Journal of Telecommunication, Electronic and Computer Engineering
ISSN: 2180 – 1843 e-ISSN: 2289-8131 Vol. 16 No. 1
jtec.utem.edu.my
DOI: https://doi.org/10.54554/jtec.2024.16.01.001

e-Waste Bin: An Interactive Waste Management and Monitoring System Via IoT Platform

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Article Info

Article history:
Received Sep 27th, 2022
Revised Jun 12th, 2023
Accepted Mar 6th, 2024
Published Mar 31st, 2024

Index Terms:
Mobile Application
Solar Power
Waste Management

Abstract

Nowadays, waste management has become a challenge faced by the developing and the developed countries. The main problem occurred when waste accumulates beyond capacity before schedule collection. This situation may led to huge environmental pollution and potential outbreaks of disease in the society. In this case, waste pickers are essential in waste management by ensuring timely waste collection and preventing bin overflow. However, monitoring bin levels in real-time poses a challenge for them. Hence, this research proposes a mobile application for solid waste management, designed to monitor the garbage fill level of the waste bin. The app alerts both users and waste pickers to potential overflowing bins, allowing users to communicate directly with waste management company. Employing an ESP8266 NodeMCU, HC-SR04 ultrasonic sensor, MQ-4 gas sensor, and solar power for energy efficiency, this system results in a user-friendly mobile application. This innovation is aimed at mitigating the issue of waste overloading and improves the environmental quality.

I. INTRODUCTION

Waste management is crucial and challenging issue in developed countries [1]. As information and Communication Technology (ICT) continues to grow, centralized information information is increasingly important for accelerating national growth. Therefore, there is a pressing need for sustainable urban living solutions that leverage innovative technologies for long terms viability. This can be realized with the “Internet of Things” (IoT), which promises a better opportunity to build smarter, more efficient living spaces, especially in densely populated areas.Traditional waste collection methods are often inefficient, requiring sustainable time and effort. However, current research is exploring the use of real-time systems, intergrated with technology to manage and solve waste management problems [2] - [4].

Numerous solutions for waste management have been proposed, and some have been put into action, yet there is potential for further refinement to achieve an effective system. For example, [2] describes the development of a smart recycling bin. This bin is designed to monitor its fill level and alert the collection service when it is time to be emptied.

In another study, [5] proposed a system equipped with sensors in bins located in the metropolitan area. These sensors send fill-level data to a centralized server, allowing municipal authorities to monitor waste levels. The collected data is analyzed to improve waste collection routes. The system aims to support decision-making by predicting future waste accumulation, taking into account factors such as traffic congestion, balanced cost-efficiency functions, and other affecting factors which are beyond human foresight.

In [6], the author has proposed a system that can notify the management authority of the need for waste clearance via sensor and microcontroller within a trash bin. This system uses an infrared (IR) sensor to detect the level of trash, while a gas sensor detects the presence of any toxic gases. An alarm is installed in the trash bin to alert the corporation office, enabling prompt waste disposal.

Authors in [7] presents a concept of smart bins that utilize an Arduino UNO with an ultrasonic sensor and a radio frequency transmitter mounted on the lid for monitoring purposes. For control, the system integrates an Arduino Mega 2560, an Radio Frequency (RF) receiver, a SIM900, GSM/GPRS module, and a GLCD screen that reviews the bins’ condition through RF communication. The dustbin's ID and location will be sent to the waste management authority when the dustbin reaches its full capacity.

In another study proposed in [3], a microcontroller consisting of an Arduino UNO board and interfaced with a GSM modem is developed.The system is also equipped with an ultrasonic sensor to monitor the trash level, which was set at a threshold of 10 cm. When the trash level exceeds the threshold, the GSM modem sends an SMS notification to the relevant authority.

Furthermore, some studies have explored the use of cloud technology and mobile applications as innovative approaches to waste management [4][8-9]. In [4], an IoT-enabled waste management system designed for smart cities was proposed.

It features a Wi-Fi module (ESP8266) and a GPS module for precise bin location tracking. This function enables the authorities to easily locate bins and manage the route taken for waste collection. Additionally, the system incorporates an HC-SR04 ultrasonic sensor to assess the fill level of the bins.

Mobile technology also plays a crucial role in enhancing waste management by fostering interactive communication between authorities and citizens. Cooperatively, the use of the mobile phone can help in communication among the citizens and authorities for active participation in waste collection, recycling awareness, or even learn on the waste reduction technique to avoid thrash overflow and frequent waste collection by the authorities [8].

Another study [9] proposed 'SmartBin', an application that leverages a web portal combined with IoT sensors for the real-time bin monitoring. It also proposes a smart navigation feature, installed to the authorities' mobile phones that is routed only to bins requiring emptying. This project includes capabilities for waste detection, automated sorting of materials like glass, plastic, paper, metal etc., and compression feature to minimize waste volume, making collection more space-efficient. These prototypes could be further enhanced by adding addtional features that contribute to better interactions with the management systems to the end-user.

Therefore, an addition to the ICT technology is necessary by adding more features to solve those problems, such as a platform to give user feedback or complaints regarding waste collection services and minimal performance load. While most of the research works described in this paper focused on solid waste collection system, this paper presents a development of mobile app for waste management that offers real-time monitoring of bin levels and sends alerts to users when bins reach their maximum level. The app provides a user-friendly interface for feedback or complaint issues regarding waste management services, facilitating better user engagement and service quality.

II. METHODOLOGY

The eWaste bin system consists of the smart bin, the IoT platform, and the user's application. Figure 1 displays the basic working block diagram of the system.

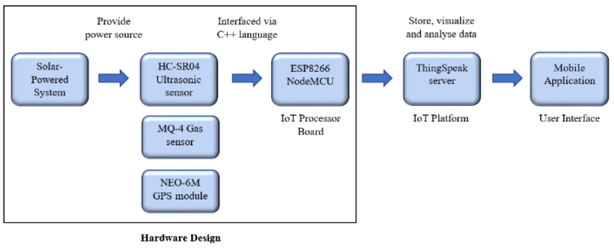


Figure 1. Basic working block diagram

A. e-Waste Bin Prototype

In this project, the prototype used a container with a lid together with the integrations of electronic components such as NodeMCU ESP8266, MQ-4 gas sensor, HC-SR04 ultrasonic sensor, solar panel, as well as a boost converter for power.

The solar-powered circuit shown in Figure 2 energizes the main controller, the NodeMCU ESP8266. The system features a 6V solar panel, TP4056 charging module, 3.7V Li-ion battery, and a DC-DC boost converter circuit. The solar panel absorbs photons in natural daylight and converts it into electricity that functions as battery charging, whereas the battery-charging module protects the battery from overcharging. The circuit of the DC-DC boost converter was designed purposely to increase the DC voltage from 3.7 V to 5 V since the microcontroller needs a 5 V power supply.

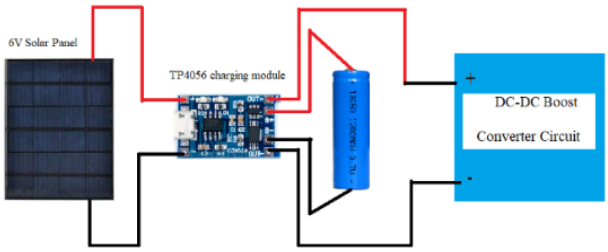


Figure 2. Solar power system block diagram

Then, the ultrasonic sensor produces ultrasonic sound waves that convert the reflected wave to an electrical signal. In this project, the purpose of the ultrasonic sensor is to measure the trash level in the bin. This sensor was installed on the lid of the bin. MQ-4 gas sensor was to detect the methane gas concentration in the dustbin and output its reading as an analogue voltage. Then, the microcontroller reads and processes these signals from the sensors and relays the information to the IoT platform for monitoring and action.

B. IoT Platform

An open-source IoT platform, ThingSpeak is used to store and monitors real-time data such as bin level, gas concentration, and location. It provides various services to users, such as real-time data collection, data visualization, and creating apps. It is convenient to use because users can monitor and analyse sensors data in real-time. Hence, users can easily find errors immediately through the output graphs. To use ThingSpeak, user must first register for an account and then set up a channel by configuring the fields in channel settings. Figure 3 shows the created channel in ThingSpeak.

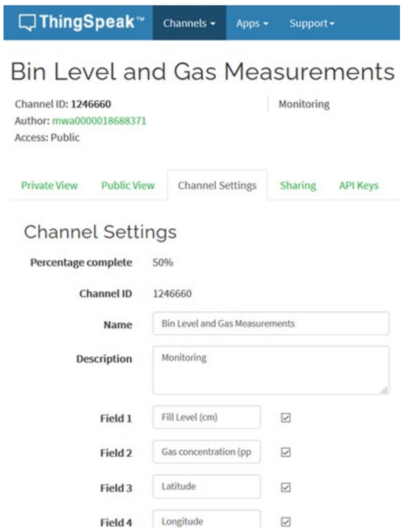


Figure 3. Channel settings in ThingSpeak

The mobile application provides a platform for users to monitor and analyze the real-time garbage level and methane gas concentration. It shows the bin level in two conditions.

For instance, when the trash is in full condition, it will display a 'dustbin is full' message to alert users. Otherwise, it will display 'dustbin is in normal condition'.In addition, mobile users can send their feedback or complaint to the concerned authorities through the apps. All the feedback and complaints will be stored in the database Firebase for future reference.

Another significant development is the use of MIT App Inventor. This application is cloud-based tool that is used to easily initiate mobile applications simply by dragging and dropping the components into a design view. The mobile applications allows users to monitor the bin level, gas concentration, and bin location. Users will also be able to give their feedback or complaint to the waste management authorities. The app includes five main functionalities: login, monitoring of bin level and gas concentration, tracking bin location, and a page for users' feedback. Figure 4 and Figure 5 show a design view of mobile apps.

Figure 6 shows the Web browser, which links as a medium for the authority to collect information on the status of waste bins. This interface helps in optimizing collection route planning. It also provides users with access to pre-schedule collection timetables and maintenance updates, such as notifications for waste pickup schedules or bins out-of-service for maintenance. Additionally, the system evaluates areas with high usage to ensure that new waste bins are allocated quickly in response to users' requests.

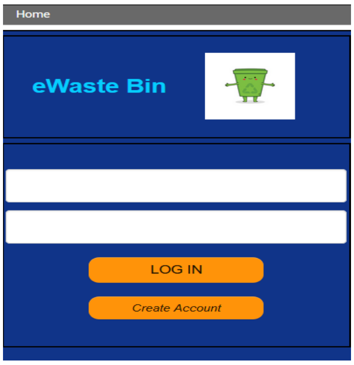
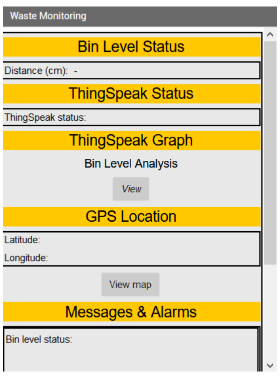
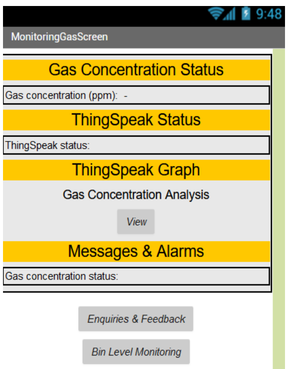


Figure 4. Main Page



(a)



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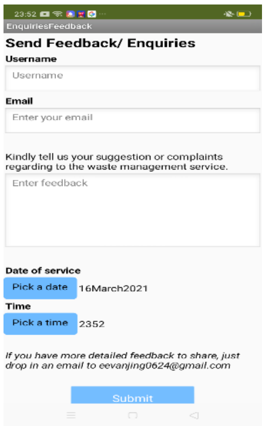

(c)

Figure 5. eWaste Bin App; (a) Bin Level Monitoring Page, (b) Gas concentration monitoring system, (c) User feedback and enquiries screen.

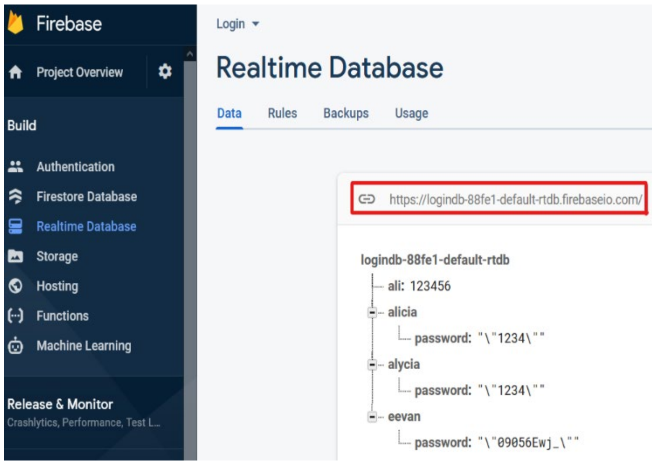

Figure 6. Image from the Firebase platform showing the login of smartbins.

III. PROTOTYPE REPRESENTATION AND FUNCTIONALITY

The designed IoT-based waste monitoring system was tested and compared with the microcontroller-based waste bin to determine the perceived usefulness of the proposed system. The experiment was conducted at a different locations shown in Table 1. The final prototype is shown in Figure 7. Through the use of a real-scale experiment, the performance evaluation of the e-Waste bin is described in this section.

Table 1. Waste Disposal Details For Different Locations

Location	Types of waste	Frequency of waste disposal	Number of bins placed	Overflowing bins frequency
99 Speedmart	Food/Plastic	Once in 2 days	1	Sometimes
Restaurant	Food/Plastic	Once in 2 days	1	Frequent

Figure 7. e-Waste bin prototype

A. Analysis for Bin Level

Figure 8 shows the comparison of bin level between the normal waste bin and the IoT waste bin at different locations. The overflowing garbage bin is preset to once a day so that users can track their bin status from time to time. The total duration of a normal waste bin in full condition is approximately 1 hour and 30 minutes. On the other hand, the IoT waste bin is fully filled for half an hour only. Therefore, mobile apps can inform the collector to collect the garbage if the bin is full. Consequently, the collection process can be done without difficulty. As a result, the time for users or waste pickers to be informed using a normal waste bin is comparatively longer than the IoT waste bin.

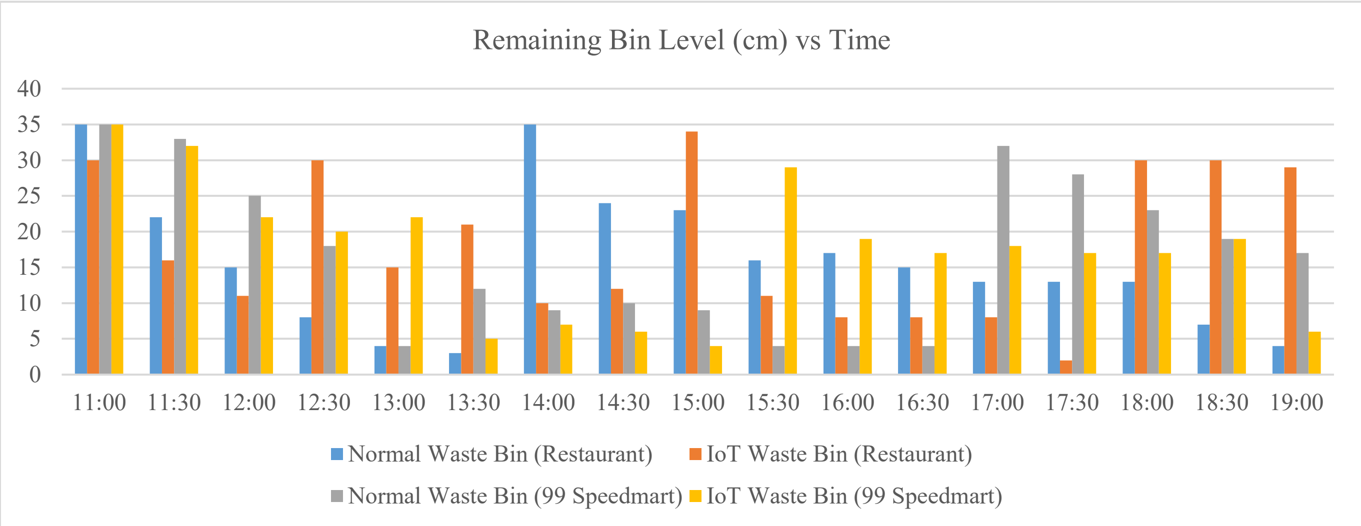

Figure 8. Comparison between normal bin and IoT e-Waste bin based on a bin level

B. Analysis for Gas Concentration

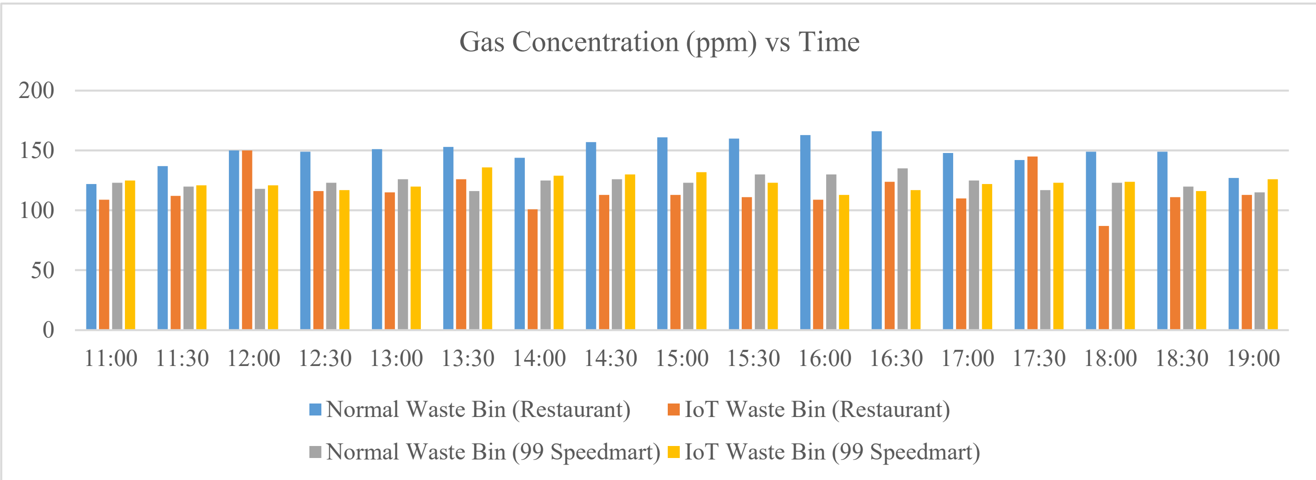

Figure 9. Comparison between the normal and IoT e-Waste bin based on gas concentration

Figure 9 presents a graph comparing gas concentration between the normal and IoT waste bin in different locations. The gas concentration in a restaurant is relatively higher than those at a place like 99 Speedmart because food waste decomposes faster than plastic waste. Hence, the decomposition of food waste will increase methane gas emissions in a short time. Data shows that the IoT waste bin's gas concentration is substantially lower than the normal waste bin. The IoT waste bins typically reach capacity once a day at 5.30 p.m and they remain full approximately 30 minutes.

In conclusion, the estimated peak hours start from 12.30 p.m. to 1.30 p.m. and from 5.30 p.m. to 7 p.m. In comparison, there is a significant difference between normal and IoT waste bin gas concentrations. This is because the user can keep track of the bin status via mobile apps and immediately dispose of the food waste to prevent waste accumulation. Therefore, output data of bin level and gas concentration help users deploy the suitable dustbin amount and plan a waste disposal schedule to prevent overflowing bins.

C. User Feedback or Complaint

In addition, the users are allowed to send their feedback or enquiries to the waste management authorities. They can fill up and submit the feedback form to tackle the problem of inefficient waste collection service. All those feedback and enquiries will be stored in the Firebase. Figure 10 shows the sample of messages received from mobile applications.

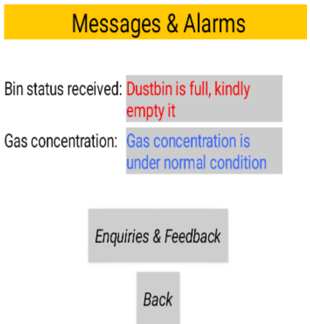

Figure 10. Sample of messages received

IV. CONCLUSION

In this paper, an interactive waste monitoring system is designed for real-time data monitoring. The implementation of this project helps to enhance the waste collection service and waste management system. Users can use mobile applications to obtain real-time information avoiding the need for manual bin status checks. An email notification system is used to alert users when the bin is filled. Besides, the waste monitoring system contributes to environmental cleanliness and helps prevent the spread of infections by ensuring cleaners are promptly notified by the cloud server once the dustbin is in full condition. Hence, it can prevent overflowing garbage bins in public area.

V. FUTURE WORKS

The proposed system is unable to detect and show the real-time location of the bin to the user. Hence, a GPS module sensor can be used to overcome this issue. In addition, the project can be further enhanced by adding the feature of waste segregation. It is an important process that helps to divide the dry and wet waste separately. Hence, the implementation of a waste segregation system makes it easier to reuse, recycle, and eliminate waste materials.

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ACKNOWLEDGMENT

The authors would like to acknowledge the support provided by the Centre for Telecommunication Research and Innovation (CeTRI), Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer (FKEKK) of Universiti Teknikal Malaysia Melaka (UTeM), Melaka, Malaysia.

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