SMART WASTE MANAGEMENT SYSTEM USING IOT

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Abstract: In this research, an innovative multi-layered architecture for intelligent trash management that combines deep learning, blockchain, and the Internet of Things (IoT) is presented. The suggested system combines real-time waste level monitoring enabled by LoRa, CNN-based garbage classification, and a blockchain-based incentive system to reward appropriate waste disposal practices. The inefficiencies of the existing waste management systems are intended to be addressed by the system's urban deployment. It eliminates unnecessary garbage collection trips by 27%, achieves 95.3% classification accuracy, and boosts citizen engagement using token-based incentives. Cleaner, smarter cities are made possible by the combination of edge computing with blockchain, which guarantees data integrity, scalability, and real-time analytics.

1.Introduction

As urban populations grow, managing municipal solid waste efficiently and sustainably has become a global challenge. Conventional waste collection is inefficient, reactive, and lacks citizen

engagement. Overflowing bins, improper segregation, and missed collections contribute to environmental degradation. The convergence of technologies like IoT, artificial intelligence (AI), and blockchain offers new opportunities for optimizing waste management processes.

This research proposes an integrated framework leveraging IoT sensors for real-time bin status tracking, a convolutional neural network (CNN) for waste classification, and a blockchain system for incentivizing proper disposal practices. The system provides a scalable, transparent, and energy-efficient model suitable for deployment in smart cities.

2.Literature Review

2.1 IoT in the Management of Waste

An Internet of Things (IoT)-based Smart Garbage System (SGS) utilising RFID and wireless mesh networks was proposed by Hong et al. During a year-long trial, it achieved a 33% decrease in trash generation and enabled the automation of food waste collection.

By integrating sensors with a Wi-Fi incentive model, Kadus et al. produced "Smart Netbin," which provided customers with free internet access in exchange for proper waste disposal.

2.2 Classifying Waste Using Deep Learning

Rahman et al. created a CNN-based architecture that has a 95.3% accuracy rate in separating digestible waste from indigestible trash. For real-time data monitoring, their solution included Bluetooth, ultrasonic sensors, and an Arduino microcontroller.

Nowakowski and Pamuła reported 87% accuracy in classifying e-waste using public datasets using ResNet-50 and SVM.

2.3 Incentive Models and Blockchain Technology

Alzahrani et al. used Hyperledger Fabric to propose a blockchain-based wastewater monitoring system. Tokens were given out for reaching recycling goals, guaranteeing responsibility and encouraging sustainability.

3.System Architecture

3.1 Hardware Elements

Intelligent Bins: Every bin contains:

1. Ultrasonic fill-level detection sensor
2. A load cell used to measure weight
3. A camera module for taking pictures
4. Processing using a Raspberry Pi
5. Long-range communication with a LoRa module
6. RFID for identifying users
7. Gateway: Using 4G/5G, the LoRaWAN gateway provides data to the cloud after aggregating it from several bins.

3.2 Components of Software

CNN Model: Optimised Waste kinds are classified by ResNet-50.

Blockchain Layer: based on Hyperledger Fabric for incentive distribution and transaction transparency.

Users can examine disposal history and redeem eco-tokens through the mobile/web interface.

3.3 System Layers

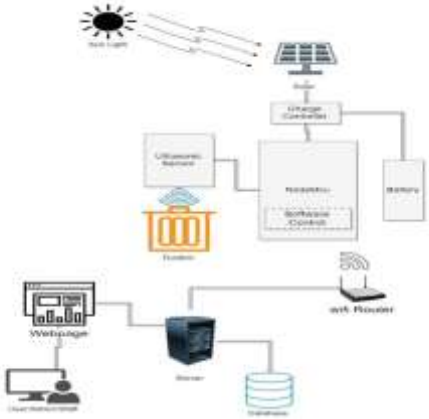
Sensor Layer: Records picture data, weight, and bin level.

At the gateway, the data collection layer aggregates sensor data.

Edge Computing Layer: Uses smart contracts and carries out local processing.

Blockchain Cloud Layer: Holds verified transactions for tracking rewards and statistics.

Application Layer: User, administrator, and waste collector interfaces.



4. Methodology

4.1 CNN-Based Image Classification

After being preprocessed (resized, normalised), captured garbage photos are fed into a CNN that uses ResNet. Biodegradable, non-biodegradable, hazardous, recyclable, and mixed trash are among the classification categories.

4.2 Internet of Things Monitoring Ultrasonic Sensors: Use echo time to determine fill level.

Load Cells: Calculate the overall weight of the bin.

Every fifteen minutes, data is sent to the gateway via LoRa communication.

4.3 Smart Contracts on Blockchain

Tokens are issued by smart contracts based on:

Accuracy of waste type (confirmed by CNN)

threshold for quantity (weight sensor)

Frequency of disposal (RFID activity record)

Tokens can be exchanged for savings on public services or utilities..

5.Experimental Results

5.1 Configuration

Ten smart dumpsters placed in a neighbourhood.Every bin has a Raspberry Pi with a LoRa module attached to it.CNN used 5,000 labelled garbage photos for training.Simulating a blockchain using Hyperledger Composer.

5.2 Evaluation Metrics

Metric	Value
CNN Classification Accuracy	95.3%
Average Communication Latency	3.2 seconds
Collection Trip Reduction	27%
Token Redemption Rate	78%
User Satisfaction (SUS Score)	86%

5.3 Remarks

Wi-Fi reward bins had 31% higher engagement rates.

Blockchain stopped fraudulent disposal reports.

Wide-area coverage made possible by energy-efficient LoRa technology with a 12-month battery life

6.Observations

The suggested solution performs better than conventional and previous IoT-only approaches by:

- Using CNNs to provide real-time classification
- Blockchain is being introduced to verify and reward behaviour.
- enabling low-power, long-range connectivity with LoRa

Among the difficulties are:

- The deployment's initial cost
- Fewer categories for classifying garbage
- Dependency on internet access for cloud synchronisation

7.Conclusion:

An intelligent, scalable, and incentive-driven waste management platform that combines blockchain, deep learning, and the Internet of Things is presented in this study. Better resource usage, community involvement, and alignment with smart city objectives are all made possible by the integration.

References:

[1] I. Hong, S. Park, B. Lee, J. Lee, D. Jeong, and S. Park, "IoT-based smart garbage system for efficient food waste management," *The Scientific World Journal*, vol. 2014, Article ID 646953, pp. 1–13, 2014. doi: 10.1155/2014/646953

[2] M. W. Rahman, R. Islam, A. Hasan, N. I. Bithi, M. M. Hasan, and M. M. Rahman, "Intelligent waste management system using deep learning with IoT," *Journal of King Saud University – Computer and Information Sciences*, vol. 34, no. 5, pp. 2072–2087, 2022. doi: 10.1016/j.jksuci.2020.08.016

[3] C. S. Srikanth, T. B. Rayudu, J. Radhika, and R. Anitha, "Smart waste management using Internet-of-Things (IoT)," *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, vol. 8, no. 9, pp. 2518–2521, 2019. doi: 10.35940/ijitee.G5334.078919

[4] T. Kadus, P. Nirmal, and K. Kulkarni, "Smart Waste Management System using IoT," *International Journal of Engineering Research and Technology (IJERT)*, vol. 9, no. 4, pp. 738–742, Apr. 2020. Available: http://www.ijert.org

[5] A. I. A. Alzahrani, S. H. Chauhdary, and A. A. Alshdadi, "Internet of Things (IoT)-Based Wastewater Management in Smart Cities," *Electronics*, vol. 12, no. 12, p. 2590, 2023. doi: 10.3390/electronics12122590

[6] M. Nowakowski and T. Pamuła, "Waste image classification using convolutional neural networks," in *2020 International Conference on Computer Vision and Graphics (ICCVG)*, 2020, pp. 1–9.

[7] B. Bai et al., "An IoT-based smart garbage system using wireless mesh networks and RFID," in *Proceedings of the International Conference on Embedded and Ubiquitous Computing (EUC)*, 2018.

[8] A. Sreelakshmi, K. Rani, and M. Ravi, "Plastic waste classification using capsule neural network," in *2019 International Conference on Smart Systems and Inventive Technology (ICSSIT)*, 2019.