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Bin Bay: An Optimized Smart Waste Disposal System for a Sustainable Urban Life using LSTM and Fog Computing

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Abstract: To create green and smart cities, a smart and planned Waste Management System (WMS) is a vital requirement. With the increase in the urban population and service delivery difficulties, smart cities are integrating technologies such as smart waste bins and Radio Frequency Identification (RFID) tags into their day-to-day operations to make solid waste management and control more effective. Fog computing in waste management is becoming common in smart utilities as it provides benefits like a minimal amount of data sent to the cloud, reduced bandwidth, and Low data latency. The proposed work focuses on residential customers using waste collection services. Smart Waste Disposal System for a sustainable urban life using Fog Computing called Bin Bay is proposed to optimize the collection of waste with the shortest path using Google Map API support from Fog Layer for which four major parameters are considered namely: The distance between truck and bin, the status of the bin (what percentage of it is filled), the capacity of the truck and the position of the truck. The Bin Bay model helps to save time by determining the most efficient waste pickup route for waste disposal. The RFID Reader and Scanner help in updating the fog nodes with the date, time, and volume of trash pickup which could be further analyzed to keep on-time service delivery. Also, predictions on future waste growth shall be determined by doing in-depth analysis in the cloud using LSTM which will intelligently learn and predict the waste patterns based on the summary submitted by the aggregate node of the fog layer and since the optimized routes lead to less fuel consumption, CO_2 emission also shall be greatly reduced.

Keywords: Waste Management, Internet of Things, Fog Computing, Supervised Learning Algorithm, Sensors, CO_2 Emission

Introduction

Every year, India produces garbage of 62 million tonnes, out of which 60% or less is collected and just 15% is managed. Waste management discusses the activities and actions needed to manage waste from its beginning to its final disposal. Waste management that is unplanned and unsuitable, results in an unhealthy environment and poses a threat to our lives. Garbage collection is divided into three categories: Residential, commercial, and industrial. Garbage generation and insufficient waste collection, transportation, treatment, and disposal are major environmental challenges in India as a result of the country's rising urban population. The current waste management systems in India are unable to cope with the rising volumes of trash produced by an expanding urban population, posing a hazard to the environment and public health (Kumar *et al*., 2017). In addition, another challenge is cleaning the bins by the Garbage collector on certain days of the month based on their schedules, but they do so without considering the amount of waste in the container thereby reducing the operational efficiency and resulting in emptying unfilled bins. India's population surpassed 1.2 billion in 2013 and it presently stands at over 1.4 billion. India's land area of 2.9 million square kilometers accommodates nearly 18% of the population of world, with a population mass of 325 persons per square kilometer. According to the Census Department, urban India is divided into six tiers depending on population. According to the 2011 census report, there are three megacities with populations of ten million or more, 53 urban agglomerations with populations of one million

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or more, and 468 towns with populations of 100,000 or more. India's fundamental needs are frequently disregarded while megacities fuel the country's 30.47 percent growth. According to the Press Information Bureau, India produces 62 million tonnes of garbage (mixed waste includes both biodegradable and non-biodegradable waste) per year, with a yearly growth rate of 4%. (2016, PIB). The three major forms of waste generated are organic trash (all types of biodegradable garbage), dry waste (or recyclable waste), and biomedical waste (or hygienic and hazardous waste) (Swaminathan, 2018). A landfill has been detected in at least one location in every Indian town. The Indian government has tragically forgotten another crucial public service: Rubbish disposal or waste management, with a larger emphasis on amenities such as water, energy, and food for the rising inhabitants. The process of classifying, collecting, transporting, recycling, and disposing of garbage as a group is known as waste management as depicted in Fig. 1 and the traditional procedure of waste collection and management is shown in Fig. 2.

One of the primary sources of pollution in the environment is improper waste management. As depicted in Fig. 3, India's Union Ministry of Environment, Forests and Climate Change is in charge of trash regulation and administration.

The ministry's principal operations include pollution prevention and control and it has issued numerous strategies over the years to ensure a fresh environment by prudently treating and disposing of trash.

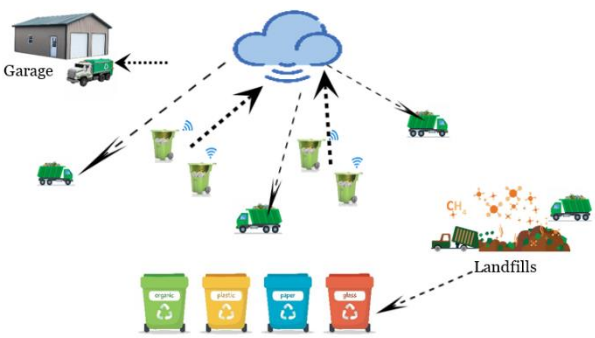

Fig. 1: Waste collection from smart bins to disposal in landfills

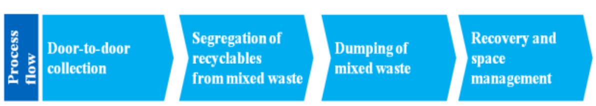

Fig. 2: The traditional procedure of waste collection and management

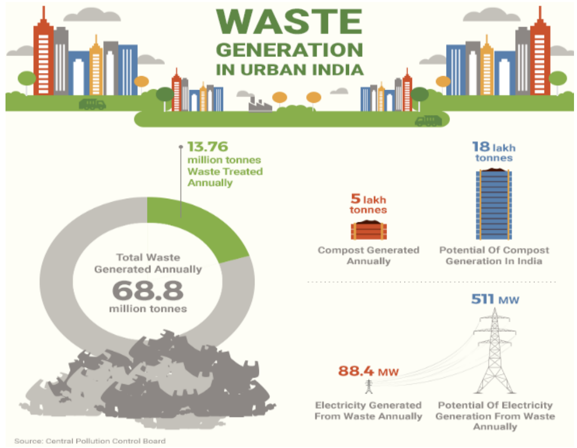

Fig. 3: Source is taken from the central pollution control board

Fig. 4: Overflowing dustbin

India's Challenges in Waste Management:

1. Cities will house over two-thirds of the world's population by 2030. This reality necessitates the development of sustainable urban solutions, as waste management is a major health concern
2. Future city demands include energy-efficient waste management, as well as reductions in CO_2, air pollution, and vehicle exhaust emissions. As a result, resource efficiency and sound management are becoming increasingly important
3. Effective waste management is crucial in developed countries. Even though trash management can take up to half of a city's budget, it only serves a small portion of the population
4. Up to 60% of rubbish is not collected and it often overflows over the side of the road as in Fig. 4. It can contaminate drinking water and spread disease to those who live close by
5. Even if the worker's route is optimized to perfection, he or she must still physically visit the trash can to

verify garbage levels. As a result, trucks frequently visit containers that do not require emptying, wasting both time and fuel

6. By minimizing the volume and dangerous nature of residential and industrial trash, waste management protects human health and the environment

As mentioned in Tables 1 and 2, in Tamil Nadu, unsorted municipal solid trash is composed and either disposed of in lowland areas or water forms or disposed of along the wayside and set on fire, producing air contamination. Water contamination has resulted from the putrefaction of organic matter present in desegrated community solid wastes, while odor nuisance is mostly caused by leachate from discarded solid wastes. In Chennai, the municipal solid waste dumping sites are at Kodungaiyur and Pallikaranai. Therefore, a promising solution with the incorporation of technological advancements like the Internet of Things (IoT), Edge, and fog computing integrated with cloud infrastructure would suffice to handle the waste management need of the country so that the standard of urban living would improve even if the population increases.

Objectives

The primary objective of Bin Bay: A smart waste disposal system for a sustainable urban life using fog computing is the following:

1. To develop a cost-effective and hygienic model called Bin Bay for monitoring waste disposal by providing a smart technology resulting in a healthy and waste-ridden environment
2. To predict future waste growth by doing an in-depth analysis using the data summary from the fog layer
3. To test the automation of the Bin Bay model for operational excellence in waste collection and disposal
4. To validate the model for efficient management of Operation, fleet, and resource

Related Work

The accumulation of rubbish in cities following the advent of industrialization, as well as the ongoing urban growth of significant population centers, led to a rapid deterioration of sanitation and urban life quality. The streets became packed with garbage due to a lack of waste disposal laws. The proportion of the world population living in cities is expected to rise to 66% by 2050, up from 52% in 2014, according to the United Nations Department of Economic and Social Affairs, leading to increased rubbish generation in cities. The statistics from the World Bank Group reveal that garbage generation is increasing. Cities around the world produced nearly 1.3 billion tonnes of solid waste in 2012 or 1.2 kilograms of garbage per person each day. The increased production of municipal and industrial waste, combined with tougher regulations aimed at avoiding illegal rubbish disposal, drives the development of innovative waste management applications. The continued use of reprocessing techniques, the cycle of practical novelty, the application of progressive waste collection techniques, and the practice of IoT and big data technologies are all factors that have fuelled the development of applications designed for operative waste management around the world. There is also the idea of improving waste management through public programs that aim to produce additional correct and harmless surroundings while dropping greenhouse gas releases.

Without a doubt, the largest antecedent of technological growth that has directed advancements in the waste management segment is the advancement of the Internet. The Internet has altered the world by allowing people to connect from anywhere in the world. Similarly, the Internet of Things (IoT), sometimes identified as the next generation of the Internet, is on the verge of bringing about significant change (i.e., the Fourth Industrial Revolution). Industry, markets, transportation, agriculture, education, healthcare, the environment, and smart cities are just some of the sectors that can benefit from the Internet of Things (IoT) depicted in Fig. 5.

In practice, however, the detection of all accessible data items received by a smart object and then transmitting the entire seized data to the cloud is a little less advantageous. In addition, such a system would be wasteful of resources (e.g., network, storage, etc.). The Fog (Edge) computing paradigm has been proposed to address this problem by relocating knowledge-finding operations based on data analytics to the boundaries. On the other hand, edge devices have limited processing capability. Neither Cloud computing nor Fog computing can tackle these difficulties on its own due to their intrinsic strengths and weaknesses. As a result, to figure out a long-term IoT structure for smart cities, both paradigms must work together as shown in Fig. 6.

Table 1: An analysis done for the highest five most crowded cities in India (Jain *et al*., 2022)

Name of city	Population (millions)	Land area (ha)	No of landfill sites	Area of landfill (ha)	Population per unit landfill area (persons/ha)
Mumbai	1.2400	60300	3	140.0	8,857
Delhi	1.1030	148400	3	66.4	16,611
Bengaluru	0.8400	74100	2	40.7	20,639
Chennai	0.7088	42600	2	465.5	1,523
Hyderabad	0.6730	65000	1	121.5	5,539

Table 2: Solid garbage created in Tamil Nadu's largest cities- Source: TNPCB report (Jain *et al*., 2022)

Major cities	Amount of solid wastes produced in T/day
Chennai	3500
Madurai	711
Coimbatore	710
Tiruchirappalli	408
Salem	330
Tirunelveli	210

Fig. 5: IoT in several vertical applications

Fig. 6: Cloud and fog paradigms collaborating to create a long-term IoT infrastructure

The proposed system can collect waste efficiently, detect fire in waste materials and forecast future waste output. An IoT-based device controls and monitors the electric bins. These devices communicate wirelessly with the central hub to send information about the filling levels of the bins to the present location. The system's key advantage is that it collects waste on time, eliminating overflowing bins and thereby preventing contamination of the environment (Ali *et al*., 2020; Ab Wahab *et al*., 2022). An ultrasonic level sensor and a variety of gas sensors are used in the recommended smart waste bin to automatically identify harmful gases and the garbage's maximum limit. The system is unique in that it is based on cloud and mobile app monitoring. It not only checks the bin's maximum trash level, but also various foul gases, which is an important component of the work. The information must also be shared with the proper authorities. This unique technique enlists the support of a cloud server because of its benefits in terms of usability, accessibility, and disaster recovery. The information can be linked to the municipality's website for immediate action. A unique number identifies each waste bin and shows its location (Misra *et al*., 2018).

A mixed integer linear programming model has been designed to determine the total number of bins required at any given location, taking into consideration numerous factors such as various types of sources, garbage bins, and waste categories, as well as safety and rag-picking. The system for allocating bins has been described and the bins are capable of serving the entire intended site. The created model is evaluated using data from an Indian city to demonstrate its use. The model's effectiveness is evidenced by a 15% reduction in collection sites, a 25% reduction in idling expenses, and a 35% reduction in carbon emissions (Rathore *et al*., 2020). An advanced automated system is included in the suggested smart waste management system, which incorporates an ultrasonic sensor within the garbage cans and a weight sensor at the bottommost. Trash can sensors determine whether the cans are empty or full, allowing garbage collectors to plan. The information gathered by the sensors is then sent to the cloud, where it is stored and utilized by various authorities. They also looked at the creation of waste management algorithms (such as Dijkstra's Algorithm and the Ant Colony System). They've also recommended the quickest route for the trash collector to collect the rubbish (Garach and Thakkar, 2017; Pereira *et al*., 2019). A sophisticated alarm system for garbage collection is in place, which sends an alert signal to the cleaner. They implemented a real-time waste management system to keep track of how full the bins are. They used an ultrasonic sensor and an Arduino Uno to track how much rubbish was in the bin and send notifications to the cleaners via their phones. This process enables people to obtain and act on information. This system was put in place to save money, make better use of resources and minimize traffic in the city (Venkatesan *et al*., 2017). This study includes field training to evaluate SWM arrangements in line with waste management standards, as well as a survey of present waste management operations, and financial and institutional demographics in six Indian Smart Cities. To gather data from local forms

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and investors for the study, a participatory method was adopted. Indicative plans for the growth of waste management systems were developed based on the findings of this study. Among the subjects mentioned to establish a combined solid waste management system for a Smart City are trash classification, funding sources, data technology, and service level benchmarking. The outcomes of this study will help local governments develop waste systems to speed up the transition to creative and sustainable waste management (VCheela *et al*., 2021). An intelligent bin that monitors waste with sensors and delivers the resulting detailed data to the internet. Sensors have been installed in the bins and these bins are linked to one another, providing data about the quantity of waste matter to the cloud, where higher establishments can utilize the data to yield necessary action on the city's rejected matter (Maddileti and Kurakula, 2020). The proposed model is a waste management system based on the construction of intelligent garbage cans and the usage of a sensor-equipped IoT prototype. These internet-connected smart bins are capable of reading, collecting, and sending vast volumes of data. The simulation results are based on real Global Information System (GIS) data (Shyam *et al*., 2017). Two sub-models are built in this study using the vehicle-directing problem concept. The first sub-model uses modern traceability IoT-based sensors to collect data in real-time, which allows the TWL parameter to be determined. The first sub-model is crucial not only for identifying an effective and creative collection strategy for achieving long-term social and environmental benefits on WMS but also for prioritizing bin visits based on their importance. Both waste sorting and transmission to the recovery value center are considered in the second model, to maximize recovery value while minimizing visual pollution (Salehi-Amiri *et al*., 2022). We presented an automatic method for developing an effective and intelligent waste management system utilizing the Internet of Things by anticipating the potential of trash objects. IoT-based dustbins can continuously monitor garbage volume, gas level, and metal level and may be deployed anywhere in the city. The proposed method can then be tested using machine learning classification techniques such as linear regression, logistic regression, support vector machine, decision tree, and random forest algorithm. Machine learning classification techniques are used to test the proposed strategy for accuracy and time analysis. The random forest method has a precision of 92.15 percent and takes 0.2 milliseconds to process. According to this data, our proposed approach, which employs the random forest technique, outperforms existing classification algorithms by a significant margin (Uganya *et al*., 2022).

The purpose of this research was to create a ground-breaking new IoT-based framework to address the numerous challenges that SWM services encounter. The framework calculates the best routes for waste pickup based on the amount of trash in the bin in real-time. The three essential components of the whole system are the smart dustbin, smart truck/vehicle, and work server. The smart bin design includes ultrasonic, humidity, temperature, load cell, accelerometer sensors, and proximity, as well as a Radio Frequency Identification (RFID) tag and wireless communication module. The smart car includes an RFID reader, a Global Positioning System (GPS), and wireless connectivity components. The work server includes a web server, database management system, route optimization, and decision-making tools. The framework's widespread use will result in lower staffing requirements and operating costs (Anjum *et al*., 2022). The Internet of Things is used to present a smart garbage disposal prediction and monitoring system that uses off-the-shelf components that can be installed to any size bin and measure fill levels. An Arduino microcontroller is used to connect the Infrared (IR), Ultraviolet (UV), and weight sensors, as well as a GPS module to monitor the status of bins at predetermined intervals. The data is sent over the cluster network to the master module, which is connected to the backend via Wi-Fi. A powerful neural network technique known as Long Short-Term Memory (LSTM) is used to learn and predict future wastage from waste generation trends as data is collected (John *et al*., 2022). Using numerous sensors installed in IoT-based garbage bins and network points, smart waste management collects rubbish as well as data associated with it. These IoT-assisted sensor devices then send the collected data to FNs in the region. Fog architecture is used by the models to help them organize their waste (Jain *et al*., 2022).

Initiatives by the States of India (Smart Utilities, 2021)

Smart Bin by the Chennai Municipal Corporation

The Chennai Municipal Corporation is putting in place a smart bin system, in which sensors are implanted in public rubbish bins to detect how much waste is thrown in them. The data is communicated in real-time via wireless networks by the sensors. A top Thiruvanmiyur Beach (Valmiki Nagar) in Chennai, five Airbin devices were mounted on regular trash cans as a test. This ground-breaking technology is likely to enter the market soon. IoT-enabled solutions are likely to help with trash separation at the site of generation in the long run.

Airbins by IIT, Madras

Urban Local Bodies are increasingly utilizing smart bins as a creative solution. Airbins is an Internet of Things (IoT)-enabled smart bin system developed by Antariksh Waste Ventures Private Limited, a start-up funded by the Indian Institute of Technology Madras. When a GPS-enabled sensor in each of these bins detects that it is full of trash, it sends a signal to officials at the appropriate contractor's/waste corporation's control monitoring room. This ensures prompt clearance and gives end users the ability to seek clearance on demand. Additionally,

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geotagging all garbage cans and pickup locations enables a more in-depth assessment of the collection process.

Smart Bin by Bhopal Municipal Corporation

A similar approach has been followed by the Bhopal Municipal Corporation. It has installed approximately 150 smart bins throughout the city as part of the Smart Cities Mission. It is predicted that the usage of these bins will make garbage collection easier and more efficient.

Artificial Intelligence-Based Sensor-Fixed Dustbins by New Town Kolkata Development Authority (NKDA)

In February 2021, the New Town Kolkata Development Authority (NKDA) announced plans to install artificial intelligence-based sensor-fixed dustbins throughout Kolkata. When these containers are full, they will stop the garbage from overflowing. Each of these smart bins will be equipped with an ultrasonic sensor, which will close the lid when the rubbish level within the bin reaches the ideal level. An alert will be sent to the competent authority's control center and garbage collection vehicles will be on the scene to collect the trash. From Nazrul Tirtha to Rabindra Tirtha, the NKDA wants to install about 50 of these smart bins across New Town.

Smart Bins by Tirupur District in Tamil Nadu

Smart bins have also been used in Tamil Nadu's Tirupur area to enable efficient rubbish collection. The effort is supposed to help keep roads clean by reducing overflowing trash cans.

RFID-Based Bin by the Lucknow Municipal Corporation

To maintain effective tracking of door-to-door waste pickup, the Lucknow Municipal Corporation has deployed RFID sensors at the household level. The RFID project in Lucknow is based on the waste management system of the Pune Municipal Corporation, which includes GIS mapping, awareness, and capacity-building programs, and the deployment of garbage processing projects.

Community Bins in Agra with RFID and GPS Enabled

As of January 2021, Agra had 1,044 RFID-tagged communal dumpsters. In addition, QR codes have been placed on 350,000 homes and GPS tracking devices have been installed on 150 key collections and vehicles. When sanitation staff remove trash from homes and scan the RFID barcodes placed there, automatic notifications are sent to the Agra Smart City office's command-and-control center.

QR Code-Enabled Door-To-Door Garbage Collection by Patna Municipal Corporation

For Rs 130 million, the Patna Municipal Corporation plans to implement QR code-enabled door-to-door garbage pickup in the city. By planting a QR code-based RFID tag at each home, the endeavour will track the routes of door-to-door garbage pickup vans and keep track of the work done by sanitation workers.

Other Initiatives

The Pune Municipal Corporation- GPS-Based Vehicle Tracking System

The Pune Municipal Corporation has developed a GPS-based vehicle tracking system for its rubbish collection vehicles. Among the system's main features are real-time vehicle tracking, alerts for excessive speeding, halt time, and fuel usage, and a web-enabled live map with playback history and route replay.

RFID Tag Enabled Vehicles at Bengaluru

All primary collection vehicles and secondary vehicles in Bengaluru are equipped with RFID tags, ensuring that only authorized vehicles are permitted to access designated locations. Bengaluru also intends to establish a centralized smart control room to supervise the city's trash management efforts. All composting plants in Bengaluru will be outfitted with 24-h CCTV camera monitoring systems, with all data being kept digitally at the control center.

The Municipal Corporation of Greater Mumbai- Vehicle Tracking and Monitoring System

All primary collecting vehicles and secondary vehicles in Bengaluru are fitted with RFID tags, ensuring that only authorized vehicles have access to restricted areas. Bengaluru also intends to establish a centralized smart control room to manage the city's waste-collecting efforts (Prabavathi *et al*., 2021). All of Bengaluru's composting plants will be outfitted with 24-h CCTV camera surveillance systems, with all data being digitally recorded at the control center.

Proposed Methodology

The complete proposed architecture could be divided into five modules as depicted in Fig. 7. A cost-effective and hygienic model called Bin Bay is proposed for monitoring waste disposal by providing a smart technology resulting in a healthy and waste-ridden environment.

Designing of the Bin and Robotic Trucks

The smart bin is built with a capacity of about 300 L and all of the necessary sensors are safely fitted in the bin.

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Sensors in the bin include an ultrasonic sensor, an MQ4 sensor, an HX711 sensor, a QS-01 sensor, and a metal oxide sensor. On the internal side of the lid, facing the solid waste, an ultrasonic sensor will be installed. The distance between the ultrasonic sensor and the trash reduces as the amount of rubbish grows (Baras *et al*., 2021). The HX711 sensor is a weight sensor that is installed at the bottom of dustbins to monitor the load. The other sensors are hidden inside a tamper-proof receptacle near the bin's brim. The MQ4 sensor is used to track the amount of methane asphyxiating gas produced by waste accumulation. Other harmful gases are detected using QS-01 and Semiconductor Metal Oxide (SMO) gas sensors. An RFID tag is also preserved to track the date and time of the truck's collection.

Setting up the LoRA WAN, Fog Nodes, and the Cloud Layer

LoRa WAN:

It's a type of Low Power Wide Area Network (LPWAN) that leverages open-source technologies and transmits over unlicensed frequency bands. As shown in Fig. 8, LoRa WAN (Long Range Wide Area Network) technology, designed for the Internet of Things (IoT), has a much longer range than WiFi or Bluetooth connections, works well indoors, and is particularly useful for applications in remote locations where cellular networks have limited coverage.

Fog Server: We relocate certain intelligence, computation, and storage resources from the cloud back to the local network with fog computing (Network Lessons, 2013). This enables us to process and evaluate data in fog nodes or IoT devices on a local level. Low latency, high bandwidth, and better security are all advantages of fog computing. Figure 9 shows how it minimizes the quantity of northbound traffic to the cloud provider.

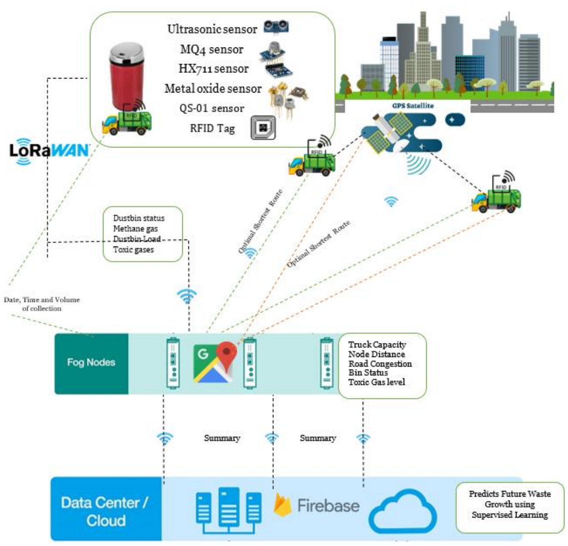

Fig. 7: Bin bay-system model

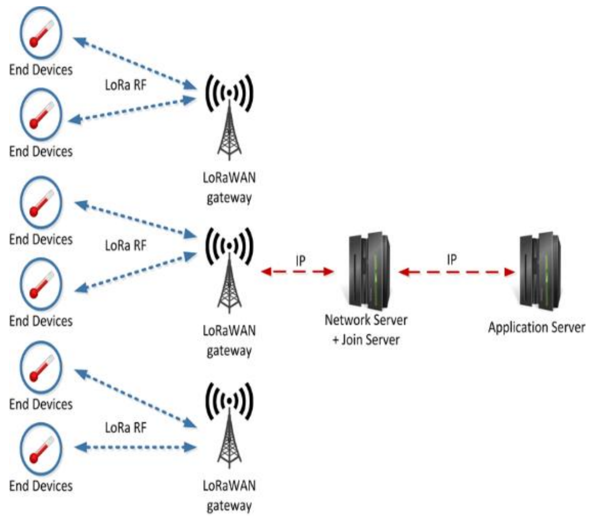

Fig. 8: LoRa gateway architecture

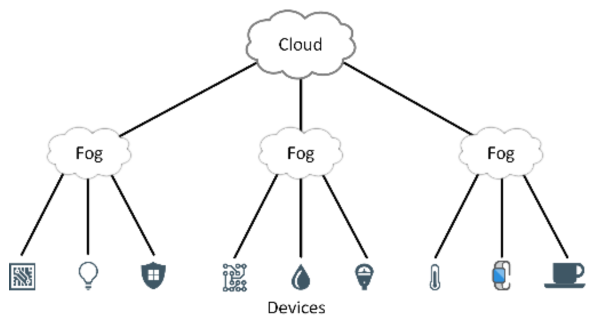

Fig. 9: Fog architecture

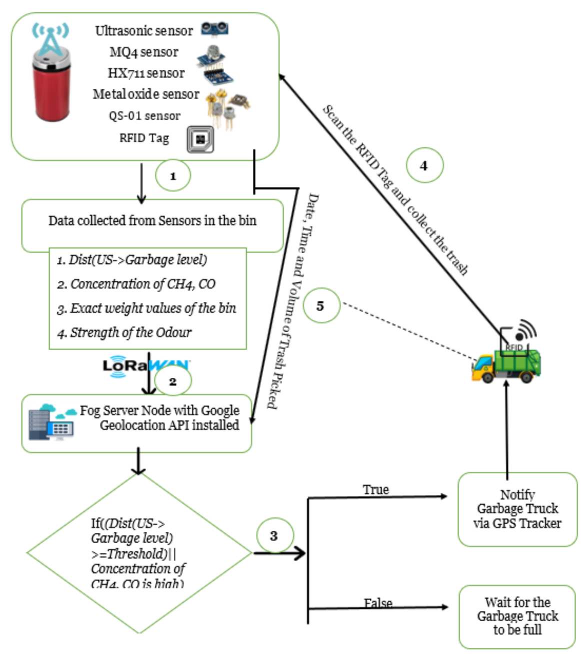

Fig. 10: Data collection and analysis steps

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A node is assigned to act as a fog server and it is placed closer to the network of the sensor devices so that data from sensors and the garbage collecting truck would be easily captured by the fog node. Google's Geolocation API installed in the fog server would be able to capture the GPS location of the truck and the ultrasonic sensor in the truck would share the truck capacity with the help of the ESP8266 Wi-Fi module. The fog server would be interfaced with Cloud servers.

Firebase Cloud Storage

Firebase is an application developer API that allows application data to be synchronized across clients and stored on Firebase's cloud. The summary of the processed data from the fog server would be transferred and stored in the firebase cloud so that the future waste growth prediction of the city would be done and services like truck availability and frequent emptying of the bins could be made accordingly.

Data Collection and Analysis

The second objective of doing an in-depth analysis using the data summary from the fog layer is done. In data collection and analysis, there are 5 major steps. The data from the sensors embedded in the smart bin is transmitted to the fog server node at the edge of the network using LoRa WAN technology (Ziouzios *et al*., 2021). The LoRa Gateway helps in collecting the data and transmitting the same to the Fog node. The primary data sent are the distance between the ultrasonic sensor and the garbage level, the concentration of methane (CH4) and Carbon Monoxide (CO) gases, the weight of the garbage, and the odor strength. Based on the data sent, the fog node analyses the data and decides on fetching a truck to empty the bin by using the google geolocation API to track the location of the truck, so that truck that is nearer to the bin could be redirected to collect the trash. The steps are shown in Fig. 10.

Data Processing and Truck Management

The third objective is to test the automation of the Bin Bay model for operational excellence in waste collection and disposal. Once data about the status of the bin is collected from the smart bin, the fog node has to activate the Google API to locate the nearest truck based on the location information from the bin. The trucks are assumed to have GPS facility enabled so that tracking the location of the truck would be easy. The truck is chosen by the fog node by comparing the distance between the bin and the truck and the truck which is the shortest distance from the bin would be given the signal to do the trash pickup (Sreya *et al*., 2022). The optimal route is passed to the truck by the Google API so that the route with less congestion is selected thus reducing the fuel consumption and emission of CO_2. Once a truck is identified, the truck using the ESP8266 Wi-Fi module has to report the truck capacity to the fog node using the ultrasonic sensor in the truck and the so that the fog server would decide on whether to send the same truck or to prefer another truck (Shanthini *et al*., 2022). The load of the bin is compared with truck capacity and only if there is sufficient space in the truck for the trash in the bin, the truck is selected. The steps involved are given below:

Requirements

The trucks are GPS enabled with ultrasonic sensors and RFID reader.

The bin has RFID Tag

The fog server has google API activated

Procedure

Step 1: If the bin is full or if the toxic gases are heavy than the threshold fixed, the fog nodes will do the following
Step 2: The fog node search for the truck
Step 3: The location of the truck is sent by the GPS module
Step 4: The capacity of the truck is sent by the ESP8266 Wi-Fi module using an ultrasonic sensor
Step 5: The fog node computes the storage space for garbage in the truck using the bin status received
Step 6: The fog node also computes the distance of the garbage truck from the bin
Step 7: The fog node also checks for congestion on the road of the truck using the Google Map API
Step 8: The optimal route is selected and the truck is routed toward the desired source

Future Waste Growth Prediction

Finally, the model is validated for efficient management of Operations, fleet, and resource. The truck once emptying the bin, the RFID reader in the truck scans the RFID tag attached to the bin, and using the ESP8266 Wi-Fi module, the truck transmits the date, time, and volume of trash emptied to the fog node. The fog server collects the data and the summary of the data is sent to Firebase Cloud using Firebase API. The cloud performs supervised learning on the data received and future prediction on the waste growth in a particular residential area is done so that resource management in terms of operation of truck and service delivery could be done efficiently. This kind of prediction tends to improve the standard of urban living.

Results and Discussion

Waste is primarily generated in both residential and industrial settings, as well as in rural and urban areas. However, traditional collection methods are done manually, making it difficult and daunting to keep our environment clean (Lu *et al*., 2020; John *et al*., 2022). Timely identification of filled waste bins for effective disposal necessitates significant human resources as well as time consumption due to frequent bin status checks. Despite the availability of waste bins in various locations, the sight of overfilled waste bins that serve as breeding grounds for pests and rodents remains an eyesore. This frequently resulted in the spread of diseases and human illness in our environment. The time has come to use smart technology for proper waste collection and disposal to maintain a clean environment for the long term (Rath *et al*., 2022).

The proposed system sends data via the cluster network to the master module, which is linked to the backend via LoRa WAN. After the data has been collected and pre-processed, the Long Short-Term Memory (LSTM) is used to intelligently learn and predict future waste generation patterns.

Forecasting experimentation is carried out to forecast the volume fill-up from the garbage station as time passes in days depicting the forecasting of waste volume production, with a training set of 15, 20, and 30 days as shown in the graph. Figure 11 depicts the garbage fill data for the previous 30 days. When increasing the days, the performance results are good compared to 15 and 20 days of forecasting waste production. Figure 12(a) and 12(b) show the performance analysis of the machine learning algorithm based on accuracy and time.

Finally, the bins are tracked using an efficient management system known as fog architecture. Fog Computing architecture combines high-performance computing power with intelligence to enable the development of smart cities. Greater business agility with the right tools, where machine manufacturers offer machine-as-a-service to their customers, better security protecting the fog nodes, deeper insights, with privacy control where privacy and secrecy are maintained, and lower operating expenses by conserving network bandwidth are all benefits of fog computing.

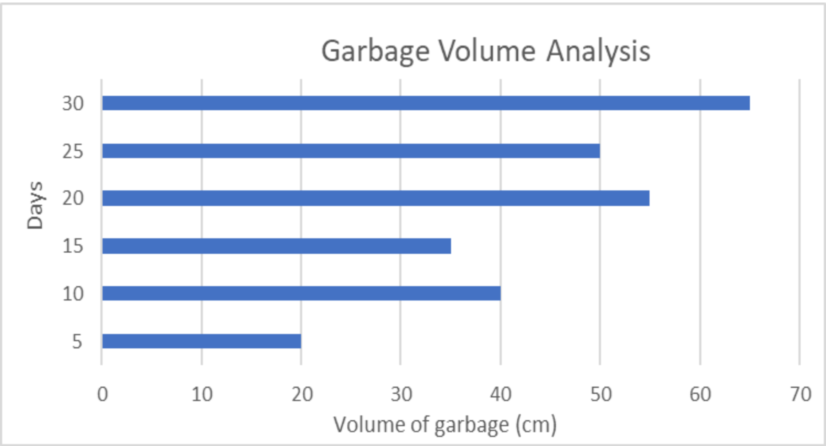
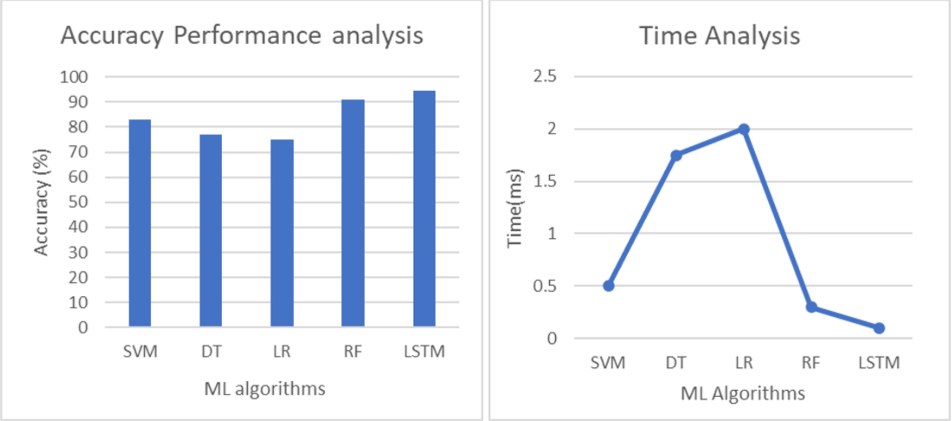


Fig. 11: Garbage volume analysis



(a) (b)

Fig. 12: (a) Accuracy analysis (b) time analysis

Conclusion

Using the Internet of Things, the suggested system would be able to automate the solid waste monitoring and management process, as well as the full collection method (Internet of Things). IoT can help cities enhance collection services while lowering costs by converting garbage management to data-driven collection systems. Bin Bay only collects trash when the bins are full. This saves a lot of energy and time, as well as pollution caused by unnecessary collection trips. Bin Bay monitors garbage can full levels using sensors and alerts city collection providers when bins need to be emptied. Sensor data may be utilized to discover fill trends, optimize truck routes and timetables and save money in the long run. These sensors are becoming more affordable, making IoT garbage containers more practical to use and appealing to local government authorities.

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Author's Contributions

Shiny Duela: Participated in all experiments and contributed to the writing of the manuscript.

Dioline Sara: Participated in framing the architecture of the Bin Bay Model.

Prabavathi: Participated in framing the literature study.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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