

Smart Waste Management System Using Lora Technology

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Abstract. In residential areas and commercial spaces, garbage houses serve as important disposal sites. However, rapid urbanization has led to a surge in population, increasing waste production. The conventional waste collection schedules have proven to be inefficient: frequent visits to empty bins are waste resources, while delayed cleaning of overflowing bins harms the environment. To address this challenge, proposals to integrate IoT into smart waste management systems by using LoRa communication for real-time monitoring of fill levels bin and indoor air quality emerge. It involves the integration of sensor technology, IoT connectivity, data analytics, and LoRa technology, leading to more efficient, data-driven, and technologically advanced waste management practices. This digitalization aims to increase operational efficiency, reduce costs, minimize environmental impact, and optimize resource allocation in waste collection and processing.

1 Introduction

An effective Smart Waste Management System is essential for creating a smart, appealing, and sustainable environment and cities. The use of the Internet of Things (IoT) offers a new generation approach to improve the global waste management system effectively and efficiently in developed countries. The wide coverage is crucial for IoT systems, surpassing Wi-Fi, which requires multiple access points for costly infrastructure and improving IoT deployment efficiency [1]. IoT integration includes the use of local sensors, data integration, thing analytics, and cognitive action in waste management. The entire waste generation, collection, transportation, and disposal process can be remotely managed with the implementation of IoT in the waste management system to respond quickly in troubleshooting the current inefficient waste management, [2].

An effective way to enhance waste management systems is by integrating passive RFID with camera, GPS, and GSM technology. While these systems offer significant advancements, there remains considerable room for further improvement. Key areas include reducing operating costs, increasing reading accuracy, and speeding up data exchange processes. Waste management authorities can increase operational efficiency, improve monitoring accuracy, and foster collaborative data-sharing practices by leveraging emerging technologies and refining existing systems, ultimately advancing waste management efficacy

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and sustainability [3]. Furthermore, continuing innovation and investment in these areas have the potential to produce major advances in waste management systems, allowing for more efficient operations and decreasing environmental impacts on a broader scale.

In various studies, ZigBee is frequently selected for power monitoring, control, and management due to its unique features based on the IEEE 802.15.4 standard, including mesh networking topology. This mesh topology enhances the robustness, scalability, and self-healing capabilities of ZigBee-based wireless sensor networks (WSNs), making it a preferred option. ZigBee's data rate ranges from 20 to 250 Kbps, making it an effective and versatile wireless communication solution for a variety of applications [4][5]. On the other hand, LoRa is a wireless technology with the potential to elevate IoT applications. It operates across multiple frequency bands, including 433 MHz, 868 MHz, 915 MHz, and 923 MHz, tailored to different regions around the world. LoRa devices can enable ultra-long range spread spectrum communication while consuming little power and being immune to interference. Long range, low battery consumption, high transmission power, small and secure data transmission are all features of the LoRa chipset.

The LoRa spread spectrum modulation technique is based on chirp spread spectrum. In LoRa, the message is encoded using chirp signals as carrier signals. A chirp is a tone that changes in frequency over time. It is immune to channel noise since the entire designated bandwidth is used to transmit signal. Because each spreading is orthogonal, many transmitted signals can occupy the same wireless channel without interfering. Unlike Wi-Fi based systems, which require many access points to increase coverage area, a single LoRa receiver can manage numerous nodes located across that region, [6]. This paper has two main objectives. First, it aims to improve an ICT-based system for real-time monitoring of fill levels and air quality in waste collection sites. Second, it seeks to provide timely updates through LoRa technology, enhancing the efficiency of waste management monitoring.

2 Method and Materials

The electric components needed to construct the system are shown in Figure 1. The red box highlights the transmitter side, while the blue box represents the receiver side. The transmitter includes a GPS module and a LoRa shield, controlled by an Arduino Uno and powered by a Li-Po battery, for monitoring fill levels, humidity, and temperature. The receiver comprises a LoRa shield and an Arduino Uno, connected to a laptop and NodeMCU for uploading data to ThingSpeak.

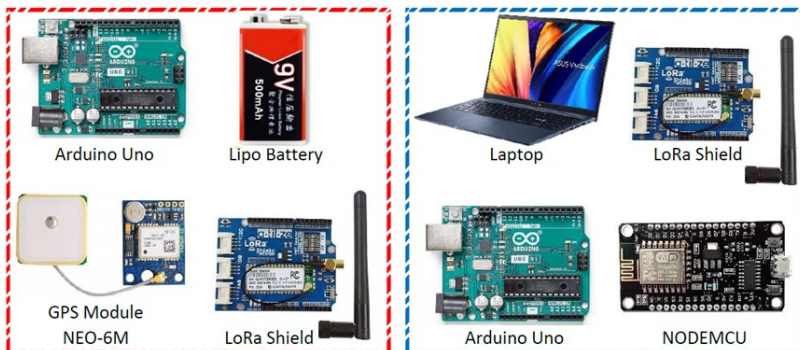


Fig. 1. Electric component required to construct the system.

The method for updating the status of smart bins requires the inclusion of a GPS module, which adds to the data collected from ultrasonic and DHT11 sensors to identify the bin's real-time position. Using the LoRa shield, user may get information about the smart bin's fill level, temperature, humidity and current position from several kilometres away via wireless communication. The data obtained is useful in helping management plan efficient waste collection routes. Figure 2 shows the flowchart of development of IoT Based Smart Waste Management System with GPS. An "A" in figure 2 is a flowchart that is further detailed in figure 3, which specifically focuses on the wireless LoRa module mechanism.

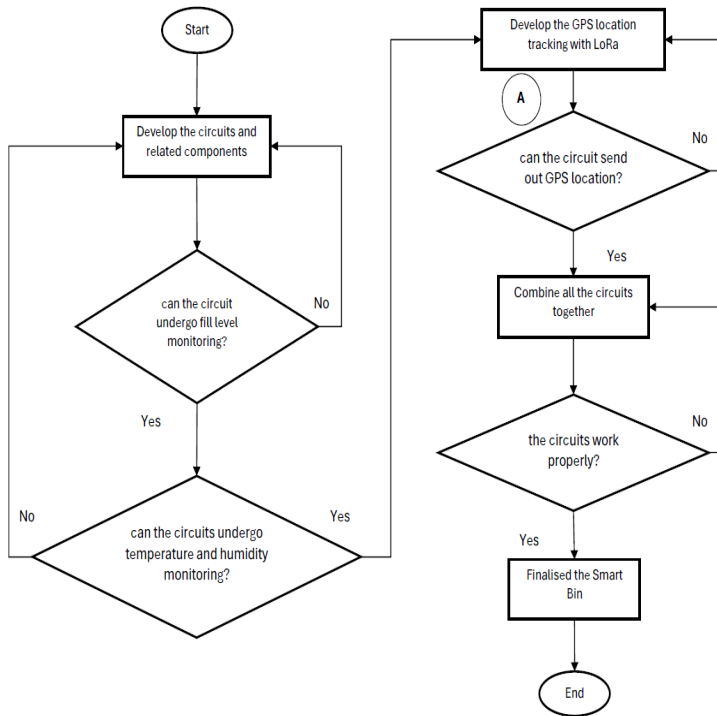


Fig. 2. Flowchart of development of IoT Based Smart Waste Management System with GPS.

Ultrasonic HC-SR04 sensor uses sound waves to determine distance. The sensor generates a wave that travels and reflected after colliding with an object. The sensors will calculate the distance between them by measuring the duration between wave transmission and reception. The sensors have four pins: VCC, trigger, echo, and ground. The trigger pin is an input pin, whereas the echo pin is an output pin. To create the Ultrasonic waves, the Trigger pin is held HIGH for a minimum of 10 microseconds. As a result, an ultrasonic burst is generated, resulting in eight cycles of 40 kHz frequency. The sensor is initially calibrated to assess its accuracy and error deviation. The sensors have been calibrated to the depth of the waste bin, and when waste is placed into the bin, the duration of the pulse created by the Echo pin fluctuates, allowing us to use the distance calculation to measure the distance between the lid and the waste.

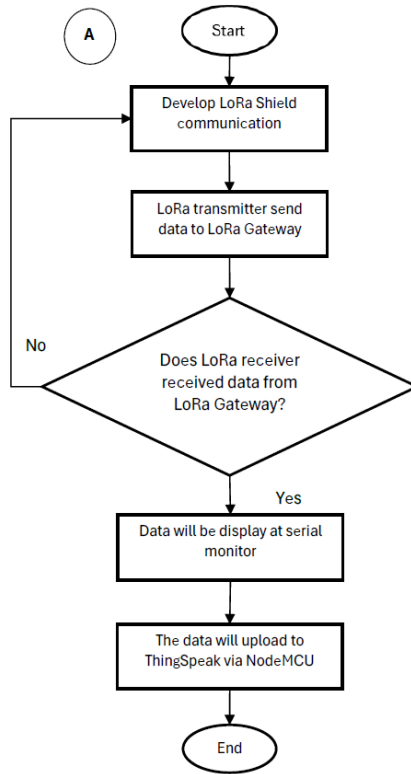


Fig. 3. Flowchart of wireless LoRa Module Mechanism.

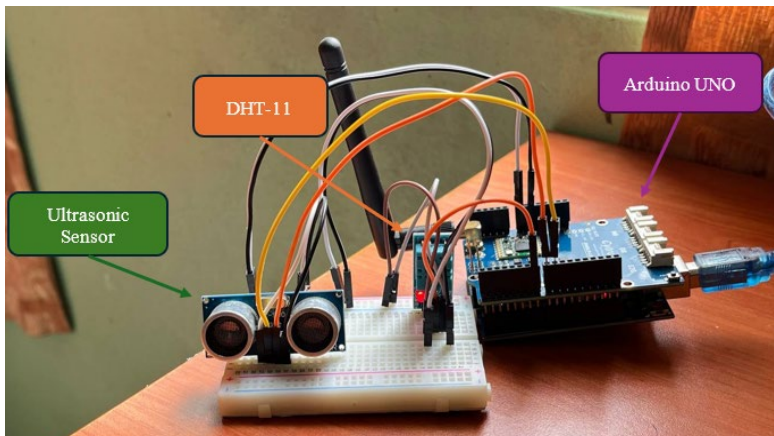


Fig. 4. Setup of the Circuit with DHT-11 Sensor and HC-SR04 Ultrasonic Sensor.

The DHT-11 sensor measures temperature and humidity and has four pins: VCC, GND, Data, and a not connected pin. This sensor has four pins, however the DHT-11 sensor with a breakout PCB only has three. To communicate with a microcontroller, the sensor requires a 5k to 10k ohm pull-up resistor. The DHT11 has a capacitive humidity sensor and a thermistor for temperature measurement. The humidity detecting capacitor consists of two electrodes separated by a moisture-holding substrate, which causes capacitance to alter with humidity level. The integrated circuit (IC) measures and processes these changes, transforming them into a digital form. For temperature measurement, the sensor uses a Negative Temperature Coefficient (NTC) thermistor, which decreases its resistance as the temperature increases [7]. Figure 4 presents a picture of the assembled circuit, highlighting the detailed placement of components and the connections for both the DHT11 sensor and the HC-SR04 ultrasonic sensor on the Arduino Uno platform. This image illustrates the practical implementation and wiring details.

3 Results and Discussions

By accessing this information, users can effectively track the fill levels, humidity, temperature and respond accordingly as they approach either empty or full level bins. Bin's level indicator will light up when the fill level is $\leq 30\text{cm}$ which indicates the bin is nearing full capacity. Bin's humidity indicator threshold is set to 90%. High humidity levels will create a moist environment that supports the growth of bacteria, mold, and fungi. These microorganisms contribute to the breakdown of organic materials, releasing odorous compounds in the process. Temperature indicator threshold is set to 60°C . High temperatures can accelerate the growth and activity of bacteria and other microorganisms that break down organic matter. This decomposition process produces gases such as ammonia, hydrogen sulfide, and methane, which are often associated with foul odors.

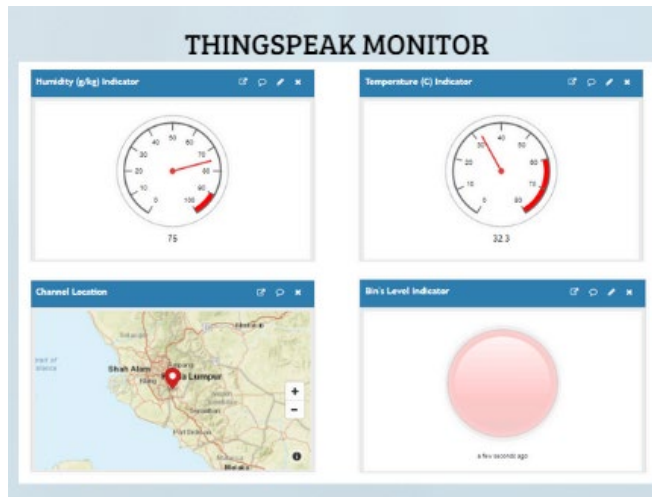


Fig. 5. Visualized Data ThingsSpeak Monitor for Bin 1.

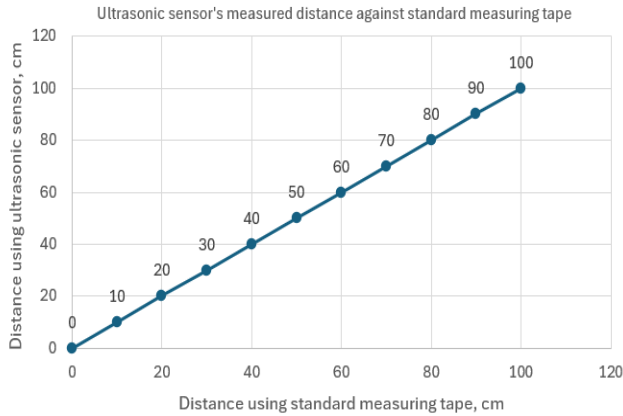


Fig. 6. Comparisons between Ultrasonic and standard measuring tape in open space.

The HC-SR04 ultrasonic sensor is an important electrical component used to measure the fill level or height of waste within the smart bin. To test the accuracy of the HC-SR04 ultrasonic sensor's distance measurements, a comparison was made using a standard measuring tape. Figure 6 depicts the comparison's results graphically that was conducted in open space. The distances were found to be highly accurate within the ultrasonic sensor's working range. The result of this test shows that the measured distance using ultrasonic sensor HC-SR04 is accurate and effective when comparing with measurements obtained using a standard measuring tape in open space.

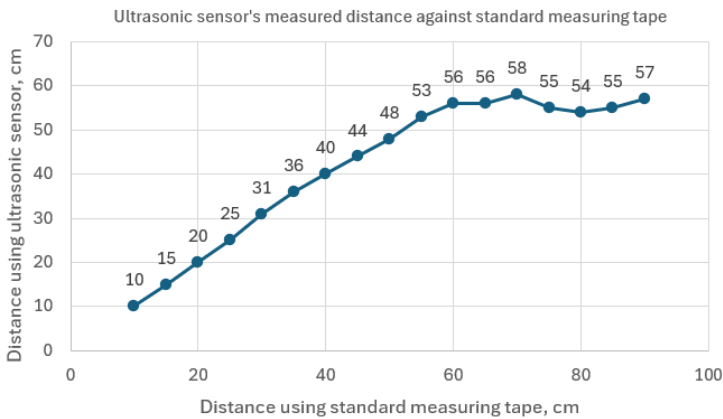


Fig. 7. Comparisons between Ultrasonic and standard measuring tape inside the waste bin.

When the ultrasonic sensors are installed in the smart bin, the distance measured by the ultrasonic sensor is not accurate for empty and partially filled bins. The graph in figure 7 compares the measurements taken by the ultrasonic sensor to the actual values that measured with a tape measure in the waste bin. This inaccuracy is caused by the confined width and shallow depth of the inner bin, which causes some of the sound waves to be reflected back to the ultrasonic sensor before reaching the bottom of the bin. In other words, the time of the sound wave's travel is reduced, producing a smaller reading. The error cannot be easily

eliminated with the current bin size and electronic components used for the proposed system, but further research might be done to solve it. However, when the waste bin is half filled, the fill level monitoring system works effectively. This improvement in accuracy is likely related to the decreased possibility of sound waves being bounced off the bin walls before reaching the surface of the waste. As a result, the ultrasonic sensor is only 89.9% accurate.

Table 1. Difference in MET Malaysia website data with DHT-11 sensor measurements for air in Petaling Jaya.

Time (24-Hour System)	Humidity (%)			Temperature (°C)		
	DHT-11	MET Malaysia	Error (%)	DHT-11	MET Malaysia	Error (%)
1000	81	87	6.9	26	28.2	7.8
1100	83	87	4.6	26.8	28.6	6.3
1200	86	90	4.4	31	27.9	11.1
1300	98	96	2.1	26	24.9	4.4
1400	98	96	2.1	26.1	26.5	1.5
1500	97	92	5.4	25.7	27.3	5.9
1600	79	81	2.5	30	28.8	4.2
1700	80	80	0	30.1	29.3	2
1800	80	81	1.2	28	29.5	5.1
1900	78	77	1.3	31.9	29.5	8.1
Average	86	86.7	3.1	28.2	28.1	5.6

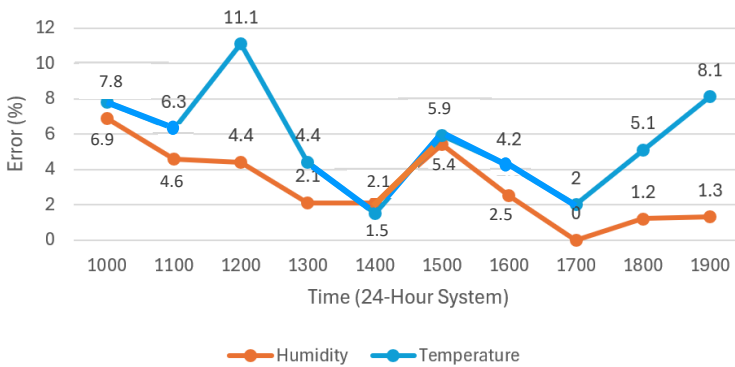


Fig. 8. Variation of Error (%) for Humidity and Temperature Over Time.

DHT-11 sensor is an important electrical component used to measure the humidity and temperature within the smart bin. To test the accuracy of DHT-11 sensor measurement, a comparison was made using a data from Department of Meteorology Malaysia (MET Malaysia) using air temperature and humidity. The data was taken on 15 June 2024 at 10.00am until 7.00pm. Table 1 shows difference data between MET Malaysia website with DHT-11 sensor measurements for air in Petaling Jaya.

Figure 8 illustrates the trend charts of error margins for both humidity and temperature readings. The reading of the DHT11 sensor for humidity has an error value of 3.1%, the maximum error limit for the sensor is 5%. While the sensor reading for temperature has an error value of 5.6 °C, in this case it exceeds the maximum sensor limit which is only 2 °C. The accuracy can be influenced by environmental conditions, sensor limitations, calibration issues, electromagnetic interference, and sensor placement. The accuracy rates are 96.9% for humidity and 94.4% for temperature.

4 Conclusion

The Smart Bin Management System using LORA Technology has been promoted sustainable waste management practices. The incorporation of contemporary technology is consistent with worldwide objectives to develop smarter, more ecologically sensitive urban landscapes. By providing actionable data on waste production patterns, the system allows authorities to take targeted steps that lead to more sustainable waste disposal practices. The new concept represents a significant step towards smarter and more sustainable municipal waste management solutions.

Acknowledgements

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