TRASH DISPOSAL MONITORING AND MANAGEMENT SYSTEM

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ABSTRACT: Traditional waste management systems often face challenges such as overflow and missed collections. The Trash Disposal Monitoring and Management System integrates IoT sensors with a web-application to improve waste management. The system uses ultrasonic sensors to measure bin fill levels and location tracking to monitor bin positions in real-time. The data is sent to a web application, allowing users to track bin status, receive SMS alerts for full bins, and optimize collection schedules. Initial results demonstrate significant improvements in operational efficiency and resource management.

Keyword: Internet of things , Trash Management , IOT Device , Arduino uno , sensor dectection , Bin monitoring , smart bin alert system

1.INTRODUCTION

Trash Disposal Monitoring and Management System is a modern approach to addressing the persistent problems associated with traditional waste collection methods in urban areas. As cities continue to expand and populations grow, municipal services face increasing pressure to maintain cleanliness, ensure timely garbage collection, and minimize environmental impact. However, conventional waste management techniques often rely on fixed schedules and manual bin inspections, leading to inefficiencies such as overflowing bins, missed pickups, and unnecessary fuel consumption by collection vehicles

II. LITERATURE SURVEY

One significant contribution in this field is the work, Smart Waste Management System Using Ultrasonic Sensors for Real-Time Bin Monitoring. Their system utilizes ultrasonic sensors to continuously monitor the fill level of trash bins and transmit the data in real-time to a central server. This architecture allows authorities to act proactively rather than reactively, thereby improving collection frequency, reducing labor, and enhancing environmental cleanliness. However, their system lacks geolocation integration and has limited dashboard interactivity.

A similar implementation titled "Smart Garbage Management System for a Sustainable Urban Life" introduced an Arduino Uno-based smart bin equipped with automated lids and basic alert mechanisms. The study emphasized the use of embedded hardware to automate lid operation and send status updates. While this approach helps reduce human effort, it primarily focuses on lid automation rather than full-scale monitoring, lacks real-time mapping capabilities, and does not support advanced cloud-based features.

III. EXISTING SYSTEM

Conventional trash management systems rely heavily on fixed schedules and manual inspections. In most urban environments, garbage collection is carried out along predetermined routes, regardless of whether bins are full, half-filled, or empty. This leads to inefficient use of resources, unnecessary fuel consumption, and frequent instances of overflowing trash bins especially in densely populated or high-traffic zones.Field workers often lack visibility into the real-time status of bins across various locations. As a result, some bins may remain overflowing for extended periods before being serviced. The absence of tools for live tracking and condition assessment leads to delayed actions, unsanitary conditions, and rising dissatisfaction among the public. These systems typically offer little to no automation, no proactive alerts, and lack any form of data history or analytics.

IV. PROPOSED SYSTEM

To fill these gaps, the proposed Trash Disposal Monitoring and Management System (TDMS) introduces a comprehensive and modular solution tailored for large-scale, smart city waste management. It incorporates ultrasonic sensors connected to an Arduino Uno to detect bin fill levels, which are then transmitted to a Node.js backend and stored in Firebase, enabling real-time data sync and storage. For precise location awareness, the system uses the Google Geolocation API, mapping each bin's exact coordinates to an interactive dashboard. When bins reach a configurable threshold (e.g., 70% full), automated SMS alerts are triggered through the Twilio API, notifying cleaning personnel in real time.To provide better control and visibility, TDMS offers a web dashboard that displays all bin statuses in real-time. The dashboard features dedicated buttons to mark cleaning operations, such as “Start Clean” and “Clean Finished”, enabling proper task management. Every bin activity, including alerts and cleaning actions, is recorded in an activity log, allowing administrators to review historical data and ensure accountability. Additionally, the dashboard includes a dark and light theme mode, offering a customizable and user-friendly interface for monitoring during various lighting conditions.

V. IMPLEMENTATION

The implementation of the Trash Disposal Monitoring and Management System (TDMS) required a carefully coordinated integration of embedded hardware, backend server logic, real-time cloud storage, third-party APIs, and a responsive web-based user interface. The primary objective was to build an efficient system that could automatically detect trash bin fill levels, trigger notifications when thresholds are exceeded, store all related data, and present this information in a centralized, accessible dashboard.

The system uses an Arduino Uno as the central microcontroller, programmed via the Arduino IDE. An ultrasonic sensor (HC-SR04) is connected to measure the distance from the bin top to the trash surface using Trigger and Echo pins. The time measured with pulseIn() is converted to distance and fill percentage, which is sent to the host via USB using Serial.println()

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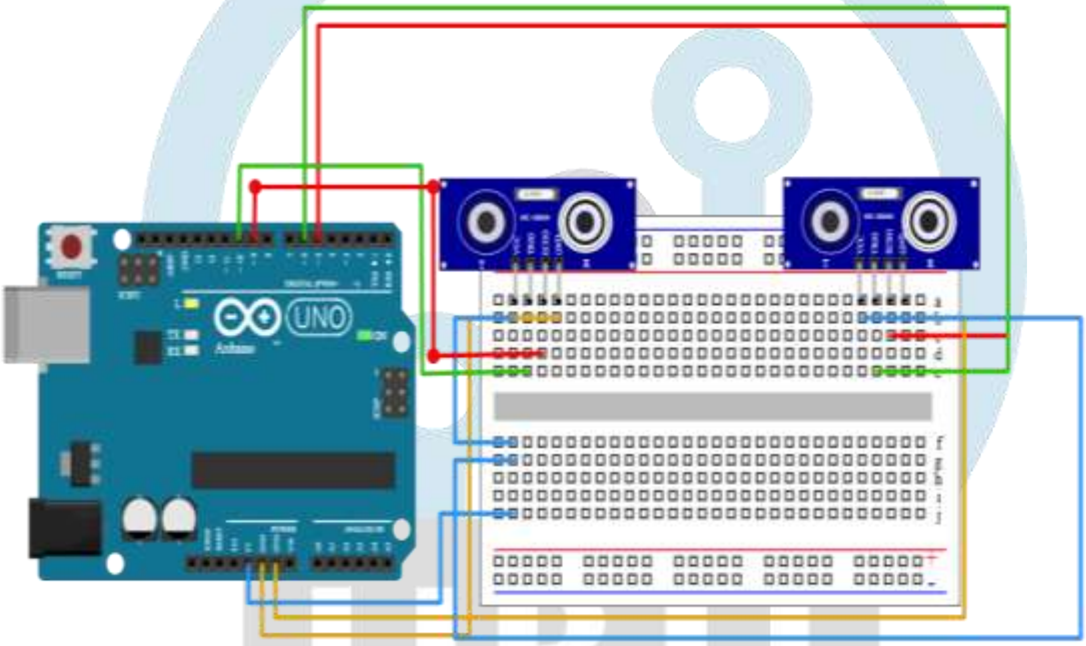

Figure 1 – IOT Setup blueprint

Figure 1 illustrates the IoT setup for the trash bin monitoring system. It shows the Arduino Uno connected to two ultrasonic sensors via a breadboard and jumper wires. The sensors are linked to the Arduino’s digital pins for real-time bin fill level detection.

Table. 1: Sensor Connection

COMPONENT	PIN NAME	CONNECTED TO (ARDUINO PIN)
Ultrasonic Sensor 1	VCC	5V
Ultrasonic Sensor 1	GND	GND
Ultrasonic Sensor 1	TRIG	Digital Pin 8
Ultrasonic Sensor 1	ECHO	Digital Pin 9
Ultrasonic Sensor 2	VCC	5V
Ultrasonic Sensor 2	GND	GND
Ultrasonic Sensor 2	TRIG	Digital Pin 10
Ultrasonic Sensor 2	ECHO	Digital Pin 11

On the backend, a Node.js server is employed to receive and process sensor data from the Arduino. It uses the serialport library to listen to the serial interface and extract fill level data from the incoming strings. The server applies a logical condition to compare the current fill level with a predefined threshold value, which is commonly set to 70%. If this threshold is exceeded, an SMS alert is triggered using the Twilio API. The SMS message includes key information such as the bin's unique ID, the detected fill percentage, and optionally, the bin's geographic coordinates obtained from the Google Geolocation API.

In addition to triggering alerts, the server updates the Firebase Realtime Database using the firebase-admin SDK. Regardless of whether a bin is full or not, all readings are logged to Firebase, maintaining a continuous and accurate record of bin statuses. The data is organized in JSON format, with each bin represented as a structured node.

The schema includes the following key fields:

- trashLevel: Represents the current fill level of the bin in percentage (%).
- isCleaning: Boolean flag indicating whether the bin is currently undergoing cleaning.
- alertVisibleUntil: Timestamp that controls how long the alert remains active on the dashboard.
- lastSMSTime: Timestamp of the last SMS alert triggered for the bin.
- location.lat & location.lng: Latitude and longitude of the bin, captured using the Google Geolocation API.
- logs: A nested object containing historical records of bin events, such as alerts and cleanings. Each log contains:
    - alertTime: Timestamp when the alert was triggered.
    - cleanStartTime: Timestamp when the cleaning process began.
    - cleanEndTime: Timestamp when cleaning was completed.
    - trashLevel: Fill level at the time of the event.

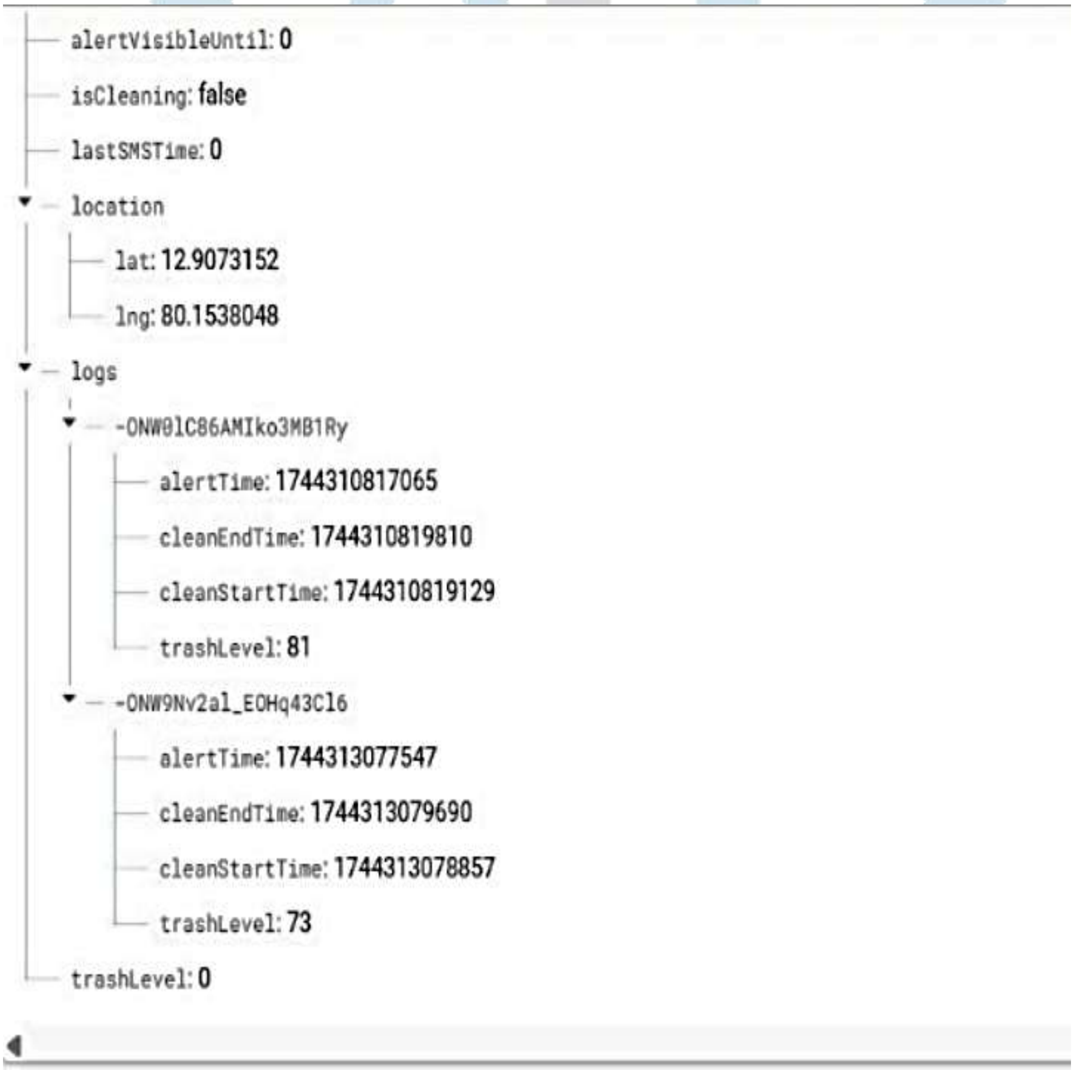

Figure 2 : Firebase realtime database

This database acts as the central real-time data hub, ensuring that updates are instantly reflected across all connected clients and interfaces.

On the frontend, a responsive web dashboard was developed using HTML, CSS, and JavaScript. The dashboard connects to Firebase through the Firebase Web SDK, enabling real-time data visualization and control. The interface features include:

- Bin fill levels displayed using progress bars or colored icons representing status: green (safe), yellow (moderate), and red (full).
- SMS alert logs for bins that exceed the predefined fill threshold.
- Bin location visualization using embedded Google Maps, where each bin is pinned to its real-time GPS location.
- Administrative controls, including interactive buttons such as "Start Cleaning" and "Clean Finished" for each bin entry.

To enhance usability across different lighting environments, the dashboard also includes a dark/light mode toggle, implemented using JavaScript and CSS toggling techniques. Additionally, the dashboard is mobile-responsive, ensuring that both administrators and cleaners can manage and monitor the system effectively on a variety of devices, including desktops, tablets, and smartphones.This seamless interaction between sensor hardware (Arduino), backend services (Node.js), cloud database (Firebase), alert system (Twilio API), location tracking (Google API), and the frontend dashboard results in a real-time, efficient, and scalable smart waste management solution.

VI. ARCHITECTURE DIAGRAM

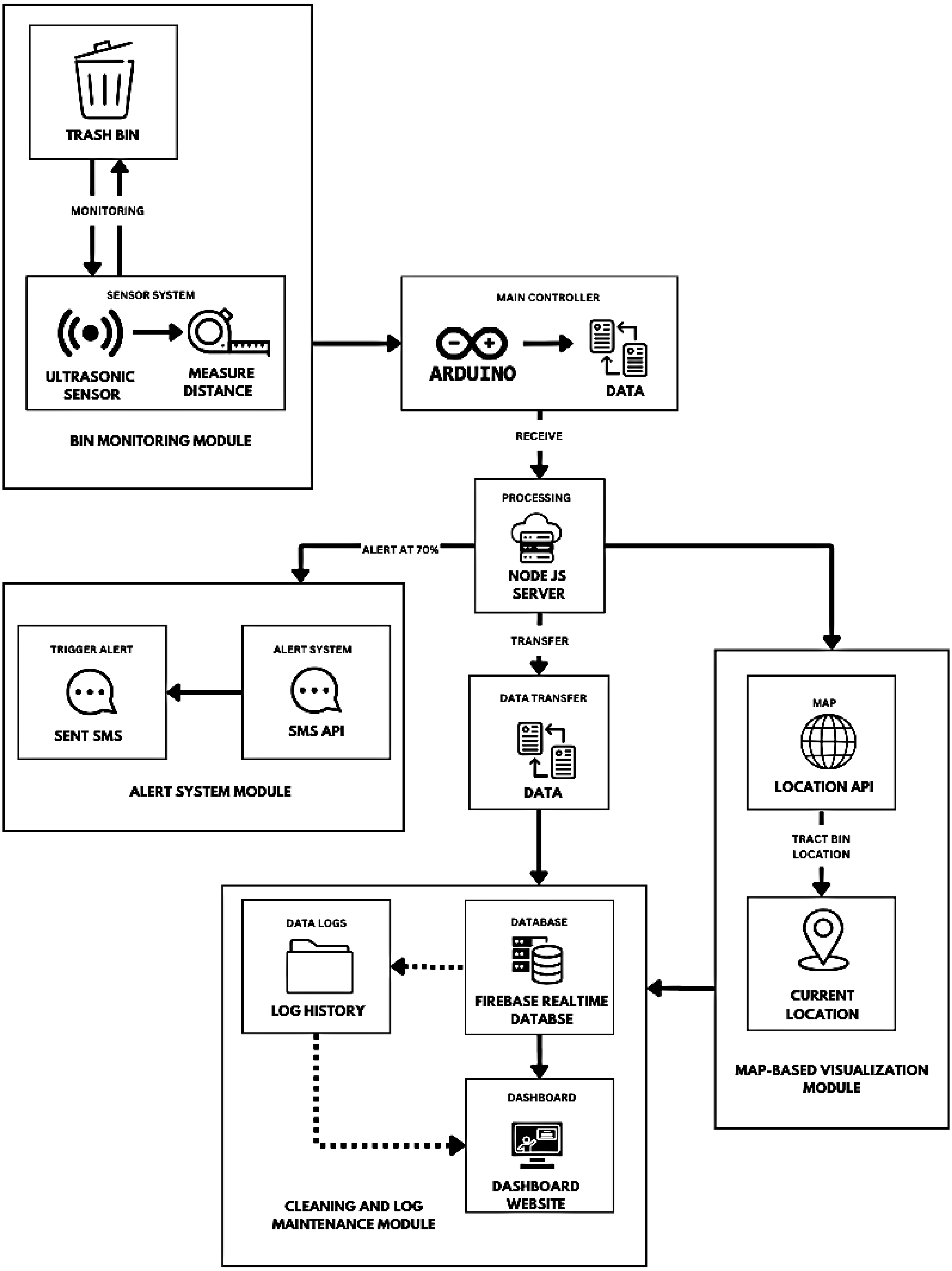

Figure 3 : Architecture Diagram

VII. FLOW CHART

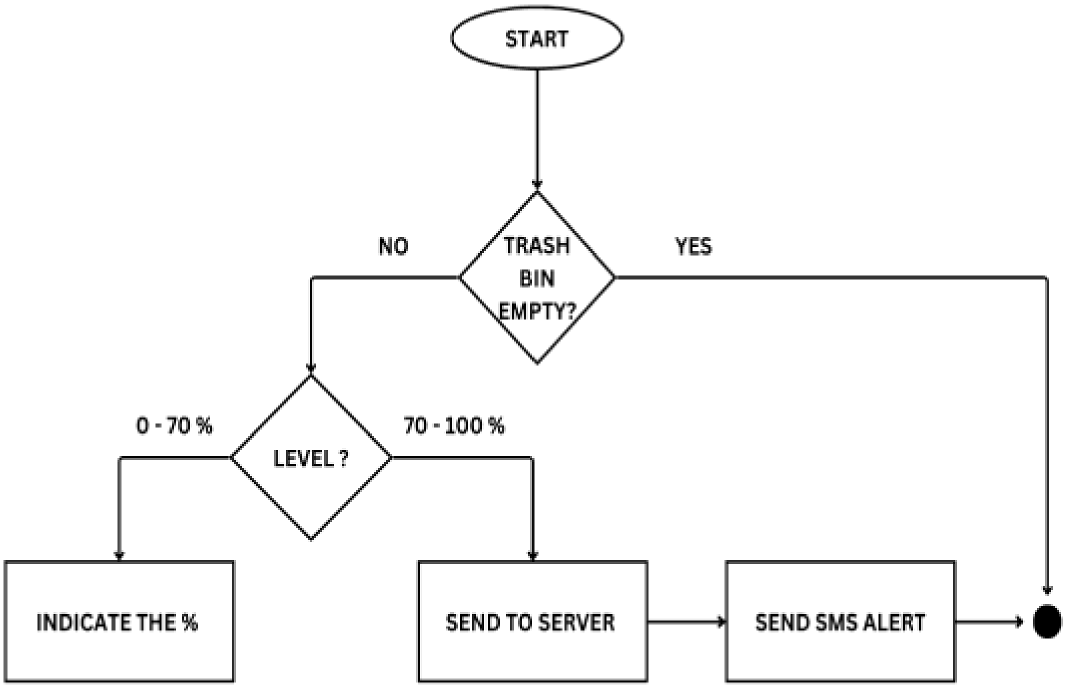

Figure 4: Flowchart Diagram

VIII. RESULT AND DISCUSSION

The Trash Disposal Monitoring and Management System, built using Arduino, ultrasonic sensors, Node.js, Firebase, and Twilio API, successfully achieved the core objectives defined during the project design phase. The system provided real-time bin level monitoring, SMS alerts when thresholds were reached, and location-based bin tracking through Google Geolocation API. The web-based dashboard allowed users to visualize bin status, manage cleaning operations, and access historical logs.

Key results include:

- Accurate detection of bin fill levels using ultrasonic sensors.
- Real-time data transfer to Firebase and immediate reflection on the dashboard.
- SMS alert functionality triggered when bin levels exceeded 70%, using Twilio API.
- Live location detection through Google Geolocation API.
- Management controls, such as "Start Cleaning" and "End Cleaning," for logging bin clearance.
- Responsive dashboard UI with both dark and light theme modes for better accessibility.
- Detailed log maintenance, storing timestamps, bin IDs, fill percentages, and status updates to help administrators review records

Overall, the system demonstrated consistent performance, achieving low response latency, high data accuracy, and smooth integration of all modules in real-world test conditions.

The successful implementation of the Trash Disposal Monitoring and Management System (TDMS) is showcased through the seamless integration of multiple components working together. These components include sensors for trash level detection, microcontrollers for data transmission, a cloud-based database for real-time data storage, and a user interface for monitoring and alert notifications. Each module plays a crucial role in ensuring the system's efficiency, reliability, and responsiveness. The sections below provide a detailed overview of each feature, emphasizing how every part contributes to achieving the project's overall goals of effective waste management, timely alerts, and data-driven decision-making

Figure 5 : Monitoring bin level

Figure 6 : Alert received when bin above 70% full

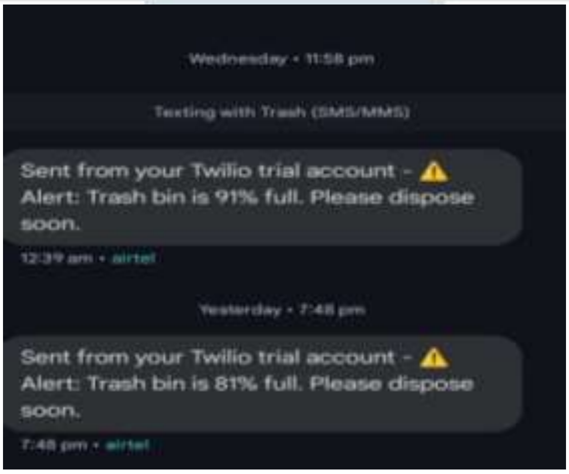

Figure 7 : SMS alert Received

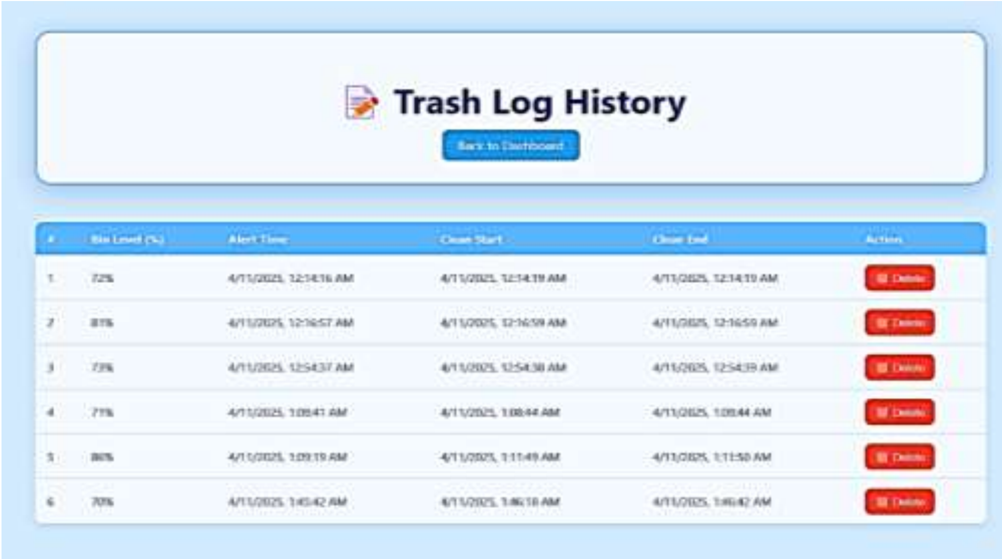

Figure. 8: Log records display for bin activities

IX. CONCLUSION

In conclusion, the system meets its goal of reducing manual monitoring efforts, minimizing the risk of waste overflow, and enabling better decision-making in sanitation operations. It is cost-effective, easy to maintain, and scalable making it suitable for deployment in smart cities, institutions, or public waste management departments. The Trash Disposal Monitoring and Management System has effectively demonstrated how IoT technology, cloud integration, and web-based interfaces can be combined to improve urban waste management. By using ultrasonic sensors to measure bin fill levels, the system provides accurate, real-time data that is transmitted to Firebase and reflected instantly on a user-friendly dashboard. When the waste in a bin reaches or exceeds 70% capacity, SMS alerts are sent to authorized personnel via the Twilio API, ensuring prompt cleaning operations.

The system also utilizes the Google Geolocation API to track and display the live location of each bin, which enhances monitoring and planning. The dashboard interface includes cleaning controls such as “clean in progress” and “Cleaning done ” buttons to record bin maintenance events along with timestamps and status logs. Additionally, the availability of Dark and Light theme modes ensures accessibility and comfort for users across various environments.

X. FUTURE ENHANCEMENT

While the current implementation has achieved core functional goals, several enhancements can further improve its intelligence, usability, and scalability:

- Wireless IoT Modules (e.g., ESP32): Transitioning from Arduino UNO to ESP32 or similar microcontrollers can eliminate the need for wired connections and power dependency, allowing easier deployment in remote or outdoor locations.
- Camera Integration for Visual Monitoring:
- Attaching a camera to bins can provide visual confirmation of bin content, allowing the system to detect anomalies or cross-check sensor accuracy.
- Mobile Application for Field Staff:
- A dedicated mobile app can give real-time alerts, route updates, and allow cleaning staff to update bin status directly from their smartphones, enhancing mobility and operational speed.
- Route Optimization for Garbage Collection:
- Using GPS and bin data, the system can suggest the most efficient routes for garbage trucks, reducing fuel costs, travel time, and unnecessary stops.

These future enhancements aim to transform the system from a reactive monitoring tool to a fully proactive, intelligent waste management solution ready for smart city integration.

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