

Design and Implementation of a Wide Area Network Based Waste Management System Using Blynk and Cayenne Application

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Abstract: Waste management is crucial for maintaining the hygienic environment in urban cities. The establishment of a reliable and efficient IoT system for waste management is based on integrating low power and long-range transmission protocol. Low Power Wide Area Network (LPWAN) is specially designed for the aforementioned requirement of IoT. LoRa (Long Range) is an LPWAN transmission protocol that consumes low power for long-range transmission. In this study, we are implementing long-range (LoRa) communication and cloud applications for real-time monitoring of the bins. The customized sensor node and gateway node are specifically designed for sensing the level of bins using ultrasonic sensor and communicating it to the cloud via long-range and internet protocol connectivity. Blynk and cayenne are the two cloud-based applications for storing and monitoring the sensory data receiving from the gateway node over internet protocol (IP). The customization of nodes6 and utilization of two cloud-based apps are the unique features in this study. In the future, we will implement blockchain technology in the study for enabling a waste-to-model platform.

Keywords: ESP 8266 Wi-Fi, LPWAN, LoRa, Ultrasonic Sensor, Waste Management.

1 Introduction

MANKIND has witnessed enormous growth after the emergence of computers in the public domain. However, information technology benefits us in a range of areas, from a high-speed network to global reach, automation to artificial intelligence. Another proven example is the Internet of Things (IoT) that is an emerging technology that is widely implemented in the smart cities for achieving the digitalization [1, 2]. IoT is a network for monitoring physical objects through internet connectivity. At present, IoT is implemented in

various applications like smart irrigation, smart tracking, intelligent transportation, home automation, waste management; etc. [3]. The physical things in IoT are provide with communication capability so that it can be monitored from anywhere via internet protocol (IP) [4]. Waste management is an important area in urban areas for conserving the surroundings clean and green. In the initial stage of a waste management system, the monitoring of the bins is functioned with RFID (Radio Frequency Identification) by embedding to the bins [5]. Later, RFID and GSM (Global System for mobile communication) are integrated into the bins and trucks for tracking the status of the bins and trucks [6]. A concept of integrating three distinct sensing units for automating the bins is designed [7] however, this concept is having limitations like lack of communication protocol for the transmission of the sensory data of the bins. The evolution of wireless sensor networks enables automation in the bins by wireless sensing and alerting the level of the bins and applying the closest vehicle first algorithm for optimizing the routes of municipal trucks was carried out by the concerned researcher [8].

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So far, significant drawbacks are no real-time tracking, high power consumption, and short-range connectivity. Several studies have explored various solutions for overcoming the aforementioned drawbacks. Internet of Things (IoT) based real-time monitoring system is proposed for sensing the distinct kinds of waste and for storing the sensory data azure cloud server is utilized [9]. The advantage of cloud server is widespread for the waste management system, in [10] a cloud-based system is implemented for monitoring the amount of waste in the bin and pungent gas. In order of reducing the greenhouse emission evolving from waste, a green Internet of Things (IoT) platform for waste management for eliminating the waste and reducing greenhouse gas emissions [11]. A smart container with a cloud storage facility is proposed for solving the issue of waste overflow from the bins [12, 13]. Wi-Fi networks are absolutely Wireless Local Area Network (WLAN) [14]. WLAN based IEEE 802.11 Wi-Fi is integrated with WeMos board for realizing the IoT-based waste management system [15]. Ubidots cloud-based waste monitoring system is introduced for tracking the volume of garbage in the bin [16]. However, the drawbacks of high-power consumption and short-range connectivity still existed in waste management. In IoT, the energy-constrained devices are embedded for sensing the physical things, here IoT is demanding low power and long-range transmission protocol. However, with the evolution of LPWAN (Low Power Wide Area Network) technologies, the problem of connectivity and power consumption are overcome for the IoT. LoRa (Long Range) communication is one of the LPWAN technologies that are capable of long communication with less power consumption. Few studies have taken the advantage of LoRa with a cloud-based system for enhancing waste management [17]. LoRaWAN (Long Range-wide area network) based wireless protocol was implemented for communicating with the cloud server. Low power consumption-based sensor nodes are designed for monitoring the bins [18] and optimizing waste collection routes [19]. An IoT framework with machine learning is proposed for forecasting the garbage level in the bins (IoT) [20]. An intelligent waste management system using LoRa communication protocol and a deep learning is employed for classifying the distinct waste [21]. Arduino IDE and GSM (Global

System for communication) based smart IoT system is established for real-time monitoring and communicating the filling levels of the bins [22]

In this study, we are proposing a novel architecture for a waste management system by integrating the LoRa communication, cloud-based cayenne, and blynk application. LoRa communication enabled sensor nodes are deployed in the bins for transmitting the sensory data where the internet connectivity is unavailable. Sensor nodes transmit the sensory data of the bins to the gateway node and the gateway node with the assistance of the ESP 8266 Wi-Fi module logs the data on the cloud server. The data received from the gateway node is stored in the blynk and cayenne applications. The rest of the paper will explain the advantages of low power wide area network (LPWAN), generalized architecture, hardware, and software description with the results. In Section 2, the low power wide area network (LPWAN) is discussed, a generalized architecture is discussed in Section 3. In Section 4 proposed architecture is explained in detail. Hardware description and software description is discussed in Sections 5 and 6. Results were discussed in Section 7 and concluded in the final section.

2 LPWAN

By 2020, wireless communications will connect more than twenty-five billion phones [23]. LPWAN (Low Power Wide Area Network) technologies are playing a vital role in the Internet of things because LPWAN supports long-range with low power consumption. LoRa (Long Range, Sigfox, and NB-IoT) are the LPWAN technologies for supporting the requirements of the internet of things, and a comparison of all these LPWAN technologies is shown in Table 1.

2.1 Long Range (LoRa)

LoRa is a robust low-power wireless networking that is used for long-distance communication. LoRa uses modulation of the chirp spread spectrum to modulate ISM (Industrial, Scientific, and Medical) signaling [25]. Modulation of the chirp spread spectrum broadcasts a narrow band signal over broader channel bandwidth. LoRa operates on ISM 868 MHz in Europe, 915 MHz in

Table 1 Comparison of LPWAN Technologies [24].

Parameters	Technology		
	LoRa	Sigfox	NB-IoT
Modulation	Chirp spread spectrum	Binary phase shift keying	Quadrature phase shift keying
Spectrum band	433/868/780/915MHz (Unlicensed ISM band)	868/902 MHz (Unlicensed ISM band)	Licensed LTE bands
Data rate	50 kbps	100 bps	200 kbps
Two-way communication	Half-duplex	Half-duplex (limited)	Half-duplex
Connectivity range	5 km (Urban), 20 km(Rural)	10 km (Urban) 40km (Rural)	1km (Urban), 10km (Rural)
Interference resistance	Very high	Very high	Very low
Localization	Time difference of arrival	Received signal strength indicator	-
Administration	LoRa-Alliance	Sig-Fox company	3GPP

North America, and 433 MHz in Asia [24]. In rural areas, LoRa can communicate between 10 and 40 kilometers, while urban areas coverage is between 1 and 5 kilometers.

3 Generalized Architecture

The architecture comprises a customized sensor node, gateway, network server, and web application are shown in Fig. 1. Customized sensor nodes and LoRa based gateway are implemented in this study for waste management application. With the assistance of the LoRa communication, the level of the bins is sensing with an ultrasonic sensor and transmits to the gateway. Here the gateway node transmits the sensory data to the cloud server with the assistance of the ESP 8266 Wi-Fi module present in the LoRa gateway. Through an internet protocol (IP) connection the data from the cloud server can be accessed through the blynk and cayenne application.

4 Description of Architecture

A novel architecture is proposed for enhancing the existing waste management system is shown in Fig. 2. This architecture is the integration of different nodes, nodes are having a long-range and Wi-Fi communication capability. Intelligent garbage bin, LoRa based gateway, Eye on bin server, intelligent waste management server, and application server are the key components present in the architecture. Initially, the function of this architecture initiates from the sensor nodes. Sensor nodes are integrated with LoRa (Long Range) communication module for conducting point-to-point communication with the intelligent waste management server (cloud server). These sensor nodes

with level measurement sensors are embedding in the intelligent garbage bin for sensing the level of garbage in the bins. When the garbage reaches the preset threshold level, the LoRa (Long Range) module, automatically transmits the data of the bins to the cloud server. With the assistance of Ethernet connectivity, the bin information is transmitted to the network server. Details like the fullness of the garbage bin and the location of the garbage bin directly communicate to the intelligent waste management server (cloud server) and network server. The cloud server receives the data through the internet protocol connection. Through REST (Representational State Transfer) API the complete information regarding the bin can be tracked and monitored continuously. Additionally, a vision node is positioned at the top of the bin, to captures the visuals of the bins.

4.1 Intelligent Garbage Bin

Intelligent garbage is an integration of ultrasonic sensors and LoRa communication. The components of the intelligent garbage bin are shown in Fig. 3. The intelligent garbage bin consists of an Atmega microcontroller, ultrasonic sensor, LoRa (Long Range) module, LCD, and power supply. Atmega microcontroller is an 8-bit AVR microcontroller with a programmable flash of 32 K bytes In-System. Atmega 328 runs on RISC architecture, running 131 efficient instructions in single clock cycle execution. This microcontroller achieves a rate of 16 MIPS at 16 MHz when the operating voltage is between 2.7–5.5 V by executing powerful instructions in a single clock cycle. Two low power modes exist 1.5mA of active mode and 1 μA of power-down mode.

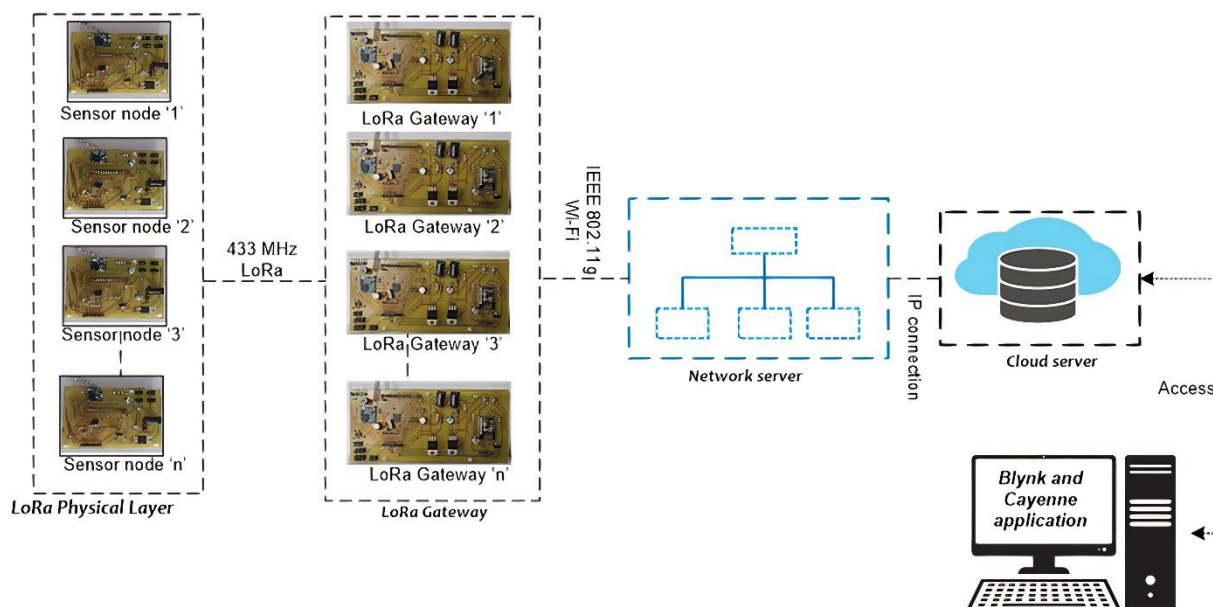


Fig. 1 Generalized architecture.

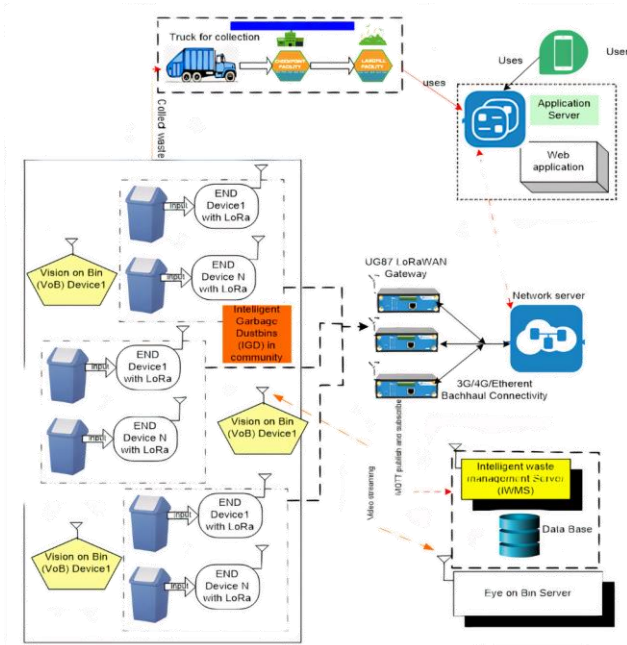


Fig. 2 Architecture for waste management system.

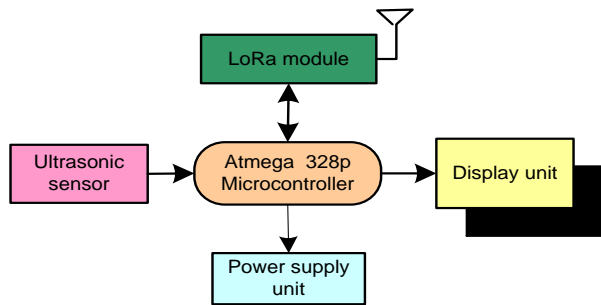


Fig. 3 Intelligent garbage bin.

HC SR 04 ultrasonic sensor uses for measuring the distance to an object by sending ultrasonic waves. This ultrasonic sensor is a four-pin module, whose pin names are Vcc, trigger, echo, and ground. Power the ultrasonic sensor using a regulated +5V through the Vcc and ground. Two I/O pins are trigger and echo, and they are connecting to the I/O pins of the microcontroller. This ultrasonic sensor is useful to measure the distance with the range of 2cm to 400 cm. LCD 20×4 is a primary 20 character by the 4-line display. It utilizes the standard HD44780 parallel interface chipset. We require 11 I/O pins for interfacing this LCD to any device. The operating voltage is 3.3 V or 5V.

4.2 LoRa Gateway

LoRa gateway is useful for communicating the information of end devices to the application server and intelligent waste management server. The components of the LoRa gateway are shown in Fig. 4, and they are the Atmega 328P microcontroller, LoRa module, ESP 8266 Wi-Fi module, and a power supply. ESP 8266 Wi-Fi module is developed by Espressif system for

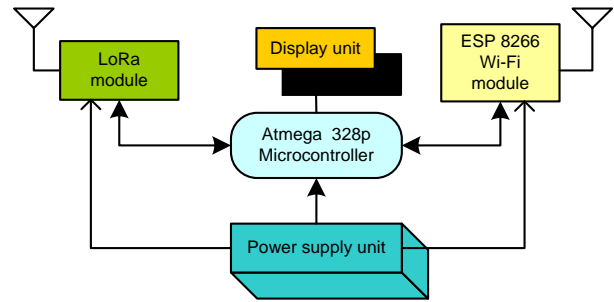


Fig. 4 LoRa Gateway Node.

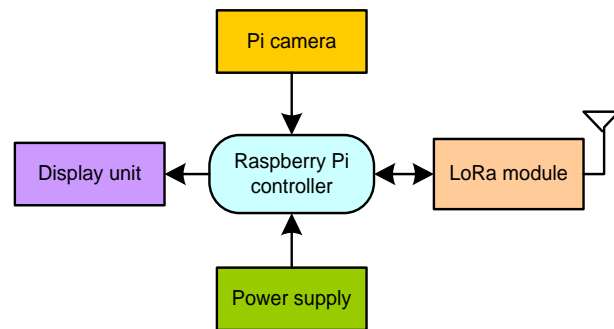


Fig. 5 Vision on bin device.

implementing the Internet of Things (IoT) applications. ESP 8266 is IEEE 802.11b/g/n standard and it works at a frequency of 2.4 GHz. Wi-Fi interfaces with the cloud server for communicating and controlling the sensors and other devices through the internet.

4.3 Vision on Device

A vision on the bin device is positioned at the bins to capture the visuals of the bin. Vision on bin device comprises of components, Raspberry Pi controller, RF modem, camera, and power supply and these components are shown in Fig. 5.

Raspberry Pi controller is a system on chip (SoC) device which comes with a single-core 700 MHz CPU and 256 GB RAM. This controller consists of GPIO (general purpose input/output) pins for controlling the physical devices using physical computing. Due to these features, the Raspberry pi controller is integrating with the bin server. RF modem helps receive the trigger request from the sensor node. After receiving the request from the sensor node, the controller initialized the camera to capture the visual of the bin and transmits the visuals to the LoRa gateway node. The selection of choosing the controller is a critical aspect, as power consumption is an essential concern in this work. We have selected the microcontroller board according to the research work requirements.

5 Hardware Specifications

A customized sensor node allows utilizing the necessary components for a specific application. Fig. 6

shows the physical diagram of the customized sensor node which will be integrating the garbage bin. The components which are embedded in the sensor nodes are the Atmega 328P microcontroller, LoRa radio module, LED (Light and TTL (Transistor-transistor Logic) pin. 12v external power supply is supplied to the board through a jack with a power adapter. ICSP header enables the user for programming. LCDs the information regarding the garbage level in the bin. LED indicates that the power is ON for the board. LoRa radio module transmits the information to the gateway.

Fig. 7 depicts the LoRa based gateway node and the components embedded on the sensor node are also embedding in the LoRa gateway for receiving the data from the sensor node. Additionally, in the gateway node, IEEE 802.11 g based esp 8266 Wi-Fi module is embedded for initiating the communication with the

cloud server.

Internet of Things is classified into six stages based on information complexity, numerous nodes, data analysis, data storage, and the controlling unit. Complexity information refers to the computing energy required for information execution. A local server or cloud server is useful for analyzing and processing the information.

6 Software Description

In level 6, multiple endpoints will be present, and they are independent of each other. Fig. 8 presents the architecture of level 6 internet of things. Our proposed architecture comes under level 6 internet of things. From these endpoints, sensor devices transmit the data of different sensing parameters to the nearest coordinator node.

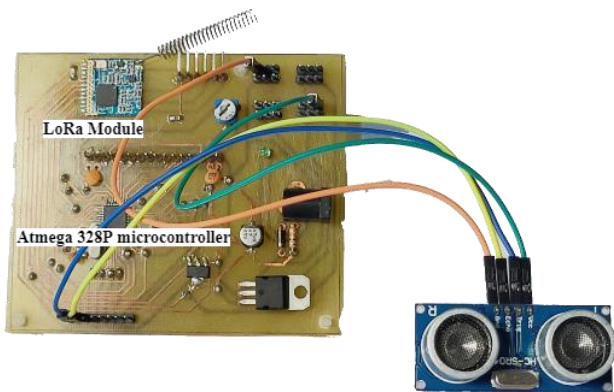


Fig. 6 Sensor node.



Fig. 7 LoRa gateway.

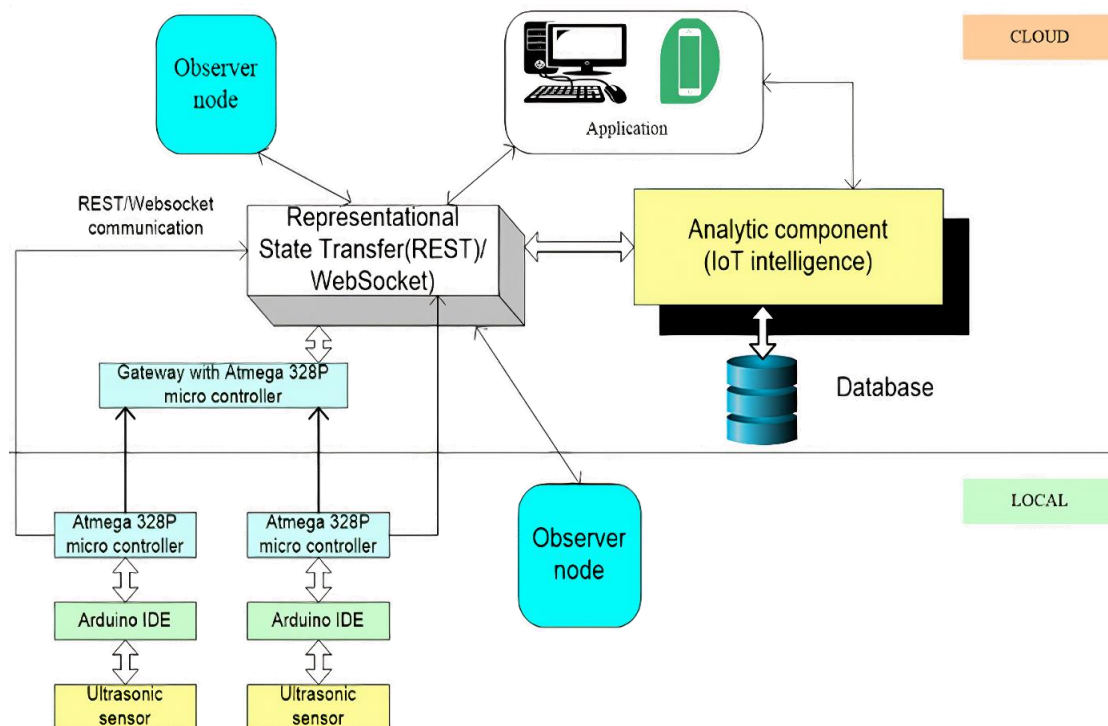


Fig. 8 Architecture of level 6 internet of things.

As compared to other levels of IoT, this centralized controller sends the data from endpoints to the cloud. In this architecture, the gateway act as a centralized controller, the sensing data from the bins transmits to the cloud server through the gateway. Here the data is stored in cloud storage, and the cloud server will analyze the information because a large amount of information is receiving from the sensor require high computational power.

6.1 Flow Chart

Sensor node comprises of level measurement sensor, load cell sensor, and LoRa modem. The flowchart of the sensor node is shown in Fig. 9. The function of the sensor node is to send the quantity and level of the waste in the bin. Initially, serial communication and SPI are initialized. After the initialization of serial communication, it is verified that the sensor node is in functioning mode. If the sensor is in functioning mode, the sensor node reads the level and quantity of the waste in the bin. For transmitting the data, the LoRa modem is set into transmission mode. After that data of the bins are converted into packet form and transmit via LoRa.

The gateway comprises of LoRa modem and ESP 8266 Wi-Fi modem. This gateway creates a bridge between the sensor node and the cloud server. The flowchart of the gateway node is shown in Fig.10. Serial communication and SPI are initialized. After that, the LoRa modem is functioning. Later, power on the gateway node for receiving the level and quantity data of the bin checks whether the LoRa modem receives the

sensor data from the sensor node of the bin. Here the data is exchanged and stored into the sending buffer of the Wi-Fi modem. After that verifying the node address there is a necessity of checking whether the Wi-Fi modem is in online mode or not. If the Wi-Fi modem is online, then the buffer data is transmitted to the server and in case of non-availability of the Wi-Fi modem, the data will be returned to the starting point as depicted in Fig. 11.

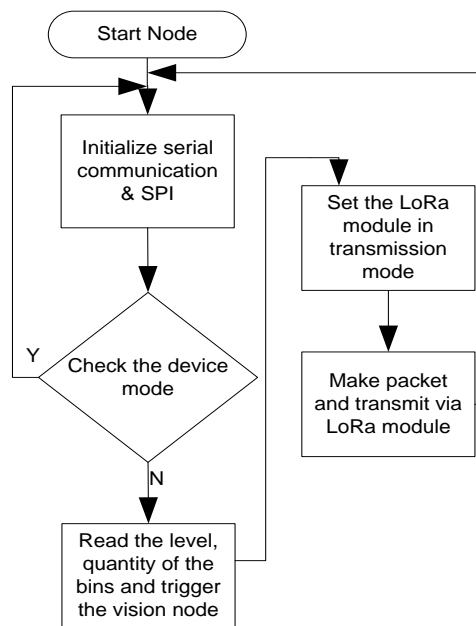


Fig. 9 Sensor node.

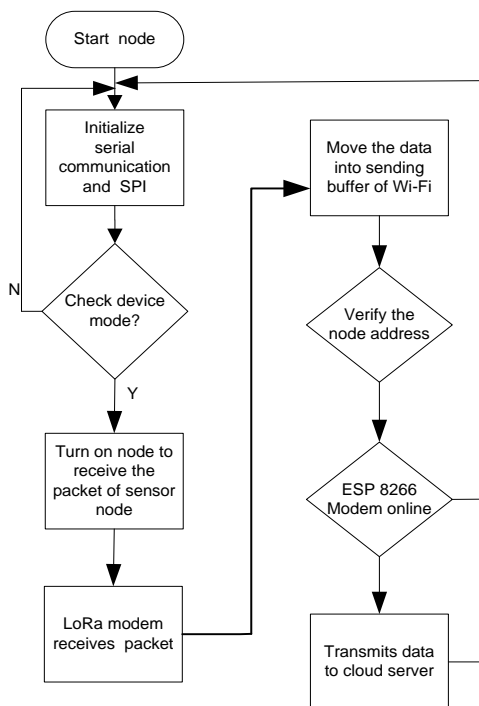


Fig. 10 LoRa gateway de.

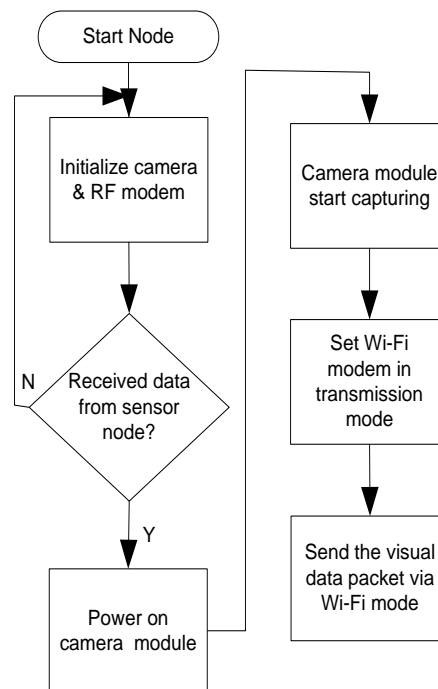


Fig. 11 Vision on bin device.

7 Results and Discussion

The prototype is placed inside the intelligent garbage bin (Fig. 12), and the bin consists of the ultrasonic sensor, LoRa module, and LCD. The ultrasonic sensor at the lid of a garbage bin detects the waste level. The ultrasonic sensor starts sending the alerts through the controller to the user once the waste crosses the threshold level. In this study, four bins are deployed in a region for evaluating the proposed architecture. The snapshots of the blynk dashboard (Fig. 13) describe the level of waste in four garbage bins at different time intervals. From Fig. 13, L1, L2, L3, and L4 are the names given to the bins in blynk. Upon installing an ultrasonic sensor in the bin, the readings can be tracked via the blynk app, which gives an idea of the waste occupancy in the bin. With blynk, one can track the bin's status in real-time and collect waste on time as well. Cayenne is a cloud-based IoT solution dashboard that takes most of the complications out of creating hardware-oriented programming. With a sensor installed, the dashboard will show the current reading of the bins, and it is shown in Fig. 14. The cayenne dashboard shows the data on the level of different bins, and it also shows the location of the bins.

Concerning hardware design, the compiling is processed using Arduino IDE (Integrated Development Environment). Arduino IDE is an open-source programming platform that is flexible for programming, and it is a secure platform for writing, debugging the

code, and sends it to the board. In this study, TTL (Transistor-transistor logic) is used for uploading the program into the sensor node and gateway node. Fig. 15 shows the serial data regarding the level of waste in a bin. The message 'Motel 86' describes that packet is receiving from the motel (Sensor node 1). '86' in the message presents the level of the garbage in the bin and the distance between the sensor & garbage is 86 cm. RSSI (Received Signal Strength Indicator) is the measurement of the power level that a radiofrequency device is accepting from the gateway, and it is represented in decibel (dB).

Table 2 illustrates the comparison of the proposed



Fig. 12 Intelligent garbage bin.

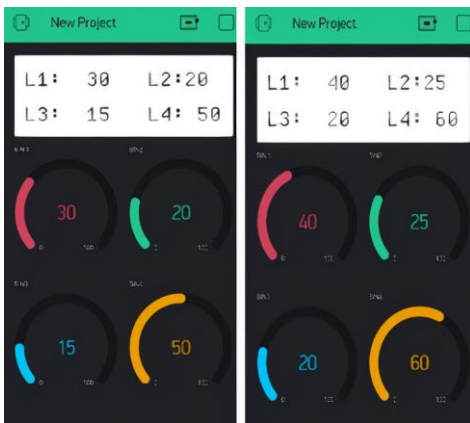


Fig. 13 Blynk dashboard.

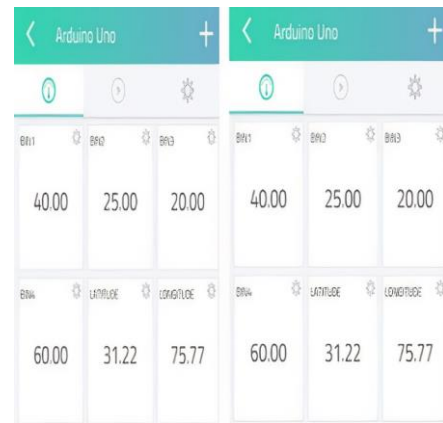


Fig. 14 Cayenne dashboard.

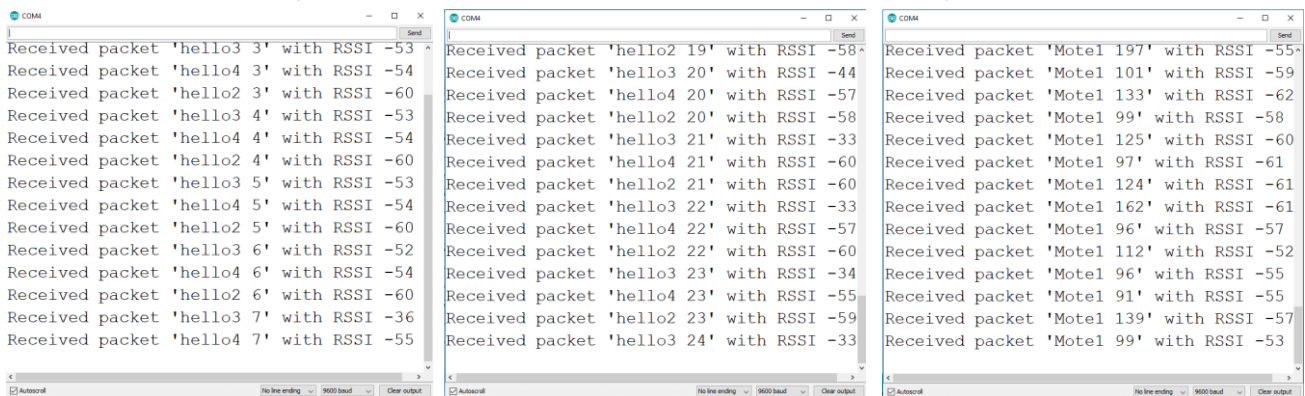


Fig. 15 Serial data from sensor node.

Table 2 Comparison of our study with recent studies.

Parameters	[9]	[13]	[19]	[20]	[21]	[22]	Proposed study
Sensor node	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Gateway node	Yes	Yes	No	Yes	Yes	No	Yes
Communication	Long-range, GSM	Zigbee	Long-range	Long range, ESP 8266	Long-range, Wasp mote	GSM	Long range, ESP 8266
Customized prototype	GSM	No	Yes	Utilized readymade boards	Utilized readymade boards	Yes	Customized sensor node and gateway prototype is designed
Cloud server	Azure IoT	No	Not implemented	Firebase cloud	NA	Not implemented	Cayenne and blynk server
Mobile/Web application	Azure web	No	No	No	No	No	Cayenne and blynk based mobile & web app

system with recent studies for the waste management system. The comparison is categorized into distinct parameters like availability of sensor node and gateway node, type of communication implemented, design of the customized prototype, and implementation of the cloud server. In [12], [18-20] the customized prototype is done with available boards like Arduino and wasp mote. In our study, the design of the sensor node and gateway node is especially performed by us after the thorough analysis of the controllers and communication protocol for establishing an effective and reliable real-time monitoring system. In [20], the integration of GSM communication consumes high power for the transmission of the sensory data of the bins. The information related to the bins communicated in SMS (short message service) in the [20], however in our study and [18] the real-time monitoring is established with long-range and Wi-Fi connectivity.

The implementation of a cloud server enables to visualize the data in the digital dashboard, in [18], the firebase cloud server is employed, and, in our study, we have utilized two distinct cloud-based application such as cayenne and blynk. These two applications record and visualize the real-time data of the bin continuously at distinct time intervals in the dashboard.

8 Conclusion

Waste management plays a vital role in establishing a clean and green environment towards a sustainable environment. Nevertheless, the municipal authorities are facing difficulties in preserving clean and pollution-free cities due to traditional practices. Here, we require a waste management system that consumes low power and long-range transmission. This study aims to implement a wide area network for waste management systems using LoRa (Long Range) and ESP 8266 Wi-Fi communication. For achieving the objective, we have designed and implemented customized nodes (sensor node, gateway node) which are having a feature of transmitting the data over the cloud server. Sensor node embedding in the bins senses the level of the bins with the ultrasonic sensor and transmits the level of sensory data due to the gateway node via long-range communication. The gateway node receives the ultrasonic sensory data from the sensor node and transmits the data to the cloud server over internet protocol with ESP 8266 Wi-Fi module. In order of

visualizing the real-time data in the digital dashboard, we have employed cloud-based cayenne and blynk app that can record the sensory data from the gateway through internet protocol. The visualization of sensory data in the cayenne and blynk app is shown in the results section. When compared to the recent studies, the customization of the prototype and implementation of the cayenne and blynk app are the unique parameters that are implemented in our system. The data stored in the cayenne and blynk app is useful for getting an outcome by performing analytics on the data. In the future, we will employ blockchain technology to implement the waste to money model for generating the income to the waste generated.

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