Efficiency Improvement of IoT-based Smart Garbage Management System

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Abstract: - The rapid growth of urbanization has led to the emergence of smart cities that aim to enhance the quality of life for citizens through the integration of technology and infrastructure. An integral aspect of smart cities is efficient waste management, which not only contributes to environmental sustainability but also improves the overall urban experience. This paper presents the design and development of an IoT-based Garbage Management System tailored for smart cities. The proposed system comprises several interconnected components. Smart bins equipped with sensors, including fill-level, temperature, humidity, and GPS modules, collect real-time data about the waste content and environmental conditions within the bins. This data is transmitted to a central gateway, which acts as a bridge between the smart bins and the cloud platform. The cloud platform plays a pivotal role in data storage, processing, and analysis. It stores historical sensor data, processes real-time information, and generates actionable insights. Through a user-friendly mobile application and web portal, both citizens and administrators can interact with the system. Citizens gain the ability to locate nearby available bins and contribute to proper waste disposal, while administrators can monitor the system's health, optimize collection routes, and generate reports for decision-making. The system's efficiency is enhanced through automation and optimization algorithms. Predictive analytics are employed to forecast fill-levels, enabling waste collection teams to plan their routes effectively. Additionally, mechanisms for automatic bin compaction and remote lid operation further increase the capacity and convenience of the system. Security and privacy are maintained through secure communication protocols and proper authentication mechanisms.

Keywords: Designing, IOT system, Garbage management, Waste Collection

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Introduction

In today's world as far as, smart cities are concern the garbage collection and management with an efficient manner is very big deal, because according to rate of increasing population everywhere the rate of generated garbage is also suddenly growing up and overall, gradually affecting not only on workload of municipal corporation but also some health issues of all planet [1]. Smart and advanced management of Garbage is very big challenge in front of all municipal corporations according to that some municipal corporation refers solid waste monitoring and management system using radio frequency identification (RFID) associate with intelligent systems [2]. Some of the corporation's tried in many application fields such as home, industry, environment and health, different Wireless Sensor Network (WSN) applications have been developed to solve management problems with smart implementations. This approach can be applied in the field of solid waste management [3-5].

The existing work pattern and technology of municipal corporations did so many modifications to balance these deals i.e., route decision of garbage collection according to status of garbage in container and its continuous monitoring [4]. To deal these problems again IOT also referred an IoT based architectural solution to tackle the problems faced by the present solid waste management system. By providing a complete IoT based system, the process of tracking, collecting, and managing the solid waste can be easily automated and monitored efficiently [9]. Zigbee and Global System for Mobile Communication (GSM) are the latest trends and are one of the best combinations to be used in the project. Hence, a combination of both of these technologies is used [5].

An Automatic garbage collection and information gathering system which is based on Image processing as well as on GSM module. The main concept is that a Camera will be placed at every garbage collection point along with load cell sensor at bottom of the garbage can. The camera will take continuous snapshots of the garbage can. A threshold level is set which compares the output of camera and load sensor [6,]. But still lagging in efficient management hence by some development in technology and management to handle garbage, the municipal corporations can improve their performance to keep clean and healthy environment in smart cities as per their motto.

1. Literature Review

The study by the first author focuses on addressing the basic vehicle routing problem (VRP) using a genetic algorithm (GA). The VRP involves delivering known-demand customers from a central depot using vehicles subject to weight and distance constraints. While tabu search and simulated annealing are commonly used for benchmark VRPs, GAs have found application in certain VRP variations with time windows. However, GAs haven't had a significant impact on the described VRP type. The paper introduces a pure GA approach and hybridizes it with neighbourhood search methods, demonstrating competitive performance in terms of solution time and quality compared to tabu search and simulated annealing [8,9]. A solid waste monitoring and management system utilizing radio frequency identification (RFID) was proposed and intelligent systems. The system integrates RFID, GSM communication, and geographical information systems (GIS) to track vehicle positions during waste collection. This system enhances solid waste collection efficiency by providing real-time monitoring, optimal route planning, reduced fuel consumption, and a cleaner environment [10]. The benchmark VRP solutions using search techniques like simulated annealing are highlighted. While GAs are applied to various combinatorial optimization problems, their impact on the described VRP remains limited. The paper presents computational results for both a pure GA and a hybrid approach with neighbourhood search methods. This hybrid approach competes favourably with tabu search and simulated annealing in terms of solution time and quality [11]. Waste management system in Pudding, addressing waste collection challenges due to increasing waste production are focused. The system employs sensitized waste containers connected to a data management system to monitor waste quantity, measure content at collection points, and identify waste material types, with the aim of efficient waste collection [12]. Wireless sensor network (WSN)-based architecture for on-site handling and transfer optimization in solid waste management was introduced. The architecture employs sensor nodes and Data Transfer Nodes (DTN) to retrieve data from garbage bins and transmit it to a remote server. The system offers remote monitoring and decision support for organizing resources in solid waste management [13]. The author's proposal addresses overflowing municipal garbage bins by introducing a "Smart Garbage Bin" system. This system alerts authorized personnel when bins are nearing capacity and proposes the separation of plastic resins using NIR spectroscopy, along with utilizing biodegradable waste for biogas production [1,2]. The author’s work proposes an optimization solution for garbage removal in large cities. They describe a system architecture within the "Smart Clean City" project for dynamically optimizing garbage truck routes based on a formal mathematical model and optimization criteria [3]. The author emphasizes the need for smart waste management systems to address hygiene degradation caused by waste spillover.

Their IoT-based smart waste clean management system uses sensors to monitor waste levels, sending alerts via GSM/GPRS. An Android app provides information on waste levels, contributing to a cleaner environment [4]. The author presents an IoT-based solution for solid waste management in smart cities. The system automates and efficiently monitors the tracking, collection, and management of solid waste, addressing challenges in waste management [5]. The author introduces the concept of "Smart Bins," a network of dustbins integrated with IoT and wireless sensor networks. This network aims to improve efficiency by addressing the inadequacies of routine checks and providing real-time status updates on dustbin fill levels [6].

2. Proposed Methodology

Designing and developing an IoT-based Garbage Management System for a smart city involves integrating various technologies to efficiently collect, monitor, and manage waste disposal. Proposed work flow is shown in figure 1. A comprehensive overview of the process with the flow chart of Proposed System is depicted in figure 2.

System Architecture:

- The system can be divided into several components:
- *Smart Bins*: Equipped with sensors to monitor fill-level, temperature, and humidity.
- *Gateway*: Collects data from bins and sends it to the cloud.
- *Cloud Platform*: Stores and processes data, provides analytics, and manages the system.
- *Mobile/Web Application*: Allows administrators and citizens to monitor and interact with the system.

Hardware and Sensors:

- *Fill-level Sensors*: Ultrasonic or infrared sensors to measure bin fill-level and trigger alerts when bins are full.
- *Temperature and Humidity Sensors*: Monitor environmental conditions inside the bins.
- *GPS Modules*: To track bin locations.
- *Communication Modules*: GSM, LoRa, or Wi-Fi modules for data transmission.

***Data Collection*:**

Sensors on the smart bins collect real-time data about fill-level, temperature, and humidity. Data is sent to the gateway, which aggregates and forwards it to the cloud platform.

Cloud Platform:

- *Data Storage*: Store sensor data in a database for historical analysis.
- *Data Processing*: Analyze data to optimize collection routes and schedules.
- *Alerts and Notifications*: Send alerts to waste collection teams when bins are full.
- *Analytics*: Generate reports and visualizations to monitor trends and efficiency.

***Waste Collection Optimization*:**

Analyze historical data to optimize waste collection routes and schedules, reducing fuel consumption and operational costs. Implement predictive algorithms to forecast fill-levels and plan collections accordingly.

User Interface:

Develop a mobile app or web portal for citizens and administrators. Citizens can view bin fill-levels and find nearest empty bins. Administrators can monitor system health, schedule collections, and generate reports.

Integration of Automation:

With the help of Garbage compression mechanism, weight sensor and level sensor controller will provide the information regarding current status of bin i.e. Weight, level and location to the corporation office where continues monitoring is also possible. Accordingly, route is decided of Garbage collection vehicle. And for user end RFID module gives an access to user to throw garbage.

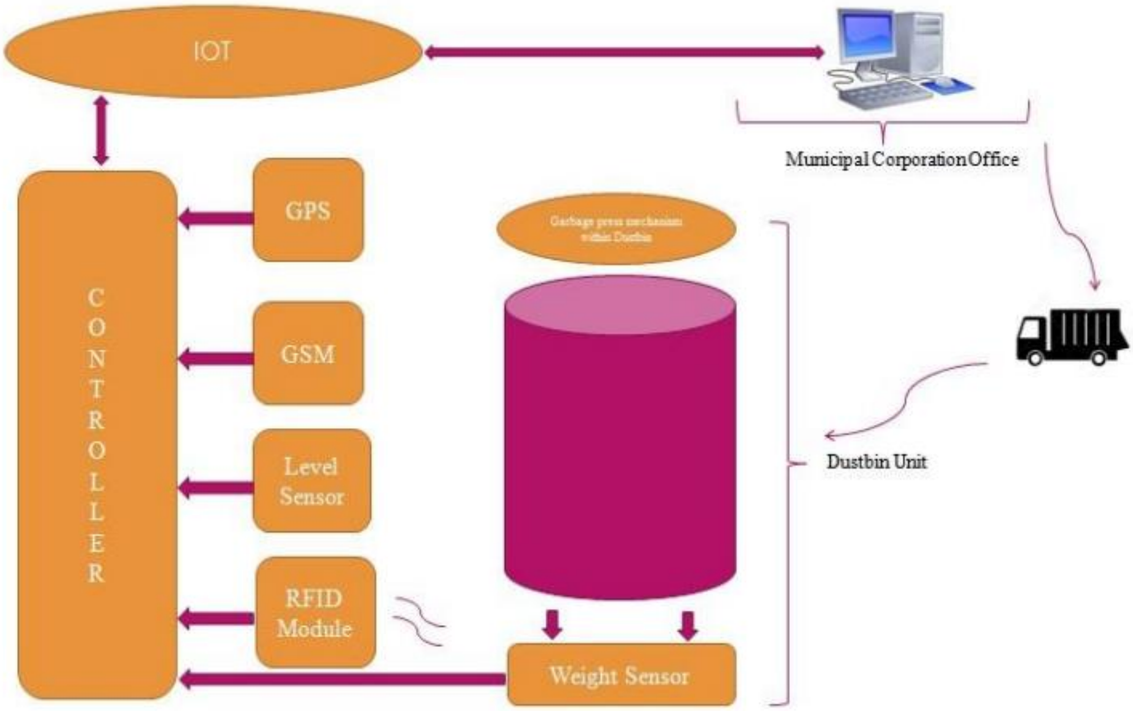

Figure1: Proposed work flow

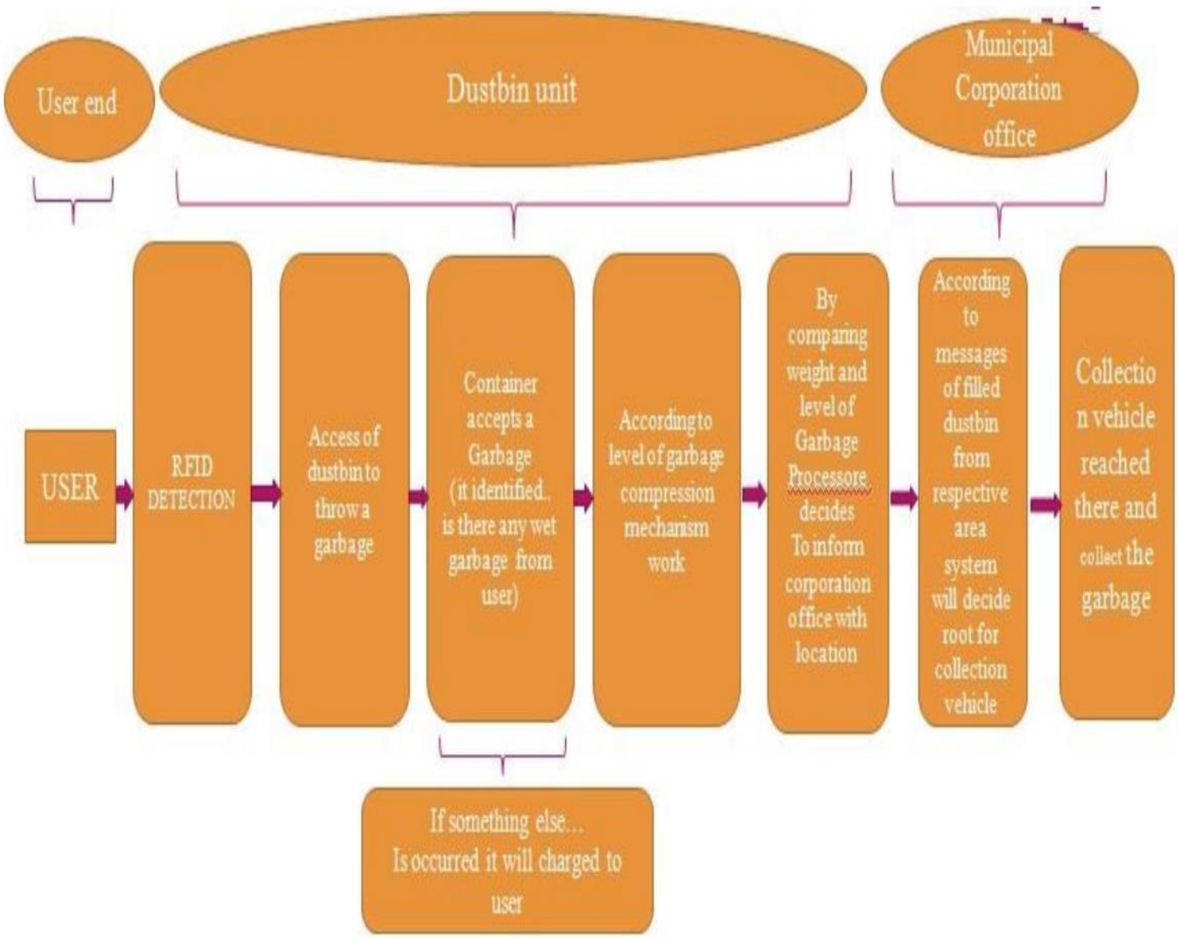

Figure 2: Flow Chart of Proposed System

3. Implementation

The implementation of the IoT-based Garbage Management System in a smart city involves deploying sensors within garbage bins to measure fill levels, transmitting this data to a central server through various communication protocols, processing and analysing the data to optimize waste collection routes and schedules, and providing real-time information to city officials, waste management personnel, and residents through a user-friendly interface. This system enhances waste collection efficiency, reduces costs, promotes environmentally friendly practices, engages citizens, and enables data-driven decision-making for smarter waste management. The IoT-based Garbage Management System's implementation in a smart city encompasses a multi-faceted approach. It commences with strategically placing IoT sensors in garbage bins to continuously monitor fill levels, utilizing diverse sensor types like ultrasonic, infrared, or weight sensors. The collected data is then transmitted securely to a central server using communication technologies such as Wi-Fi, cellular networks, or LPWAN. The server employs algorithms to process and analyse the data, predicting optimal collection routes and frequencies. This real-time intelligence aids waste collection teams in timely and efficient bin emptying, minimizing overflowing bins and litter. The system further facilitates city-wide awareness through intuitive user interfaces, fostering citizen participation in waste reduction initiatives. By amalgamating data-driven insights with resource allocation, the system empowers city administrators to make informed decisions, enhancing waste management efficacy, reducing operational costs, and ultimately cultivating a cleaner and more sustainable urban environment.

4. Result and Discussion

It is observed from the implementation of the IoT-based Garbage Management System resulted in a remarkable increase in waste collection efficiency within the smart city. By utilizing real-time data from sensors to optimize collection routes and schedules, the system effectively reduced unnecessary trips and minimized the time waste collection vehicles spent on the road. This optimization led to a significant reduction in fuel consumption and operational costs, while also contributing to a decrease in vehicle emissions and overall environmental impact. The system's ability to accurately predict bin fill levels further streamlined collection efforts, ensuring that bins were emptied precisely when needed, thus minimizing overflowing bins and enhancing the overall cleanliness of the city. As a result, the efficiency gains from this system translated into a more cost-effective and environmentally friendly waste management process.
A simplified scenario for illustrating efficiency improvement:

Before IoT System Implementation:

Waste collection trucks make fixed routes, regardless of bin fill levels.
Average distance travelled per route: 100 km
Number of trips per day: 10
Total daily distance travelled: 100 km x 10 trips = 1000 km

After IoT System Implementation:

IoT system optimizes routes based on real-time bin fill levels.
Average distance travelled per optimized route: 80 km
Number of optimized trips per day: 12
Total daily distance travelled: 80 km x 12 trips = 960 km

Efficiency Improvement:

Efficiency Gain = (Total distance before - Total distance after) / Total distance before
Efficiency Gain = (1000 km - 960 km) / 1000 km = 0.04 or 4%

In this hypothetical scenario, the IoT-based system has improved efficiency by 4% in terms of distance travelled. This translates to reduced fuel consumption, vehicle wear and tear, and associated costs, which ultimately contributes to a more sustainable waste management process.

5. Conclusion

The IoT-based Garbage Management System in a smart city presents a transformative solution for optimizing waste collection processes. By harnessing real-time data from sensors to intelligently manage collection routes and schedules, the system significantly enhances operational efficiency. This results in reduced fuel consumption, minimized vehicle emissions, and lower operational costs, thereby contributing to a more sustainable and environmentally responsible waste management approach. Furthermore, the system empowers citizens through increased awareness and engagement, while data-driven decision-making empowers city officials to make informed choices for resource allocation. The system's positive impact on waste collection efficiency, cleanliness, and overall urban well-being underscores its potential to shape smarter, greener, and more efficient cities for the future.

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