© January 2025 | IJIRT | Volume 11 Issue 8 | ISSN: 2349-6002

Real-Time Waste Tracking and Segregation with IoT-Driven Smart Dustbins

Santhoshini P[1], Mohana priya H[2], Keerthana S[3], Kanishka A[4,] Kanna Reddy BhavyaSree R[5]
[1] *Assistant Professor, RMD Engineering college.*
[2,3,4,5] *UG Student, RMD Engineering college.*

***Abstract*—The IoT-Enabled Smart Dustbin is an advanced waste management solution designed for public spaces. Utilizing Internet of Things (IoT) technology, the system employs ultrasonic sensors and weight sensors to monitor waste levels, while GPS modules enable location tracking for efficient municipal waste collection. The system incorporates an automatic locking mechanism to prevent overflow, sealing the bin when a certain threshold is reached and sending overflow notifications to authorities. Additionally, the dustbin segregates waste into categories such as plastic, metal, and biodegradable using mechanical sorting mechanisms or infrared sensors. A mobile app provides real-time data on bin status and locations, aiding waste management. This IoT-enabled smart dustbin optimizes waste collection, enhances sustainability, and ensures efficient, eco-friendly public waste disposal.**

***Index Terms*—IoT, smart dustbin, waste segregation, location tracking, waste management, sensors.**

I. INTRODUCTION

The rapid urbanization and exponential growth of populations in cities have led to a significant increase in waste generation, with over 1.3 billion tons of urban waste produced annually, a figure expected to rise to 2.2 billion tons by 2025 [1]. This rise in waste volume poses serious environmental challenges, including overflowing waste bins, inefficient waste collection methods, and improper waste segregation. Traditional waste management techniques, such as scheduled collections and manual handling, are becoming inadequate for managing the growing waste load efficiently. These methods often result in overflows and delays, contributing to environmental pollution [2].

To address these challenges, integrating Internet of Things (IoT) technologies into waste management has emerged as a promising solution. IoT enables real-time monitoring of waste levels and provides actionable data to municipal authorities for optimizing waste collection. Using ultrasonic sensors and weight sensors, waste bins can report their fill levels, allowing authorities to prioritize collections and avoid overflow.Furthermore, GPS tracking of waste bins can help in planning more efficient collection routes, reducing fuel consumption and minimizing environmental impact. An important aspect of modern waste management is waste segregation, which reduces the volume of waste sent to landfills and increases recycling rates. Using sensors to distinguish between different types of waste, such as plastic, metal, and biodegradable materials, has become an integral part of IoT-based waste management systems. This automated segregation of waste not only optimizes resource recovery but also simplifies the overall waste management process.

II. LITERATURE SURVEY

PAPER 1: "Smart Waste Segregation and Collection System with IoT-enabled Monitoring and Analytics" by Subhash B Suthar (2023): A waste management monitoring application is proposed to effectively segregate metal and plastic waste, track waste levels, and optimize collection efforts, leading to a cleaner, healthier, and more sustainable environment. The proposed system uses sensors to segregate waste into different categories, including plastic, biodegradable, and metallic waste, and incorporates an android application for real-time monitoring and data storage.

PAPER 2: "IoT based smart waste management system" by Anagha Gopi, Jeslin Anna Jacob, Riya Mary Puthumana, Rizwana A K, Krishnapriya S, BinuManoha (2021): The paper proposes an IoT-based smart waste management system that uses ultrasonic sensors, GPS, and a servo motor to monitor waste levels, automatically open and close the lid, and notify authorities when the bin needs to be emptied.The proposed system is reliable, cost-effective, and can be easily implemented, providing an efficient way of waste disposal and collection.The ultrasonic sensor that detect the level of waste, servo motor and microcontroller will be placed inside the bin. The other ultrasonic sensor placed outside the bin will be shielded on its top to protect it from any environmental conditions.

PAPER 3: "Smart bin and intelligent waste segregator using IoT" by R Helen; P. Karthika; R. Selvakumar, and others (2022):

The proposed system aims to develop an IoT-based intelligent system that measures trash levels, sends notifications to the municipal corporation, and separates waste into categories using a smart separator.The system can detect the level of garbage inside the dustbin and notify authorities when the dustbin gets filled. Ultrasonic sensor data is displayed in the app and the location is displayed in the location tracker via wifi module.

PAPER 4: "Automatic Waste Segregator as an integral part of Smart Bin for waste management system in a Smart City" by Chander Partap Singh; Manisha Pathania; Pao-Ann Hsiung, and others (2019): The proposed system uses a combination of sensors, including infrared, raindrop, and moisture sensors, to differentiate between dry and wet waste, and an actuator unit to segregate the waste into their respective containers. This system can effectively separate dry and wet wastes into their respective compartments automatically, with an accuracy of around 90% based on detecting the right type of waste in the bin.

PAPER 5: "Smart Bin (Waste Segregation and Optimisation)" by Wesley Pereira; Saurabh Parulekar; Sopan Phaltankar, and others (2019): The Smart Bin can segregate waste into different categories, including wet, dry, and plastic waste, using capacitive values and infrared spectroscopy. The system provides real-time analysis and optimization of waste disposal through automation and IoT technology.

PAPER 6: "Development of Automatic Waste Segregator with Monitoring System" by Shah Alam, Malaysia nurishahania(2020): The system is designed to sort waste into four categories: wet waste, paper, plastic, and aluminum, and monitor daily waste disposal rates. It uses IoT technology, including sensors, microcontrollers, and Wi-Fi modules, to detect the type of waste and notify janitors when the bins need to be emptied. The system successfully identified different types of materials using sensors, including ultrasonic sensors, inductive proximity sensors, light dependent resistors, and liquid sensors.

III. PROPOSED SYSTEM

This project aims to develop a cost-effective and efficient smart waste management system to address challenges in urban waste collection and segregation. Inspired by the literature review, the system incorporates IoT-enabled technologies for waste monitoring, collection, and segregation, while also proposing innovative methods for waste recycling to ensure environmental sustainability.

The proposed solution uses proximity sensors and wet sensors to classify waste into three categories: biodegradable, non-biodegradable, and dry waste. Once segregated, these waste types can be directed to appropriate recycling or disposal channels. Unlike existing systems, this solution focuses on both preventing overflow and addressing recycling inefficiencies.

To prevent overflow, the system employs an ultrasonic sensor to monitor the fill level of the bin. If the bin reaches its threshold capacity, a notification with the GPS location of the bin is sent to the municipal corporation via a Wi-Fi-enabled microcontroller. Simultaneously, the bin automatically locks to prevent additional waste deposition, thereby avoiding overflow and maintaining cleanliness around the bin area. Upon receiving the notification, municipal authorities are guided to the bin’s location using the GPS module, and the bin is unlocked via a command from the mobile application. Once the waste is collected, it is passed through an intelligent segregator that classifies the waste using inductive proximity sensors, capacitive proximity sensors, and wet sensors. This process ensures precise segregation of waste into categories, facilitating efficient recycling and reducing environmental hazards.

The entire system is managed through a cloud-enabled mobile application, which monitors bin levels, tracks waste collection schedules, and displays waste segregation data in real-time. By integrating IoT-based monitoring, automated segregation, and recycling solutions, this project ensures a sustainable and comprehensive approach to urban waste management.

Fig 1: Block Diagram:

Hardware Requirements:
1.NodeMCU&ArdinoUNO
2.UltrasonicSensor
3. Load cell
4. IR sensor
5. Moisture sensor
6. Capacitive Sensor
7.GPS Module
8.Battery

IV. COMPONENTS AND MODULES

The proposed IoT-enabled smart waste management system integrates a range of hardware components that work together seamlessly to enable waste segregation, monitoring, and efficient disposal. The primary components and their roles in the system are described below.

A. NodeMCU ESP8266 (Wi-Fi Module)

The NodeMCU ESP8266 serves as the core of the IoT system, enabling communication between hardware components and the cloud. This low-cost module is built on the ESP8266 SoC, which features an integrated Wi-Fi transceiver and GPIO pins. It operates at 3.3V, making it energy-efficient and ideal for IoT applications. The module processes data from connected sensors and transmits it in real-time to a cloud platform using TCP/IP protocols. In this system, the NodeMCU collects data such as waste levels, bin status, and GPS location, sending notifications to the mobile application for monitoring and control. The RX and TX pins facilitate UART communication, ensuring smooth data transfer between the module and the sensors.

B. Ultrasonic Sensor (HC-SR04)

The ultrasonic sensor is responsible for monitoring the fill level of the dustbin. It operates by emitting ultrasonic waves from the transmitter, which reflect off the waste surface and return to the receiver. The time taken for the echo to return is measured and converted into distance, allowing the system to determine the amount of available space in the bin. When the bin reaches a predefined threshold, the NodeMCU sends a notification to municipal authorities via the connected mobile application. This prevents overflow and ensures timely waste collection.

C. Inductive Proximity Sensor

The inductive proximity sensor is employed to detect metallic waste within the bin. It operates by generating an electromagnetic field and sensing any changes caused by the presence of metallic objects. This sensor categorizes and directs metallic waste to its designated compartment for efficient segregation. Its non-contact sensing ability ensures reliable and maintenance-free operation.

D. Capacitive Proximity Sensor

The capacitive proximity sensor is used to identify plastic waste. It works by detecting variations in the dielectric constant of the surrounding environment when plastic materials are present. The sensor directs plastic waste into a specific compartment, aiding in the segregation process. Its versatility makes it suitable for identifying a wide range of non-metallic objects.

E. Moisture Sensor

To classify biodegradable waste, a moisture sensor is utilized. This sensor detects the moisture content of waste materials, providing a signal to the NodeMCU for categorization. Biodegradable waste is directed to a separate compartment, ensuring proper sorting for composting or recycling. The sensor operates at low voltages, making it compatible with the overall system design.

F. GPS Module (Neo-6M)

The GPS module provides real-time location tracking for the dustbin. This data is sent to the cloud via the NodeMCU, enabling authorities to pinpoint the exact location of the bin. This feature optimizes waste collection routes, saving time and resources while reducing carbon emissions from collection vehicles.

G. Servo Motor

It automates the opening and closing of the dustbin lid. It is controlled by the NodeMCU based on input from the infrared sensor. When waste is detected near the bin, the servo motor opens the lid for disposal and closes it after a set duration to maintain hygiene and prevent odor leakage.

H. Infrared Sensor

The infrared sensor detects user proximity, triggering the automatic lid mechanism. When a user approaches the bin to dispose of waste, the sensor sends a signal to the NodeMCU, which activates the servo motor to open the lid. This hands-free operation enhances hygiene and user convenience. These components, when integrated with the NodeMCU microcontroller and supported by a mobile application, create an efficient and intelligent waste management system. The system leverages IoT capabilities to monitor waste levels, segregate materials into biodegradable, metallic, and plastic categories, and notify municipal authorities for timely collection. The use of real-time data transmission and cloud storage ensures scalability and reliability in smart city applications.

V. EXPERIMENTAL RESULTS

The experimental evaluation of the IoT-enabled Smart Waste Management System confirmed its effectiveness in waste segregation and monitoring. The ultrasonic sensor accurately tracked bin fill levels, sending timely notifications to prevent overflow. Waste was efficiently sorted into metal, plastic, and biodegradable categories using inductive, capacitive, and moisture sensors with minimal errors.

The GPS module enabled precise location tracking, optimizing waste collection routes. Users reported high satisfaction with the system's ease of use and the mobile application interface, which provided real-time updates. The system demonstrated reliability, scalability, and improved operational efficiency, validating its potential for large-scale implementation in smart cities.

Fig 2: Experimental Setup

VI. RESULTS AND DISCUSSIONS

The results obtained from the experimental evaluation of the IoT-enabled Smart Waste Management System underscore its effectiveness in improving waste management processes and enhancing user convenience. The following discussions highlight key findings and their implications:

A. Waste Level Monitoring and Notification**:** The system demonstrated precise waste level monitoring through the ultrasonic sensor, accurately tracking bin fill levels in real-time. Notifications were promptly sent when bins reached their capacity, ensuring timely waste collection and preventing overflow. This feature significantly contributes to efficient waste management and timely interventions.

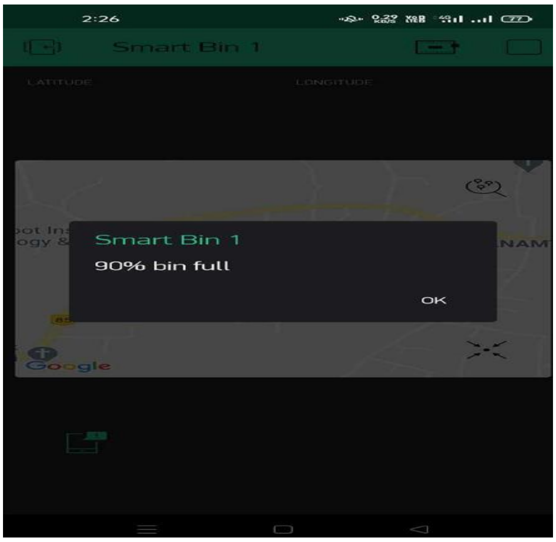

Fig 3: App Screen shot

B. Waste Segregation and Categorization: The waste segregation mechanism, powered by the inductive proximity sensor, capacitive proximity sensor, and moisture sensor, effectively categorized waste into metal, plastic, and biodegradable materials. The system achieved high accuracy in sorting waste, with minimal errors, which aids in better recycling and composting efforts, promoting environmental sustainability.

C. User Interface and Convenience: Users reported high satisfaction with the system's mobile application interface, which provided real-time updates on bin status, waste categorization, and fill levels. The hands-free operation of the bin lid, triggered by the infrared sensor, added convenience by offering a hygienic waste disposal experience. The system's ease of use significantly improved user engagement with the waste management process.

D. Reliability and Robustness: The system exhibited high reliability and robustness in diverse environmental conditions, accurately detecting waste types and maintaining communication between sensors and the cloud. The system was responsive to changing waste patterns and continued to function reliably under various weather and operational scenarios, ensuring consistent performance and instilling confidence in users regarding the system's ability to manage waste effectively.

E. Scalability and Adaptability: The architecture of the system proved to be scalable and adaptable, allowing for easy integration with various bin types, sensors, and waste collection frameworks. This scalability ensures that the system can be deployed in residential, commercial, and industrial settings, with customization options for different user needs and environmental contexts.

Overall, the results highlight the system's significant contribution to optimizing waste management, improving operational efficiency, and ensuring environmental sustainability. By leveraging IoT technology, the system offers an advanced solution to the challenges of traditional waste management.

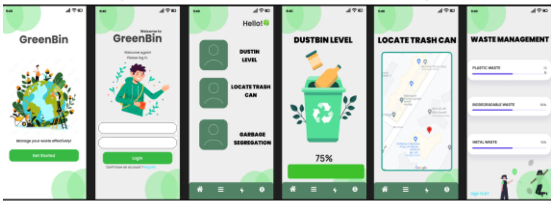

Fig 4: App-Dashboard Screenshots

VII. CONCLUSIONS AND FUTURE WORK

The IoT-enabled Smart Waste Management System has demonstrated its effectiveness in optimizing waste segregation, monitoring, and collection. Through the integration of advanced sensors and IoT technology, the system ensures accurate real-time waste tracking, timely notifications, and efficient categorization of materials. The system's reliability, user-friendly interface, and scalability make it ideal for implementation in both urban and industrial settings. Looking forward, future enhancements could include the incorporation of a dry sensor to improve waste classification, allowing for better segregation of dry and wet waste. Additionally, the system could integrate with smart city infrastructure for optimized waste collection routes and enhanced environmental sustainability. These advancements will further enhance the system's efficiency and contribute to a cleaner, more sustainable urban environment.

REFERENCES

[1] A. Kumar, R. Sharma, and P. Singh, Waste Management Trends in Urban Areas, Journal of Environmental Management, vol. 25, 2022. [2] S. Patel and M. Mehta, IoT Applications in Waste Management Systems, International Journal of IoT and Applications, vol. 18,2023

[2] Subhash Suthar B, Dr. Chithra R, Abhinaya G K, Haritha Harikumar Smart Waste Segregation and Collection System with IoT-enabled Monitoring and Analytics.

[3] Anagha Gopi, Jeslin Anna Jacob, Riya Mary Puthumana, Rizwana A K, Krishnapriya S, Binu Manohar IoT based smart waste management system © 2021 IEEE

[4] Helen R, Karthika P, Selvakumar R,

Thenmozhi T Smart bin and intelligent waste segregator using IoT IEEE Xplore Part Number: CFP22P17-ART; ISBN: 978-1-6654-0118-0
[5] Chander Partap Singh, Manisha, Pao-Ann Hsiung, Shivani Malhotra Automatic Waste
[6] Segregator as an integral part of Smart Bin for waste management system in a Smart City 978-1-7281-4042-1/19/$31.00 ©2019 IEEE
[7] Subhasini Dwivedi, Michael Fernandes, Rohit D'souza, "A Review on PLC-based Automatic Waste Segregator" International Journal of Advanced Research in Computer Engineering & Technology (IJARCET), Volume 5, Issue 2, February 2016.
[8] Suchitra V, Shariq Mohammed Shaikh, Stuti Jha,"Automatic Waste Segregator", Project Reference No: 38S0128.
[9] T.M.B.Shankar Balu, R.S.Raghav, K.Aravinth, M.Vamshi, M.E.Harikumar, Rolant Gini J,"Arduino based Automated Domestic Waste Segregator", Proceedings of the Fifth International Conference on Communication and Electronics Systems (ICCES 2020) IEEE, ISBN: 978-1-7281-5371-1.
[10] Kolhatkar, C., Joshi, B., Choudhari, P., & Bhuva, D. (2018), "Smart E dustbin",2018 Conference on smart city and emerging technology (ICSCET), IEEE.
[11] "Automatic Waste Segregation and Management", International Journal of Engineering Research and Technology (IJERT), vol-09 Issue-06, June 2020.
[12] "Garbage Monitoring System using IOT", IOP conference series: Materials science and Engineering,14th ICSET 2017.
[13] Lai, Kong-Long, and Joy Iong Zong Chen. "Development of Smart Cities with Fog Computing and Internet of Things." Journal of Ubiquitous Computing and Communication Technologies (UCCT) 3, no. 01 (2021): 52-60.
[14] Madhura, S. "IoT Based Monitoring and Control System using Sensors." Journal of IoT in Social, Mobile, Analytics, and Cloud 3, no. 2 (2021): 111-120.
[15] Sungheetha, Akey, and Rajesh Sharma. "Fuzzy Chaos Whale Optimization and BAT Integrated Algorithm for Parameter Estimation in Sewage Treatment." Journal of Soft Computing Paradigm (JSCP) 3, no. 01 (2021): 10-18.
[16] Hamdan, Yasir Babiker, and A. Sathesh. "Construction of Efficient Smart Voting Machine with Liveness Detection Module." Journal of Innovative Image Processing 3, no. 3 (2021): 255- 268.
[17] Bano, A., Ud Din, I., & Al-Huqail, A. A. (2020). AIoT-Based Smart Bin for Real-Time Monitoring and Management of Solid Waste. Scientific Programming, 2020.
[18] Ashwin, M., Alqahtani, A. S., & Mubarakali, A. (2021). Iot based intelligent route selection of wastage segregation for smart cities using solar energy. Sustainable Energy Technologies and Assessments, 46, 101281.
[19] Karthik, M., Sreevidya, L., Devi, R. N., Thangaraj, M., Hemalatha, G., & Yamini, R. (2021). An efficient waste management technique with IoT based smart garbage system. Materials Today: Proceedings.
[20] Maddileti, T., & Kurakula, H (2020). Iot Based Smart Dustbin. International Journal of Scientific & Technology Research Volume 9, Issue 02, February 2020.