Smart Waste Bin Network Using IoT and Fog Computing

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***Abstract*—In urban areas, waste collection is usually done at fixed times without knowing the actual fill level of dustbins. This causes overflow in crowded areas and unnecessary collection in low-usage areas. This report presents a conceptual IoT-based smart waste bin network using an ultrasonic sensor, ESP32 microcontroller, LoRa communication, and fog computing. The system monitors bin fill levels, estimates how fast bins are filling, and helps in planning efficient waste collection.**

***Index Terms*—Smart Waste Management, IoT, ESP32, Ultrasonic Sensor, LoRa, Fog Computing**

I. Problem Statement and Objective

Urban cities face problems such as overflowing dustbins, bad smell, and unhygienic conditions due to inefficient waste collection. Some bins overflow quickly in crowded areas, while others remain half empty. This leads to poor hygiene and increased fuel cost for garbage vehicles.

The objective of this project is to design a smart waste bin monitoring system that:

- Detects and reports the fill level of waste bins
- Notifies authorities when bins are nearly full
- Helps in deciding which bins should be collected first

II. System Architecture

A. Hardware Architecture

Each smart dustbin consists of the following components:

- JSN-SR04T waterproof ultrasonic sensor
- ESP32 microcontroller
- LoRa communication module
- Rechargeable battery and charging circuit

The ultrasonic sensor is mounted at the top of the dustbin to measure the distance to the waste. The ESP32 reads this data, calculates the fill level, and performs local processing. The LoRa module sends important data to a nearby gateway.

B. Software Architecture

The software architecture explains how data is processed and transferred in the system.

The working flow is:

1) Ultrasonic sensor measures distance to waste
2) ESP32 converts distance into fill percentage
3) Fog logic checks whether fill level exceeds 50%
4) Data is transmitted through LoRa only when required

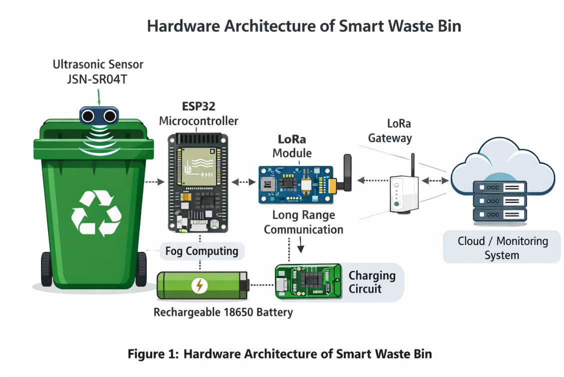

Figure 1: Hardware Architecture of Smart Waste Bin

Fig. 1. Hardware Architecture of Smart Waste Bin

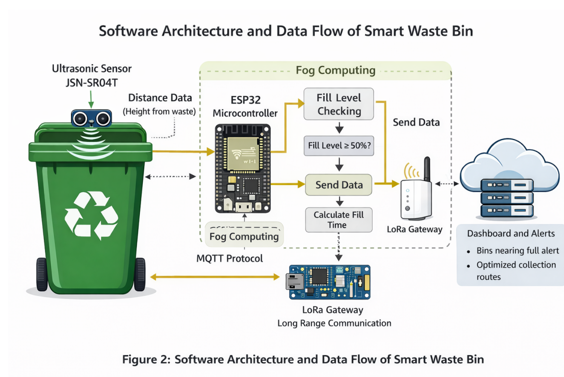

Figure 2: Software Architecture and Data Flow of Smart Waste Bin

Fig. 2. Software Architecture and Data Flow

III. Data Flow Design

The data flow in the system is as follows:

1) Ultrasonic sensor sends distance data to ESP32 using digital pins
2) ESP32 calculates the fill percentage
3) ESP32 decides whether data transmission is required
4) Important data is sent via LoRa to the gateway
5) Gateway forwards the data to a monitoring system

Only necessary data is transmitted, reducing network traffic and power consumption.

IV. TECHNOLOGY JUSTIFICATION

A. Why LoRa is Used

LoRa is used because dustbins are distributed over large outdoor areas where Wi-Fi is not reliable. LoRa provides long-range communication with very low power consumption. One gateway can support many dustbins, making the system cost-effective and scalable.

B. Why Fog Computing is Used

Fog computing allows data to be processed near the sensor instead of sending all raw data outside. The ESP32 calculates fill level and checks conditions locally. This reduces unnecessary communication, saves battery power, and enables faster decision making.

C. Why Time to Reach 50% Fill Level is Calculated

Different locations generate waste at different speeds. By calculating the time taken to reach 50% fill level, the system identifies fast-filling bins. This helps assign higher priority to such bins and prevents overflow before collection.

V. POWER MANAGEMENT PLAN

To ensure long battery life:

- ESP32 remains in deep sleep mode most of the time
- Ultrasonic sensor is powered only during measurement
- LoRa module transmits data only when required

This allows the system to operate for long durations using a single battery.

VI. RELIABILITY AND FAULT HANDLING

System reliability is improved by:

- Using a waterproof ultrasonic sensor suitable for outdoor conditions
- Detecting abnormal or constant readings to identify sensor faults
- Reporting fault status to the monitoring system

VII. SCALABILITY AND NETWORK CONSIDERATIONS

The system follows a star topology:

- Many dustbins communicate with one LoRa gateway
- One gateway can support hundreds of dustbins
- Additional gateways can be added for larger areas

This makes the system suitable for city-wide deployment.

VIII. COST AND FEASIBILITY

Approximate cost per dustbin is shown in Table I.

TABLE I
ESTIMATED COST PER SMART BIN

Component	Cost ()
ESP32 Microcontroller	450
LoRa Module	950
Ultrasonic Sensor	250
Battery and Charger	250
Total	1900

The system is cost-effective and suitable for smart city applications. hyperref

IX. PROJECT REPOSITORY

The complete project files and documents are available at:

https://github.com/JAHNAVI-0512/-WM-Jahnavi-IIITNuzvid

X. CONCLUSION

This report presented a simple and effective IoT-based smart waste bin system. By using fog computing, LoRa communication, and fill-level prediction, the system helps avoid overflow, reduce fuel usage, and improve waste collection efficiency. The design is scalable, reliable, and suitable for urban environments.