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# Designing an Intelligent System for Garbage Management in Residential Districts Using IoT

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***Abstract*— Nowadays, solid waste is a significant environmental problem that has a significant impact on the health and well-being of society. There is currently a lack of infrastructure and inadequate management involved in the current garbage collection process, which does not utilize the latest technology for real-time disposal of waste. This issue may be solved by promoting a sustainable and clean environment through the use of Internet of Things (IoT) technologies. In this article, we will use Zigbee technology and environmental sensors to build and construct an efficient smart system. The suggested framework senses and gathers data from each bin, tracks the position of the bins, and detects the discharge of hazardous gasses to monitor the amount of waste in the bins. The gathered data is transmitted using Zigbee technology from the waste bin on the transmitter side of the system to the control unit on the server side. Additionally, the suggested study analyzes the power consumption and packet delivery ratio of two wireless transmitting technologies, namely Wi-Fi and ZigBee. A comparison of Zigbee and Bluetooth network performance Moreover, the proposed paper provides an analysis of the packet delivery ratio and power consumption of two wireless transmitting technology including ZigBee and Wi-Fi. A comparison of the network performance using Zigbee and Wi-Fi technology has demonstrated that Zigbee technology provides better performance in terms of the suggested metrics.***

***Index Terms*— Arduino, Smart City, IoT, Garbage, Ultrasonic Sensor**

## I. INTRODUCTION

The rapid expanding of cities and the growing population have contributed to the emergence of various challenges, one of the essintail issue is controlling, managing and processing general waste [1], [2]. Recent studies indicate that the amount of solid waste generated in the world of more than two billion tons annually, and a third of these tons are mishandled in a manner that is not environmentally safe [3]. The average amount of waste generated worldwide each day is 0.74 kilograms and can range from 0.11 to 4.54 kilograms. High-income countries generate approximately 34%, or 683 million tonnes of the world's total waste, per person every day, even though they only account for 16% of the world's population [4]. As the world's population increases, the amount of global waste is anticipated to increase by more than double over the next two decades to 3.40 billion tonnes. The majority of the world's waste is generated in East Asia and the Pacific, approximately 23 percent, whereas the Middle East and North Africa generate only about 6 percent. In contrast, the amount of waste expected to be generated by 2050 is expected to be highest in Sub-Saharan Africa, South Asia, the Middle East and North Africa. Consequently, total waste generation is expected to more than triple, double, and double as shown in **Fig. 1** [5].

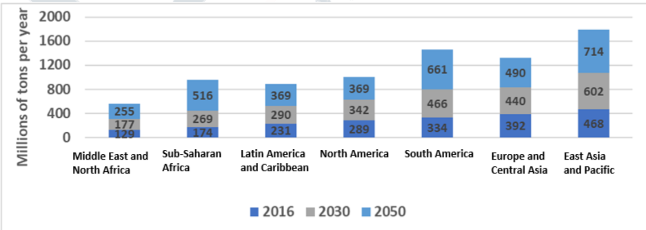


**Fig. 1.** Waste generation perspective by region to 2050 [5]

The improper management of Global garbage serves as a breeding ground for disease vectors, contributes to global warming through methane generation, and creates a risk for a large number of city residents. In many developing countries it continues to be a challenge to manage waste in environmental friendly way [6]. An innovative concept called smart city has emerged in light of the Internet of Things (IoT), which has been developed to combat waste and maintain a clean and hygienic environment. The Internet of Things (IoT) technology is new innovation of the Internet which is regarded as the basis for future communication systems. Beside connectivity, IoT provides provision of a variety of services through the Internet and the ability to connect all devices with any ideal route at any time anywhere in the future [7]. In the past few years, IoT has been applied to a wide range of applications, including smart health, smart cities, environmental monitoring, smart homes, traffic management, intelligent education systems, smart farming, and many others [8]. The detection, collection, monitoring, and disposal of garbage is one of the major challenges faced

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by cities that negatively impact the environment. Garbage collection and management currently takes a very long time, requires a great deal of manpower, and consumes a significant amount of fuel, leading to adverse environmental effects. In the near future, smart garbage management systems based on IoT and sensors will be an integral part of the construction of smart cities [9]. Thus, to promote a sustainable and clean environment, these sensors are capable of reading, collecting, and transmitting a great deal of data over the Internet. This paper proposes an IoT-enabled smart garbage bin that utilizes a variety of wireless sensors and IoT technology by providing an efficient garbage collection platform, it will be possible for city authorities to better manage their resources when it comes to the collection of garbage. A variety of sensors are being utilized in the proposed system, including Arduino UNO microprocessors, ultrasonic, GPS, and MQ-2s. The ultrasonic sensor is used to determine the level of the garbage bin, while the MQ-2 sensor detects harmful gases contained within bins, and GPS sensors determine location of garbage bins. Data transmission from senders to receiver side employ ZigBee technology. Additionally, this paper presents the state-of-the-art that releted to the employed technologies for waste management.

This study contributes the following: (i) proposing the development of smart bins utilizing the Internet of Things; (ii) monitoring trash bins in real-time in a smart city. (iii) Using trash bins in a manner that facilitates the municipal department and citizens in achieving their objectives.

This paper consists of four sections. Section 2 presents background and related work. Section 3 describes the configuration of the evaluating scenario and the proposed system. Results and discussion is given in section 4. Section 5 concludes the paper.

## II. LITERATURE REVIEW

A smart garbage management system involves the use of endpoints (sensors), gateways, IoT platforms, as well as web and mobile applications to collect and manage waste. Smart waste management with IoT technology has the ability to provide useful information about waste generation patterns. Therefore, authorities, can employ such information to optimize waste operations to be sustainable and could help of make more accurate decisions [10], [11] . This section, explains the recent solutions of waste management in IoT environment. Mishra et al presented a classifying approach for both non-biodegradable and biodegradable waste employing ultrasonic technology alongside MQ4 sensor to measure levels of waste and odour in bin, then upload the collected data to NodeMCU [12]. Furthermore, an mobile application have been developed to help authorities to be notifying about possible failure in the IoT system, the notification could be sent by individuals. In [8] a smart system to manage waste has been proposed, the system constantly measure the level of waste in bin and feed it into control station. IoT based solid waste management systems have been proposed by Nirde et al. [13] for smart cities, enabling municipalities to continuously monitor the level of waste in their dustbins remotely via web servers. GSM technology is utilized to send a message when the dustbin is filled to the appropriate authority. Once the authority receives the message, vehicles are sent to the informed location to collect waste. According to Kumar et al. [14] a smart waste management system is proposed based on the use of IoT to monitor the level of waste in dustbins using sensors. The whole system has been integrated using an Android-based application. Additionally, it provides information regarding the waste level of various bins in various locations. The work of Baby et al. [12] proposed a system that alerts the appropriate authority when waste bins are about to be emptied and alerts them to collect the waste before it is too late. A machine-learning concept had utilized in order to gather information concerning how garbage is generated in a certain region, as well as to make predictions about how much garbage will be generated in a particular area in light of the data gathered. By using this information, the garbage trucks are only directed to locations where the bins are severely full. Wijaya et al. [15] point out, smart waste bins are able to help with waste management and contribute to building smart cities. A sensor is included in every smart waste bin to measure the level and amount of waste.

There are several technologies being used by the authors, including Arduino, Zigbee, Raspberry Pi, Ultrasonic, and Infrared. Various research studies are compared with the proposed system in Table 1.

**Table 1.** Comparison of related works

| Ref. | Idea | Hardware | Limitation | Technology |
|---|---|---|---|---|
| [14] | According to the authors of this paper, a smart alert system for garbage clearance has been developed by sending an alert signal to the web server of the municipal government for instant cleaning of the trash cans and the level of garbage filling is verified by the server | Ultrasonic sensor, Arduino UNO, | Local Host is limited to seeing the output only on the laptop within the area of the experimental setup. | RFID |

| | | | | |
|---|---|---|---|---|
| [16] | In this paper, an IR wireless system is integrated with microcontroller-based systems for dustbins and central system that displays garbage status in mobile web browser via HTML using Wi-Fi. | Microcontroller ARM (LPC2148), UV Sensor, GPRS Module | A limitation of the system is that a user may not receive notifications of the bins' status and allocation of collections trucks if they do not have access to a phone or if their battery runs out or their internet fails. | Wi-Fi |
| [17] | The authors have developed an IoT-based system based on Arduino UNO and an Ultrasonic sensor for identifying and reporting the level of garbage bins. However, this design is applicable only to small-scale garbage bins. | Microcontroller Arduino UNO, GSM SIM800L, Ultrasonic Sensor, LCD (16x2). | This system only solves the small-scale garbage bin problem. In addition, it is not possible to monitor the bin in real-time. | GSM module |
| [18] | This paper proposed a system to collect data from ultrasonic sensors and write this data on the thing speak platform channel in order to manage waste. Through the use of smart technology utilizing WeMos and Ultrasonic sensors, it is able to monitor the garbage in real time. | WeMos D1 mini and Ultrasonic Sensor. | When the threshold value is reached, the system will only illuminate the led in the ThingSpeak channel upon reaching the threshold value, so if the bin is full then the led will illuminate itself. | Wi-Fi |
| [3] | As part of the monitoring of the waste bin, this system also analyzes the waste products to make sure that the waste products are segregated according to their biodegradability, non-biodegradability, and recycleability. Additionally, the system recognizes objectionable materials in the bin using the Computer Vision API and sends alerts as soon as the materials are disposed of. | Ultrasonic Sensor, Servo Motor, RC-A-524 Metal Detector Sensor Module, IR Motion Sensor, OV7670 image sensor, Arduino Uno, ESP8266 Wi-Fi Module | A warning message will not be sent to the truck driver if the fill level in a dustbin falls below the threshold level, thereby alarming the driver to collect the fill from the dustbin. Furthermore, it is not capable of dealing with multiple bins at the same time | Wi-Fi |

## III. METHOD

For the purpose of managing and monitoring garbage bin status, the proposed system incorporates Arduino UNO microcontrollers, ultrasonic sensors, MQ2 sensors, and GPS modules type NEO-6M. The sensors collect data regarding the level of garbage bins, harmful gases inside the bins, and the bin location. The collected data is then transmitted through Zigbee technology from the sender side (garbage bin). Data is also received via Zigbee technology on the receiving side (receiving gateway). Additionally, A cloud platform is used to upload the data so that it can be accessed and viewed remotely. Since Zigbee technology is extremely popular among Internet of Things applications, it has been used as a medium for transmitting data because it can be used at low power and at a data rate up to 250 kbps. In addition, it can be coordinated with other wireless products easily and can be interoperated with them.

### A. System Architecture

The block diagram of the proposed system is shown in Fig. 2, which presents the architecture as it consists of two main components: Hardware and Software.

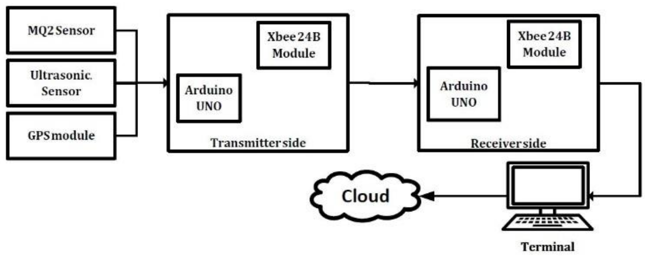


**Fig. 2.** The proposed system description

### B. Hardware Component

This proposed smart garbage bin is designed to operate efficiently by using sensors and additional peripherals. It includes Arduino UNO, Ultrasonic sensor, MQ2 Gas/Smoke sensor, GPS module, Xbee 24B module, and Xbee shield.

### C. Software Component

The proposed system has been used the following software:

#### *1. Arduino IDE*

The Arduino IDE is an open-source software application used to program Node MCU and upload it to the board. A

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NodeMCU ESP8266 is used to transmit sensor data to a web server periodically using the developed Arduino software code. It is compatible with Windows, Mac OS, and LINUX [24].

***2. X-CTU***

X-CTU is a free software package provided by Digi (the manufacturer of XBee). It used for the configuration, management, and testing of the XBee networks. Two XBee 24B chips were used in the proposed system, connected to the XCTU software via COM port serial settings, and several parameters were set, for example, Baud: 9600, Flow Control: None, Data Bits: 8, Parity: None, and Stop Bits: 1. Both XBee chips are configured as Router Device Mode AT and End Device Mode AT [23].

### D. MODELING THE EXPERIMENT SCENARIO

As described in section 3.2, we implemented a platform that contained two main components to evaluate the proposed framework; the first of which consists of an environmental sensor and microcontroller, and the second of which includes Zigbee and WiFi components. The monitoring application, a C++ script, also serves as a software component that reads the information that is to be analysed and stores on a cloud platform (Beebotte). The experiments were performed using a client-server model that consists of a transmitter and a receiver that are separated into two parts. With the Zigbee communication system, the transmitter collects and transmits information from garbage bins (level of garbage, harmful gases, location) via Zigbee to the microcontroller. Data transmitted by the transmitter is viewed on the receiving terminal and then uploaded to Beebotte's cloud platform in real time. A transmitter side implementation can be demonstrated in Fig. 3 by including sensors that read data and transmit information to the server. The Arduino UNO is an edge computing node that executes a C++ script to initiate variables and pin modes, and then transmits data through the transmitter gateway.

As shown in Fig. 4, the receiving side receives data and then sends it to the terminal, which is connected to the programmable gateway. A C++ script is then executed to decode the receiving information in order for it to be visualized and uploaded to the Beebotte cloud platform in real time.

### E. EXPERIMENRAL SETUP

The following section outlines how the proposed system works. The system consists of several technologies, such as a processing unit and a method of transferring data that is used to complete the processing. The dustbin used in our experiments measured 15 X 10 X 35 cm, weighed 500 grams, and held 5 liters. The dustbin is equipped with an ultrasonic sensor, an MQ sensor, a GPS module, and a ZigBee module as shown in Fig. 5. We have installed sensors on the tops of the bin, which are used to monitor the fill level of the bins. The threshold level has been set at a height of 10 centimeters. The system determines whether the dustbin is full based on a predefined threshold. In case of a distance below a defined threshold, the system sends a notification message to the control unit otherwise empty. The Zigbee technology is used for data transmission and collection. It has a low power consumption and a 250 kbps data rate. In order to access and view the data remotely, we made use of a platform for uploading the data into the cloud.

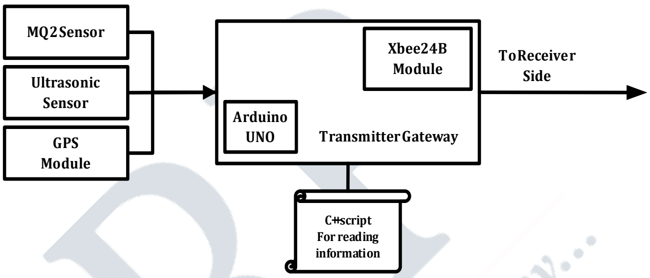


**Fig. 3.** The Transmitting Side Scheming

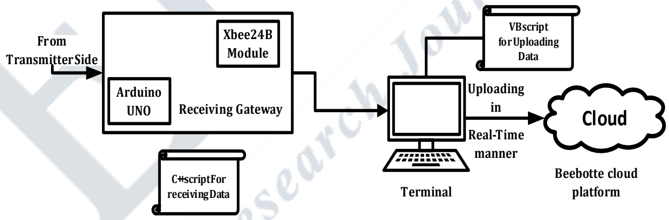


**Fig. 4.** Receiving Side Scheming

**Fig. 5.** The proposed bin and hardware setup

## IV. RESULTS AND DISCUSSION

Our evaluation of the proposed system was based on packet delivery ratio (PDR) and power consumption. PDR is a metric used to measure network performance (lost data during transmition and received by server side). It represents the ratio between the number of sended and received packets. Fig. 6 illustrates the network performance using the selected technologies (Wifi and Zigbee) based on PDR. Obviously Zigbee outperform Wi-Fi in term of Packet Delivery Ratio (PDR) as Wi-Fi has more hand-shaking technique which can lead to radio bands become more congested that will make more data lose compare to ZigBee which consider a lightweigh technology [25]. The mobility was kept stationary in all experiments. As the number of nodes increases up to 10 nsodes, Wi-Fi PDR decreases from 96% to 39%. In contrast, ZigBee consistently shows almost 100% PDR.

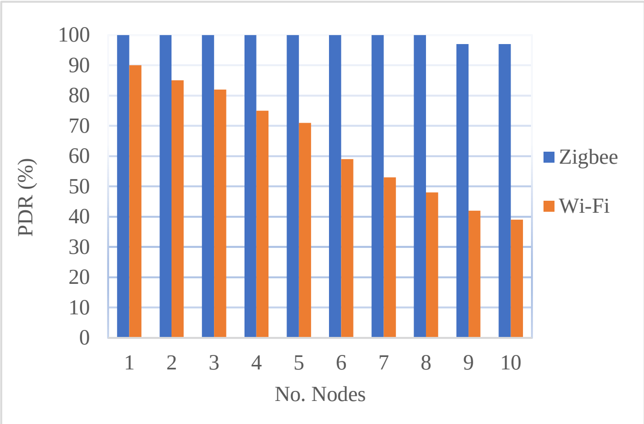


**Fig. 6.** Packet Delivery Ratio for Zigbee and Wi-Fi

With ZigBee, portable devices are capable of communicating over short distances and operate on limited battery capacity. Therefore, it consumes less power compared to Wi-Fi. On the other hand, Wi-Fi technology is designed to provide a more prolonged connection and to support devices that require a substantial amount of power. Figure 6 provides a comparison between Zigbee and Wi-Fi protocol for power consumption in terms of transmitting (TX) and receiving (RX). The consumption of power (mW) for each protocol is depicted. ZigBee consumes relatively less power than Wi-Fi because Wi-Fi signals require high bandwidth to provide fast data rates.

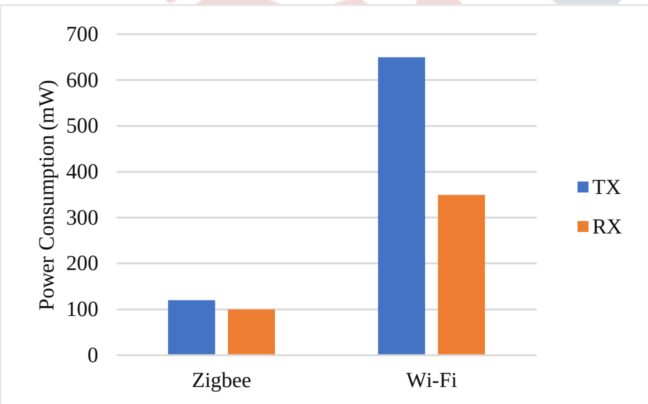


**Fig. 7.** Power Consumption for Zigbee and Wi-Fi

WiFi and Zigbee are two different technologies. The Zigbee network is a WPAN-based network, while the WiFi network is a WLAN-based network. Regarding security and data delivery, Zigbee is more reliable and secure. In contrast, Wi-Fi connections have a maximum transfer speed of 11 Mbps and 54 Mbps for 802.11b and 802.11a/g, respectively. Compared to Zigbee, Zigbee offers a maximum speed of 250Kbps. Table 2 compares and features of Zigbee and Wi-Fi connection standards. In spite of the fact that WiFi has a higher bandwidth for data transmission than Zigbee, the proposed framework does not require a high bandwidth to transfer data to the control unit, therefore, the differences between the two transmission technologies are not significant. Zigbee network is more reliable with a long battery life and a secure network than Wi-Fi network. Using the proposed model, municipal officials are able to monitor the status of garbage bins 24*7, and all relevant waste data will be automatically updated.

**Table 2.** Wi-Fi vs ZigBee Protocol Features [26]

| Features | Zigbee | Wireless fidelity |
|---|---|---|
| IEEE Standard | 802.15.4 | 802.11b |
| Data Transfer speed | 250 Kbps | 11-54 Mbps |
| Security | High | Low |
| Topology architecture | Ad-hoc, point to point, Star or Mesh | Point to multi point |
| Complexity | Low | High |
| Application | Automation, Control | Web, Email, Video |
| Frequency Band | 850-930 MHz | 2.4-5GHz based on Wi-Fi protocol |
| Network Coverage area | 10-100 m | 100-250m |

## V. CONCLUSION

In the world today, waste is increasing rapidly, posing a threat to both humanity and the environment. It is because of this increase and the desire to make cities more environmentally friendly, safe, and efficient that the world is moving towards using Internet of Things (IoT) technologies, which can play a significant role in reducing waste on a daily basis. As part of the proposed system, Zigbee technology and environmental sensors have been utilized to control, manage and process general waste. By providing a platform that will allow for an efficient garbage collection system, it will help the municipal staff manage their resources better during garbage collection. This system provides an effective method of monitoring the garbage level, detecting harmful gases inside the garbage bin, and locating the garbage bin. As well as presenting a comparison of two wireless protocols, ZigBee and Wi-Fi, the paper also examined network performance in terms of packet delivery ratios (PDR) and power consumption. The system can be extended in the future to classify waste using machine learning techniques, and it may even be possible to use LoRa technology in order to cover an even wider area at a very low cost.

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