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IoT based garbage monitoring and management system

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ABSTRACT

Solid waste management has become an increasingly critical issue in Bangladeshi cities, particularly in major urban centers like Dhaka. Overflowing garbage bins are commonly observed, leading to unhygienic environments, pollution, and the spread of various diseases. To address this problem, an IoT-based Garbage Monitoring and Management System has been designed and implemented to enhance waste collection efficiency. This system enables real-time detection of waste levels in garbage bins. Using the Blynk application on smartphones, authorities can remotely monitor the status of each bin and take prompt action to empty them before they overflow, thereby reducing environmental pollution. Each bin is equipped with a microcontroller (ATMEGA328), an ultrasonic sensor, and a Wi-Fi module installed on the lid. When the bin reaches its full capacity, it sends a signal to the control center, notifying them of its status. Upon receiving the information via the Blynk application, authorities can direct the waste collection truck to empty the full bin promptly. This system can be implemented in any city to enhance garbage monitoring and management, ensuring a cleaner and healthier environment.

Contribution/Originality: This project introduces a low-cost, IoT-based solution for real-time garbage monitoring to enhance waste management in urban areas such as Dhaka. The system uses an ultrasonic sensor, ATMEGA328 microcontroller, and Wi-Fi module, integrated with the Blynk app, to detect bin status and send timely notifications. Its key contribution is a practical, scalable design that offers a smart alternative to conventional waste collection methods, promoting cleaner and healthier urban environments.

1. INTRODUCTION

An overwhelming amount of garbage generated in the cities of our country is not collected and managed properly by the appropriate authority. The management of the waste collection process is one of the most complicated tasks because the amount of solid waste generated by residential and commercial-industrial sites is huge. Waste is either burned openly in the streets or ends up in empty lands, canals, and rivers, thereby creating a serious health issue for the public. Today, solid waste management has come a long way from the old days when garbage was collected by horse and disposed of outside of town. Now, it is almost impossible to manage the waste collection process and management without high technology to pinpoint the locations of vehicles and recycling bins [1].

The waste management cycle includes the generation of waste from industries, houses, markets, etc., from which the waste is thrown into garbage bins. This waste is further picked up by the municipal corporations to finally dump it in dumping areas and landfills. However, due to a lack of resources and ineffective groundwork, some waste is not collected, which poses a serious health hazard to the surrounding environment. Proper cleaning intervals may provide a solution to this problem. However, keeping track of the status of the bin manually is a very difficult job. Therefore, a smart waste monitoring and collection system is needed to be designed and developed to reduce the cost and time of waste collection, as well as to protect both the public environment and public health and provide a safe life [2, 3].

The waste disposal can be managed more properly and efficiently by constantly monitoring the bin status and the garbage level. In addition, the authority can be alerted when the bin is full or almost full, thus promoting dynamic scheduling and routing of garbage collection. By comparison to the conventional static scheduling and routing, this dynamic scheduling and routing are said to allow operational cost reduction by reducing the number of trucks, the manual labor cost, and the transport mileage savings. This work presents an alternative in managing domestic waste, especially in flat areas, via a smart monitoring system for garbage management, which is developed based on a Microcontroller (ATMEGA328). This system will automatically monitor the garbage level at each bin and will alert the authority in the case where the bins are almost full [4, 5].

2. LITERATURE REVIEW

Rapid urbanization and population growth have posed significant challenges to effective solid waste management. Conventional waste collection systems often lead to issues such as overflowing bins, inefficient disposal, and increased environmental pollution. In response, researchers have turned to advanced technologies, including the Internet of Things (IoT), Wireless Sensor Networks (WSN), Global System for Mobile Communications (GSM), and Vehicular Ad-Hoc Networks (VANETs), to develop smart waste management solutions. This review explores recent technological advancements in this field, analyzing their benefits, limitations, and overall impact on improving waste management efficiency.

The rapid growth of IoT technology has enabled the creation of smart waste management systems that provide real-time monitoring of garbage bins. These systems incorporate microcontrollers, sensors, and wireless communication modules to streamline and automate the waste collection process. In a study by Bhatia et al. [1], a smart waste monitoring system was developed using ultrasonic sensors to measure the garbage levels inside bins. The data is then sent to municipal authorities via a cloud-based platform, allowing for timely collection and preventing bin overflow.

Similarly, Wijesooriya et al. [2] proposed a waste collection system powered by GSM technology, where each garbage bin is assigned a distinct identification number. When a bin reaches its full capacity, a GSM module sends a notification to a central control unit, facilitating optimized waste collection scheduling. This approach enhances resource efficiency while reducing operational costs.

Researchers have also investigated the use of GSM in combination with ZigBee technology to optimize waste collection processes. A study by Yusof et al. [4] focused on door-to-door waste collection, using ARM 7 controllers to send SMS notifications to waste collectors when a bin was full. This strategy helped minimize waste accumulation and improve cleanliness in residential areas.

A different study combined ZigBee and GSM technologies to optimize public waste collection through real-time bin status monitoring. The ARM7 controller processed the data from the bins, while GSM technology enabled direct communication between garbage trucks and control centers. The results revealed that this system significantly enhanced resource allocation and service efficiency. In addition to IoT and GSM-based solutions, researchers have explored image processing and sensor-driven technologies for waste management.

A study by Thakker and Narayanamoorthi [6] proposed an automated waste detection system that employed image processing to identify full bins. However, this system was hindered by high energy consumption and the need for a constant power supply, limiting its potential for large-scale implementation. Another study investigated city-wide waste collection strategies aimed at preventing overflowing bins in streets and public spaces. The research emphasized the importance of dynamic scheduling for waste collection trucks, which could reduce fuel usage and enhance operational efficiency.

Several studies have explored the application of GPS tracking and WSN technologies in waste management to improve navigation accuracy and data reliability. Research on GPS-based vehicle tracking systems has highlighted their role in optimizing waste collection routes by enabling real-time monitoring of garbage trucks, which results in faster response times and lower fuel costs. Additionally, a study on WSN and VANETs proposed a long-range communication system for waste management that does not rely on GSM networks. This system used sensor networks to detect bin fill levels and transmitted data via vehicular communication networks. The study concluded that this approach offers a cost-efficient and scalable solution for effective waste management.

Current research emphasizes how IoT, GSM, ZigBee, GPS, and WSN technologies have transformed waste management by improving real-time monitoring, resource efficiency, and sustainability. However, challenges such as high power consumption, network dependency, and scalability limitations remain. Future studies should focus on AI-driven predictive analytics, solar-powered sensors, and GPS-based dynamic routing to advance more automated and sustainable waste management solutions.

2.1. Background Study

Nowadays, people are more likely to engage their work with modern technologies. Consequently, the concept of IoT is spreading very rapidly and is used for various purposes. As a result, a number of research works have been completed on IoT-based systems. Researchers have been focusing on waste management using modern technologies for the last two to three years.

Numerous research works related to GSM-based waste management as well as collection systems have been studied. Sensors have been used to get the fill level of the garbage, whereas GSM modules have been used to transfer the required data to the control room. The microcontroller interfaces between the sensor systems and the GSM module. Overall, monitoring and maintenance of garbage-related information have been achieved through user-friendly interfaces. A unique ID has been provided for each garbage bin available in the city so that it is easy to identify which garbage bin is full. When the garbage level reaches the limit, the device transmits the level along with the unique ID provided. These details will then be accessed by the authorities from their location through the Internet, and immediate action will be taken to clean the dustbins. Benefits of this system include cost reduction and resource optimization, intelligent management of the services in the city, and effective use of dustbins [1, 2].

Then, another research article on door-to-door garbage collection tradition was studied. Here, research has been conducted to ensure a zero garbage level with services at minimum cost. The ARM 7 Controller was sending short message services to the cleaner to clean the dustbin. When the dustbin was filled, an SMS was sent to the cleaner using the Global System for Mobile Communication (GSM). Then, an integrated system was combined with an integrated system of ZigBee and GSM. Garbage bins in public places have been targeted in this research. When the garbage reaches the level of the sensor, that indication is given to the ARM 7 Controller. The controller will then notify the driver of the garbage collection truck to get immediate attention. The ARM 7 used GSM technology to send out the SMS to the driver. ZigBee technology was used for garbage bin details, real-time monitoring of garbage bins, information transfer, resource optimization, and a truck monitoring system using GSM [2, 3].

Another automated smart garbage collection technique has been suggested using image processing and GSM for data transfer. When the garbage is full, the cleaner can collect the garbage. These systems can reduce the productivity of the vehicles and manpower. Those that didn't mention the following features need electricity at all times, and these systems can only monitor the garbage fill level and weight.

Another study explained the management of the waste collection system of an entire city. The project provided one of the most efficient ways to keep our environment clean and green. Research clarified the waste management in urban areas and targeted encouraging further research on the topic of waste management. Then, research provided ideas to stop the overflowing of dustbins along roadsides and localities [4-6].

GPS-based navigation systems are common in a variety of land-based vehicles. Sufficient explanation and ideas about GPS were obtained from this research. It helped to understand the different difficulties, implementations regarding the GPS system in various applications and identified some issues in each application [7].

Another system is "Disposal of the waste with Wireless Sensor Networks (WSN) using VANETs." It was an easy way for long-distance communication without a GSM module, and the driver could easily understand where the garbage was filled. Methodologies such as Vehicular Ad-Hoc Networks (VANETs) were used to provide communication between the vehicles. Then, sensors were used to estimate the fill level [8].

A lot of systems have been designed and developed that contribute to reducing pollution in the city, stopping many health problems for the citizens, and reducing the fuel consumption of the trash bins. The locations of the trash bins can also be easily identified via those systems [9].

3. METHODOLOGY

The IoT-Based Garbage Monitoring and Management System is developed to enhance waste collection efficiency through smart technology. At its core, the system utilizes a microcontroller (ATmega328), which processes data from an ultrasonic sensor (HC-SR04) that continuously monitors the fill level of garbage bins. Once the waste reaches a predetermined threshold (80-90%), the microcontroller sends a signal via the Wi-Fi module (ESP8266), transmitting real-time data to a cloud-based server. This information is then displayed on the Blynk application, allowing waste management authorities to monitor bin statuses remotely and streamline collection schedules.

When a bin is identified as full, an automatic alert is sent to the control center, enabling the prompt dispatch of the nearest garbage truck for waste collection, thereby minimizing response time and operational inefficiencies. The system also incorporates LED indicators to provide a visual alert for full bins. A regulated power supply (220V/12V Transformer & 7805 Voltage Regulator) ensures consistent operation without interruptions. By utilizing real-time data transmission, remote access, and automated alerts, this system significantly reduces manual intervention, optimizes resource utilization, prevents bin overflow, and promotes a cleaner urban environment. Potential future improvements include GPS tracking for efficient route planning and automated bin-locking systems to prevent illegal waste disposal.

Below is the Block diagram for making IOT Based Garbage Management System Assemble the Block as shown in the Figure 1.

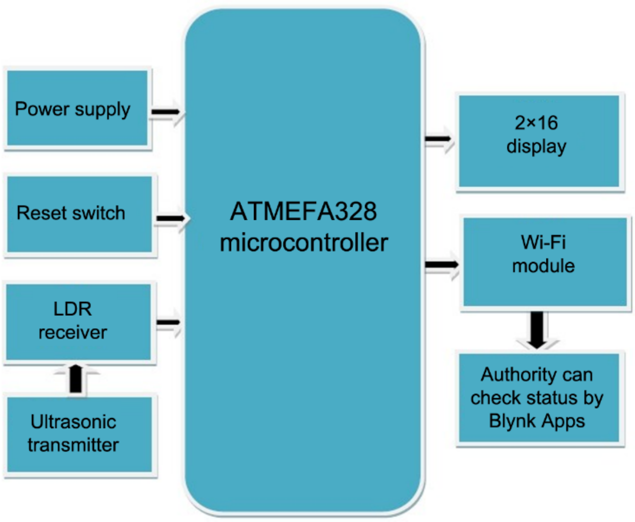

Figure 1. Block diagram of the system.

Figure 1: The IoT-enabled Garbage Monitoring and Management System employs an ATmega328 microcontroller, an ultrasonic sensor, and a Wi-Fi module to monitor waste levels in bins in real-time. The ultrasonic sensor detects the garbage level and transmits the data to the microcontroller, which processes the information and presents the bin status on a 2×16 LCD display. Concurrently, the Wi-Fi module sends updates to the Blynk mobile application, allowing authorities to oversee bin conditions remotely. When a bin reaches its full capacity, an alert is triggered, facilitating prompt waste collection. This system enhances waste management efficiency, prevents overflow, and contributes to a cleaner urban environment.

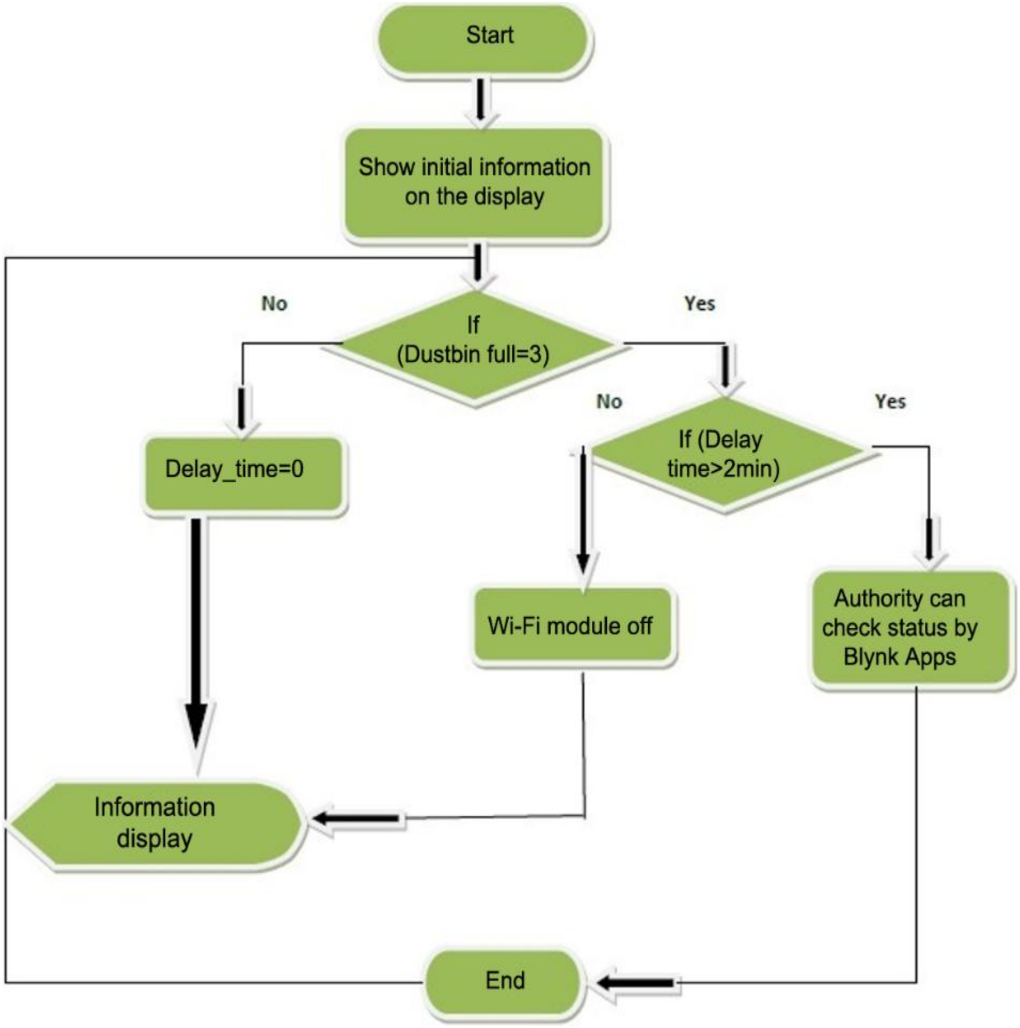

Figure 2. Flow chart of the system.

Figure 2. The flowchart represents an automated smart dustbin monitoring system that tracks and displays the bin's status. The process begins with the system initializing and displaying relevant information. It then checks whether the dustbin is full. If the bin is not full, the delay timer resets to zero, and the system returns to displaying information while continuing to monitor the status. However, if the dustbin reaches full capacity, the system checks whether the delay time has exceeded two minutes. If it has, authorities can check the bin's status using the Blynk App, an IoT-based monitoring application. If the delay time is less than two minutes, the Wi-Fi module is turned off to conserve energy. The process then moves towards termination, ready for the next monitoring cycle. This system improves waste management efficiency by continuously tracking fill levels, reducing unnecessary power consumption, and allowing remote monitoring through a smart application.

4. IMPLEMENTATION

The image Figure 3 depicts a well-structured model of an automated container sorting system, possibly designed for waste management or logistics applications. The setup is built on a flat base resembling a roadway, complete with dashed lane markings. On one side, there is a "Control Room" with a tunnel-like opening, connected to various electronic components, including microcontrollers and circuit boards. Several labeled containers in different colors (gray, red, and yellow) are arranged in a row, each equipped with sensors and mechanisms to facilitate automated sorting. A small LCD screen is present, likely displaying real-time system information. In addition, a crane-like structure with a horizontal beam is situated in front of the containers, likely serving the purpose of transferring or sorting items. The entire setup rests on a checkered fabric surface, indicating that it is a prototype model, probably designed for a research project.

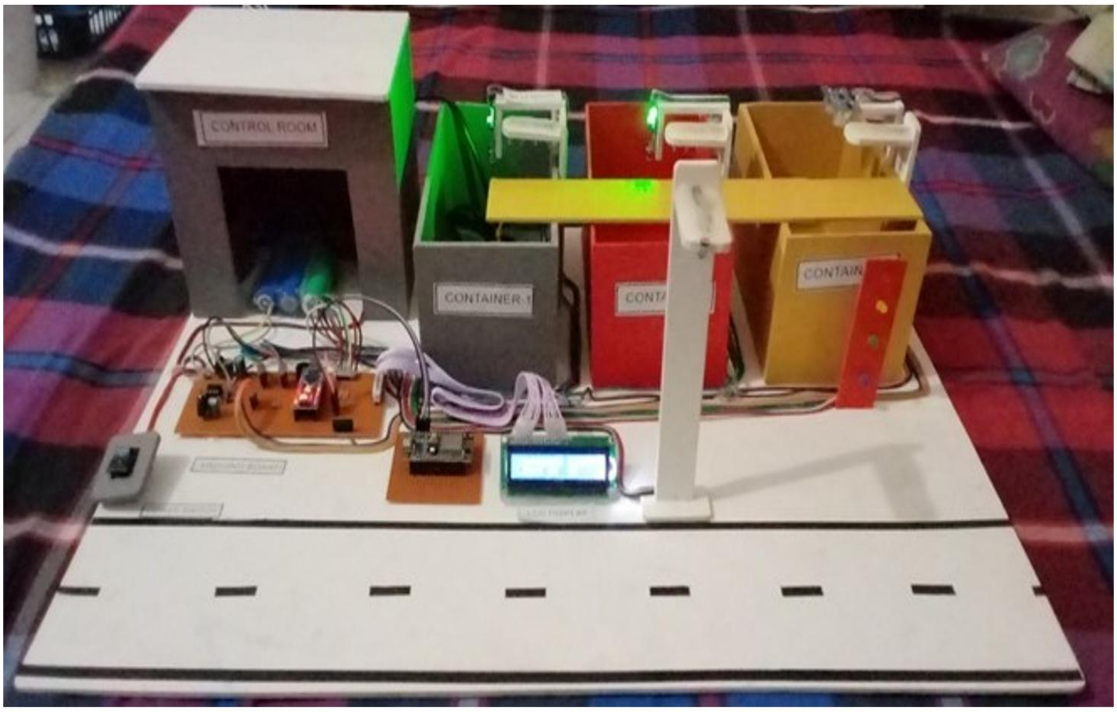

Figure 3. System design.

Figure 4 illustrates an electronic circuit schematic based on an Arduino Nano microcontroller. The circuit includes various sensors, such as IR sensors, an ultrasonic sensor, and an LDR sensor, which are likely used for object detection, distance measurement, and light intensity sensing. A 16x2 LCD display is incorporated to show real-time system data. The schematic also features a Wi-Fi module, indicating wireless communication capabilities. Visual status indicators, labeled "LEVEL LED" and "STRAIGHT LIGHT," are connected via resistors and likely serve as feedback indicators. A buzzer (BUZ) is included, presumably for alerts or notifications. The power supply section consists of a transformer, rectifier diodes (1N4004), and a voltage regulator (7805), ensuring a stable power source. Additionally, a rechargeable battery and a switch are included to control the power flow. This schematic likely represents a smart monitoring or automation system, designed for tasks such as sorting, detection, or IoT applications, utilizing sensors, visual indicators, and wireless communication.

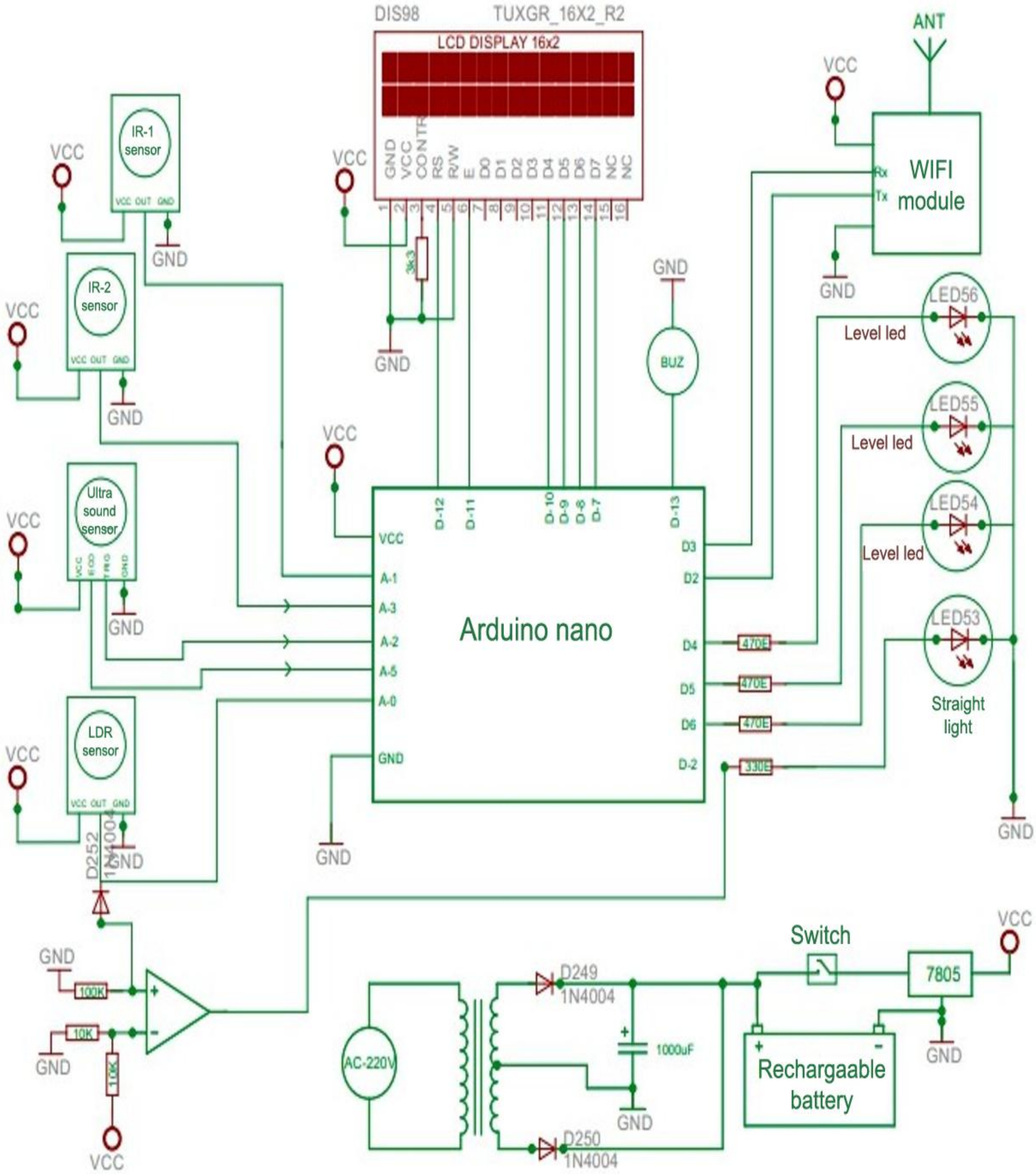

Figure 4. Circuit diagram of the system.

4.1. Working Principle

- Waste Level Detection: An ultrasonic sensor mounted on the dustbin lid constantly monitors the distance to the waste inside. When this distance drops below a predefined threshold, it signals that the dustbin is nearly full.
- Data Processing: The microcontroller processes the data received from the sensor by comparing it against a set waste level threshold. If the threshold is surpassed, it triggers a signal to initiate the necessary response.
- Wireless Communication: The microcontroller communicates with the Wi-Fi module, which transmits the bin's status to a centralized monitoring system or the responsible authority. The system can display alerts on a dashboard or notify personnel of necessary action.
- Response by Authorities: The waste management team receives the notification and schedules waste collection as needed. This ensures efficient waste disposal, prevents overflows, and supports cleanliness.

Figure 5 system status check for the smart dustbin monitoring setup.

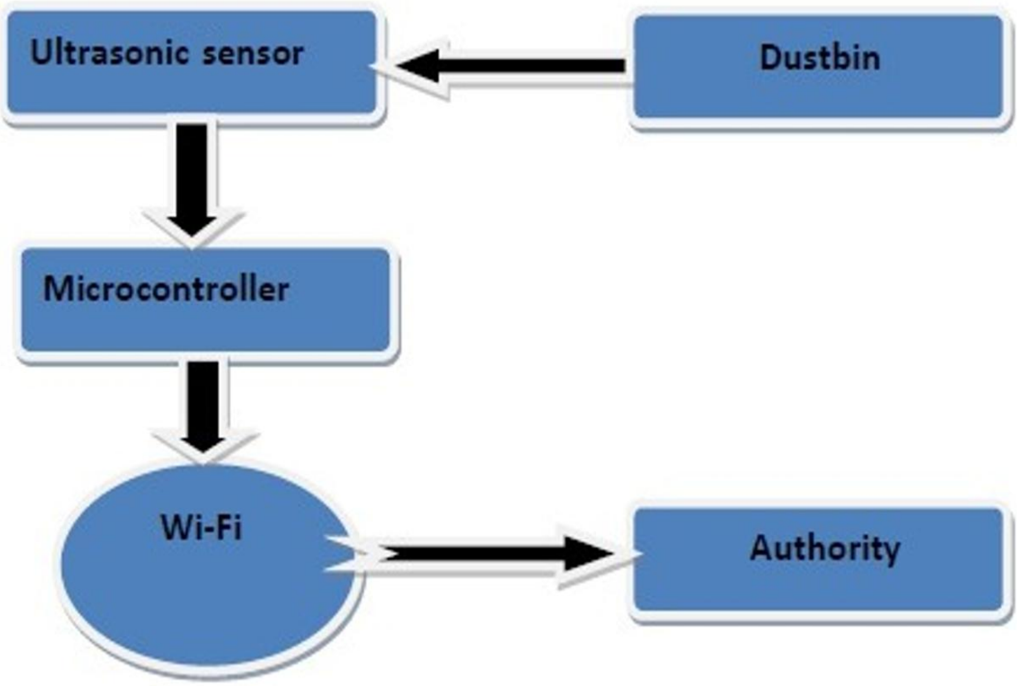

Figure 5. Smart dustbin monitoring system.

The signals from the garbage containers indicate that they are over 80% or 90% full and signal to the ESP8266 system, and the ESP8266 module sends the message through the Blynk app to the person, who will collect the garbage from the located bins. This reduces transportation costs and consumes less time. Another application added to this system is the Light Emitting Diode, which works on the intensity of light. A set of sensors is installed in the garbage bin to detect the level of the bin. As soon as the garbage bin is 90% full, it will send a notification to the authorized person. By using Wi-Fi technology, as soon as the vehicle is notified about the condition of the garbage bin, it will collect the garbage. After the collection, it will send a message about the empty bin.

5. RESULTS

The garbage collection is mostly prepared in the urban part of Bangladesh. Most of the waste is collected from urban areas. Most of the time, we see that the garbage bins placed in public places are overflowing. This overflowing garbage creates unhygienic conditions and causes deadly diseases. To avoid this condition, we have implemented a real-time waste management system using a Wi-Fi system. In the proposed system, automation techniques have been used to reduce human efforts. A sensor is provided for the detection of garbage levels and passes signals to the microcontroller. The microcontroller provides signals to the Wi-Fi system, and the Wi-Fi module sends messages to the authorized person, who collects the garbage from the bins. The information on the performance of the system is given in the following Table 1:

Table 1. Real-time garbage bin monitoring data.

Sl. no.	Garbage bins	Level of garbage (%)	Central monitoring unit
1.	Garbage bin-1	0	Monitored properly
2.	Garbage bin-2	50	Monitored properly
3.	Garbage bin-3	60	Monitored properly
4.	Garbage bin-4	80	Monitored properly
5	Garbage bin-5	100	Monitored properly

6. CONCLUSION

Our designed and developed project, "IoT-Based Garbage Management System," primarily focuses on enhancing waste monitoring, integrating smart technology into waste management, and reducing human intervention, time, and effort. The system aims to create a clean and waste-free environment by offering an innovative and effective real-time garbage monitoring and management solution. Additionally, this system addresses the issue of unsanitary environmental conditions in urban areas by preventing waste overflow, which can lead to the emission of toxic gases and the spread of diseases. By minimizing garbage accumulation on streets, it promotes a healthier and cleaner city.

Furthermore, the system enables efficient database management for each garbage bin, ensuring that authorities can keep accurate records. It also facilitates seamless communication between garbage bins, authorities, and waste collection trucks, streamlining the waste disposal process. Overall, this system contributes to the vision of a smart, sustainable, and environmentally friendly city.

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Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: Both authors contributed equally to the conception and design of the study. Both authors have read and agreed to the published version of the manuscript.

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