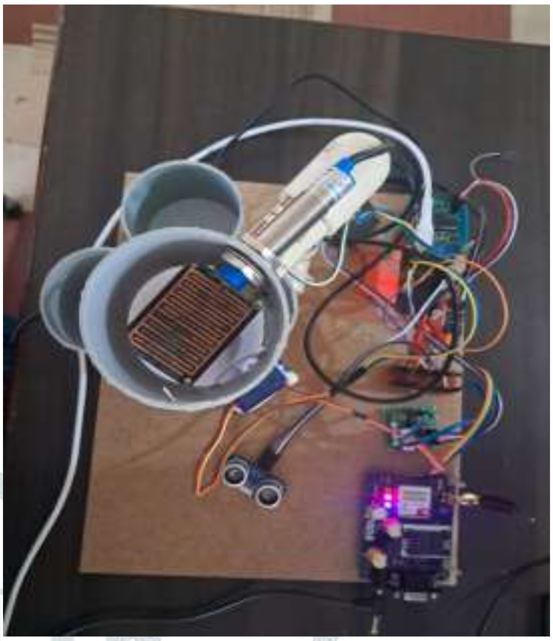

Fig 12: receiver

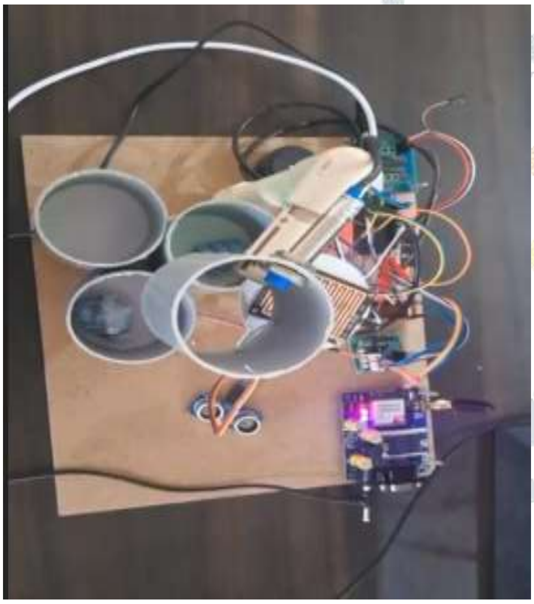

Fig 13: output

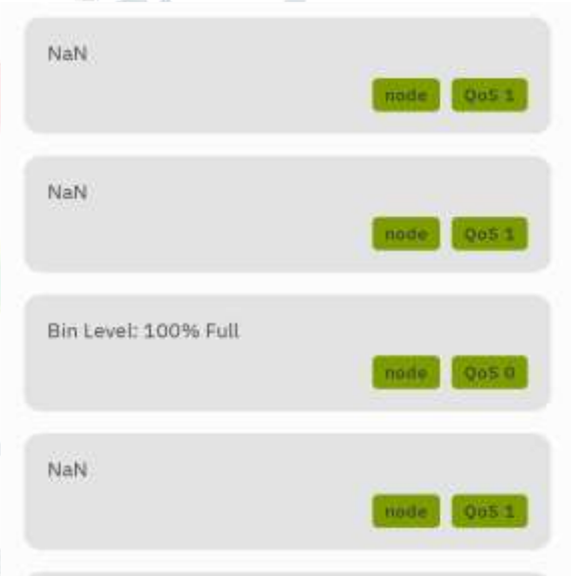

Fig 14: identifying the bin level

VI. Conclusion and Future Scope

The developed system efficiently monitored waste levels in real-time using sensor and GSM technologies, reducing manual effort and preventing bin overflow. In the future, the system can be upgraded with solar power, GPS tracking, and AI-based analytics to enable smarter routing, predictive maintenance, and improved sustainability in waste management.

ACKNOWLEDGMENT

We sincerely thank Bapatla Women's Engineering College for the support and resources provided during the course of our project. We are grateful to the Department of Electronics and Communication Engineering for their encouragement and help. Our heartfelt thanks to our project guide for offering valuable insights, timely suggestions, and guidance that helped us successfully complete our work. We also thank all the teaching staff for their assistance and cooperation throughout the project.

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