



## IoT based smart waste management system in aspect of COVID-19

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### ARTICLE INFO

**Keywords:**

COVID-19  
IOT  
Smart City  
Smart Waste Management  
Quality of Service

### ABSTRACT

The rapid evolution of the IoT has led to various research challenges for improving smart city applications. Owing to the characteristics and virtues of IoT services, waste management has emerged as a prominent issue in today's society. An undiscerning illegal eviction of waste, lack of waste disposal and management systems, and inept waste management policies have resulted in severe health and environmental challenges. Based on an integrative review, the proposed technique provides insight into the potential of smart cities and associated communities in assisting waste management initiatives. This study has referred to the existing waste management issues in urban areas and proposed an IoT-based smart waste management system of India in aspects of COVID-19 afflicted houses. Our system intends to improve waste management by making regular environmental sterility and making COVID situations more convenient. The proposed framework ensures a solution for efficiently handling waste generated in urban areas, focusing on the interaction among concessioners and waste generators to monitor the unfilled level of bins. This proposal offers dynamic waste collection scheduling and route optimization while achieving quality of service.

### 1. Introduction

The Internet of Things is part of a communication framework in which smart devices are used to augment common things. Sustainability has become an essential issue for inhabitants where the dynamic development of IoT delivers a variety of practical benefits. The rapid development of IoT-based smart technologies has legalized a slew of new capabilities in numerous areas of life. IoT intends to offer plug-and-play technologies for easy operation, remote access control, and configurability.

The IoT (Ferrari et al., 2020; Khan and Salah, 2018; Kamble et al., 2019; Abba and Light, 2020) is an ecosystem of numerous embedded digital devices communicating via Internet services. Through real-time monitoring and supervision of urban operations, the Internet of Things is essential to improving smart city applications. The setup of heterogeneous sensors that can detect environmental data allows the observation of complex nodes with well-managed properties. IoT (Lawal and Rafsanjani, 2021; Shafique et al., 2020) provides cutting-edge solutions for boosting security and safety, enabling remote control of systems, observing inhabitants, optimizing efficiency, and improving visual and thermal comfort. IoT (Kaza et al., 2018) aims to simplify procedures in diverse domains, enhance system efficiency, and improve living quality.

According to the World Bank (Zanella et al., 2014), cities worldwide created 2.01 billion tons of solid waste in a single day in 2016, resulting in a 740 g per person footprint. Due to fast population expansion and urbanization, annual waste generation is estimated to increase by 70% from 2016 to 3.40 billion tons in 2050. Waste management applications include various activities ranging from waste collection, segregation, reclamation, and recycling. Waste management has become a significant concern, from daily living to administrative objectives; as a result of the social repercussions, insufficient waste management regulations have contributed to severe environmental problems.

COVID infected more than 3.0–3.5 lakh people a day in India in April-May 2021 (Worldometer, 2021), with most infected living in-home quarantine or near a safe house and the very ill admitted to hospitals. In most urban areas of our country India, the waste collection has traditionally taken place on every alternate day of each week. Experienced that regular garbage collectors did not collect waste materials from COVID affected houses. However, how waste would be collected from COVID affected family members would not be considered at all.

IoT paradigm (Ramson and Moni, 2017) integrates application solutions and communication technologies such as identification and tracking, sensor networks, wired and wireless actuators, better communication protocols, and distributed intelligence for objects. RFID

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tags, sensors, actuators, wireless sensor network, near field communications, and GPS are used in waste management to annotate and communicate information. Advances in IoT have enhanced the present waste management system. IoT based waste management models play an important role in illuminating human existence by enhancing energy efficiency, improving governance, and lowering costs. Several remote monitoring solutions based on WSN and IoT have been developed (Ramson et al., 2020) to address the constraints of conventional waste management systems. Short-range wireless network techniques were used by several of the monitoring systems including Bluetooth, Infrared, ZigBee, and Wi-Fi, to monitor the bins while others used wide-area network technologies like Sigfox and LoRa, etc (Harith et al., 2020; Ramson et al., 2021; Jutta Gutberlet and Sayed Mohammad Nazim Uddin, 2017).

In this article, we have proposed the IoT based framework for the smart waste management system of India in aspects of COVID-19. The main contributions of this work are presented below:

- This is a novel proposal for a smart waste management system that is specially designed for COVID affected houses in our country.
- This technique helps regular waste collectors easily identify the COVID impacted houses, and they would not collect the garbage from those houses. According to the proposal, specific waste collectors would collect garbage from only COVID affected households, preventing COVID infections from spreading from one affected home to another regular home.
- The proposed framework introduces hybrid network architecture that offers a cost-effective waste level monitoring system.
- The proposal deals with two different types of smart waste bins to segregate biodegradable and non-biodegradable waste at source levels that help to minimize the cost of separating collected waste.
- This proposal offers dynamic waste collection scheduling along with route optimization mechanisms and achieves quality of service.

The multilayer approach allows ubiquitous integration of physical objects, communication infrastructure, and IoT based services in COVID affected and conventional houses. Environmental, economic, and social aspects would be considered as the waste collection is a common chore in metropolitan areas. It involves designing garbage collector routes, and the route length should be optimal to minimize work quantities. Waste segregation at the source point can aid in the development of a simple and efficient system in which recycling is considerably easier, resulting in a significant decrease in post-processing cost.

The communication distance between the garbage collection location and the collector's location is crucial in determining the system's efficacy. The bins are deployed with sensors and interconnected via WSN, which can be enriched with several IoT components. Residential smart bins are connected through the Wi-Fi network, whereas public area bins are connected through the LoRaWAN gateway. The sensors may gather garbage filling levels and communicate data to the cloud server based on the threshold level. The communication between the waste bin and the server has been executed through the communication network. BLYNK APP is used as a specialized IoT android application to control garbage levels. Push Notifications and Message Alert Telegram Applications are used in this framework. Concerned requests have been forwarded to the nearest available waste collector through the central monitoring office to collect the garbage from the designated houses. Along with typical dwellings, waste collectors got predefined information on COVID impacted houses.

The rest of the paper is outlined as follows. A comprehensive study of existing techniques has been pursued in Section 2. In Section 3, we have proposed an IoT-based framework for the smart waste management system of COVID-affected houses. The result analysis along with discussion are presented in Section 4. The conclusion is offered in

Section 5, along with some future directions with open research issues.

## 2. Related works

Smart waste management is one of the most discernible of the many IoT based services available in smart cities. Proper waste disposal management services are challenging due to the large population and large metropolitan areas. In light of growing urban populations and the consequent demand for advanced amenities like waste management, many IoT-based strategies have been proposed to address these issues. Improper waste disposal, a lack of systematic waste collection and management plans, and inadequate methods have resulted in significant environmental difficulties and costly waste disposal expenses (Rohit et al., 2018). Researchers have studied several waste management techniques centered on IoT technologies to solve the challenges associated with waste management due to the beneficial consequences of IoT services.

The authors presented a smart wastebasket model (Tripathi et al., 2018) that is utilized in smart cities and consists of two wastebaskets. This will prevent the waste from overflowing into the landfill. The authors (Shyam et al., 2017) explored a cloud-based garbage monitoring system powered by small solar panels to make the unit ecologically sustainable. The developers of (Bharadwaj et al., 2016) created an IoT based system that analyses garbage levels in household waste bins and communicates data to a server in order to enhance waste collection routes in cities. Authors (Pritchard et al., 2017) implement LoRa communication technology to notify collection systems when trash bins are full. There are various waste bins dispersed across the city (Ogbodo et al., 2017), and these bins are fitted with low cost onboard electronics that allow the level of the garbage bins to be monitored.

In (Kokkonis et al., 2016), connected via a cellular network, sensor-enabled smart bins produce vast amounts of data, which is then processed and displayed in real time to shed light on the city's waste management problem. Authors (Wu et al., 2018) illustrated smart transport protocols that allow effective data transmission for monitoring systems, including flow management and a synchronization mechanism to increase system efficiency. The authors (Wang et al., 2017) attempted to decrease transmission latency for IoT based networks through a synchronous learning based strategy.

The authors (Al-Jabi and Diab, 2017) presented a utility-based adaptive duty cycle and offered an energy efficient strategy to decrease transmission delay between end-to-end delivery. The authors proposed an intelligent waste management system (Norhafiza et al., ), emphasizing the social aspects of this smart system. The architecture employs IoT with RFID tags and ultrasonic sensors to monitor and assess local community interest in WMS. In (Vigneshwaran et al., 2019), the authors offered an automated system for recycling material segregation, with the recycling bin loaded with four distinct types of sensors, namely inductive sensors to identify plastic, capacitive sensors to detect metal, photoelectric sensors to detect paper, and proximity sensors to monitor motor position.

A smart bin using LoRa technology is proposed in (Ziouzios and Dasygenis, 2019), which consists of a LoRa gateway, a remote diagnostic system, sensors to monitor the amount of garbage, and a cloud platform. The authors presented a smart recycling bin in (Bueno-Delgado et al., 2019) where the data from the Bin is transmitted from a sensor node to the gateway over a LoRa communication network; however, this system includes a waste segregation mechanism. Authors (Andrade and Yoo, 2019) proposed a waste treatment and management system based on LoRaWAN technology and presents an optimization of the route used by waste collection vehicles. In (Zeb et al., 2019) authors present a comprehensive analysis of the evolution of smart cities based on long-distance communication technology, emphasizing IoT systems developed with the LoRaWAN network protocol.

**Table 1**

Comparison of Existing Waste Management Techniques.

References	Technology	Network Type	Power Consumption	Wireless Range	Geo-Location of Bin	Storage	Visualization
Rohit et al., (2018)	Arduino Uno	WSN	12 V Battery	Short	No	No	Yes
Tripathi et al., (2018)	RFID	WWAN	Two Solar Panels of 5 V	Long	No	Yes	Yes
Shyam et al., (2017)	IoT Sensing Prototype	Wi-Fi	Battery	Long	Yes	Yes	Yes
Bharadwaj et.al. (2016)	IoT based Architectural Solution	LoRaWAN	Low	Long	Using Google Map	Yes	Yes
Al-Jabi et al., (2017)	IoT Units, RFID, Sensors	IEEE 802.15.4	Solar Cell	Short	No	Yes	No
Ziouzios et al., (2019)	Neural network	LoRaWAN	Low	Long	No	Yes	No
Vishnu et al., (2021)	IoT Enabled	Hybrid (LoRaWAN and Wi-Fi)	Low	Long	Yes	Yes	Yes
Kumar et al., (2020)	IoT Enabled	WSN	Low	Long	No	No	No

In (Das et al., 2021), authors compared multinational healthcare solid waste management techniques, outlined problems inherent in international healthcare solid waste management, and proposed solutions to these challenges. It also offers important insights into healthcare solid waste management scenarios during the COVID-19 pandemic and a possible way forward. To solve the constraints of traditional waste management systems, the author developed an IoT-compatible solid waste management system for smart cities (Vishnu et al., 2021). Authors (Kulkarni and Anantharama, 2020) presented a worldwide context of MSW management during the COVID outbreak, which concentrated on the various forms of garbage created during the COVID-19 epidemic and how they affect current MSW management methods. The development and validation of a hybrid network architecture strategy for managing trash bins in cities' public locations and residential areas. The authors proposed (Kumar et al., 2020) an effective routing strategy smart waste management system utilizing the ERS algorithm to overcome data transmission latency by considering one of the vital QoS parameters.

The author developed AirBin to prevent the spread of COVID through waste generated in high-risk sites such as hospitals, clinics, public garbage bins, and quarantine zones. Though IoT devices provide remote monitoring of garbage buildup levels and clearing. This system was solely concerned with data collection and did not specify the route optimization method. The competent authority has established many recommendations for collecting and disposing of biomedical waste. COVID-19 waste management requirements for quarantine centers and home-care workers are specified here (CPCB, 2021). CPCB provided recommendations for the processing, treatment, and disposal of waste generated by COVID patients (COVID Guidelines 2020) to facilitate waste generators and common disposal facilities in collecting, transporting, and disposing of trash in perfect safety.

From the above study, it is apparent that researchers have come up with several IoT based smart waste management techniques for smart cities and metropolitan areas. The waste disposal system is affected if the waste bins in affected localities are not cleaned in frequent intervals. The contagious nature of the disease made the health authorities

devise special cleaning schedules different from the regular ones. From the study of existing smart waste disposal schemes, it becomes evident that the existing cleaning schedules fail to match the speed with which the bins got filled up in COVID affected areas.

Various proposals deal with collecting COVID-19 biomedical waste from hospitals and medical institutions for disposal. But very little attention is paid to collecting garbage from COVID affected houses. It is observed that there is still not enough evidence of work aimed specifically toward the management of the waste generated due to COVID-19. Given the highly contagious characteristic of the said waste, it becomes extremely important to attend to its collection in a timely and efficient manner.

Hence in this paper, we aim to identify the important parameters responsible for efficient management of COVID waste from patient households. One of the most important parameters in this regard is the timeliness of cleaning for obvious reasons. The timeliness of cleaning depends on the accuracy of the alarm triggered by the waste bins. This can be ensured by the fast response of the collector vehicles to the alarms from the bins. Maintained the network response time at maximum while discovering the shortest path to the available vehicles.

By experiencing the situation, we developed a layered smart waste management system that integrates physical objects, communication infrastructure, and IoT based services in COVID affected and conventional houses. This proposal deals with two types of smart garbage bins that segregate biodegradable and non-biodegradable waste at the source level, reducing the expense of separating collected waste. Using this mechanism, waste collectors received pre-determined information about COVID affected households in addition to regular residences. Local garbage collectors would collect waste from normal dwellings while additional collectors would collect waste from COVID-19 infected houses, limiting disease spread in communities. This scheme offers cost-effective waste level monitoring and dynamic waste collection scheduling to decrease operational expenses and improve service quality.

In the next section, the working principle of the said proposal will be presented along with a case study of the same.(Table 1,2).

**Table 2**

Comparison of Different Communication Protocols.

Characteristics	Bluetooth	ZigBee	Wi-Fi	LoRa
Max. end-devices	255 (2 billion in BLE)	More than 64000	Depends on number of IP address	More than 5000
Peak Current Consumption	30 mA	30 mA	100 mA	17 mA
Range	10 m	10–100 m	100 m	More than 15 km
Data Rate	1 Mbps	250 kbps	11 Mbps and 54 Mbps	290 bps to 50 Kbps
Relative Cost	Low	Low	Medium	Low
Topology	Star	Star and Mesh	Star and Point-to-point	Star
Transmission Technique	Frequency Hopping Spread Spectrum	Direct Spread Spectrum Sequence	Orthogonal Frequency Division Multiplexing	Chirp Spread Spectrum

 <p><b>Residential Biodegradable Waste Bin</b></p> <p>Example: RBDG_WBin = [BKP_43-W10-1/1-8576-12346-9812345789-RB1]</p>	 <p><b>Residential Non-Biodegradable Waste Bin</b></p> <p>Example: RNBDG_WBin = [BKP_43-W10-1/1-8576-12346-9812345789-RB2]</p>	<p>Where,</p> <ul style="list-style-type: none"> <li>• Municipality Code: BKP_43</li> <li>• Ward Number: W100</li> <li>• Holding Number: 1/1</li> <li>• Aadhar Card (First Four and Last Four Digit): 85764921</li> <li>• Swasthyasathi Card / Ayushman Card (Last Five Digit): 12346</li> <li>• Registered Mobile Number: 9812345678</li> <li>• Bin Type: Resident_Biodegradable:RB1 Resident_Non-Biodegradable:RB2</li> </ul>
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Fig. 1. Allocation of Residential Waste Bin.

### 3. Proposed framework

The proposed framework is composed of three layers that will outline the smart waste management system to ensure enhanced waste handling operations for both COVID impacted and conventional residences. The first section deals with Smart Bin Deployment. The second section discusses the architecture of the proposed framework and explains efficient data connection between waste bins and distant servers to achieve QoS in data transfer. The third section describes the dynamic waste collection procedure and identifies the optimal path between the smart bins and the waste collectors.

#### 3.1. Smart bin deployment

The first section is employed to distribute smart trash bins in residential areas and public spaces to monitor the garbage level properly. The 'Aadhar Number,' 'Holding Number,' 'Swasthyasathi Card' (An unique initiative of Govt. of West Bengal, India) or 'Ayushman Card' (Applicable for PAN India except West Bengal), and the Mobile Number connected with the Holding Number are used to assign a unique id to a residential garbage container. Each 'Swasthyasathi Card' or 'Ayushman Card' contains information on all family members, including their Aadhar numbers. The local municipality simply recognized family members' data of each holding number based on the aforesaid allotment. In each holding number, the local municipality assigns two types of garbage bins (biodegradable and non-biodegradable).

#### ✓ Residential Waste Bin Allocation:

##### • Residential Biodegradable Waste Bin ID:

$RBDG\_WBin = f\{Municipality\ Code, Ward\ Number, Holding\ Number, Aadhar\_Card, Swasthyasathi\_Card/Ayushman\_Card, Mobile\_Number, Bin\_Type\}$

##### • Residential Non-Biodegradable Waste Bin ID:

$RNBDG\_WBin = f\{Municipality\ Code, Ward\ Number, Holding\ Number, Aadhar\_Card, Swasthyasathi\_Card/Ayushman\_Card, Mobile\_Number, Bin\_Type\}$ .

#### ✓ Public Waste Bin Allocation:

The local municipality deploys biodegradable and non-biodegradable waste bins at different locations of each street. Each bin is labelled with a unique identity based on the characteristics listed below.

##### • Public Biodegradable Waste Bin ID:

$PBDG\_WBin = f\{Municipality\ Code, Ward\ Number, Street\ Id, Bin\_Type\}$

##### • Public Non-Biodegradable Waste Bin ID:

$PNBDG\_WBin = f\{Municipality\ Code, Ward\ Number, Street\ Id, Bin\_Type\}$ .

In Figure 1, 'Residential Biodegradable Waste Bin' is represented by 'Blue' color, whereas 'Green' indicates 'Residential Non-Biodegradable Waste Bin.' In Figure 2, 'Public Biodegradable Waste Bin' is represented by 'Red' color, and 'Public Non-Biodegradable Waste Bin' is identified by 'Yellow' color. Figure 3 represents the system flow of the proposed framework. Figure 4 represents the different components of Smart Bin. Each residential garbage bin is constructed with a Servo Motor, Ultrasonic Sensor, IR Sensor, Node MCU, Wi-Fi Module, Arduino UNO, etc. Aside from the essential components, the LoRa module includes public waste bins to communicate with the LoRaWAN network through the LoRaWAN gateway.

The Figure 3 represents the system flow of the proposed framework. Different types of waste bins are deployed in the corresponding location

 <p><b>Public Biodegradable Waste Bin</b></p> <p>Example: PBDG_WBin = [BKP_43-W10-3/2-PB1]</p>	 <p><b>Public Non-Biodegradable Waste Bin</b></p> <p>Example: PNBDG_WBin = [BKP_43-W10-3/2-PB2]</p>	<p>Where,</p> <ul style="list-style-type: none"> <li>• Municipality Code: BKP_43</li> <li>• Ward Number: W100</li> <li>• Street Id: 3/2</li> <li>• Bin Type: Public_Biodegradable:PB1 Public_Non-Biodegradable:PB2</li> </ul>
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Fig. 2. Allocation of Public Waste Bin.

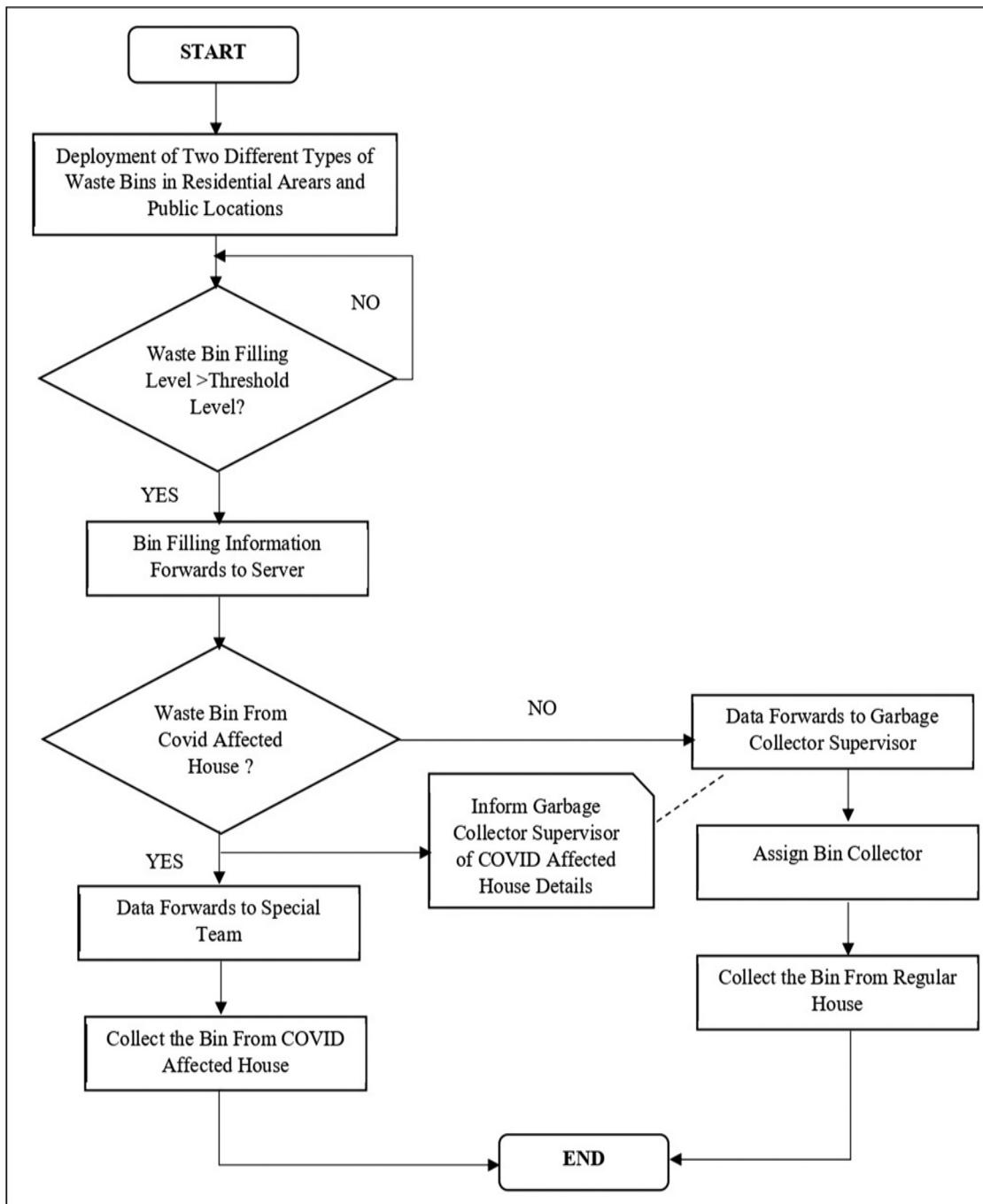


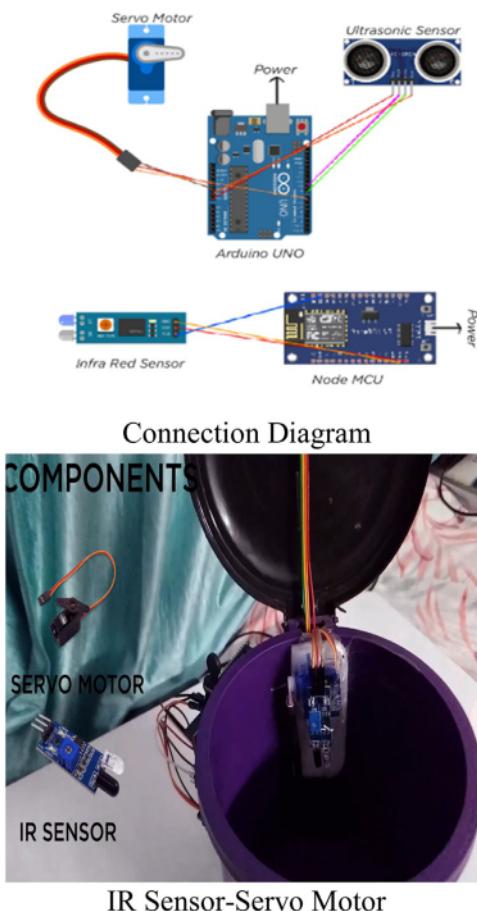
Fig. 3. System Flow of the Proposed Framework.

based on the 'Smart Bin Deployment' module. Depends on the threshold level, smart bin filling information is forwarded to central authorities. Based on the bin filling information, the category of the houses are identified based on the 'Identification of COVID Houses' method. The concerned authority forwards the bin filling information to the garbage collector supervisor for collecting the waste bin from regular houses. The bin filling information is forwarded to the special team for collected the waste materials from COVID affected houses. Based on the 'Waste Collection Procedure' mechanism the waste collection process is executed.

### 3.2. Architecture of the proposed framework

The second section describes the proposed IoT-based smart waste management framework and is presented in Figure 5. It employs a hybrid network architecture to efficiently manage garbage containers in public places and private residential areas.

Wi-Fi and LoRaWAN are two of the most extensively used technologies, and they cover a wide spectrum of IoT use cases when combined. LoRaWAN stands for low-power, wide-area network, and it is a network protocol created specifically for wirelessly linking



**Fig. 4.** Architecture of Smart Bin.

battery-operated "things" to the Internet and other worldwide networks.

It covers critical Internet of Things requirements such as bidirectional communication and end-to-end security, mobility, and location services. Wi-Fi provides high data speeds for short- and medium-range use cases at what appears to be a penalty in battery life. LoRaWAN accommodates low-frequency device communications across great distances, allowing for battery lifetimes of up to ten years. The LoRaWAN network architecture connects IoT devices, gateways, network servers, and application servers in a star topology. In LoRaWAN operations, the LoRaWAN gateway collects data from IoT devices and sends it to the application server. Wireless communication makes use of the LoRa physical layer's long-range features, enabling a one-hop link between the end device and one or more gateways.

This framework intends to depict how LoRaWAN may be implemented alongside an existing Wi-Fi network while allowing operational cost minimization. A mutualized deployment's lower cost and operational efficiency become obvious compared to establishing both networks independently. By creating convergent solutions, users may benefit from the complementarity of Wi-Fi and LoRaWAN. Collect data via LoRaWAN on Access Points from various devices across the facility and transmit data to network servers via Wi-Fi.

Two public regions and two residential areas are present in the proposed framework. In public locations (Public Region\_1, Public Region\_2), two types of waste bins (Public Biodegradable Waste Bin: PBDG\_WBin, Public Non-Biodegradable Waste Bin: PNBDG\_WBin) are

deployed. Residential Biodegradable Waste Bin: RBDG\_WBin, Residential Non-Biodegradable Waste Bin: RNBDG\_WBin are deployed in each home (Residential Area\_1, Residential Area\_2).

For implementing PBDG\_WBin and PNBDG\_WBin, a LoRaWAN networking framework is used. Wi-Fi-based communication is used for RBDG\_WBin and RNBDG\_WBin that are connected with residences.

In the proposed framework, the data from the Public Biodegradable Waste Bin and the Public Non-Biodegradable Waste Bin are collected by the LoRaWAN gateway and uploaded to the server. Wi-Fi module is integrated with the Residential Biodegradable Waste Bin and the Residential Non-Biodegradable Waste Bin for data uploading to the server.

The server receives the data via the IoT framework, and there is no delay in data sending and data receiving, resulting in quality of service. The central monitoring office monitors the records and assesses the unfulfilled levels as well as the positions of the waste bins, and corresponding execution would be taken place.

### 3.2.1. Identification of COVID houses

Before collecting waste products from COVID affected residences, waste collectors should have prior information of the households. The local municipality received information on COVID-19 impacted people from the relevant authorities (e.g.: Swasthya Bhawan, West Bengal, India). The municipality's health department identifies the COVID patient's address and notifies the waste collection department. The departmental administrative officer communicates the information to the

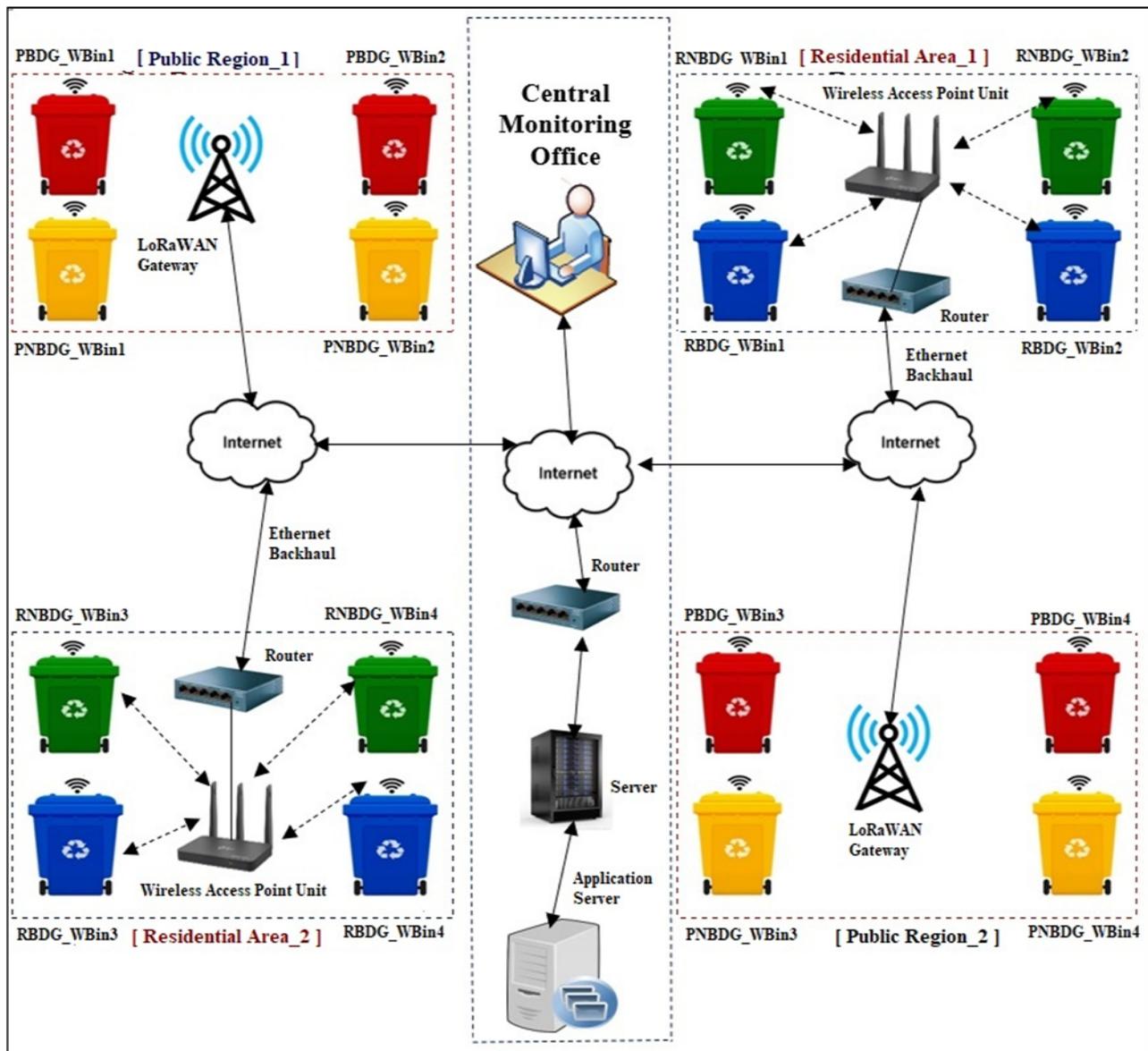


Fig. 5. Architecture of the Proposed Framework.

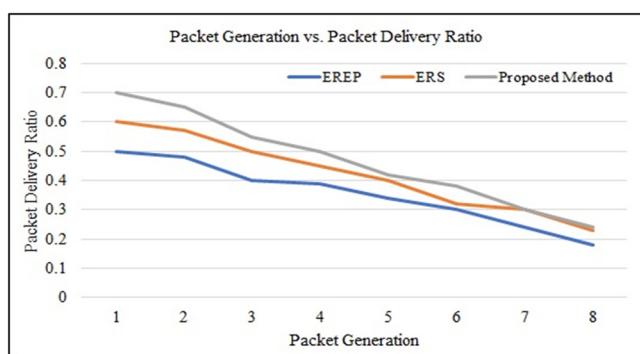


Fig. 6. Packet Generation Vs. Packet Delivery Ratio.

waste collector supervisor for the corresponding zone and recommends assigning a designated waste collector to collect the garbage from the COVID impacted dwelling. This strategy attempts to prevent infection from spreading from one household to another through the garbage

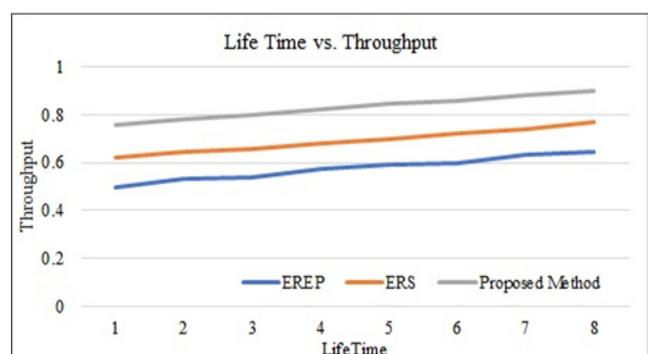


Fig. 7. Lifetime vs. Throughput.

collection procedure. Here are four separate instances where the system created notification for dustbin filling for different types of family members, [Case-I, Case-II: Covid Affected Family], [Case-III, Case-IV: Regular Family].

Notification for Dustbin Filling for COVID-19 Affected Family [Case-I, Case-II]		
 Gmail <b>Peak Value for Floor 0 - Building XYZ , Landmark ABC, City : ### - Non Biodegradable Dustbin Reached</b> jissuman2017@gmail.com <jissuman2017@gmail.com> To: som.brata@gmail.com Please Reach Out To Apartment, XYZ - Floor 3 For Collection Of Wastage @ c/o Non Biodegradable Dustbin.Distance From Your Location To Apartment Is: 4km. Also Please Note You Have Been Assigned for this because you are marked for allotting tasks in covid infected or near by apartments. Do Take utmost care for the execution of your job.	Soumyabrata Saha <som.brata@gmail.com> Sat, Jul 3, 2021 at 11:20 PM	<b>Case-I</b> <b>Non-Biodegradable Dustbin Notification:</b> Floor-0, Family-1 <b>#COVID-19 Affected Family</b>
 Gmail <b>Peak Value for Floor 3 - Non Biodegradable Dustbin Reached</b> jissuman2017@gmail.com <jissuman2017@gmail.com> To: som.brata@gmail.com Please Reach Out To Apartment, XYZ - Floor 3 For Collection Of Wastage @ c/o Non Biodegradable Dustbin.Distance From Your Location To Apartment Is: 2.5km. Also Please Note You Have Been Assigned for this because you are marked for allotting tasks in covid infected or near by apartments. Do Take utmost care for the execution of your job.	Soumyabrata Saha <som.brata@gmail.com> Sat, Jul 3, 2021 at 11:16 PM	<b>Case-II</b> <b>Non-Biodegradable Dustbin Notification:</b> Floor-3, Family-4 <b>#COVID-19 Affected Family</b>
Notification for Dustbin Filling for Regular Family [Case-III, Case-IV]		
 Gmail <b>Peak Value for Floor 3 - Biodegradable Dustbin Reached</b> jissuman2017@gmail.com <jissuman2017@gmail.com> To: som.brata@gmail.com Please Reach Out To Apartment, XYZ - Floor 3 For Collection Of Wastage @ c/o Biodegradable Dustbin.	Soumyabrata Saha <som.brata@gmail.com> Fri, Jul 2, 2021 at 11:48 PM	<b>Case-III</b> <b>Biodegradable Dustbin Notification:</b> Floor-3, Family-9 <b>#Regular Family</b>
 Gmail <b>Peak Value for Floor 2 - Non Biodegradable Dustbin Reached</b> jissuman2017@gmail.com <jissuman2017@gmail.com> To: som.brata@gmail.com Please Reach Out To Apartment, XYZ - Floor 2 For Collection Of Wastage @ c/o Non Biodegradable Dustbin.	Soumyabrata Saha <som.brata@gmail.com> Fri, Jul 2, 2021 at 11:43 PM	<b>Case-IV</b> <b>Biodegradable Dustbin Notification:</b> Floor-2, Family-5 t

### 3.3. Waste collection procedure

The third section deals with the waste collection procedure. Each smart bin monitors waste volume, and based on the threshold level, an alert would be raised and the data would be forwarded to the server. The information is forwarded by the central office to the appropriate

zone for garbage collection. Based on the assigned task, waste collector would reach to the corresponding location by following the optimal path. Before collecting waste products from residences, waste collectors should have prior information of the households, i.e., Waste\_Status\_INFO{ House\_No, COVID\_Status}.

**Algorithm.** Waste Collection Procedure.

## START

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Step 1: The city information is represented as a graph G = (N, E).
E←Set of roads in the city;
Each road in the street is denoted as a one-way link {e ∈ E};
len(e)= Length of each link;
N←number of installed waste bins, identified as {xi,yi};

Step 2: loc(x,y)← Present location of the waste collector.
Step 3: while (Bin_Status=='FULL' )
    For each i calculate,
        Step a: leni(e)=dist[loc(x,y)-(xi,yi)]
        Step b: Find min{len(e)}.
        Step c: Set Bin_Status='EMPTY'
        Step d: IF (COVID_Status=='Y')
            Collect waste by COVID_waste collector
        Else
            Step e: Collect waste by Regular_waste collector
        END IF
    END For
END While

```

## END

By using the above procedure, designated waste collector collects the garbage from the corresponding locations.

### 4. Result and discussion

In this section we intend to analysis the performance of our waste management system. Here we present the efficacy of the proposed system through a comparative analysis. Thus, in Figure 6, we have presented a comparative measure of the packet delivery ratio, followed by the throughput of the underlying sensor network in Figure 7. The best way to measure the response time is to use the packet delivery ratio and throughput of the system.

On-time packet delivery may be used to measure an algorithm's effectiveness; a better algorithm is one that maintains high levels of on-time packet delivery even when data generation rates increase. The total number of data packets arriving at destinations divided by the total number of data packets transmitted from sources yields the packet delivery ratio and calculated as;

$$\left[ PDR = \frac{\sum \text{Number\_of\_Packet\_Received}}{\sum \text{Number\_of\_Packet\_Send}} \right].$$

The simulation compares the performance in terms of Packet Delivery Ratio vs Packet Generation to existing proposals, as EREP (Zeb et al., 2019) and ERS (Kumar et al., 2020) and is represented in Figure 6. In this case the number of packet generated indicates the number of requests generated for waste collection. The measure of PDR reflects the delivery ratio of this garbage collection requests. Therefore, a high PDR value ensures a high probability of packet delivery. This is a must for the efficient functionality of the proposed system i.e., for timely collection of garbage. In Figure 6 it is identified that packet delivery ratio is better of the proposed technique than the existing EREP (Zeb et al., 2019) and ERS (Kumar et al., 2020) mechanisms.

Total data received in a certain period of time is used to calculate throughput. This is defined as; [Throughput =  $\sum_{i=0}^n P_s L_p$ ] where  $P_s$  is the total number of messages successfully received at the destination,  $L_p$  is

the length (in bits) of the payload for each node and  $i$  is the transmission time. Therefore, throughput measures the number of packet delivers in a transmission time with amounts of payload. High throughput value is always desirable for every system because it indicates the performance of a system in a unit of time. The higher value of throughput throughout the lifetime indicates that in spite of energy used in several communications the system is performing well and able to deliver its desired output in due time. In Figure 7, we have compared throughput with lifetime. It represents that the proposed system provides better throughput than the existing mechanisms (Zeb et al., 2019; Kumar et al., 2020) due to its response frequency. The notification is set off by an overflowing garbage container. As a result, less energy is used throughout the lifetime and better throughput is achieved.

Both the existing (Zeb et al., 2019; Kumar et al., 2020) proposals deal with the efficient route selection mechanism for IoT based smart waste management system. From the above two figures, it is identified that the proposed system provides better performance in terms of packet delivery ratio and throughput in comparisons of two existing methods.

### 5. Conclusions

The COVID epidemic is causing problems for municipal waste management, including personnel safety and health, and general waste sector operations. Researchers have proposed several smart waste management systems, however just very few relevant to smart waste management systems for COVID afflicted family members have been found. Regular garbage collectors did not collect garbage from COVID affected homes, adding to the hardship on COVID sufferers' families.

Experiencing this real-life situation, we have designed an IoT based smart waste management system in aspects of COVID-19 where two different types of smart bins have deployed in each house based on the municipality tax prayer's credentials and dispersed separate smart waste bins in public locations also. In our proposal, bio-degradable and non-biodegradable garbage are collected separately at the source level for both public and residential waste bins, resulting in no extra costs for

eventual garbage segregation, unlike other existing mechanisms.

This study discussed the development and validation of a hybrid network architecture strategy for efficiently managing garbage bins in public places and residential areas of cities. It is feasible to use IoT to track the position of waste containers, monitor the level of garbage deposited, identify regions with the highest demand, and suggest the optimized route for collecting waste materials. The suggested framework outlined the development and evaluation of an IoT system to monitor waste levels and efficiently inform the central monitoring office.

Separate notification for dustbin filling of COVID affected family and regular family is send to concern central authorities. The real time communication through email and SMS are presented here. The central regulating authority assigns waste collectors to collect garbage from normal residences based on the information obtained. This approach intends to satisfy the growing demand for smart services in ever expanding metropolitan contexts.

Based on the waste bin filling information, central office allocates the manpower to collect the garbage from waste bins. A separate team is assigned to collect waste from COVID affected homes. The objective is to get to the designated site using the optimized route and collect the waste materials within the allotted time. Identified the shortest route to the available automobiles while keeping the network response time as rapid as feasible. As each garbage collector team traversed by waste collector vehicle and their operational cost is minimized by following the proposed collection mechanism.

The proposal presents how the IoT waste management system enhances the capacity of cleaning waste materials during COVID outbreak and addresses the real time problems. Two different types of waste collectors are assigned to collect waste materials. The garbage of COVID affected houses would be collected separately by the concerned collectors so that other people would not be affected through the direct contact of the waste collector. As per the Govt. directive COVID waste would be collected and processed separately so that it would not affect others. The waste materials are separated at the collection site by using two different types of waste bins that eliminates the need for additional manpower for waste material segregation. This technique contributes to enhance the cleanliness of society. The proposed method outperformed existing techniques in terms of packet delivery ratio and throughput. This proposal accomplishes dynamic waste collection scheduling and route optimization mechanism and achieves the quality of service.

In future more emphasis will be given on the optimization of energy consumption and continual power supply to the smart bins. Further research is needed to assess differences in waste composition and production rates. The commercial and non-commercial waste collection and management scheme should be integrated through one framework so that administrative authorities can easily look after both the systems as one integrated mechanism. Finally, future work will entail implementing the solution on a bigger scale, which will include reaching an agreement with a local government to implement the proposal across the state.

## Ethical approval

Not required.

## Funding

There is no funding support present for this research work.

## Conflict of Interest

Authors do not have any known conflict of interest either with any individual or institution.

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