Dynamic Routing For Waste Collection In Campus: A Data Driven Approach

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Abstract

Waste management has become a significant challenge in urban areas, leading to environmental pollution, unhygienic conditions, and severe health hazards. Overflowing garbage bins not only degrade the surroundings but also attract pests and contribute to the spread of diseases. Traditional waste collection methods rely on fixed schedules, which often result in either premature collection or overflowing bins left unattended for long periods. To address this issue, this project presents a Smart Garbage Monitoring System that leverages IoT technology for efficient and automated waste management. The proposed system integrates ultrasonic sensors to monitor the levels of food and common waste in bins, providing real-time data on garbage accumulation. When waste levels exceed a predefined threshold, notifications are automatically sent to municipal authorities via the Blynk IoT platform, ensuring prompt waste disposal. A GPS module enables real-time tracking of garbage bin locations, helping sanitation workers navigate efficiently. Additionally, an RFID reader verifies authorized corporation staff during maintenance, preventing unauthorized access and ensuring accountability. A LCD display is incorporated into the system to provide immediate visual feedback on bin status, allowing nearby personnel to take action when required. The system eliminates the need for manual waste-level checking, optimizing resource allocation and reducing operational costs. With real-time data and location tracking, municipal waste management teams can make data-driven decisions, improving overall cleanliness in public spaces. By reducing unnecessary collection trips, the system minimizes fuel consumption, lowering carbon emissions and promoting a sustainable environment.

Keywords: Waste management, IoT Technology, Smart Garbage Monitoring System, Ultrasonic Sensor, Real Time Monitoring, Automated Waste Collection, GPS Tracking, RFID Reader, Municipal Solid Waste Management, Sustainable Environment.

1. INTRODUCTION

Urban areas are experiencing rapid population growth, leading to an exponential increase in waste production. As cities expand, the challenge of efficient waste management becomes more complex, contributing to environmental pollution, unhygienic conditions, and health hazards. Overflowing garbage bins in public spaces degrade the surroundings, attract pests, and serve as breeding grounds for bacteria, leading to serious public health concerns. Traditional waste collection systems rely on fixed schedules and manual inspections, which are inefficient, resource-intensive, and often result in delayed waste disposal. As a result, some bins remain uncollected for extended periods, while others are cleared prematurely, leading to unnecessary resource wastage. To address these inefficiencies, this project proposes a Smart Garbage Monitoring System that leverages IoT technology for real-time waste tracking and management. The system utilizes ultrasonic sensors to continuously monitor waste levels in garbage bins, ensuring that collection is carried out only when necessary. When a bin reaches its capacity, an automatic alert is sent to municipal authorities via the Blynk IoT platform, allowing for timely intervention and optimized collection routes. This approach eliminates manual waste-level checking, improves operational efficiency, and reduces collection costs. The integration of RFID technology ensures that only authorized personnel can verify waste clearance, enhancing system security and accountability. Additionally, a GPS module provides real-time location tracking of filled bins, allowing municipal teams to navigate efficiently and reduce response time. The system also includes an LCD display on the garbage bins to visually indicate 1 their status, enabling local residents and sanitation workers to monitor waste levels instantly. By implementing data-driven decision- making, this system revolutionizes traditional waste collection practices. The ability to monitor waste accumulation trends enables better resource allocation and long-term planning for waste disposal infrastructure. Furthermore, by minimizing unnecessary collection trips, the system contributes to reducing fuel consumption and carbon emissions, promoting a more sustainable environment. The Smart Garbage Monitoring System not only enhances cleanliness in urban areas but also significantly improves public health and hygiene standards. This intelligent approach to waste management fosters eco-friendly waste disposal, encourages smarter city planning, and enhances the overall quality of urban life. By leveraging IoT, this project paves the way for a more efficient, cost effective, and sustainable waste management system, making cities cleaner, healthier, and smarter.

2. METHODOLOGY

2.1 Surveying inside the campus

Choose Nehru Group of Institutions as the case study site to investigate the existing waste management practices. We conducted an in-depth analysis of the type of waste generated, including its composition and quantity, as well as the current waste collection and disposal methods employed by the institution. This initial assessment provided valuable insights into the existing challenges and opportunities for improvement in the institution's waste management system.

Table.1 surveying data collected from campus

NAME OF COLLEGE	NO OF STUDENTS AND STAFFS
JCET	1241
NCA	194
NAl	656
JAI	62
PKDLCAS	252
OTHERS	88
TOTAL NO OF STUDENTS AND STAFFS	2679
TOTAL NO OF DAY SCHOLARS	2330
TOTAL NO OF HOSTELLERS	349

2.2 Develop Waste Bins With Integrated Sensors

Designing and developing a novel waste bin with two separate compartments, one for food waste and the other for plastic waste. The bin was integrated with an ultrasonic sensor to monitor the fill level of each compartment in real-time. The sensor was programmed to send alerts when the compartments reached a predetermined capacity, ensuring timely collection and disposal of waste. The development process involved iterative testing and refinement to ensure the bin's efficiency, durability, and user-friendliness. The resulting smart waste bin aimed to promote segregation of waste at source, reduce contamination, and streamline waste management processes.

2.2.1 Development of wastebin capacity

Biodegradable waste :
As per G.S.R (E): Solid waste management rules (2016)
The amount of Biodegradable waste generated in an institution per capita per day = 0.1-0.5 kg per day
Total no of students and staffs =2679
Total no of day scholars =2330 Total no of hostellers=349
Assuming that all hostellers and 75% day scholars are generating biodegradable waste daily. So, total no of hostellers and day scholars = 931
Hence the total amount of biodegradable waste generated per day= 94kg – 466kg As per survey in campus
waste produced in a day=100kg
wastebin filling rate = 80% (To avoid overflow) Recommended volume of each wastebin= 110 L
Nonbiodegradable:
As per Indian standard code IS 16046: 2015
Average amount of nonbiodegradable waste generated per day= 0.015 kg per capita per day Total waste generated in a day= 40 kg
Waste bin filling rate = 80%
Recommended volume of each waste bin = 110L
Hence providing 3 waste bin with 2 compartment of 110L capacity

2.3 Implementing a GPS monitoring system to track location

Implementing a GPS monitoring system in both the plastic and food waste bins, enabling real-time location tracking through the Blynk app. A GPS module was integrated into the waste bins, allowing for precise location tracking and monitoring. The GPS data was transmitted to the Blynk app, providing a user-friendly interface for tracking the location of the waste bins. This system enabled waste management authorities to monitor the movement of waste bins, optimize collection routes, and prevent unauthorized movement or theft of the bins. The Blynk app provided a centralized platform for monitoring and managing the waste bins, enhancing the efficiency and transparency of the waste management process.

2.4 Deploying Prototype system in a controlled environment

- The Smart Garbage Monitoring System is an IoT-based automated solution designed to enhance waste management by providing real-time monitoring and efficient garbage collection.
- The system utilizes ultrasonic sensors to continuously measure the fill levels of garbage bins, differentiating between food waste and common waste. These sensors send data to a central server

for analysis.

- An RFID-based authentication mechanism ensures that only authorized municipal staff can confirm garbage clearance, reducing the risk of tampering and illegal dumping.
- A GPS module is integrated to track the exact location of garbage bins, allowing authorities to monitor and optimize waste collection routes in real-time.
- The system displays waste levels on an LCD screen installed on each bin, providing visual feedback to sanitation workers and the public.
- IoT-based connectivity using the Blynk platform enables authorities to receive real-time notifications when bins are full, allowing for prompt action and reducing instances of overflowing waste.
- Automated waste tracking eliminates the need for manual inspections, significantly reducing labor costs, saving time, and improving operational efficiency.
- The system improves hygiene and public health by ensuring timely garbage disposal, reducing environmental pollution, and preventing the spread of diseases caused by uncollected waste.
- By providing optimized collection schedules, the system helps reduce fuel consumption, operational costs, and carbon emissions, making it an eco-friendly solution.
- The integration of real-time data, sensor-based monitoring, and secure authentication mechanisms makes this solution efficient, scalable, and suitable for modern smart cities, ensuring a cleaner and more sustainable urban environment.

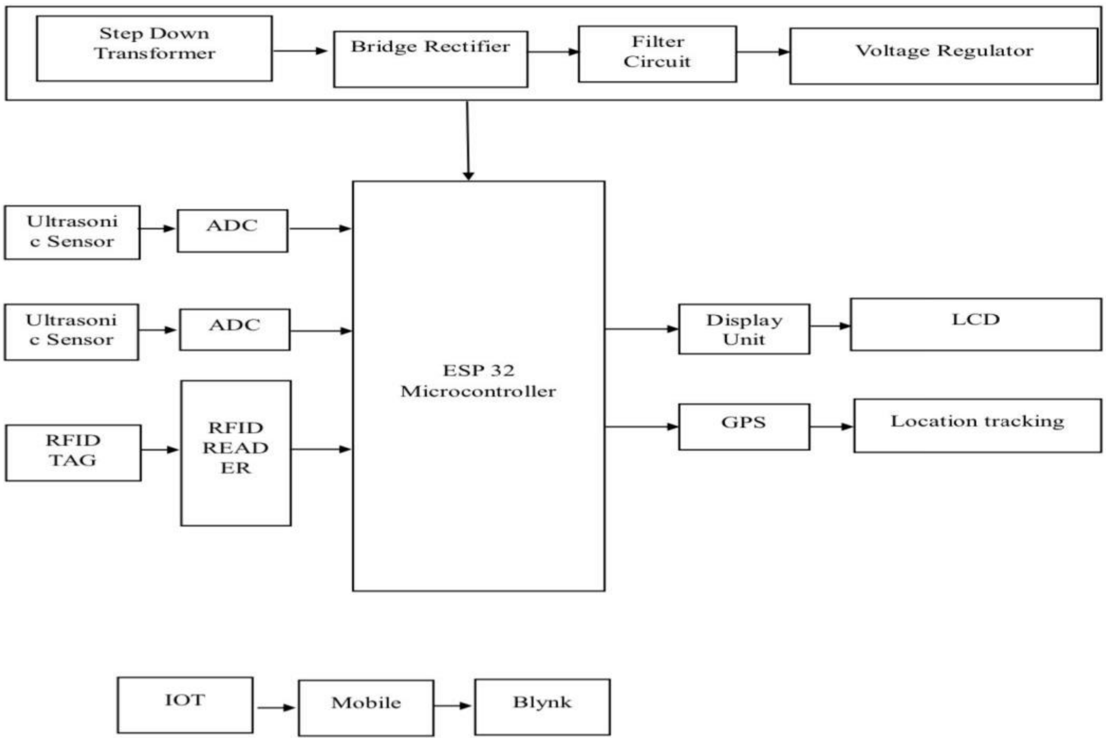

Fig 1: Block diagram of system's performance

2.5 Collect realtime data from wastebins

Designing and developing a smart waste bin with two compartments for food and plastic waste, and integrating it with an ultrasonic sensor to monitor fill levels in real-time. The sensor data is transmitted to the Blynk app, enabling real-time monitoring, tracking of waste generation patterns, and notifications for filling. The system automates waste management, ensuring efficient and timely collection and disposal. Additionally, the collected data is analysed to identify trends and patterns in waste generation, informing waste management strategies and policies. Furthermore, the system incorporates RFID tags to facilitate communication between the maintenance personnel and the waste management authorities. When the maintenance person clears the waste, they scan the RFID tag, sending a confirmation message to the app, ensuring accountability and transparency in the waste clearance process.

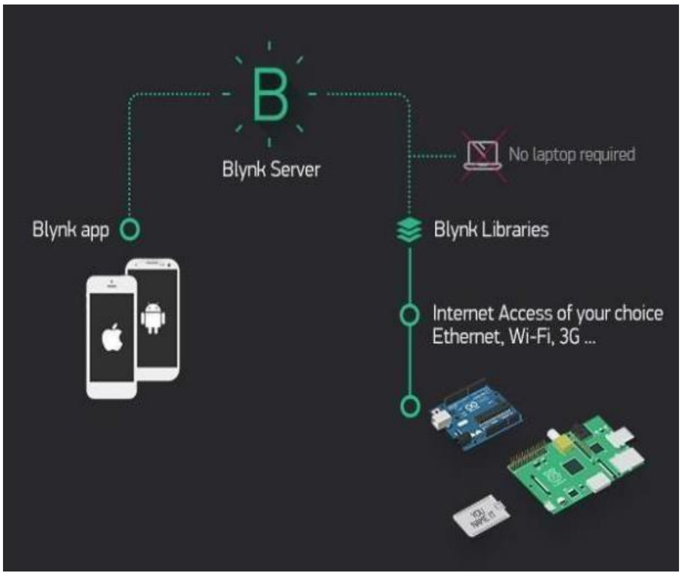

Fig 2: Data processing

2.6 Analyse the data and optimize collection routes

The Blynk app, integrated with GPS tracking, provides real-time location details of the waste bins, enabling the waste management authorities to track the bins' current location, monitor fill levels, and identify the most efficient collection routes. The app's data analytics capabilities help identify trends and patterns in waste generation, allowing for informed decisions on waste collection frequency, vehicle routing, and resource allocation. By optimizing the collection route, the system aims to reduce fuel consumption, lower emissions, and improve the overall efficiency of the waste management process.

2.7 Monitor the system’s performance

The power supply unit (PSU) is designed using a transformer, rectifier, and capacitor to convert AC to DC. The transformer steps down the high voltage mains supply to a safer low voltage. The rectifier converts the AC voltage to DC, and the capacitor smooths the pulsating current.The ESP32 microcontroller is used to control and monitor the PSU. It provides Wi-Fi and Bluetooth connectivity for remote monitoring and control. The ESP32 is programmed to read sensor data, control the PSU, and transmit data to a remote server. The system is designed to optimize power supply and provide real- time monitoring and control capabilities.

Fig 3: ESP32 Controller

2.8 Waste conversion

The food waste is converted into fertilizer through a controlled process, where innoculum is added to facilitate decomposition. This approach enables the transformation of organic waste into a valuable resource, reducing the environmental impact of landfills and promoting sustainable agriculture practices. Meanwhile, the plastic waste is recycled, ensuring that non-biodegradable materials are processed and transformed into reusable products, minimizing plastic waste in landfills and oceans. By integrating these eco-friendly disposal methods, the system demonstrates a closed-loop approach, where waste is managed in an environmentally responsible manner, and resources are

3. CONCLUSION

The dynamic routine for food and plastic waste collection in a campus setting, utilizing smart waste bins and advanced disposal methods, highlights the significant impact of data-driven strategies in promoting efficient waste management. By incorporating smart waste bins equipped with sensors and real-time data collection systems, the campus can achieve optimized waste collection schedules based on actual waste accumulation patterns rather than fixed times. This approach reduces unnecessary pickups, conserves resources, and enhances operational efficiency. Additionally, the data-driven model allows for detailed insights into waste generation trends, enabling the identification of peak waste periods and specific areas with high waste output. This insight leads to better planning and resource allocation, contributing to more sustainable waste management practices. Furthermore, the integration of smart disposal methods ensures that both food and plastic waste are segregated efficiently, promoting recycling and minimizing environmental impact. The conclusion emphasizes the importance of continuous monitoring and adaptation of waste collection routines, allowing the campus to reduce its carbon footprint, decrease waste overflow, and improve the overall sustainability of its operations. Through the combination of technology, data analysis, and effective disposal techniques, the campus can significantly improve waste management practices, benefiting the environment and the community as a whole.

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