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The Internet of Things envisioned a waste collection paradigm.

Niraj Yadav
Dept. of Computer Science and Engineering
Graphic Era Deemed to-be University
Dehradun,India
nirajyadav733@gmail.com

Ashish Garg
Dept. of Computer Science and Engineering
Graphic Era Deemed to-be University
Dehradun,India
geuashishgarg@gmail.com

Anmol Narang
Dept. of Computer Science and Engineering
Graphic Era Deemed to-be University
Dehradun,India
ianmolnarang@gmail.com

Divyanshu Bathla
Dept. of Computer Science and Engineering
Graphic Era Hill University Dehradun, India
bathlad33@gmail.com

***Abstract*— This research explores the feasibility of utilizing Internet of Things (IoT) technology in improving solid waste management and its collection in India, explicitly increasing collection rates within Municipal Corporations. Information is collected through a literature review and examination of various sources, such as government reports and research papers. The data indicates that India generates 62 million tonnes of solid waste annually, with only 70% of it being collected, 12 million tonnes treated, and 31 million tonnes sent to landfill sites, which means about 30% of the waste generated is not collected. The study's findings suggest that integrating IoT technology in solid waste management can significantly enhance collection rates and ultimately increase revenue for the nation. The study concludes that further research is necessary to understand the underlying causes of the problem and develop practical solutions. This research suggests solutions for managing garbage and trips in cities, resulting in a more efficient route for rubbish collection while lowering cost and time.**

Keywords—IoT, Solid Waste Management, Shortest Path Spanning Tree, Municipal Corporation

I. INTRODUCTION

The Internet of Things (IoT) is a system of connected devices that can share data and perform actions. The Internet of Things is a broad term that includes everything from smart fridges that can order groceries when they sense you are running low on milk to connected cars that report traffic conditions.

The Ministry of Housing and Urban Affairs aims to create economically vibrant, inclusive, efficient, and sustainable urban habitats. Ministry can achieve the vision of a smart city by working closely with ICT and IoT technology to help a city be safe and manage its assets. An intelligent city includes an innovative economy, people, governance, environment, business, and mobility. It provides quality of life for its residents. The world's population growth over the years has caused various problems for society, including deforestation and global warming. Still, the most worrying one is that city need more clever solutions for trash management since improper garbage disposal and discards may have several negative repercussions. Residential garbage is collected using rubbish bins at a usual location along a road or in an area. One of the most challenging chores in garbage collection is inspecting the trash cans. It sounds simple but it becomes a very tedious task to spot every such dustbin and collect waste because this process is time-consuming and in this process lot of manpower is used to spot filled dustbins and collect wastes. The major goal of the investigation and determination was to characterize the current system management activity and waste [1]. The implementation of various Internet of Things (IoT), including RFID tags, weight sensors, and ultrasonic sensors integrated with bins. Up until this point, no discussion has been held regarding the most cost- and energy-effective route for vehicles to take when collecting waste [2]. Though various approaches that can be used to optimize waste collection routing, including standard GPS-based route optimization, GIS-based waste management systems, and item RFID-based Collection, Detection and Segregation systems. However, no reliable and cost-effective optimized routing for waste collection has yet been achieved [3]. The sensor aids in determining the volume of rubbish at its highest point are observed [4]. The development of smart bins and the effective conveyance of data utilizing new technologies and the integration of IoT, such as NFC (near field communications), WSN (wireless sensor network), RFID, and GPS. Vehicle scheduling and route for rubbish collection are poorly optimized and are given very little weight but the

routing is only done for one bin at a time and in this way, it is using a lot of vehicles, manpower, and fuel is also done for collection of waste from various bins installed across the city [5][6]. One approach to solve this bottleneck is every time person eager to throw garbage into the bins, they must use their credentials wisely for doing so, and every collecting vehicle has been assigned their geographical area from where they must collect the waste [7]. An intelligent waste management system based on the IoT is presented from the perspective of India. It provides real-time dustbin status information. Both the degree of toxicity and the dustbin's percentage filling are measured. The website stores information about the dustbin's toxicity level and fill percentage so it can be accessed anytime. This database is regularly updated with time and date to ensure accuracy. When the trash can is full or the level of toxicity is excessive, it notifies the person who should be informed. There is no mention of garbage collection in this model [8]. It is the simplest solution for this as of right now. A proposal for an automated waste management system architecture has been made, with that as the basis. In the suggested model, intelligent bins are placed at an appropriate distance from one another and incorporate a GPS module. Using the camera mounted on the buses, pictures of the bin are rapidly taken and sent to the cloud with the assistance of city transportation buses. Image processing is then used on the cloud image to monitor the container's level. When the queue request from the surrounding areas meets our threshold value, the vehicle is directed for waste collection.
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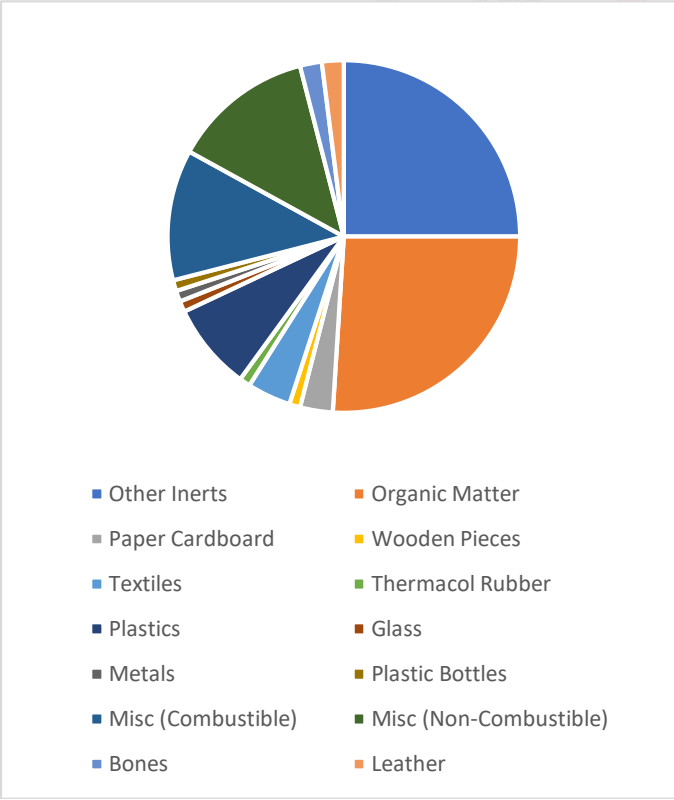


Fig 1. Waste management statistics of Indian state

Fig 1. Demonstrates how a portion of municipal solid trash is transported to Uttarakhand and the Himachal Pradesh area of India. Organic matter is the most critical component, followed by various inert, non-combustible, combustible wastes and so on.

II. LITERATURE SURVEY

This concept has been introduced previously; IoT-based dustbins have been used and put into practice much earlier. Some writers described systems that used sensors within the trash cans to determine whether the container was empty.
The Arduino board is equipped with a SIM module to send messages automatically. When the dustbin is complete, the server receives a statement from the application. Once the server gets the news, it is transmitted to the worker in charge. If the person is available, they would accept the assignment, indicate their availability, and go to the specified location. If the original worker is unavailable, the task is assigned to another worker.
Some writers also used intelligent trash cans to monitor the amount of fill in trash cans as part of a real-time waste management system. There needs to be a plan for the effective collection and disposal of garbage gathered from multiple sources in this system, which is why writers primarily focused on integrating bins with IoT sensors.

Several models have been proposed in the past with the proliferation of IoT accounts to improve the waste management system. Still, there is no reliable model that, with the help of technology, becomes more cost-effective, fuel-efficient, and highly reliable. Some authors have proposed their model, which talks only about the intelligent bin. Some are there who have spoken about the real-time waste collection but have yet to inform about the proper disposal and recycling of waste. After learning from these mistakes, many authors have tried to propose a model that concentrates mainly on the collection and disposal part. Still, most of the models are unreliable so everyone needs to improve their innovative waste management model. The conceptual model for innovative management of garbage bins, which comprises proper monitoring of smart bins and proper collection of waste from different sites and its dumping, has been created. The model prioritizes allocation of vehicles and use of optimized routing algorithms for fuel-efficiency and cost-effectiveness, and wisely choosing IoT sensors to be implanted in bins. The study aims to address the significant concern of garbage bins in today's life and in the near future, and a cost-effective, environment-friendly model for detection and disposal of waste has been developed.

In summary, the literature review highlights that the concept of IoT-based dustbins is familiar and has been implemented in various waste management systems. Some authors have focused on using sensors within the trash cans to determine whether the container is empty, and others have used the Arduino board and SIM module to send messages to workers in charge of waste collection. However, despite these advancements, there currently needs to be a reliable, cost-effective, and fuel-efficient intelligent waste management model. This study aims to address this gap in the literature by proposing a conceptual model for innovative garbage bin management that considers both proper monitoring of the bins and effective collection and disposal of waste using optimized routing algorithms and intelligent sensor technology. The proposed model is designed to be cost-effective and environment-friendly, addressing the significant concerns of waste management today.
Relevant articles were studied to understand the current situation, how things are being done, and where there might be improvements. Context was gained, and potential areas for improvement were identified through this process. The following is a review and summary of many related works.
They emphasized mostly collection. The primary goal of the investigation and determination was to characterize the current system management activity and waste.

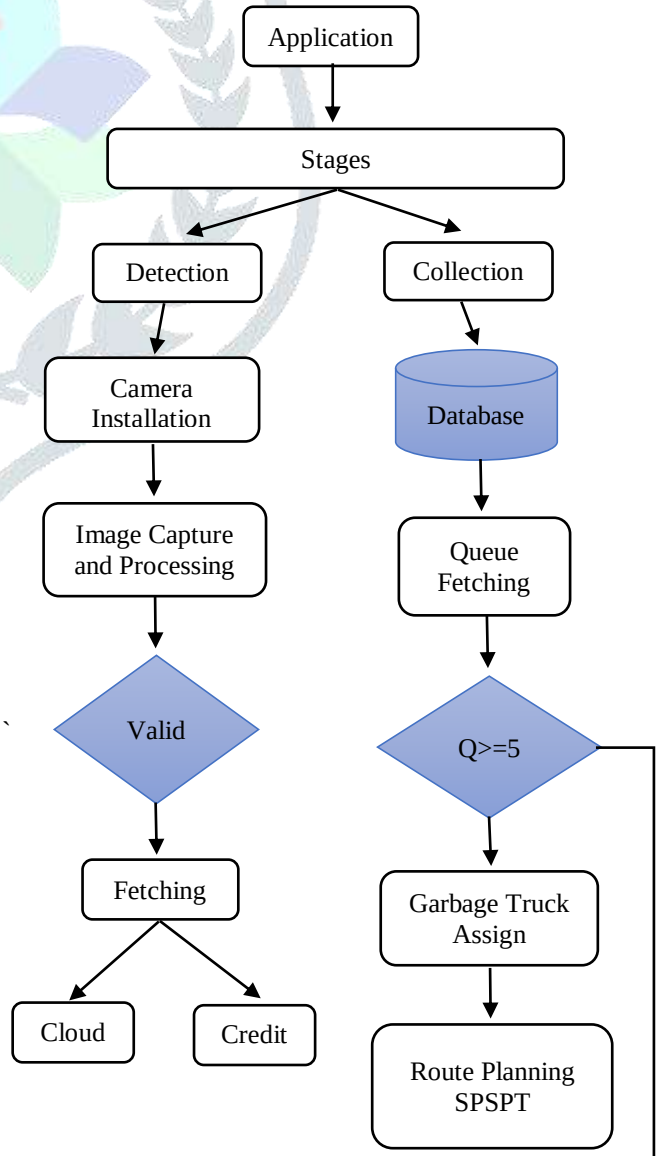
V. Ganapathy et al. [9] developed a prototype in which he connected the bins through the IOT based application which store the information about level of waste present in bins so that specific routes are given to cleaners and collectors so that cost can be waste management cost can be reduced. K. Nirde et al. [10] have proposed a model of smart dustbin where he introduced the concept of usage of ultra-sonic sensors to detect the level of waste present in the dustbin and the result shows that status of dustbins is accurately displayed on the screen. P. Bharti et al. [11] proposed a model of smart waste management by calculating the level of waste and storing the data into the database using the internet and finding the optimized route to collect waste from the filled dustbins. A. Gopi et al. [12] proposed a reliable and cost-efficient model in which they used two ultra-sonic sensors in which first sensor collect the information regarding the level of waste present in the dustbin and another one is used to automate the process of opening the lid to detect if someone is approaching near to bin. Both the sensors are controlled by Node MCU, and the data collected by the sensors are stored and monitored using the Blink app. W. Chen et al. [13] proposed an infrared based mode which detects the unpleasant smell along with the level of waste and transfer the collected to the monitoring body so that they can schedule garbage collection through an optimized route. F. Hasan et al.[14] proposed a waste management model which detect the type of waste present in the dustbin like liquid, metal, plastic etc. which include a capacitive proximity sensor, inductive proximity sensor, and a water level indicator sensor and all the data sensors can be monitored using mobile app. A. Razdan et al.[15] proposed the model which is based on sensor system. The sensors are used to measure the level of waste and to connect the IoT devices with the sensor microcontroller have been used. L Catarinucci et al. [16] proposed a Radio Frequency Identification tag equipped model which uses cloud computing to upload the store data for monetization so that required actions can be taken by municipalities for proper waste management. M. Irfan et al. [17] proposed a model which can detect the fire in the waste and to predict the future waste generating. Also, this model can measure the garbage level and using cloud computing it is able to store data which can be used to decide optimized route to save the waste management cost.

Current waste management problems include the disposal of collected trash into landfills, which accumulate over time. Global warming is exacerbated by the production of numerous hazardous gases, including carbon dioxide and methane, raising the earth's temperature daily. Solid, industrial, and medical garbage are all improperly handled and left on the side of the road for many days before collection, which leads to several ailments, such as parasite infections, lung infections, skin infections, and many more. Resources that are now available in our country's waste management system need to be used more effectively (ex: different use of human resources for a simple task). A mark of inefficiency is left on our nation's waste management system by the improper routing of the trucks used to collect wastes, which results in inefficiency, delays, fuel and money loss. People toss their domestic trash on the neighbouring open ground, which eventually turns into a landfill since there is no set schedule for rubbish pickup from the neighbourhood or society. Additionally, after reviewing numerous surveys and keeping in mind the flaws in the current waste management system, the system's creator proposed a plan that introduces optimized routing of vehicles using specific shortest path spanning tree routing algorithms. In this system, vehicles are deployed after filtering requests from the queue of nearby areas from the data centre after processing the images. Our model has further optimized this and deployed single vehicles in neighbouring areas if the status of bins becomes complete simultaneously, giving it an advantage over all other models proposed for waste management systems using IoT. Work has been done on the optimized routing of vehicles for waste collection, but they did this for single bins, which won't be of any help.

III. PROPOSED MODEL.

IoT devices are physical objects with sensors and processing ability, as well as software that allows them to connect and exchange data with other devices and systems over a network. Remote monitoring and control of these devices can be enabled by this connectivity or alerts can be received when something isn't working correctly. Help can be provided by the incorporation of IoT infrastructure and a waste management system that operates in real-time. Still, with the incorporation of IoT, many challenges need to be eradicated to create a flawless and reliable waste management system.

The internet of things has been applied in various sectors (Health care, Automobiles, Electronics, Farming), which directly or indirectly has improved the daily problems of societies and has reduced workload. Considering these vast applications of IoT, it can become handy in the community's waste management.



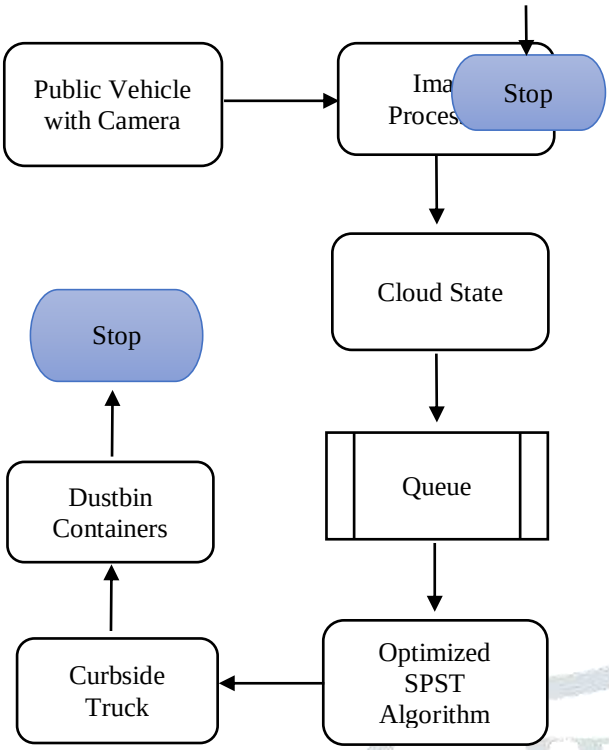


Figure 3: Proposed methodology

Fig 3 gives a brief idea of the proposed method, and each of its components is briefed below:

Sensors: Initially, the level of bins is monitored using cameras installed on different government vehicles, which are processed using image processing. Secondly, the location of different bins installed in every nook and corner of the city is known by using a GPS module.

Image processing: The different images captured from several bins are processed using image processing from other vehicles from time to time. By processing these images, the level of the containers is known and acted upon accordingly.

Database: Cloud storage is used for the collection of all the data that is being collected from time to time from several bins by our sensors and different vehicles.

Queuing: The queuing of requests for vehicles is carried out in our model to increase fuel efficiency, and it has been devised to minimize the wastage of manpower and fuel energy. In this model, requests are queued for a minimal amount of time, and after analysing the queues, the requests from neighbouring areas are filtered and screened before vehicles are allocated. This proposal is more efficient and cost-effective than previous work.

Optimized algorithm: The optimized route plan for the collection of the waste is done by the server end after the processing of the identification of dustbins, using the SPST algorithm.

Advantages:

1. Proper collection and processing of information is done

2. Shortest path-spanning tree practical routing algorithms increase the model's fuel efficiency and time-saving power.

3. Real-time monitoring and collection of wastes from different nooks and corners of the city.

4. Wastage of human resources has been reduced in this model.

5. Proposed model is more cost-effective since significantly fewer sensors are embedded in the bins. It's fuel efficient and, at present, the most reliable model.

IV. IMPLEMENTATION

The server uses the shortest path spanning tree algorithm (SPST) to optimize waste-collecting vehicle routes.

In G, the shortest path from s to v (where s is the root and v is any vertex) is the path with the least weight of edges. The problem is to find a spanning tree with a minimal length of the route from s to v.

Decoding the statements of the algorithms, it states to consider the streets as a graph and the street segment as edges and joining points as vertices of the chart, and after deducing this from the algorithms. The shortest travelling distance from two locations is found and in order to achieve the path optimization process faster, distance from one to all neighbourhood waste bins is calculated.

Inputs: Distance from containers to officer's place.

Output: Optimized routes for waste collection between two points.

Description:

1: According to the algorithm, states consider the street a graph.

2: The street segments are edges, and the joining points are vertices.

3: Calculate accurate shortest travelling distance between two locations using the SPST algorithm.

4: Calculate the distance from one-to-all neighbourhood waste bins to speed up route optimization.

V. RESULTS

The proposed approach in this study utilizes the shortest path spanning tree (SPST) algorithm to optimize waste-collecting vehicle routes. The SPST algorithm finds a spanning tree with a minimal length of the way from a starting point to a destination point. It is achieved by considering the streets as a graph, where street segments are represented as edges and joining points as vertices.

The algorithm takes the distance from waste containers to the officer's place as input and uses this information to calculate the accurate shortest travelling distance between two locations. Additionally, the algorithm calculates the distance from one-to-all neighborhood wastebins to speed up the route optimization process further.

This approach's results have effectively reduced the time and money spent on waste collection. Using the SPST algorithm to optimize routes is a novel approach to solve the problem of optimizing waste-collecting vehicle routes. The proposed method can potentially improve the efficiency of waste collection and reduce the environmental impact of waste management. The team plans to expand this concept to cover state public transport vehicles in the city and local public transport operators, such as auto-rickshaws, trucks, and e-rickshaws.

VI. CONCLUSION

In conclusion, this study proposed an intelligent waste collection system that addresses the issues identified in existing works. The system utilizes a GPS module and image processing technologies to monitor the level of rubbish in a container. A bin's location is monitored based on the quantity of garbage recorded. Path optimization is done on the stored data to reduce time and money compared to previous studies significantly. The results of this study have laid the foundation for future works that may include automated bin positioning. The team aims to make Phase 1 (Detection) more

scalable, reliable, and maintainable while expanding the concept to cover state public transport vehicles in the city and local public transport operators, such as auto racks, trucks, and e-rickshaws. A solution that solves one of the biggest problems in our society is hoped to be created through technology and collaboration. Additionally, the system includes a rewards program for drivers, through which they can earn credit points for properly disposing of waste, which will be visible to other drivers, encouraging competition and further participation in the program. It helps to increase the effectiveness and efficiency of the waste collection system and ultimately create a cleaner and more sustainable society.

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