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# Development of IoT-Based Smart Bin System for Effective Garbage Management

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***Abstract*— The cleanliness situation related to garbage management is rapidly declining, and it is essential to implement proper garbage management techniques to address the widespread garbage crisis, particularly in the Urban Environment. In order to address this problem, we developed a Smart Bin System for efficient waste management utilizing IoT technology. The system involves the use of sensors to detect garbage levels and Android applications for monitoring purposes. The integration of wireless technologies, micro-electromechanical systems, microservices, and the internet has given rise to IoT technology. This innovative development of an IoT-Based smart bin System for effective Garbage Management, also known as the Smart Bin, aims to keep cities clean and free from pollution.**

***Index Terms*—Garbage Management, IoT(Internet of Things), Micro-electromechanical Systems, Sensors, Android application, and Wireless Technology.**

## I. INTRODUCTION

Garbage pollution is a major problem in many parts of the world. The rapid increase in population and urbanization has led to an increase in the amount of waste generated. According to a report by the World Bank, global waste is expected to increase by 70% by 2050. Improper waste management is a significant contributor to environmental pollution. In many developing countries, garbage is often dumped in open spaces or burned, causing air and water pollution. This leads to various health problems, including respiratory illnesses and skin diseases.

In modern times, the utilization of applications has become more convenient with the integration of IoT technology. This advanced and widely used IoT has progressed through the amalgamation of micro-electromechanical systems, wireless technologies, microservices, and the Internet. Communication in IoT occurs between the client and the server via a device. The industrial internet is a specialized IoT application where interaction between clients and devices has increased communication over the internet.The implementation of IoT has become crucial to address issues such as overflowing garbage and viral diseases that can pose threats to human and animal health.

The IoT Garbage Management System is an innovative outcome that contributes to maintaining cleanliness

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in cities. The system consists of sensors that monitor the percentage of bins filled and transmit the information to the authorities through an Android application. To detect the garbage level, ultrasonic sensors are placed over the bins, and unique Bin Identifications are attached to the sensors to identify the bins. This enables the tracking of various bins across the city, and collectors can save time by going only to the locations where garbage needs to be cleared.

This Garbage Management System facilitates user-friendly and effective garbage management and timely collection of garbage. The smart sensors installed in the system aid in displaying the dustbin status by providing the percentage of bins filled. Additionally, when the garbage in the dustbin crosses 75%, the GSM modem sends an Alert to a designated mobile number mentioned in the system. This feature helps prevent the problem of spilled garbage and diseases caused, which can pose a threat to human and animal health. The smart dustbin uses Ultrasonic sensors to fetch the level of garbage, providing a way to monitor dustbins and manage them more precisely and cost-friendly.

Garbage left on the streets or in the local dustbins can produce harmful gases, especially when it remains in the dustbin for a long time without getting full.[7] The decomposition process of the waste can generate toxic gases that result in foul odors.[8] for this purpose, a gas sensor is attached to the dustbin to detect the presence of such toxic gases. The gas sensor can identify the gases emitted by the decomposing waste and help prevent the unpleasant odor.[9]This sensor also triggers an alert in case of unfavorable conditions

## II. Literature Review

There is a growing body of literature on IoT-based systems for monitoring and managing garbage in Metropolitan areas. According to a study, an IoT-based waste management system was developed using sensors and mobile applications to monitor waste generation and collection on a university campus. The system improved waste collection methodology and reduced collection costs. Overall it managed garbage smartly on campus.[1]

There is a proposed smart waste management system in another study that uses AI and IoT technologies to improve waste collection routes and pick-up schedules based on real-time data.[2] This system improved waste collection efficiency and reduced fuel consumption.

The use of sensors in garbage administration and handling has been studied broadly. For example, in a study [3], an ultrasonic sensor-based waste level monitoring system was developed to optimize waste collection routes on a university campus. The system reduced the number of collection trips and improved garbage management. These experiments were done in a university campus environment and we are trying to improve garbage collection and management for whole cities in an improved and more cost-friendly manner.

Another research has proposed a smart garbage can system that uses IR sensors for detecting levels of garbage and water sensors to segregate wet and dry waste and provide a proper solution. This system facilitated efficient garbage management and reduced the risk of overflow. The concept of sustainable urban development and smart cities has gained increasing scope in recent years.[4]

The authors proposed a framework for smart city assessment based on some dimensions: people, living, mobility, environment, economy, and governance.[5] This framework can help policymakers and urban planners design more sustainable and livable cities. Another study by Albino et al. [6] reviewed the literature on smart cities and highlighted the importance of ICT and IoT in creating more sustainable and efficient urban environments.

## III. Motivation

The problem of hazardous waste management is worsening with the increasing population. In many public bin locations in cities, garbage bins or dustbins are often overflowing, leading to unsightliness, unhygienic conditions, and an increased risk of serious diseases.

The ongoing "Swachh Bharat Abhiyan" campaign launched by Prime Minister Narendra Modi in October 2014 in New Delhi has been the driving force behind this project. The campaign aims to clean the streets, roads, and infrastructure of towns and cities throughout India. This project will also help in replacing traditional methods of garbage collection and management with the advanced use of IoT, Mobile apps, ML, and algorithms.In response, we developed a system called "IoT-Based Smart Bin System for Effective Garbage Management" an Arduino & GSM-based system that indicates and manages garbage bins when they are about to overflow in smart cities to contribute to clean and pollution-free cities

## IV. Problem Domain

The problem domain for this project is waste management and garbage collection in metropolitan cities. The project aims to address the widespread garbage crisis caused by the rapidly declining cleanliness situation related to garbage management. The focus is on developing an IoT-based system that utilizes sensors and an Android application to detect the levels, toxicity, and type of garbage in bins, provide specific solutions for effective waste management, and improve garbage collection. The system aims to keep streets, roads, and infrastructure of the country and towns clean and free from pollution by monitoring the garbage level in bins and detecting the presence of foul odor and toxic gases emitted by the decomposing waste. Clean the. The problem domain also includes exploring new technologies and solutions for waste management, such as IoT devices, sensors, and algorithms, to improve decision-making and minimize fuel costs and workload in waste collection.

## V. Problem Definition

The problem stated in this study is the lack of efficient waste management and garbage collection systems. Traditional waste management methods are often ineffective, leading to overflowing garbage bins and environmental hazards. The absence of an efficient garbage collection system leads to improper disposal of waste, causing pollution and health hazards. Therefore, there is a need for an innovative waste management system that can optimize garbage collection and ensure proper waste disposal. The study aims to develop a system that utilizes IoT and an Android application to detect and manage different types of garbage effectively.

## VI. Problem Statement

The traditional methods of garbage collection and management are inefficient and result in overflowing garbage bins and unhygienic conditions. The current waste management system lacks real-time monitoring and effective management of garbage bins. There is a need for an innovative and cost-effective solution that can manage and monitor garbage bins in real-time to ensure clean and pollution-free cities. The IoT-based Smart Bin System for Effective Garbage Management is proposed it aims to solve this problem by providing a smart and automated garbage management system that can monitor garbage levels and toxicity, and provide solutions for garbage management.

## VII. Innovative Content

Development of a waste management and garbage collection system that utilizes IoT and an Android application to detect the levels, toxicity, and automated collection routes. This system provides specific solutions for effective waste management and optimized garbage collection. The use of IoT technology and an Android application for waste management is a relatively new and innovative approach that can potentially revolutionize the way we manage and collect waste.

## VIII. Methodologies

The proposed study uses a multiple-methods approach to achieve the research objectives. The research began with a thorough literature review of relevant studies on waste management and IoT technology. For the data collection processes shown in Fig.1, IoT sensors are attached to smart bins in select areas of the city to collect information on garbage levels, toxic gases, and the respective locations of the bin with GPS sensors. The data is transmitted to a web server/mobile application and analyzed using statistical software machine learning tools and algorithms to identify trends and patterns to provide the best possible solutions and optimized garbage collection and management

The proposed project work includes two main Implementations: IoT-based implementation and Mobile Application-based implementation.

### *A. IoT-Based Implementation:*

The first step in this implementation is to fit the sensor under the open space bin and position it below the street light. The power from the street light is used to power the Arduino that controls the nearby bins. The circuit used for controlling the sensors using Arduino is shown in Fig.2

The proposed system is an IoT-based waste management solution that aims to improve the efficiency, effectiveness, and user engagement in waste collection and management. The system utilizes sensors, microcontrollers, wireless communication, a mobile app, and a server to monitor garbage levels, detect toxic gases, provide real-time information to users, and optimize waste collection routes.
The system consists of several key components:

- Sensors: Ultrasonic sensors are installed in the bins to measure the distance between the sensor and the garbage, enabling accurate monitoring of garbage levels. MQ-135 gas sensors are used to detect toxic gases and smoke, ensuring the safety of waste collection operators and nearby residents.
- Arduino Uno: The Arduino Uno serves as the microcontroller board that connects to the sensors and processes the sensor data. It runs the firmware responsible for reading the sensor data, applying predefined logic for garbage level monitoring and gas detection, and transmitting the data to the server.
- Mobile App: The mobile app provides an interface for users to interact with the system. Users can register themselves, receive notifications and alerts about full bins, provide feedback, and locate the nearest available empty bins. The app communicates with the server to retrieve real-time data and updates.
- Server: The server serves as the central hub of the system, receiving data from the Arduino Uno and serving data to the mobile app. It stores information about bins, sensor data, user profiles, and feedback. The server processes requests from the mobile app, triggers actions based on predefined thresholds, and sends relevant information to users.

The concept of the proposed system revolves around using real-time data from the sensors to optimize waste collection operations, improve user experience, and promote citizen participation. By monitoring garbage levels and detecting toxic gases, the system can alert waste collection operators when bins are full or hazardous conditions are detected, enabling timely collection and ensuring a safer environment.

*B. Mobile Application-Based Implementation:*

The mobile application is also used to update the bin details where users can register themselves and comment about the bin situation. The app can also view data about the bin in your area, such as the nearest bin and its level. Users can give feedback on their experience with the app.
This application is developed to enable users to access the bin information, including notifications/alerts about full bins and the ability to provide feedback as shown in Fig.3.(b). The application will communicate with the IoT system to provide real-time garbage levels and toxicity information.
Finally, the garbage collection process will be optimized using the shortest path algorithm to minimize the time and distance required to collect the garbage.[11] The proposed system has been evaluated in a real-world setting to determine its effectiveness in waste management and garbage collection.

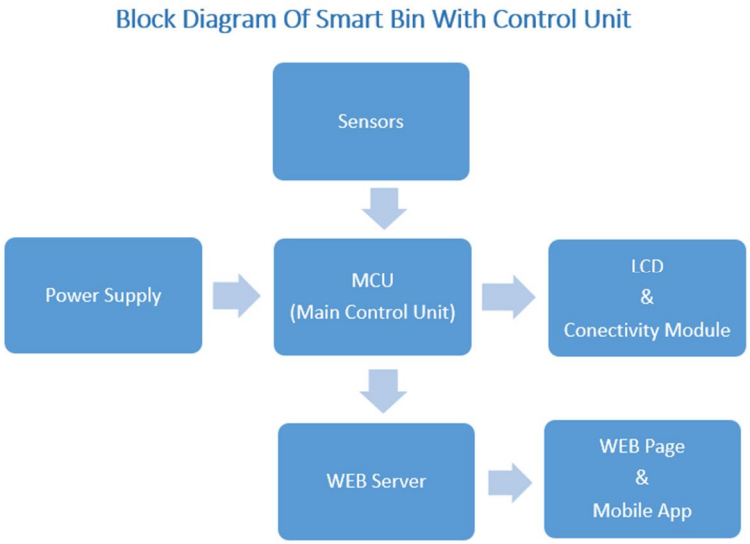



Figure 1. Block diagram of Smart Bin with Control Unit


Figure 2. Structural Representation of Open Space Garbage Bin.

## IX. RESULTS

The implementation of the proposed system can yield several positive results and benefits:

1. Improved Efficiency: The system optimizes waste collection routes by providing real-time data on garbage levels. This reduces unnecessary trips, saves resources, and improves the overall efficiency of waste collection operations.
2. Timely Notifications and Alerts: Users receive notifications and alerts about full bins, allowing them to be aware of the current status and take appropriate actions. Waste collection operators are also alerted promptly, enabling them to prioritize collection tasks.
3. Enhanced User Engagement: The mobile app encourages user engagement by providing features such as user registration, feedback submission, and the ability to locate the nearest available empty bins. This promotes active citizen participation in waste management activities.
4. Effective Resource Allocation: The system helps waste collection operators allocate their resources efficiently by providing real-time information on bin status. They can focus their efforts on bins that require immediate attention, optimizing resource allocation and reducing operational costs.
5. Safer Environment: The detection of toxic gases and smoke by the system's gas sensors enhances the safety of waste collection operators and nearby residents. Immediate alerts enable swift action to be taken to address any hazardous conditions.
6. Data-driven Decision Making: The system generates valuable data on garbage levels, gas detection, and user feedback. This data can be analyzed to gain insights, identify trends, and make informed decisions for further optimization of waste management processes.

It is important to note that the specific results and outcomes of the proposed system may vary based on factors such as implementation, deployment scale, user adoption, and operational factors. Regular monitoring, evaluation, and continuous improvement are essential to ensure

The ultimate goal of our system is to collect garbage using levels of garbage gas sensor alert and user feedback as shown in Table II. When a bin is filled above 75% Alert is sent to the control unit Bin with Unique Bin Identification if the bin is filled alert is shown regarding their levels and collecting authorities are alerted to collect the garbage from the bin.

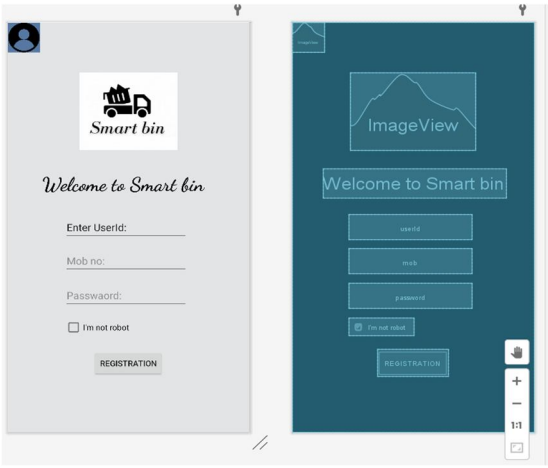
Figure 3. (a) & (b) Application Interface of Smart bin.

as shown in Fig.3 The bin details can be updated using the mobile application, which allows users to register themselves and provide feedback on the bin's status. The application also provides information about nearby bins, including their level and location. Additionally, this app also connects with the IoT system and provides data on garbage levels and toxicity in real time. The garbage collection process is streamlined using the shortest path algorithm, which minimizes distance and time for garbage collection.

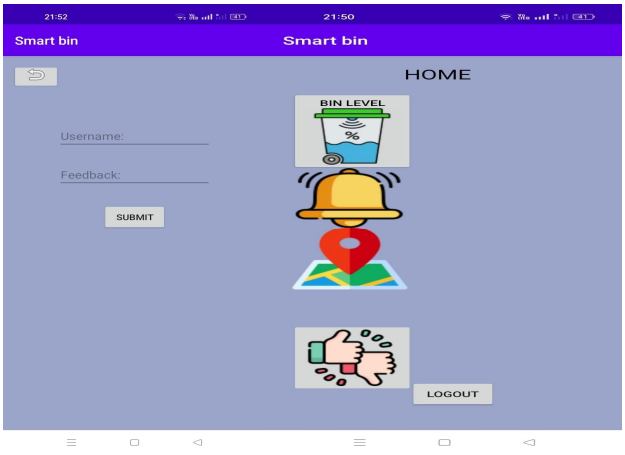
*Results from Gas Sensor*

The MQ135 sensor is suitable for our Air quality control as it can detect gases such as NH3, CO2, Benzene, NOx, alcohol, smoke, and others.[12]

Typically, the sensor outputs a reading between 90-180, indicating favorable air quality which is normal for the surrounding environment. The acceptable level of air quality is at 350 PPM and should not breach 900-




(a)




(b)

1000 PPM. Beyond this limit, it may cause unfavorable symptoms such as headaches, dizziness, and compromised air quality. A PPM level that exceeds 2000 can lead to increased heart rate and various diseases. Table I. gives us a clear idea about bin UID and gas sensor readings in ppm with the quality of the air similarly, Table II. shows levels of bins filled with the ultrasonic level which is how much empty space is left and the percentage of bins filled along with their respective UID's

*Table I - Gas Sensor Output:*

1. UBI: Unique Bin ID that identifies each specific bin.
2. Gas Sensor Range: The measured concentration of gas in parts per million (ppm).
3. Gas Indication: Indicates the quality of air based on the gas sensor readings.

TABLE I. GAS SENSOR OUTPUT

| UBI(Unique Bin ID) | Gas Sensor Range | Gas Indication |
|---|---|---|
| 1000360 | 135 ppm | Normal Air |
| 1000361 | 144 ppm | Normal Air |
| 1000362 | 1431 ppm | Poor Air |
| 1000363 | 900 ppm | Normal Air |
| 1000364 | 2200 ppm | Alert! |
| 1000365 | 2000 ppm | Alert! |

TABLE II. PERCENTAGE OF BIN FILLED USING ULTRASONIC SENSOR

| UBI(Unique Bin ID) | Ultrasonic Level per 30 min | percentage of bin filled (250cm) |
|---|---|---|
| 1000360 | 150cm | 40% |
| 1000361 | 120cm | 52% |
| 1000362 | 115cm | 54% |
| 1000363 | 90cm | 74% |
| 1000364 | 62.5cm | 75% (alerts the control unit) |
| 1000365 | 50cm | 80% |

*Explanation:*

- UBI 1000360 and 1000361 show gas sensor readings in the normal air range, indicating that the air quality is within acceptable limits.
- UBI 1000362 indicates a significantly higher gas concentration of 1431 ppm, suggesting poor air quality.
- UBI 1000363 falls within the normal air range with a gas concentration of 900 ppm.
- UBI 1000364 and 1000365 have gas concentrations of 2200 ppm and 2000 ppm, respectively, which exceed normal levels and trigger an alert.

*Table II - Percentage of Bin Filled Using Ultrasonic Sensor:*

1. UBI: Unique Bin ID that identifies each specific bin.
2. Ultrasonic Level per 30 min: The measured distance (in cm) between the ultrasonic sensor and the garbage in the bin.
3. Percentage of Bin Filled (250cm): The calculated percentage indicating the amount of garbage in the bin relative to its total capacity (250cm).

*Explanation*

- UBI 1000360 is 150cm filled, which corresponds to 40% of its total capacity.
- UBI 1000361 is 120cm filled, representing 52% of its total capacity.
- UBI 1000362 is 115cm filled, equivalent to 54% of its total capacity.
- UBI 1000363 is 90cm filled, indicating that it is 74% full.
- UBI 1000364 is at 62.5cm filled, triggering an alert as it reaches 75% of its total capacity.
- UBI 1000365 is at 50cm filled, reaching 80% of its total capacity.

These results provide insights into the gas levels and garbage fill levels of the individual bins. They can be used to monitor air quality, identify bins that require immediate attention, and trigger appropriate actions such as waste collection or maintenance tasks. The gas sensor readings help ensure the safety of waste collection operators and nearby residents, while the ultrasonic sensor readings assist in optimizing waste collection routes and resource allocation.

## IX. CONCLUSION

The implemented system is very user-friendly and cost-efficient system that utilizes IoT and mobile application technologies. The system can detect the level and toxicity of garbage in bins and provide specific solutions for waste management and garbage collection. The proposed system uses ultrasonic and gas sensors to measure the level of garbage and toxic gases in the bins. The data collected by the sensors is forwarded through GSM modems to the mobile application database. The mobile application developed allows users to register themselves and provide feedback on the bin situation, view data on nearby bins, and receive alerts when the bin is full.

the IoT-based Smart Bin System for Effective Garbage Management can replace traditional methods of garbage collection and management by optimizing the use of IoT, mobile apps, ML, and algorithms. The project contributes to lead to pollution-free and cleaner cities. The proposed system can be implemented on a large scale and can be customized based on the needs of different cities, making garbage management efficient, cost-effective, and environmentally friendly.

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