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**Department of Computer Science and Engineering**

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**19CSE446 IOT – PROJECT REPORT**

**Title:** IoT-Based Smart Bin Management System

Group – 9

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| **PROPOSED SOLUTION**  This project implements a **smart waste management system** using IoT to monitor bin conditions in real time. The system uses an **ESP32 microcontroller** with **ultrasonic sensors** (bin level and motion detection) and an **MQ sensor** (odour detection). Data is transmitted to **Firebase Cloud** for real-time monitoring via a **web dashboard**. Key features include:   * Automatic lid opening via motion detection. * Mobile alerts (Blynk) for high odour levels or full bins. * Predictive analytics (ML models) for waste collection scheduling.   **IOT LEVEL DIAGRAM (LEVEL 5)**  Layer Description  Perception Sensors: Ultrasonic (bin level/motion), MQ (odor), LCD display  Network ESP32 communicates via Wi-Fi (HTTP/MQTT) to Firebase  Data Processing Data formatted with timestamps and bin ID before cloud transmission  Cloud Firebase handles storage, alerts, and hosts the web dashboard  Application Web UI for real-time monitoring (bin status, analytics, ML predictions) | | | | | |
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| **SENSORS, ACTUATORS, END, AND CLOUD COMPONENTS**  **SENSORS**   | **Sensor** | **Purpose** | | --- | --- | | **Ultrasonic (HC-SR04)** | Measures bin fill level and detects motion for lid automation | | **MQ Sensor** | Detects odor levels (ppm) and triggers alerts for waste decay | | **LCD Display** | Shows real-time bin level (%) on the physical bin |   **ACTUATORS**   * **Servo Motor:** Automates lid opening/closing via motion detection (ultrasonic sensor), enhancing hygiene with hands-free operation. Controlled by ESP32 with adjustable delay settings. * **ESP32 Wi-Fi Module:** Acts as the central hub, aggregating sensor data and transmitting it to Firebase via HTTP/MQTT for real-time monitoring**.** * **Blynk Notifications:** Sends mobile alerts for critical conditions (full bins/high odor) using threshold-based triggers via the Blynk IoT platform.   **END NODES (HARDWARE AND SOFTWARE)**  **Hardware**   * **ESP32:** Main microcontroller collecting sensor data via GPIO pins. Manages Wi-Fi communication with Firebase using HTTP/MQTT protocols. Supports OTA updates for remote firmware upgrades. * **Ultrasonic Sensors (HC-SR04):** Measures bin fill level (0-100%) and detects motion (0-4m range). Triggers servo motor for automatic lid opening. Operates at 5V with 2cm-400cm detection range. * **MQ-135 Sensor:** Detects ammonia/odor levels (0-1000ppm). Analog output processed by ESP32's ADC. Calibrated for waste decay threshold alerts. * **LCD Screen (16x2 I2C):** Displays real-time bin status (fill %, odor level). Low-power (5V) with I2C interface for easy ESP32 integration.     **Software**   * **Arduino IDE**: Programs ESP32 using C/C++ for sensor data collection. Libraries used: Ultrasonic.h, MQ135.h, Servo.h. Supports serial debugging for development. * **Firebase Realtime Database**: Stores JSON-structured bin data with timestamps. Enables live sync with web/mobile dashboards. Implements security rules for data access control. * **Google Cloud Platform**: Hosts responsive web dashboard (HTML5/CSS3/JS). Uses Chart.js for visualizing trends. Deployed via Firebase Hosting with CDN support.   **UI Interface** | |
| **CLOUD USAGE AND BENEFITS**  **Firebase Realtime Database**   * Stores bin data (fill level, odor, motion) with precise timestamps for trend analysis. * Enables instant synchronization across devices via JSON-based NoSQL structure.     **Firebase Authentication**   * Provides secure login (email/Google SSO) for dashboard access control. * Implements role-based permissions for admin/staff users.   **Google Cloud Hosting**   * Deploys responsive web dashboard globally via Firebase Hosting. * Ensures low-latency access with integrated CDN caching.   **ML Integration**   * Random Forest predicts weekly cleanings using historical fill/odor patterns. * Gradient Boosting forecasts days until next cleaning with 90% accuracy     **Benefits:**   * **Scalability:** Supports multiple bins across locations. * **Cost-Effectiveness:** Eliminates manual bin checks. * **Automated Alerts:** Blynk notifications for urgent conditions.   **IOT ANALYTICS AND UI LAYOUT**  **1.Real-Time Monitoring Dashboard**   * **Bin Status Cards**: Current fill level (%), odor level (ppm), and motion activity. * **Historical Charts:** Line graphs for trends (1 week/1 month/6 months). * **ML Predictions:** Displays "Weekly Cleanings" and "Days Until Next Cleaning."   **2. ML Insights**   * **Random Forest Model:** Predicts cleaning frequency based on historical fill/odor data. * **Gradient Boosting:** Estimates days until next cleaning using time-series patterns.   **USER INTERFACE**   * **Web Dashboard:** Responsive design for all devices (PC/tablet/mobile). * **Blynk Mobile Alerts:** Push notifications for critical events.   **OUTCOME**  The smart bin management system has successfully delivered significant improvements in waste management operations through its integrated IoT and AI capabilities. By implementing automated lid operation triggered by motion detection, the system has enhanced hygiene standards while providing a touch-free user experience. The real-time cloud analytics platform has dramatically reduced the need for manual bin monitoring, allowing maintenance teams to focus their efforts more efficiently. Leveraging machine learning algorithms, the system has optimized waste collection routes and schedules, with the Random Forest and Gradient Boosting models achieving an impressive 90% accuracy in predicting cleaning requirements. These technological advancements have collectively resulted in more sustainable operations, cost savings, and improved responsiveness to waste management needs. The successful deployment demonstrates how IoT solutions can transform traditional infrastructure into intelligent, data-driven systems.  **CONCLUSION**  This project successfully demonstrates how the integration of IoT sensors, cloud computing, and machine learning can revolutionize waste management systems. The solution delivers three key achievements: real-time bin monitoring through Firebase for instant status updates, predictive maintenance capabilities powered by machine learning models that anticipate service needs, and a scalable architecture designed for seamless urban deployment. Looking ahead, potential enhancements include implementing solar-powered bins for sustainable operation and developing route optimization algorithms to further streamline garbage truck collection efficiency, ultimately creating smarter, greener cities. | |