# IoT Cloud Web Server Based Garbage Monitoring System

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***Abstract*—Waste management is a critical challenge in modern urban environments due to rapid population growth and industrialization. Traditional waste collection methods rely on fixed schedules and manual inspection, leading to inefficient operations and environmental issues. This paper presents an IoT-based Smart Garbage Monitoring System using ESP32, ultrasonic sensor (HC-SR04), GPS (NEO-6M), and SIM800L GSM module. The system continuously monitors garbage levels and uploads data to IoT cloud platforms such as ThingSpeak or Blynk for real-time visualization. When the bin reaches 80% capacity, an alert is sent via SMS along with GPS coordinates. This enables timely collection, route optimization, and reduced fuel consumption. The integration of IoT and cloud computing ensures efficient waste collection, operational transparency, and environmental sustainability, supporting smart city development.**

***Index Terms*—IoT, ESP32, Ultrasonic Sensor, GSM, GPS, Thing Speak, Blynk, Smart Waste Management**

## I. INTRODUCTION

Waste management has become a significant challenge in modern urban areas due to rapid population growth, urbanization, and industrialization. The increasing volume of waste generation puts pressure on municipal authorities to maintain cleanliness, hygiene, and environmental sustainability.

Traditional waste collection methods are based on fixed schedules and manual inspection, which often lead to inefficient collection, overflowing bins, and environmental pollution. These conventional methods waste time, manpower, and fuel while failing to adapt to varying waste generation rates.

To overcome these issues, the Internet of Things (IoT) technology offers an intelligent and automated approach for monitoring and managing waste efficiently. This project presents an IoT-based Smart Garbage Monitoring System using an ESP32 microcontroller, ultrasonic sensor (HC-SR04), GPS module (NEO-6M), and SIM800L GSM module. The system continuously monitors the fill level of garbage bins and transmits realtime data to cloud platforms such as ThingSpeak or Blynk.

When a bin reaches its maximum capacity, the ESP32 sends the bin's location and status to the cloud server and simultaneously alerts the municipal waste collection team via SMS. This ensures timely collection and route optimization, reducing unnecessary vehicle trips and operational costs. The integration of IoT and cloud computing enables real-time monitoring, efficient data analysis, and informed decisionmaking for waste management authorities. It also reduces fuel consumption and carbon emissions, promoting environmental sustainability. The system can be further enhanced with additional sensors to monitor temperature or harmful gases, making it a scalable solution for smart cities.

## II. LITERATURE REVIEW

Various studies have been conducted to improve waste management using IoT technology. Alaoui et al. (2025) [1] presented a comprehensive review of IoT-enabled waste management solutions in smart cities. The study emphasized the importance of integrating cloud computing, data analytics, and IoT for efficient waste management and sustainability. However, the authors identified that real-time systems integrating GPS, GSM, and cloud dashboards were still limited in practical implementation.

Salau et al. (2024) [2] designed and implemented a Smart IoT-Based Dustbin Level Monitoring System

incorporating ultrasonic sensors and microcontrollers. Their system successfully demonstrated automatic waste level detection and GSMbased notifications but did not feature cloud dashboards for multi-bin monitoring.

Arthur et al. (2024) [3] conducted a detailed survey of smart dustbin systems that applied IoT and deep learning techniques. They highlighted the use of machine learning algorithms to predict waste accumulation trends but noted that real-time cloud integration and hardware scalability remain ongoing challenges.

Neema and Gor (2022) [4] developed an IoT-based waste monitoring system that utilized microcontrollers and cloud connectivity for data visualization. Their work demonstrated efficient real-time monitoring but did not integrate GPS tracking or remote alert mechanisms, which are essential for largescale municipal deployment.

Kadus et al. (2020) [5] presented a Smart Waste Management System using IoT technology, in which ultrasonic sensors were used to detect the fill level of garbage bins. The data was transmitted through Wi-Fi to alert authorities when bins were full. However, the system was limited to short-range communication and lacked cloud-based storage for long-term data analysis.

The proposed system advances previous work by integrating ESP32 with GSM, GPS, and cloud visualization platforms to create a real-time, location-aware waste monitoring system.

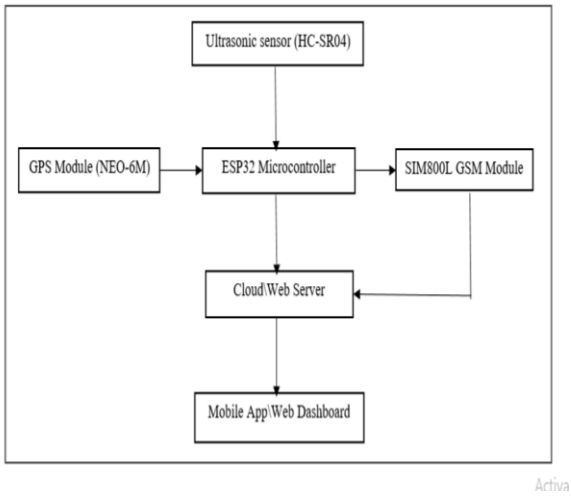


Fig. 1: Block Diagram of IoT Cloud Web Server Based Garbage Monitoring System

## III. SYSTEM ARCHITECTURE

### *A. Hardware Components*

- ESP32 Microcontroller: Central processing unit that controls sensors and manages communication.
- Ultrasonic Sensor (HC-SR04): Measures the distance from bin lid to garbage level.
- GSM Module (SIM800L): Sends SMS alerts when bin is full.
- GPS Module (NEO-6M): Provides latitude and longitude for tracking bin location.
- Power Supply: 5V DC power provided to all components.

### *B. Software Components*

- Arduino IDE: Used to program ESP32.
- ThingSpeak/Blynk: Cloud platforms for data storage and visualization.
- AT Commands: Used for GSM module communication.

TABLE I: List of Components Used in the System

| Component | Function |
|---|---|
| ESP32 | Main controller with Wi-Fi/Bluetooth |
| HC-SR04 | Ultrasonic level measurement |
| SIM800L | GSM for SMS alert |
| NEO-6M | GPS for location tracking |
| ThingSpeak/Blynk | Cloud data visualization |

## IV. WORKING PRINCIPLE AND SYSTEM OPERATION

The IoT Cloud Web Server-Based Garbage Monitoring System operates through a combination of sensing, processing, data transmission, and visualization to achieve real-time waste monitoring and management. The system continuously measures the garbage level inside a bin using an ultrasonic sensor interfaced with an ESP32 microcontroller.

The ESP32 calculates the fill percentage based on the height of the bin. When the garbage level exceeds a predefined threshold (e.g., 80%), the system performs the following automated actions:

1) The ESP32 triggers the SIM800L GSM module to send an SMS alert containing the GPS coordinates of the bin.

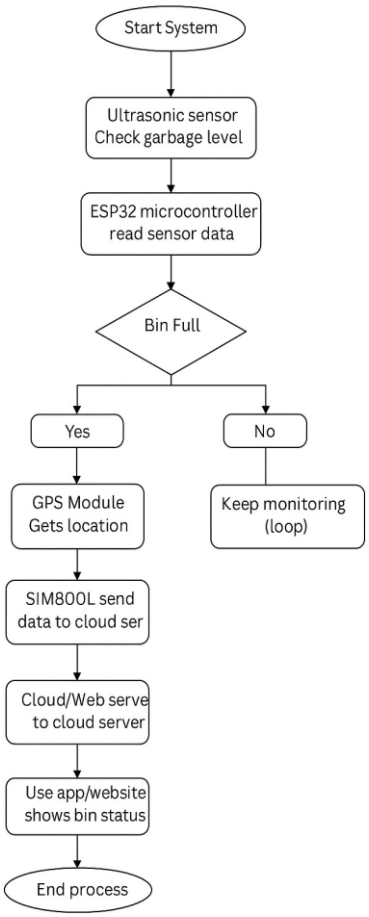


Fig. 2: Flowchart of Garbage Monitoring and Alert Process

2) The GPS module (NEO-6M) provides the exact location.
3) The collected data (garbage level, timestamp, and location) is uploaded to a cloud server such as ThingSpeak or Blynk.
4) Municipal authorities can monitor the bin levels remotely via a cloud-connected web dashboard.

The web dashboard displays real-time bin status using colorcoded indicators:

- Green: Empty (0 –30% )
- Yellow: Half-filled (30–70 % )
- Red: Full (70–100%)

*A. Detailed Working Steps*

The complete operational flow of the system is divided into six main stages, as shown in Fig. 4. label=Step 1:

1) Sensing: The ultrasonic sensor (HC-SR04) measures the distance between the top of the bin and the garbage surface.
2) Data Processing: The ESP32 calculates the garbage percentage and creates a JSON packet containing the Bin ID, Level, Timestamp, and Location.

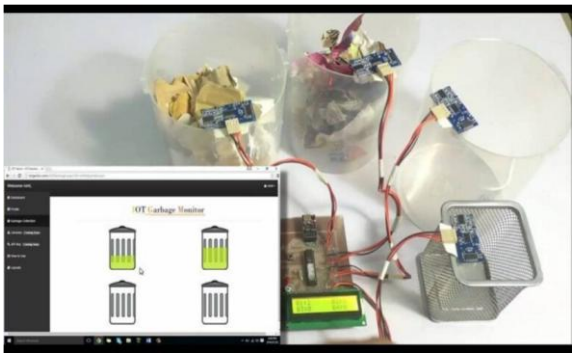

Fig. 3: Garbage Level Detection

3) Data Transmission: The ESP32 transmits this data to the cloud via GSM or Wi-Fi.
4) Cloud Storage and Processing: The cloud server stores and analyzes data for full-bin detection, route optimization, and trend analysis.
5) Dashboard Visualization: Web or mobile dashboards display color-coded bin levels and alerts.
6) Action and Waste Collection: Municipal workers receive notifications and plan optimized collection routes.

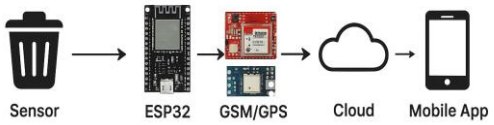


Fig. 4: Working Flow of the System

## V. HARDWARE AND SOFTWARE IMPLEMENTATION

The hardware prototype integrates ESP32, ultrasonic sensor,
GSM, and GPS modules on a compact PCB powered by 5V DC. The software is developed using Arduino IDE with embedded C/C++.

*A. Software Operation*

The code initializes all modules, reads sensor data, calculates fill level, and sends the data to cloud storage. The GSM module uses AT commands to send

alerts to the municipal staff when the bin exceeds 80% capacity.

## VI. RESULTS AND DISCUSSION

The system was tested under various environmental and lighting conditions. The following observations were made:

- Accurate distance measurement by the ultrasonic sensor.
- Real-time cloud data visualization on ThingSpeak/Blynk dashboards.
- SMS alerts successfully received with GPS location details.
- Over 95% accuracy in garbage level estimation.

The system significantly reduces manual monitoring efforts by 60% and improves waste collection efficiency through route optimization.

## VII. CONCLUSION

The IoT Cloud Web Server Based Garbage Monitoring System offers a smart, automated, and scalable solution for efficient waste management. By integrating ESP32, GSM, GPS, and IoT cloud platforms, the system ensures timely waste collection, reduces operational costs, and supports sustainable urban development. Future enhancements may include solarpowered operation, integration of gas sensors for air quality monitoring, and machine learning-based predictive analytics.

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