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LoRa Based Garbage Monitoring System over IoT

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Abstract: Municipal Solid Waste Management is still a big issue in cities, causing serious health and environmental problems. As a result, trash cans are installed in a variety of locations to handle municipal solid waste. Due to poor monitoring, the Trash in these containers overflows, damaging the environment and creating public inconvenience. As a result, a real-time remote monitoring system that alerts a municipality or a waste management firm to the level of trash in the trash bins is required.
The trashbins in many of these regions are not cleaned at regular intervals, implying that they are not properly maintained. Smart waste management and monitoring systems should be implemented to avoid this. And, with the adoption of these smart technologies, the garbage management system will be optimized, as well as the current system's fuel consumption will be reduced. IoT technology has been used in few projects involving smart garbage management and monitoring systems, and it has proven to be beneficial for only a few challenges, for example, the range of Wi-Fi and Bluetooth communication systems, is quite limited, at only 50 metres and 10 metres, respectively. As a result, the IoT-based garbage monitoring system based on LoRa provides an effective solution to the problems in the current system. The range of the LoRa communication system is significantly greater than that of Wi-Fi and Bluetooth. LoRa communication typically has a range of up to 15 kilometres.
Keywords: Internet of Things, LoRa, Remote Monitoring, Trash bin, Arduino, Node MCU, Ultrasonic Sensor.

I. INTRODUCTION

As the number of people living in cities grows significantly over time, cities face numerous issues, particularly in the waste management system. According to the World Bank, roughly 2.01 billion tonnes of trash were generated in 2016 as a result of population and economic expansion in metropolitan areas, and this number is expected to rise to 3.40 billion tonnes by 2050 [1]. According to EUROSTAT, the European Union recycled 423 million tonnes of waste in 2016, accounting for 56 percent of locally produced waste [2]. Furthermore, the European Union disposed of 24 percent of the 179 million tonnes of locally produced garbage. The European Union is home to some of the world's largest landfills, including Laogang in Shanghai, Bordo Poniente in Mexico City, Jardin Gramacho in Rio de Janeiro, and Sudokwon in Seoul. [3]–[5]. Waste management, often known as waste collection, entails a number of stages and actions, including waste collection, transportation, monitoring, and regulation. Waste management procedures differ between urban and rural settings. In most cases, the best way to deal with gathered waste is to reuse and recycle it. The expense of good waste management, on the other hand, is substantial, necessitating collaboration from both authorities and users. Although the government or authorities have made significant attempts to enhance the waste management system, it remains a major issue in every country, particularly in urban areas. If the garbage is collected on time, one of two things happens: either the bins aren't entirely filled, or it overflows.

The trash collected before the bins are full would result in a waste of manpower. Otherwise, garbage overflow would pollute the environment, resulting in air pollution and dangerous diseases. Recycling garbage is another way to reduce waste creation and help the environment. However, this strategy does not produce beneficial outcomes due to the consumers' incompetence in appropriately categorising the waste. The rapid advancement of the digital world has a significant impact on technological advancements, particularly by allowing intelligence to be integrated into current technology [6]–[8], commonly known as the Internet of Things (IoT). The combination of technologies and the Internet of Things (IoT) has given different industries, such as engineering, a whole new perspective [9]. Every second, around 127 devices connect to the internet, equating to 328 million devices connecting per month [5], [10]. In 2023, the IoT industry is estimated to reach

1.1 trillion dollars [11]. In 2023, the IoT industry is estimated to reach 1.1 trillion dollars [11]. These figures demonstrate the importance of the Internet of Things in today's world. By uniting everything in the actual world under a common infrastructure, IoT enables the control of things in the real world and educates things [8], [12]. The current waste management system can be enhanced in many ways with the use of IoT, including cost of resources, user-friendliness, ease of management, and reduction of waste to be disposed of through recycling. As a result, in the recent decade, a waste management system based on IoT has emerged. This study describes a smart waste management system that identifies and categorises various forms of waste and assigns them to one of several compartments. Furthermore, the system is integrated with IoT-based sensors and a LoRa module that accurately transmit bin status across long distances. It necessitates the use of repeaters to establish long-range communication, which leads to higher power consumption and a more complicated system architecture. [13] presents a complete analysis on the creation of smart cities using long-range communication technologies.

This research focuses on IoT systems that use the Lo-RaWAN networking protocol. Long-range connectivity, low power consumption, and distributed wireless sensor nodes are all advantages of LoRaWAN [14]. These capabilities of the LoRaWAN networking protocol can help existing IoT-based garbage bin level monitoring systems overcome their restrictions. [15] shows a smart waste collection system with LoRaWAN nodes. In addition, no practical results on sensor node transmission range were provided. As a result, a flexible IoT system is required that allows long-range data transmission, ease of scaling, cost effectiveness, and gives trustworthy information in real time to municipalities or solidwaste management companies. As a result, we developed an IoT system to meet the needs of the municipality or the solid waste management company.

II. RELATED WORKS

S. Paul et al. [16] developed a smart garbage monitoring system based on IoT and Arduino UNO that tracks bin levels and separates biodegradable and non-biodegradable waste. The technology measures the bin level in the trashcan with an ultrasonic sensor. By moving the garbage left and right, a servo motor separates the biodegradable and non-biodegradable waste. Metal Detector RC-A-524.The Sensor Module is used to determine whether or not the waste is metallic. If a trash item contains metal, it is labelled as non-biodegradable.It is designated as biodegradable otherwise. There are two infrared sensors in operation. The first IR sensor, which detects the waste, is located on the top of the bin.and turns on the metal detector . A second infrared sensor is installed at the bottom of the bin to determine whether the waste has been stored outside.The trash can The picture data is collected using an OV7670 image sensor, and a Computer Vision API is used to determine whether the waste is recyclable.Whether or not the item is disagreeable. Arduino UNO is used to connect all of these sensors and circuits. The ESP8266 WiFi module is plugged in.The technology that allows users to connect to the internet via WiFi. This monitoring system also includes an alarm system for specific wastes, such as bombs or explosives.

Kumar et al.[17] proposed an IoT-based alert system for frequent garbage collection that sends an alert signal to the web server to collect the garbage. The smart dustbins are designed with a compressing plate that allows for a greater amount of rubbish disposal than typical. The leaf switch on the dustbin is a little lower than the maximum level.The dustbin is built in such a way that the leaf switch's functionality is never harmed. This system is based on a Arduino UNO is the microcontroller unit utilised, and the sensor is an ultrasonic sensor for determining the garbage level in the bin.The data is delivered to the Thing Speak serAn RFID tag is used for verification of the garbage clearance by interrupting the RFID reader which makes ultrasonic sensor to check the garbage level and update the web server. They have also created an Android application that is linked to the Things Speak server and receive notifications.ver via the ESP8266 Wi-Fi module.

G. Azwar [18] presented a NodeMCU-based smart trash monitoring system. Ultrasonic sensors, two LEDs, and a NodeMCU are used in this setup. The ultrasonic sensor is utilised to measure distance and determine the bin's fill level. To determine if the bin is full or not, a red and a green LED are employed. When the bin is empty, the green LED illuminates; when the bin is full, the red LED illuminates.To connect all of the LEDs and the ultrasonic sensor, NodeMCU is utilised. It also connects to the WiFi network, which is where the data is saved.Data stored on the server The MQTT protocol is used to broadcast data from the sensors to the cloud server. Using PHP and AJAX programming languages, and the web application's data subscription results are then stored in a database server. This data is then displayed on a dashboard which can be accessed using any browser.

Chen et al. [19] presented a Smart Waste Management System that incorporates a microcontroller, infrared sensor, gas sensor, and 3-axis compass. Between the sensors and the server, the microcontroller unit serves as an interface. The dustbin's fill level and smell level are determined by an infrared sensor and a gas sensor, respectively. The data collected by these sensors is used to create a report.In interior circumstances, data is transferred over WiFi, while in outdoor settings, data is sent via Long Range Module (LoRa). The informationsupplied to the server is t The Data Manager then saves the information to a MySQL database. The alert function monitors the data on a regular basis and notifies you when the fill level is low.When the number of dustbins reaches a certain threshold, a notice mechanism is activated.Which sends the notification to the truck driver along with route that is created using Google Maps.

J. Das[20] proposed a smart garbage monitoring and alert system using IoT. This system uses NodeMCU, DHT-11 sensor, HCSR04 Ultrasonic sensor, and MQ4 sensor. The NodeMCU interfaces all the sensors and connects to the WiFi. The DHT-11 sensor measures the temperature and humidity which is used to segregate dry and wet waste based upon the output of the sensor. The ultrasonic sensor is used to calculate the fill level of the garbage in the bin. The MQ4 sensor measures methane and natural gas which is used to measure the odour of the garbage. The system also uses an android application which monitors the data in real-time. One has to login with valid user id and password on the application so that only authorised person can access the data. IFTTT (If This Then That) service is used for the notification service. If the threshold is crossed then an SMS or email notification is received by the authorised person. can have access to the information(IFTTT If This Then That).The notification service is provided by the Then That) service. If the threshold is exceeded, the user receives an SMS or email notification a person with authority.

III. METHODOLOGY

The proposed system "LoRa based garbage monitoring system over IoT" seeks to use an equivalent notion of the IoT and link a constructed device using LoRa Technology and IoT (Internet of Things) to transfer data from a normal trash container to the maintenance facility office. The suggested system's goal is to create a gadget that uses ultrasonic waves to determine the amount of garbage in a container.

The data acquired from the sensors will be relayed via LoRa, which will show the data on a webserver. And this system alerts the staff with a buzzer sound and also sends telegram message with the location of the trash bin, if the trash bin is filled up 90% and above. The platform will be used to notify maintenance staff that trash must be collected, allowing them to design an efficient path by emptying the trash bins that are the most full first.

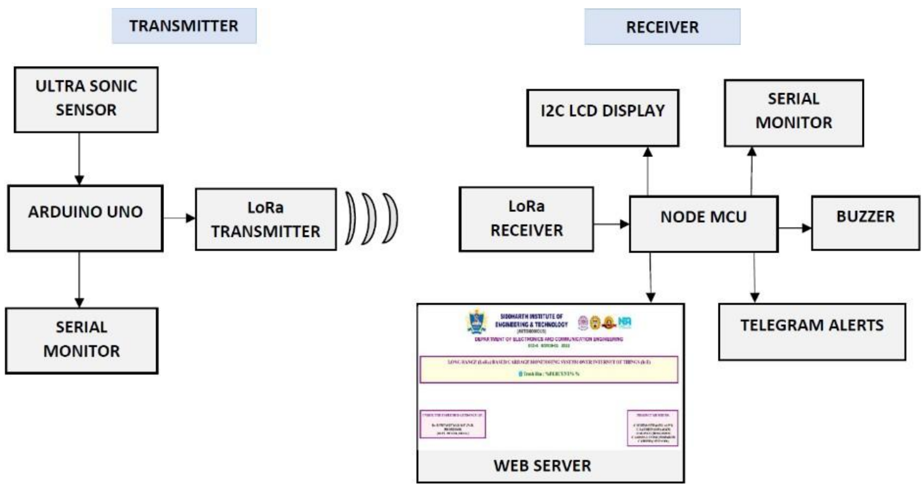

Figure 1: *Block* diagram *of the total system.*

A. LoRa Transmitter node using Arduino Uno and Grove LoRa Radio Module

There are a number of non-essential sensors that may be used in conjunction with an ultrasonic sensor, such as a temperature sensor, pressure sensor, humidity sensor, and so on, which increases the system's cost, size, and power consumption. As a result, we created a smart bin with simply an Ultrasonic sensor to measure the amount of trash collected. The ultrasonic sensor is linked to an Arduino Uno, which receives sensor data and transfers it to a LoRa gateway through the Grove LoRa Radio transmitter node, as shown in Fig.2. The Arduino Uno was chosen as a microcontroller due of its low power consumption and inexpensive cost.

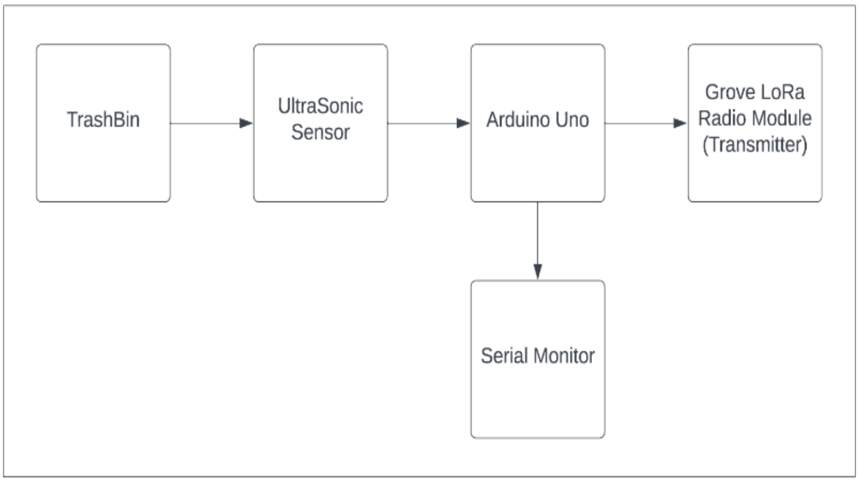

Figure 2: *Block diagram of the transmitter node.*

B. LoRa Receiver system Using Node MCU and Grove Lora Radio Module.

A receiver is built with a Grove LoRa Radio module and a Node MCU to receive sensor data from the smart bin. The trash level may be seen on the receiver, which is connected to the PC via USB cable, the Trash levels can also be seen on the I2C LCD Display connected to the Node MCU and also the trash level can be monitored wirelessly and remotely using a webserver. So, we can able to monitor the trash levels wirelessly from anywhere across the world by connecting to the internet and this is developed using the IoT Technology. And also an alarming unit is also linked to the system, which alerts the concerned department using a buzzer sound and also sends the telegram alerts to corresponding person whenever the trash bin is filled up 90% and above. The system's design is both cost-effective and adaptable.

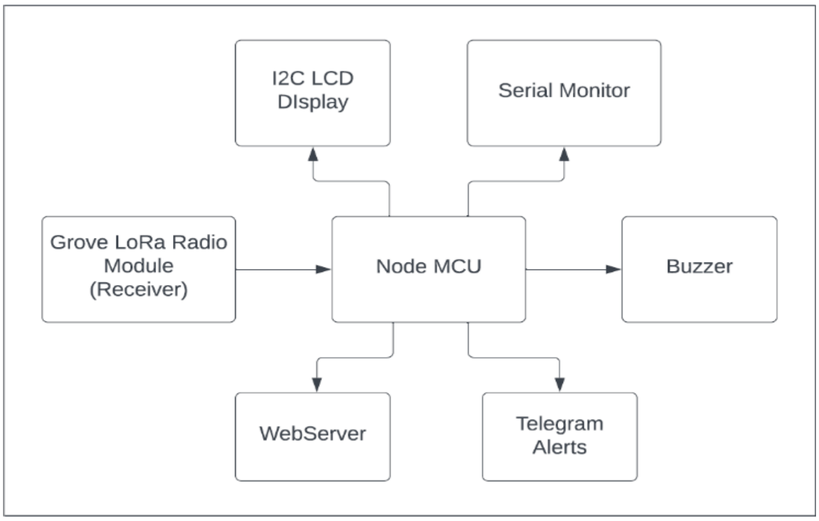

Figure 3: *Block diagram of the receiver.*

C. LoRa Communication

This is the golden era of IoT, as the number of devices linked to the Internet continues to grow. To link these gadgets to the Internet, IoT requires wireless technologies. LoRa Communication is a wireless technology that can help bring IoT to a whole new level. LoRa uses a variety of frequency bands, including 433 MHz, 868 MHz, 915 MHz, and 923 MHz, each of which corresponds to a different continent. LoRa devices can provide ultra-long range spread spectrum communication with low current consumption and good interference immunity. Long range, low battery consumption, high transmission power, tiny size, and secure data transmission are all features of the LoRa chipset. The spread spectrum modulation mechanism used by LoRa (Long Range) is based on chirp spread spectrum.

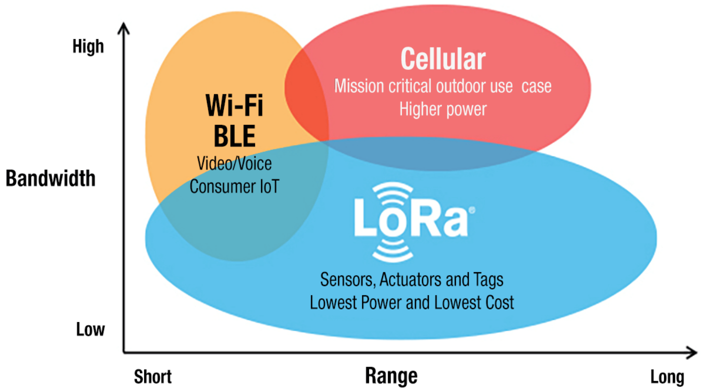

Figure 4: *Bandwidth vs Range of Some Communication systems.*

The message is encoded using the chirp signals as carrier signals in LoRa. A chirp is a tone that increases or drops in frequency over time. Because the whole assigned bandwidth is used to send a signal, it is resistant to channel noise. Multiple sent signals can occupy the same wireless channel without interfering since each spreading is orthogonal. Unlike Wi-Fi-based systems, which require several access points to enhance coverage area, a single LoRa receiver can handle many nodes at different places in that region[36-47]. The Grove LoRa Radio module is being used in this project.

D. Internet of Things

The Internet of Things (IoT) plays a critical role in making our cities smarter and people's lives simpler. These intelligent gadgets connect with one another and exchange the data they collect. The Internet of Things is a network of such smart gadgets. System integrators, network operators, and individuals aim to cooperate with the government to develop innovative and helpful solutions for city development. However, developing scalable solutions is a difficult challenge.

We utilise the Internet of Things and sensors to make garbage management more efficient. This allows us to read, gather, send, and store large amounts of data on the internet. Sensors are mostly utilised to calculate the amount of rubbish that has been deposited in the trash can. The known data collected from the sensors is sent across wireless networks and subsequently published to a server via the gateway node for storage and processing. As a consequence, the fullness of these bins may be forecast before they overflow in one particular spot. It enables the creation of a route for trash trucks to collect these partially filled and fully loaded bins in the most effective manner possible. Workers receive daily updates on the status of every bin in that channel based on the findings provided in the IoT platform. The optimum selection of dustbins to be collected is intended to increase collection efficiency, depending on the economic needs stated early on. The location of the sensor and the shape of the garbage bin are both important factors in reducing reflection mistakes.

IV. EXPERIMENTAL EVALUATION

A. Sensor mounting position, and shape of the trash bin:

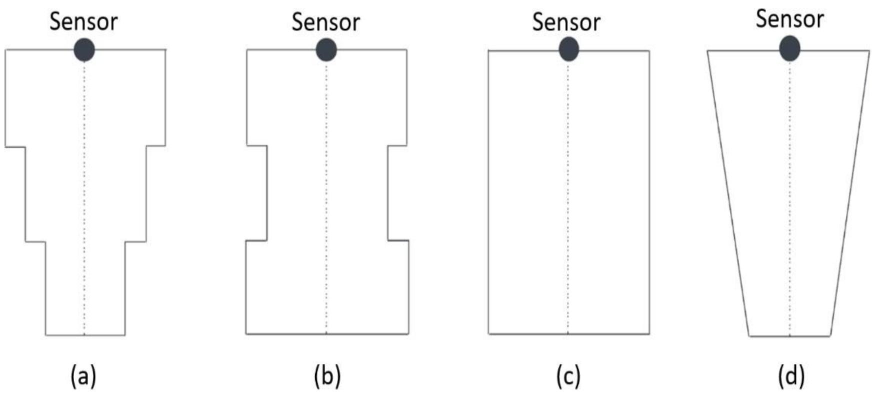

Figure 5: *Sensor mounting position, and shape of the trash bin.*
Bins (a) and (b) are not recommended, Bins (c) and (d) are recommended.

Fig.5 depicts the appropriate sensor mounting position as well as the design of the trash bins. The sensor will range to the first indentation in the garbage bin of (a) and (b). The indentation generates a huge observable reflection, but the (c) and (d) bins usually functions correctly. It is advised that the sensor be positioned in a garbage bin as indicated in Fig.1 in order to either avoid or severely limit secondary reflections that may return to the sensor due to the surface level of waste present in the trash bin.

B. Wireless Range between Trash bin and LoRa Receiver and corresponding Packet Loss Rate:

The distance between the Trash bin and the Lora receiver station should be well optimized for the better wireless communication system, because the data packet loss rate is directly proportional to the distance between the Trash bin and LoRa Receiver station. So, here the capability of data transfer to longer distances depends on the model of LoRa module used and its communication protocols. Here, we have used the Grove LoRa Radio Module of 433MHz and in its experimental evaluation, its found that the data loss rate is very less up to 3000m (3km) and the packet loss rate is very higher after crossing 6000m (6km) here, it also depends on the input voltage supply given to the system, if we use a battery, after some days the voltage will decreases it maybe considered and it may changes from location to location, in villages, with less packet loss rate in can transfer to longer distances, when compared to cities as cities contains more number of obstacles in between liketall buildings and large shopping malls.

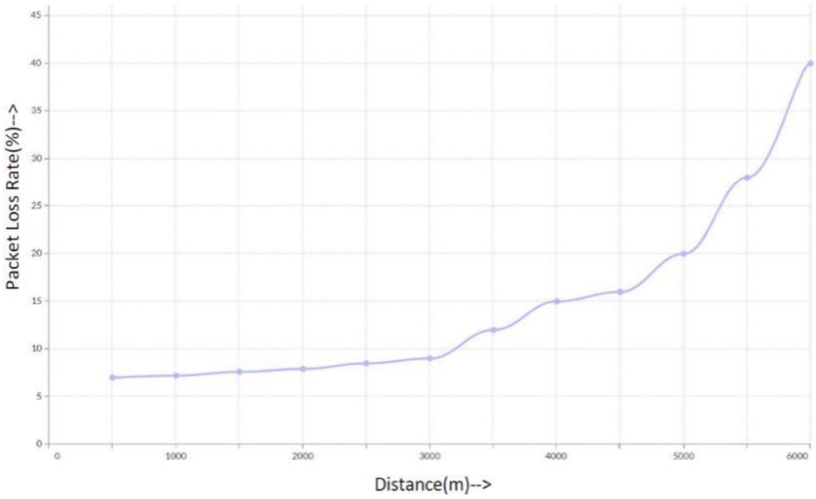

Figure 6: *Packet Loss Rate vs Distance plot*

C. Wireless Range between Trash bin and LoRa Receiver and corresponding RSSI Values:

Received signal strength indicator (RSSI) is the one of the crucial parameters in determining the reliability of the system and RSSI changes with corresponding changes in the distances between the LoRa transmitter and receiver. RSSI is directly proportional to the distance between LoRa Transmitter and Receiver. RSSI Values varies with each model of the LoRa module used as, the capability of each LoRa module varies. Here, we used Grove LoRa Radio Module of frequency 433MHz, in our experimental analysis, we found following RSSI Values with corresponding to the distances as plotted in the graph representation below.

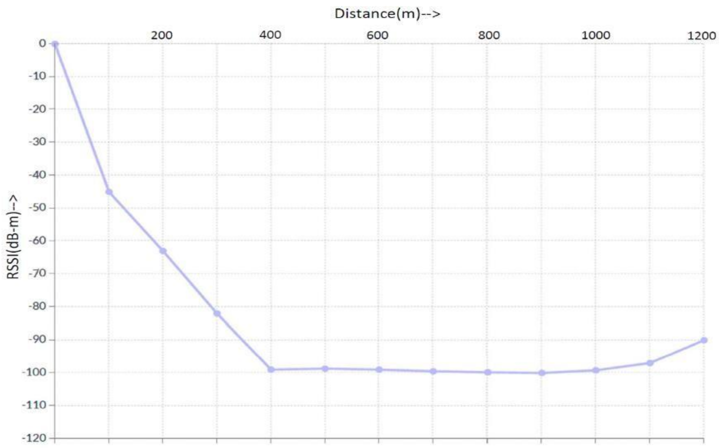

Figure 7: *RSSI vs Distance plot*

D. Wireless Range between Trash bin and LoRa Receiver and corresponding SNR Values:

The signal to noise ratio (SNR) is also a one of the crucial parameters in the wireless communication systems. Though we cannot achieve pure noiseless signal, we can atleast reduce some of the noise present in the signal. Similarly, in LoRa communication systems also the noise is present. We can determine this noise using a parameter called Signal to noise ratio (SNR). A high SNR value implies the signal strength is stronger than the noise levels present in that signal received at the LoRa Receiver station. So, it is desired to have a good SNR Ratio. The SNR also varies with varying the distances between the LoRa Transmitter and Receiver. On performing the experimental evaluation, we found the SNR values with corresponding to distance as plotted in the below graphical representation.

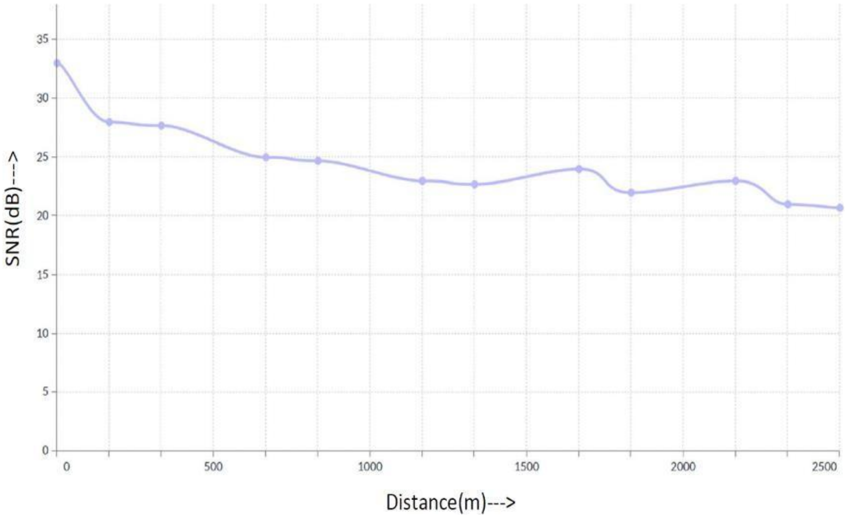

Figure 8: *SNR vs Distance plot*

E. Battery Life Expectancy at the Trash bin (Transmitter side) of the system:

The system uses around 85mA while all of the components (Ultrasonic Sensor, Arduino Uno, and Grove LoRa Radio module) are engaged. A fully charged 3000mAh battery may last up to 40 hours. The battery life was extended by modifying the code to send the microcontroller board into sleep mode. A sleep state occurs when the board disables all modules save the CPU required to operate the system. Needed processors can awaken during sleep mode to execute the required work and then return to sleep mode. Sleep mode on the Arduino Uno is good. The board will consume as little as 0.054 mA during the idle time, according to the manufacturer's datasheet. The microcontroller's current usage dropped dramatically from 50mA to 0.054mA.

S.No.	Component	Normal Mode (mA)	Sleep Mode (mA)
1	Arduino Uno	50	0.054
2	HC-SR 04 Ultra Sonic Sensor	15	5.000
3	Grove LoRa Radio Module	20	0.500
	Total	85	5.554
	Life span expectancy: (with 3000 mAh battery)	Approx. 40 hours	Approx. 540 hours

Table 1: *Current Consumption and Battery power expectancy.*

The current consumption of various components inside the system is obtained as in the Table 1. When all of the components were turned on, the system consumed 85 mA, which took up to 40 hours to deplete a charged battery completely. In a real-world scenario, the system will be configured to run every three hours, allowing the battery to last longer before it has to be recharged.

V. RESULTS

1. The system runs smoothly and efficiently in real time, with no glitches.
2. To avoid data packet loss, the arrival time of data packets at the receiver can be tuned based on our preferences.
3. Without any manual updating on the WebServer, the webserver refreshes the new data on its own.
4. From the time the data packet arrives at the receiver, the WebServer updates the new data in just 3 seconds.

5. If the trash in the trash bin has reached 90% capacity, the alarms are sent via Telegram channel along with the location of that trash bin.
6. Because the LoRa module consumes very little power, the battery life is preserved.
7. The trash level can be monitored remotely from any location with an Internet connection.
8. For efficient trash can monitoring, this system can be connected with other IoT systems in smart cities.
9. Data packets can also be received over very vast distances.
10. Can be monitored remotely from anywhere across the world.
11. Can also be integrated into other IoT systems in smart cities.

Here are some pictures of end result:

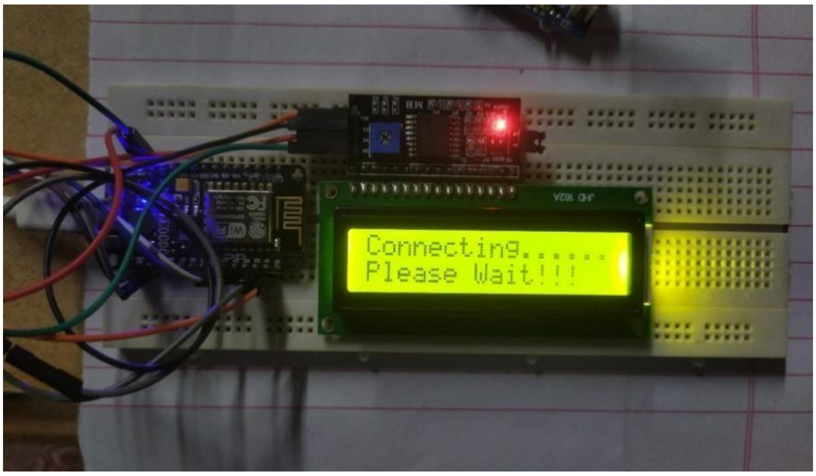

Figure 9: *Device status while connecting to Wi-Fi.*

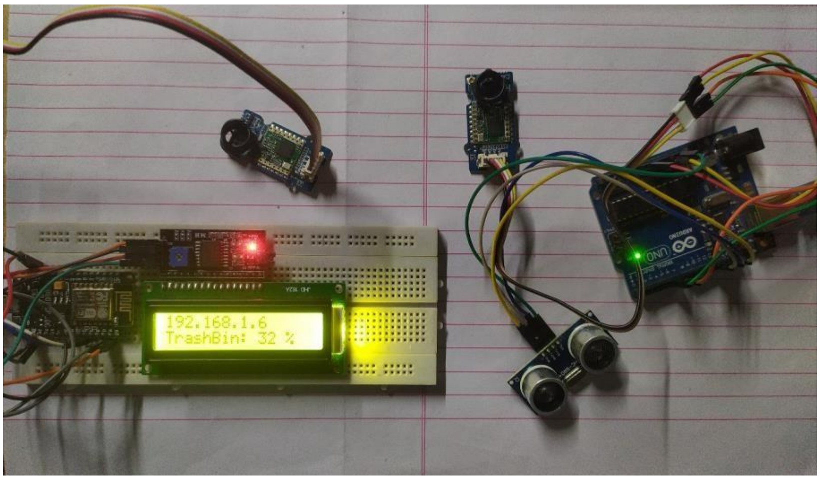

Figure 10: *Hardware part of the system which is displaying current trash level*

Figure 11: *Real-time monitoring on webserver*

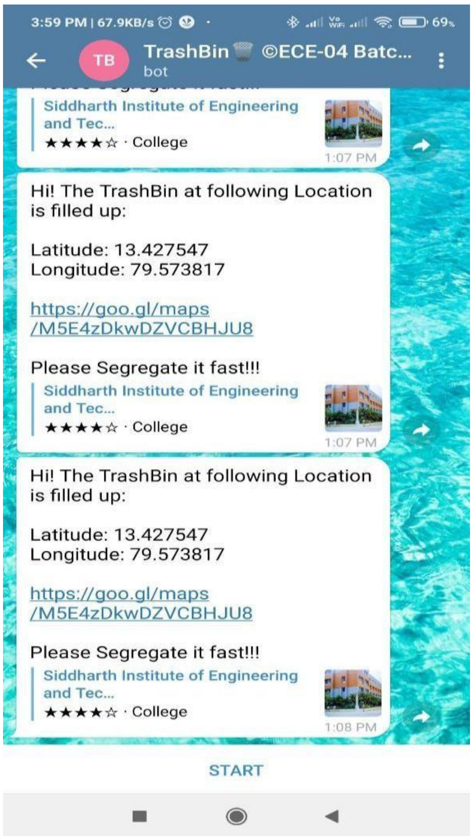

Figure 12: *Alerts using Telegram along with location, when trash level in bin is filled above 90%.*

VI. CONCLUSION

Our city can be kept clean using the stated strategy. We began with Design and implementation of a Garbage Monitoring System prototype that may be used to keep smart cities free of garbage. The real-time accurate data from the built system could be used in a network context in need a solid waste management system that is effective. The designed method creates a more accurate database for garbage pickup times and quantities at each location. By using this method, we will be able to prevent garbage containers from overflowing.

Previously, residential areas were either physically loaded with the use of loader intrucks in the classical sense. We developed an effective garbage monitoring system that may be utilised to keep track of the garbage. The system is capable of acquiring precise data in real time that can be utilized as a tool in the future. The data is fed into a management system. The Level sensors can also be added to regular garbage cans. As a result, the prototype is appropriate for use in traditional trash management infrastructure. The amount of waste in the landfill information can also be used to plan waste pickup routes more effectively, resulting in fewer overflowing bins and improved public health sanitation.

REFERENCES

[1]. S. Kaza, L. Yao, P. Bhada-Tata, and F. Van Woerden, „„Country-level dataset,"" What Waste, vol. 2, 2018.

[2]. Waste Management Indicators. Accessed: May 2021. [Online]. Available: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_ management_indicators#Overview

[3]. H. Robinson, „„The composition of leachates from very large landfills: An international review,"" Commun.Waste Resource Manage., vol. 8, no. 1, pp. 19–32, 2007.

[4]. M. A. Al Mamun, M. A. Hannan, and A. Hussain, „„A novel prototype and simulation model for real time solid waste bin monitoring system,"" Jurnal Kejuruteraan, vol. 26, pp. 15–19, Dec. 2014.

[5]. T. J. Sheng, M. S. Islam, N. Misran, M. H. Baharuddin, H. Arshad, M. R. Islam, M. E. H. Chowdhury, H. Rmili, and M. T. Islam, „„An Internet of Things based smart waste management system using LoRa and tensorflow deep learning model,"" IEEE Access, vol. 8, pp. 148793–148811, 2020

[6]. C. Zheng, J. Yuan, L. Zhu, Y. Zhang, and Q. Shao, „„From digital to sustainable: A scientometric review of smart city literature between 1990 and 2019,"" J. Cleaner Prod., vol. 258, Jun. 2020, Art. no. 120689.

[7]. M. Shahidul Islam, M. T. Islam, M. A. Ullah, G. Kok Beng, N. Amin, and N. Misran, „„A modified meander line microstrip patch antenna with enhanced bandwidth for 2.4 GHz ISM-band Internet of Things (IoT) applications,"" IEEE Access, vol. 7, pp. 127850–127861, 2019.

[8]. S. A. Hassan, M. Samsuzzaman, M. J. Hossain, M. Akhtaruzzaman, and T. Islam, „„Compact planar UWB antenna with 3.5/5.8 GHz dual bandnotched characteristics for IoT application,"" in Proc. IEEE Int. Conf. Telecommun. Photon. (ICTP), Dec. 2017, pp. 195–199

[9]. A. A. Zaidan and B. B. Zaidan, „„A review on intelligent process for smart home applications based on IoT: Coherent taxonomy, motivation, open challenges, and recommendations,"" Artif. Intell. Rev., vol. 53, no. 1, pp. 141–165, Jan. 2020.

[10]. R. Azim, M. T. Islam, H. Arshad, M. M. Alam, N. Sobahi, and A. I. Khan, „„CPW-fed super-wideband antenna with modified vertical bow-tie-shaped patch for wireless sensor networks,"" IEEE Access, vol. 9, pp. 5343–5353, 2021.

[11]. L. Atzori, A. Iera, and G. Morabito, „„The Internet of Things: a survey,"" Comput. Netw., vol. 54, no. 15, pp. 2787–2805, 2010.

[12]. S. Madakam, R. Ramaswamy, and S. Tripathi, „„Internet of Things (IoT): A literature review,"" J. Comput.Commun., vol. 3, no. 5, p. 164, 2015.

[13]. R. O. Andrade and S. G. Yoo, "A comprehensive study of lora in the development of smart cities," Appliedsciences, Vol. 9,no. 22,p. 4753, Nov 2019.

[14]. O. Khutsoane, B. Isong, and A. M. Abu-Mahfouz, " IoT devices And applications based on lora/lorawan," in IECON 2017 – 43rd Annual Conference of the IEEE Industrial Electronics Society, 2017, pp.6107-6112

[15]. A Lozano, J. Caridad, J. F. De Paz, G. Villarrubia, Gonzalez , and J. Bajo, " Smart waste collection system with low consumption lorawan nodes and route optimization," Sensors, Vol. 18 , no.5,p. 1465,2018.

[16]. S. Paul, S. Banerjee and S. Biswas, "Smart Garbage Monitoring Using IoT," 2018 IEEE 9th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON), 2018, pp. 1181-1185,doi: 10.1109/IEMCON.2018.8614896.

[17]. N. S. Kumar, B. Vuayalakshmi, R. J. Prarthana and A. Shankar, "IOT based smart garbage alert system using Arduino UNO," 2016 IEEE Region 10 Conference (TENCON), 2016, pp. 1028-1034, doi: 10.1109/TENCON.2016.7848162

[18]. A. G. Azwar, R. Haviani Laluma, R. P. Halim, Nurwathi, Gunawansyah and Gunawan, "Smart Trash Monitoring System Design Using NodeMCU-based IoT," 2019 IEEE 13th International Conference on Telecommunication Systems, Services, and Applications (TSSA), 2019, pp. 67-71, doi: 10.1109/TSSA48701.2019.8985517.

[19]. W. Chen, Y. Wang, P. Huang, Y. Huang and M. Tsai, "A Smart IoT System for Waste Management," 20181st International Cognitive Cities Conference (IC3), 2018, pp. 202-203, doi: 10.1109/IC3.2018.00-24

[20]. J. Das, A. Pramanik and S. Parui, "Smart Garbage Monitoring and Alert System Using IoT", Lecture Notes in Electrical Engineering, pp. 641-654, 2019. doi: 10.1007/978-981-15-0829-5_60

[21]. M. Y. Aalsalem, W. Z. Khan, W. Gharibi, M. K. Khan, and Q. Arshad, "Wireless sensor networks in oil

and gas industry: Recent advances, taxonomy, requirements, and open challenges," Journal of Network and Computer Applications, vol. 113, pp. 87-89, 2018, doi: 10.1016/j.jnca.2018.04.004.
[22]. A. H. Jebril, A. Sali, A. Ismail, and M. F. A. Rasid, "Overcoming limitations of LoRa physical layer in image transmission," Sensors, vol. 18, no. 10, 2018, Art. no. 3257, doi: 10.3390/s18103257.
[23]. Y.-P. E. Wang et al., "A Primer on 3GPP narrowband internet of things," in IEEE Communications Magazine, vol. 55, no. 3, pp. 117-123, March 2017, doi: 10.1109/MCOM.2017.1600510CM.
[24]. M. A. Ertürk, M. A. Aydın, M. T. Büyükakkaşlar, and H. Evirgen, "A survey on LoRaWAN architecture, protocol and technologies," Future Internet, vol. 11, no. 10, 2019, Art. no. 216, doi: 10.3390/fi11100216.
[25]. J. Petäjäjärvi, K. Mikhaylov, M. Pettissalo, J. Janhunen, and J. Iinatti, "Performance of a low-power wide- area network based on LoRa technology: Doppler robustness, scalability, and coverage," International Journal of Distributed Sensor Networks, vol. 13, no. 3, pp. 1-16, 2017, doi: 10.1177%2F1550147717699412.
[26]. J. Haxhibeqir, F. V. den Abeele, I. Moerman, and J. Hoebeke, "LoRa scalability: a simulation model based on interference measurements," Sensors, vol. 17, no. 6, 2017, Art. no. 1193, doi: 10.3390/s17061193.
[27]. F. Adelantado, X. Vilajosana, P. Tuset-Peiro, B. Martinez, J. Melia-Segui, and T. Watteyne, "Understanding the limits of LoRaWAN," IEEE Communications Magazine, vol. 55, no. 9, pp. 34-40, 2017, doi: 10.1109/MCOM.2017.1600613.
[28]. M. Bor and U. Roedig, "LoRa transmission parameter selection," In International conference DCOSS, 2017, pp. 27-34, doi: 10.1109/DCOSS.2017.10.
[29]. D. Croce, M. Gucciardo, S. Mangione, G. Santaromita, and I. Tinnirello, "Impact of LoRa imperfect orthogonality: Analysis of link-level performance," in IEEE Communications Letters, vol. 22, no. 4, pp. 796- 799, Apr. 2018, doi: 10.1109/LCOMM.2018.2797057.
[30]. A. Carlsson, L. Kuzminykh, R. Franksson, and A. Liljegren, "Measuring a LoRa network: performance, possibilities and limitations," In International conferenceon Next Generation Wired/Wireless Networking, pp. 116-128, 2018.
[31]. E. D. Ayele, C. Hakkenberg, J. P. Meijers, K. Zhang, N. Meratnia, and P. J. M. Havinga, "Performance analysis of LoRa radio for an indoor IoT applications," 2017 International Conference on Internet of Things for the Global Community (IoTGC), 2017, pp. 1-8, doi: 10.1109/IoTGC.2017.8008973.
[32]. M. H. Habaebi, I. J. Chowdhury, M. R. Islam, and N. A. B. Zainal, "Effects of shadowing on LoRa LPWAN radio links," International Journal of Electrical and Computer Engineering (IJECE), vol. 7, no. 6, pp. 2970-2976, 2017, doi: 10.11591/ijece.v7i6.pp2970-2976.
[33]. O. Kennedy, E. Chukwu, O. Shobayo, E. Noma-Osaghae, I. Okokpujie, and M. Odusami, "Comparativeanalysis of the performance of various active queue management techniques to varying wireless network conditions," International Journal of Electrical and Computer Engineering (IJECE), vol. 9, no. 1, pp. 359-368, 2019, doi:10.11591/ijece.v9i1.pp359-368 .
[34]. S. Opipah, H. Qodim, D. Miharja, Sarbini, E. A. Z. Hamidi, and T. Juhana, "Prototype design of smart home system base on LoRa," 2020 6th International Conference on Wireless and Telematics (ICWT), pp. 1-5, ,2020 doi: 10.1109/ICWT50448.2020.9243643.
[35]. F. A. R. Mu‟amar Wildan, E. A. Z. Hamidi and T. Juhana, "The design of application for smart home base on LoRa," 2020 6th International Conference on Wireless and Telematics (ICWT), 2020, pp. 1-6, doi: 10.1109/ICWT50448.2020.9243648
[36]. Premkumar, R" Investigation on Image Encryption Using Chaos Based Technique" International Journal for Modern Trends in Science and Technology, 7(05): 147-154, 2021
[37]. Premkumar, R" Image Encryption Using Chaos Maps: A Survey" JOURNAL OF APPLIED SCIENCE AND COMPUTATIONS 8 (5), 2021, pp102-116
[38]. Premkumar, R "ComparativePerformanceAnalysis of PreProcessing Techniques in CT Angiogram Image" International Journal for Modern Trends in Science and Technology, 7(04): 180-185, 2021
[39]. Premkumar, R" 116A Smart Helmet for Worker Safety in Mining Industry with Internet of Things" JOURNAL OF APPLIED SCIENCE AND COMPUTATIONS 9 (5), 2021, pp112-127
[40]. Premkumar, R " An Automated Water Quality Monitor and Fish Feed Dispenser system in Aqua Farms using Internet of Things" International Journal of Aquatic Science, 6(08), pp140-152,2021
[41]. Premkumar, R " Investigation of Image Classification Using Machine Learning Techniques" International Journal of All Research Education and Scientific Methods (IJARESM), ISSN: 2455-6211 Volume 9, Issue 7July 2021
[42]. Premkumar, R" Two dimensional Chaos based Image Encryption Algorithm for Security Applications" International Journal of All Research Education and Scientific Methods (IJARESM), ISSN: 2455-6211 Volume 9, Issue 7 July 2021
[43]. Premkumar, R" Investigation of Image Steganography for Security Application" International Journal of

Innovative Research in Science, Engineering and Technology (IJIRSET)Volume 10, Issue 7, July 2021
[44]. Premkumar, R, „Efficient Image Encryption with Pixel Scrambling and Genetic Algorithm‟, International Research Journal of Engineering and Technology (IRJET), vol. 6, no. 4, pp. 3241, 2021(Impact Factor – 7.34).
[45]. Premkumar,R, Ls Chaotic based Image Encryption System Via Permutation Models‟, International Research Journal of Engineering and Technology (IRJET), vol. 6, no. 4, pp. 2934, 2021 (Impact Factor – 7.34).
[46]. Premkumar, R & Anand, S , "Secured and Compound 3-D chaos image encryption using Hybrid mutation and cross over operator ‟, MULTIMEDIA TOOLS AND APPLICATIONS, ISSN: 1380-7501 (Print): EISSN: 1573-7721,2018 (Online) (Annexure I, Impact Factor – 2.101).
[47]. Premkumar, R & Anand, S, „Secured permutation and substitution based image encryption algorithm for medical security applications‟ in Journal of Medical Imaging and Health Informatics, vol. 6, no. 8, pp. 2012- 2018(7).ISSN:2156-7018(Print): EISSN: 2156- 7026 (Online) (Annexure I, Impact Factor – 0.549).

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