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RFID and IoT Enabled Framework to Make Pune City an Eco-friendly Smart City

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ABSTRACT

The increasing volume and complexity of waste associated with the modern economy pose a serious risk to ecosystems and human health. Due to the intensive increase in computation, Machine learning is popular. Intelligent solid waste management motivates the Swachh Bharat mission to celebrate the 150th anniversary of the birth of Rastrapita Mahatma Gandhi. In the context of smart city development, an innovative means of implementing smart solid waste collection is to improve daily solid waste collection at the household level. An intelligent solid waste collection system will be implemented in the Smart City to improve solid waste collection. It is required to educate households about solid waste handling. Municipal Corporation can implement an innovative PPP model as part of an independent India campaign to motivate startup entrepreneurs, which will generate jobs in India.

The city of Pune is in a phase of intelligent urban mobility development to improve citizens' living standards. Ensure safe traffic management, adequate water supply, smart amenities, and services such as the intelligent collection, transport, and processing of solid waste.

RFID and IoT base IT solutions have the potential to develop sustainable, innovative technology to achieve 100% household collections and transportation and treatment of waste so that to minimize waste to send landfill side.

INTRODUCTION

Through a region-based development project, the Pune Smart City will implement the Zero Waste project at the ward level under the Swachh Bharat Assignment (Swachh Bharat 2014). The 90000 household data gathering process is ongoing. Collecting waste door-to-door and identifying the source of the waste is not sufficient information available in any place 100% collection. At the present PMC, the total footprint extends to 518 square kilometers (Times of India 2021). It is estimated that the amalgamation of 23 villages increased the town's population by more than 2 lakhs, according to the 2011 Census. In the current situation, it is not feasible to physically control and maintain a record of waste collection. Pune is among the fastest-growing cities, generating between 2100 and 2400 tons of solid waste daily.

Consequently, it is compulsory to ensure the proper collection and transport of waste in instruction to prevent the dumping of hazardous waste in the surroundings. The proposed work focuses on assessing the detailed process for managing solid waste, for instance, collecting, storing, segregating, transporting, handling, and dumping consuming geospatial tools such as remote0020sensing, GIS (Anagal 2009, Municipal Corporation of Pune 2011, Khadke 2018) and GPS (Das & Bhattacharyya 2014, Jaybhaye et al. 2014, Hannan et al. 2011). It can potentially underwrite urban ecological surroundings in the city of Pune. The Municipal Corporation of Pune has issues like D2D (Hemalata 2011, Mundhe et al. 2014, Kumar et al. 2009), solid waste collection, segregation, control, monitoring, and disposal. The grouping of RFID (Kaushal et al. 2012, Mohan et al. 2016, Kumar & Agrawal 2020) and IoT computing solutions can achieve a 100% D2D collection of separate waste (Municipal Corporation of Pune 2011). Due to the continued growth in population density in urban areas, the Corporation of Municipalities does not achieve 100% of the home collection. As a result, the population density is increasing in the major city in the Maharashtra region, affecting 27 municipal corporations in Maharashtra and the existing municipal corporation waste collection infrastructure (Rahman et al. 2022).

Nevertheless, this region is one of the cities in Pune. Several municipal companies in India face this challenge

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to achieve 100% door-to-door (D2D) coverage and collect isolated municipal solid waste. Moreover, the population and rapid urbanization are increasingly difficult to health and environmental problems due to the huge amount of waste generated (Parhi 2018). However, the Municipal Corporation of Pune exerts significant additional pressure on infrastructure services by adding 23 new villages within the boundaries of the Municipal Corporation. India is experiencing significant urbanization, currently 31% based on the 2011 census (Mania & Singh 2016). From literature, surveys concluded in Maharashtra observe that most urban local bodies (ULBs) in Maharashtra are unable to achieve 100% D2D primary collection, segregation, secondary transportation, treasury treatment, and final disposal of municipal solid waste due to insufficient financial and institutional recourses and integration of technology debilities. In addition, LUBs in Maharashtra rarely have resources such as technology infrastructure and appropriate innovative strategies to improve the solid waste collection process. Scientific collection of waste is separated from every household daily from its doors, apartment doors, and communal garbage. Technological differences between segregation methods, collection, transportation, and monitoring in this waste collection process f.2

ace major challenges (Anagal 2009). Its inadequate follow-up on waste collection and inappropriate disposal is a global environmental challenge that disrupts urban ecosystems. That is why 100% of the achievement of D2D collection of segregated municipal solid waste daily is the most important priority for the addition of new villages Municipal Corporations other than the negative effect on the local infrastructure of ULB (Kumar & Pandit 2013)

MATERIALS AND METHODS

Past Studies on the City of Pune

Pune is situated in the Deccan Plateau region at about latitude 18°32" N and longitude 73°51"E, height range between 550-565 m (average 1835-1845 ft) above the sea level. The topography of the city of Pune leans slightly westward and towards the natural flow east of the river banks Mula and Mutha. The town of Pune is the 6th largest computer industry center in India. The topography stretched the city limits of Pimpri Chinchwad and the out of seven three military cantonment boards in Pune cities, such as Pune, Dehu Road, and Khadki. The Pune Metropolitans Region (PMR) stands to the right and left of the Mula River, Mutha (Rode 2018)

Pune is India's first city to receive an "Easy Living" rating. The city is believed to be the cultural capital of Maharashtra. It is also known as "East Oxford" and is now in the presence of several prominent academic institutions. The city has emerged as an important educational center recently, with nearly partial world students in the student country in Pune. Information technology, education, management, and training schools attract students and professionals from India and other countries (Kumar & Pandit 2013)

Growing Population in Pune

The population growth of Pune is growing steadily from 1901 to 2017 shown on the chart above. However, the simultaneous area of town also increases, and waste generation at the household level should be increased to affect the solid waste collection system and collection method. Moreover, out of 23 villages in the municipal Corporation, additional charges on its infrastructure and environmental problems have also increased (Mundhe et al. 2014)

Municipal Waste Challenges in Pune

The growth of waste generation as a by-product of economic development has given rise to different subordinate legislations. According to a report by IIT Kanpur (2006), it is possible to recover at least 15 percent or 15,000 tonnes of waste produced daily in the country. In addition, specific forms of waste are regulated separately and require distinct conformities, mostly like authorizations, maintenance of records, and adequate disposal mechanisms (Anagal 2009). According to the report, it could provide about half a million rag pickers employment opportunities (Anagal 2009). The report adds that despite the huge potential of large cities in the region, the involvement of associations or communities is limited. In Indian cities, people are not serious about the waste management rules 2016 for collecting household user fees and cooperating with waste collection workers.

Additionally, it should provide separate waste, such as wet and dry, daily. When biomedical waste is expected to be generated at the household level, it should be segregated and delivered separately to waste pickers. However, the reality on the ground shows that some people enjoy advantages such as inadequate monitoring of the waste collection process door to door and collection of user fees. So, it is the limits of the Municipal Corporation to keep a record of daily waste collection door-to-door in biological and home-to-home monitoring regularly is not possible in the ground situation. Therefore, that miss benefitted people disrupt municipal corporations surrounding the environment, like dumping waste at road site amenities, vacant land, barren government land, corners of the road, outskirts of road, crime spots, community bins, etc. This problem of Municipal Corporations at the primary stage of the waste collection process should be required based on RFID unique user identification with

the IT solution. To build the IT infrastructure at the primary stage and to track the collection, transport, processing, and disposal of waste, regular and timely measures will be taken to improve the waste collection process. It is a societal need to solve the problems caused by overflowing landfills, which are impossible to recover because of the disorderly way of immersion (Kumar et al. 2017)

Meanwhile, the amount of MSW-generated waste dumped on the outskirts road depends on many factors such as dietary habits, community living standards, level of commercial activity, and seasons. Determining quantity change and production is useful when planning collection, transportation, and disposal systems (Das & Bhattacharyya 2014). Moreover, the population and Prediction of MSW generation are directly proportional to municipal corporation waste collection infrastructure, so it plays an important role in waste management. The waste generation predictions depend on the implementation level of the municipal corporation effectively and efficiently of tracking waste collection, monitoring, awareness, and education are more speciously attributes affecting waste generation (Das & Bhattacharyya 2014) and untreated MSW become a factor in the spread of countless illnesses (Kumar et al. 2009).

Waste Segregation at the Household Level

Another option to effectively and efficiently manage solid waste is to separate its waste at source into categories such as recyclable waste, biodegradable waste, etc. More than 60% of household waste is biodegradable (Fig. 1). Furthermore, the water content is too high for waste, requiring extra incineration fuel. If these wastes are insulated at the source, composting under natural conditions or in engineering reactors can be carried out efficiently and economically. This will make the overall system effective by using a biodegradable portion for composting and a non-biodegradable portion of the landfill (Kumar & Pandit 2013).

The PMC divides 5 zones for the administrative division of the area, which is under 15 ward offices; each zone has 3 ward offices and 76 subdivisions of wards for the Electoral. The five zones' primary collection waste was collected at the 07 transfer stations and then separated as wet, dry, and mixed waste (Hemalata 2011). Transporting waste from the transfer station to the recycling industry includes RDF, biogas, composting, waste at the energy plant, etc. The remaining residue, like debris, is sent to the landfill site for scientific disposal of waste at landfill sites. In that process, various types of waste should be collected at the primary stage by a waste picker properly at the household level daily to minimize waste sent to landfill sites.

Table 1 shows the amount of household and household waste collected in that information is 100% properties wise waste collection, and information on daily waste given to the waste picker is insufficient for the effect on the sounding environment and aesthetic view of the city. Moreover, waste collected from out courts of road and street

Table 1: Segregation of waste at household level.

Zone Name	Ward name	No. of HH.	Amount of waste (tons.day^{-1})	No. of HH, SWM is segregated.	% of HH SWM segregated
1	Nagar Road	77151	167	73293	95.00
	Yerwada Kalas Dhanori	72121	130	59860	83.00
	Dhole Patil	44357	98	34598	78.00
2	Aund Baner	69435	130	65963	95.00
	Shivajinagar Ghole road	40268	110	31409	78.00
	Kothrud Bawdhan	76935	135	64625	84.00
3	Dhankawadi Sahakarnagar	62667	120	58280	93.00
	Sinhagad road	96102	118	76882	80.00
	Warje Karvenagar	59906	117	58109	97.00
4	Hadapsar Mundhwa	79533	105	62831	79.00
	Wanawadi Ramtekadi	73481	148	51437	70.00
	Kondava-Yewalewadi	58870	100	51806	88.00
5	Kasaba Vishrambaug	53120	105	43027	81.00
	Bavanipeth	57985	110	37600	64.84
	Bibwewadi	44795	120	40763	91.00

(Source: PMC 2016-2017).

swiping is increasing continuously at the ward level (Parhi 2018).

Overview of Primary Collection Data of PMC Around a Municipal Corporation

Fig. 2 shows the primary collection data for the city of Pune and around the municipality of Pune.

Fig. 2 above shows a review of the city of Pune for the current state of primary solid waste collection by the munic-

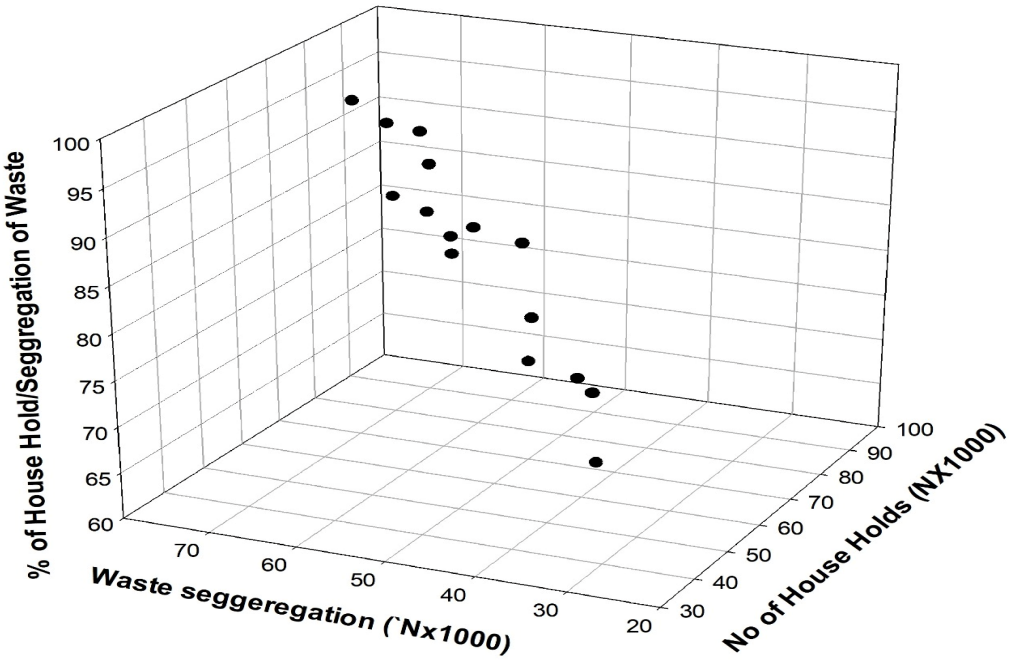

Fig. 1: PMC % of waste segregation in households.

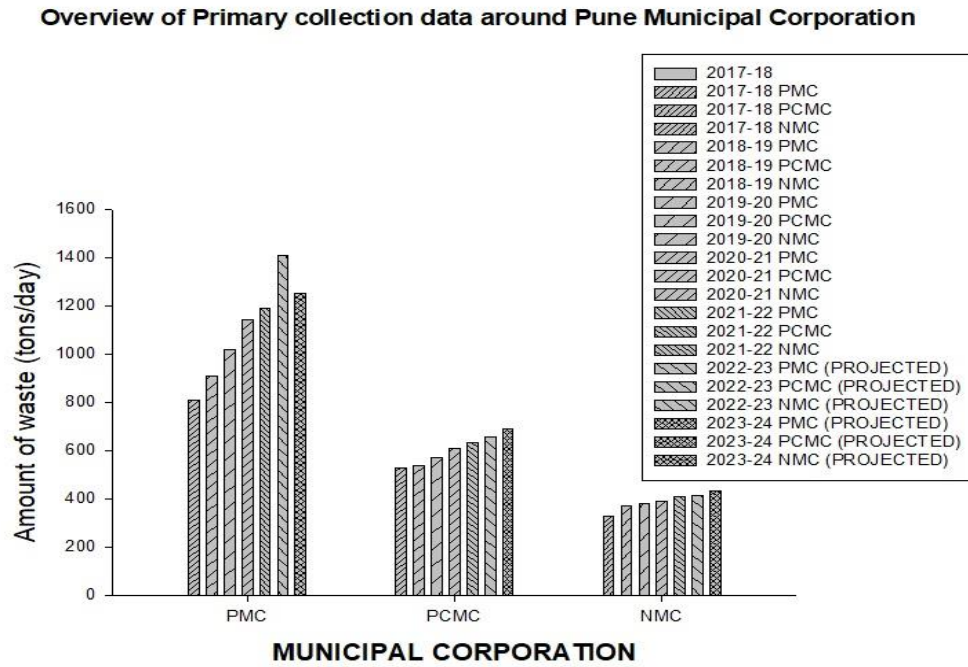

Fig. 2: Overview of primary collection data of PMC around Municipal Corporation.

ipality. The above literature survey reviews three municipal corporations around Pune city, Pimpri Chinchwad Municipal Corporation, and Nashik Municipal Corporation. When collecting all municipal data, take the waste collection data for the past three years and find the statistics for the next three projected years. It shows that waste collection should be continuously scaled up with all previous and projected municipal statistics.

Overview of Collection from Households Data of PMC Around Municipal Corporation

The chart below shows the collection of household data for the city of Pune and around the municipality of Pune.

Fig. 3 shows a review of the city of Pune and the city of Pune concerning the current state of household solid waste collection by the municipality. The above literature survey reviews three municipal corporations around Pune city, Pimpri Chinchwad Municipal Corporation, and Nashik Municipal Corporation. When collecting all municipal data, take the waste collection data for the past three years and find the statistics for the next three projected years. It shows that waste collection should be continuously scaled up with all previous and projected municipal statistics.

Reason to Collect 100% of Separated Municipal Solid Waste at the Door

The following reason behind the 100% municipal solid waste collection at the door level in the collection of primary waste daily is timely waste collection and identifying the source of the waste collection.

Following reasons for unable to achieve 100 % collected door-to-door solid waste

1. Waste is thrown at Chromic Sites daily.
2. Unevenness in waste user fee collection.
3. Daily waste is not given due to the Laziness of citizens.
4. Multi-storage building common collection not done properly.
5. Daily waste collection time and office time are different.
6. Waste is not segregated at the household level
7. Multiple days of waste to be stored in the plastic bag

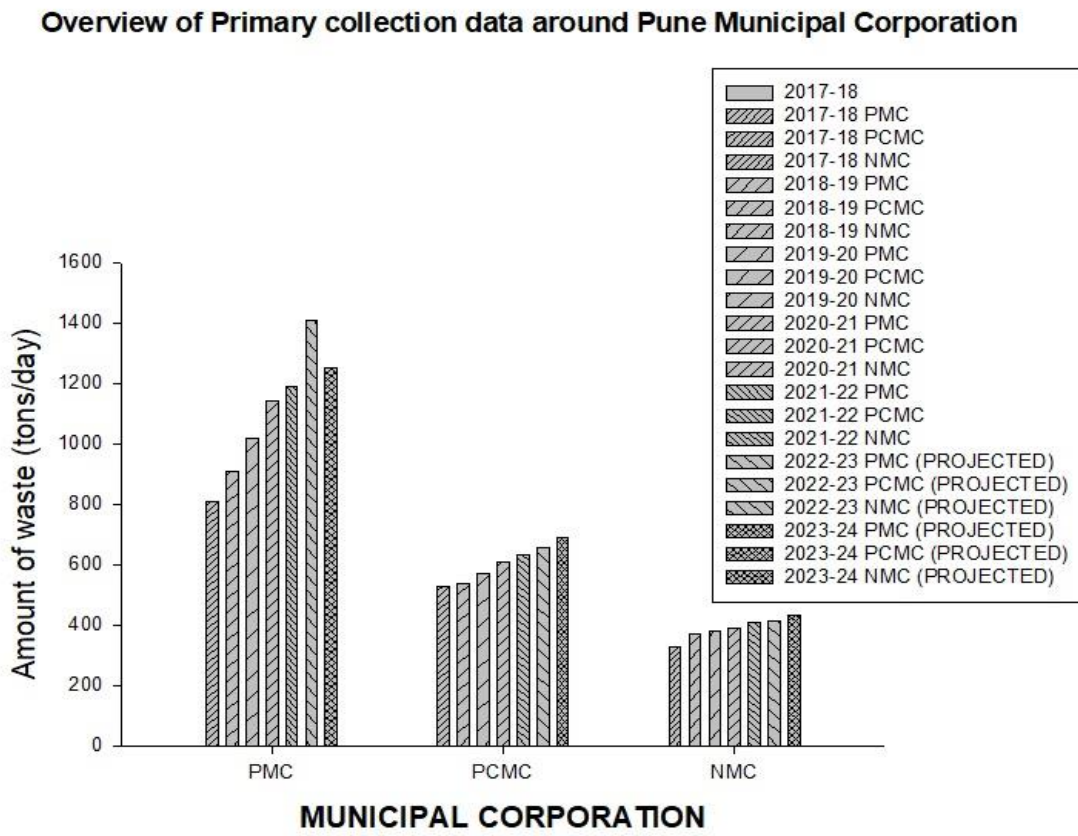

Fig. 3: Overview of collection from households data of PMC around Municipal Corporation.

Research Gap

1. Unscientific handling of MSW
2. Development of IT Solutions at the primary stage waste collection process
3. Insufficient waste monitoring and handling process
4. Development of an Eco-friendly, sustainable solution
5. Cleanness Training and Education of rag-pickers
6. Inadequate human resource management.
7. Development turnkey project BOT, PPP Mode

RESULTS AND DISCUSSION

To Collect 100% Door to Door collection of segregated waste by using dustbin tracking. The use of IT solutions in the door-to-door collection of Municipal solid waste management is needed now a day because the waste generation rate increases continuously in developing countries like India. Information technology in waste collection means integrating all technology available in modern electronic devices like RFID, GPS, GIS, ESP32 Wi-Fi Module, Web Portal, Data Center, Android application, etc.

Concept of D2D Collection of Municipal Solid Waste

This is the collection process of Municipal solid waste through waste pickers collecting waste from each household property daily rutting process is called the door-to-door (D2D) collection of urban solid waste. In those processes, waste pickers play an important role in waste collection. This is a regular process. Waste pickers' daily collected waste when reaching near the household property waste pickers announcing that time households are given to waste to the waste pickers. Those who are presented are given waste to the waste pickers, but those who are not present will be given the next day. This is an overall process of door-to-door (D2D) collection of urban solid waste (Municipal Corporation of Pune 2011).

Technologies Available for Achieving 100 % Door-To-Door (D2D) Collection of Solid Waste

To achieve 100% door-to-door collection by using technologies, it is possible to monitor and track the waste collection system. The technologies are available with us to meet this high demand for solid waste collection within the above limits. The use of High-tech communication technologies, solutions such as RFID for unique identification of households, ESP32 Wi-Fi Module for real-time information sent to sever, GPS for exact ground location, and GIS for geographic information that location must be used (Hannan et al. 2011) This research paper discusses available technology for achieving municipal corporation 100% door-to-door (D2D) primary collection, segregation, and secondary transportation of solid waste. The use of, Radio frequency identification (RFID) with an IT solution has the potential to meet the municipal Corporation's objective. Consequently, the integration of RFID, ESP32 Wi-Fi Module, GPS, GIS, Android application and Web application, data center, etc. They are used for communication technologies to collect solid waste from households daily, segregation, and transport system. RFID, GPS, ESP32 Wi-Fi Module, GIS, and the camera have been incorporated and developed into the smart bin and smart solid waste garbage collection truck surveillance systems. This article shows the innovative, sustainable theoretical framework and interface logical algorithm between communication technologies, electronic devices, and logical software technologies interface reading graphically. All parameters used in this prototype, such as RFID passive tag, RFID long-range reader, ESP32 Wi-Fi Module connectivity, and GPS and GIS, were developed to implement the user-friendly prototype. The interface algorithm can control the server on the back end, analyze the trucks' location, estimate the waste's weight in the bin, and Co-relation between its surrounding area database GPS coordinator. In this way, the proposed system could address the problem raised by a sound solution.

The Function of GPS/GIS

GPS in the waste collection relates to the exact ground location with available GPS coordinates in a dataset. The GPS coordinator data set is used to create a new waste collection route and a map with the GIS position on the ground so that tracking is easy for the integrated waste collection process. The GPS is a set of US government satellites revolving around the Earth. It is used for navigational purposes. Satellites regularly transmit radio signals to GPS receivers before receiving the data system. Review 3 to 4 satellites at the ground station and then analyze and display the exact position, speed, and time. The GPS works precisely in any climate condition, terrain, day or night, 24 hours a day, and around the globe. The use of GPS in various applications for tracking the vehicle's position on an electronic chart, like to assist waste collection van drivers in setting and selecting a waste collection route with their tracking position. Modern systems use software to collect information automatically and send it to the data center for analysis. The logical interface creates a route and provides information on turn-by-turn directions to drivers in designated areas (Kumar & Moore 2002). The GPS is used for tracking waste collection, waste picker position, and its surrounding RFID tag validation its position. Simultaneously waste collection information sends to the data center and waste collection big van bin location (Hannan et al. 2011, Tongkaw 2017).

The GIS is an application for the user interface an integrated software and hardware to locate the exact size shown for the waste collection van position, storage of waste, waste collection, waste management, and mapping of waste collection route household. The data analysis is performed according to client requirements. This system shows the presentation of all required information in dedicated forms of geographic information in a computerized system. It also assists end users in visually analyzing data and examines trends, movements, and relations that are shown graphically. The even form data are associated with the spatial use of characteristics stored in a dedicated system that synchronizes the exact place on earth.

Function of RFID

The RFID passive tag and RFID long-range readers are designed to allow readers to read the information on a range of 5m around a small waste collection by the waste picker, and the waste collection big van can read waste picker waste collection bin at a time waste bin empty on the big van automatically. When waste picker waste is collected from household waste bins, RFID passive tag information is read by RFID reader radio frequency and then transmitted to a computer system through a GSM/ GPRS/ Wi-Fi module network without any physical contactless connection between the radio frequency ranges. An RFID reader module consists of three main components: an antenna for data transfers and reading the data through radio frequency, a tag, and a reader. The passive label is loaded and activated when RFID transmits radio waves, forwarding information to the RFID reader. The RFID readers are available in different capacities; the frequency range depends on the use of contact. RFID readers are available with low frequency, contactless RFID readers with Ultra high frequency and High Frequency

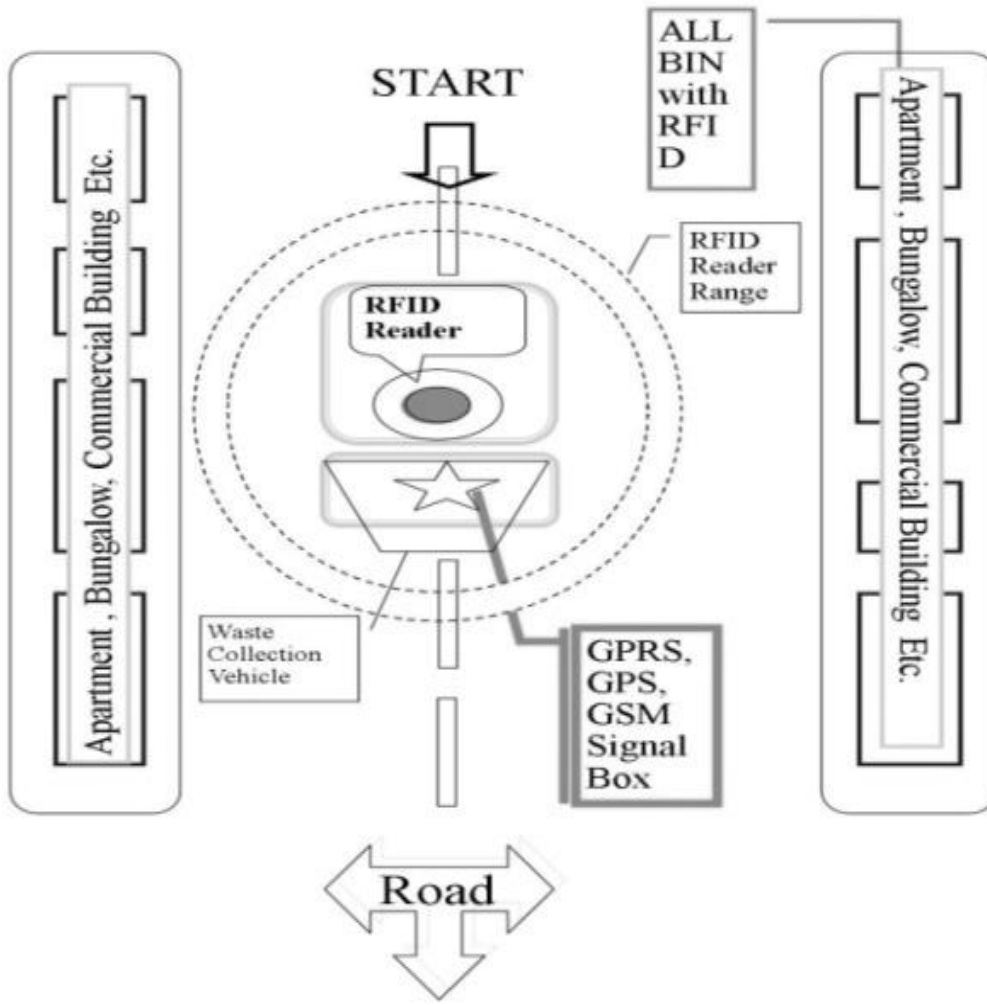

Fig. 4: Flow of information by using RFID technology.

depending on use up to 15 to 20 m long range. The integrated software gives real-time information to a user and servers to improve the entire waste collection process.

Function in ESP 32 Wi-Fi Module

The ESP32 WROOM 32D Wi-Fi Module uses for module transfer information remotely by using the 4GWi-Fi network to the data center through the internet. The mobile Wi-Fi network is provided to the ESP32 WROOM 32D module. The ESP32 Wi-Fi Module is a work-like wireless data transfer service between the device and the cloud server through the INTERNET. It provides a connection between data from users of the waste collection device to the data center over the wireless network and wireless broadband IP.

Working for RFID and IoT Solutions

The RFID tag is used for the waste collection process. The RFID tag is stuck on each household bin. In this process, when waste collection vehicles come from the waste collection before reaching the waste collection route, an alarm call is given to all households on this collection route (Fig. 4). When the empty dust tray is in the garbage collection vehicle at this time the RFID reader marks the presence, on the entry of the respective household in the database after completing the waste collection itinerary absent the property sends a message to the respective household.

1. Set RFID Tag on each household dustbin
2. Waste picker collection vehicle sets RFID Reader

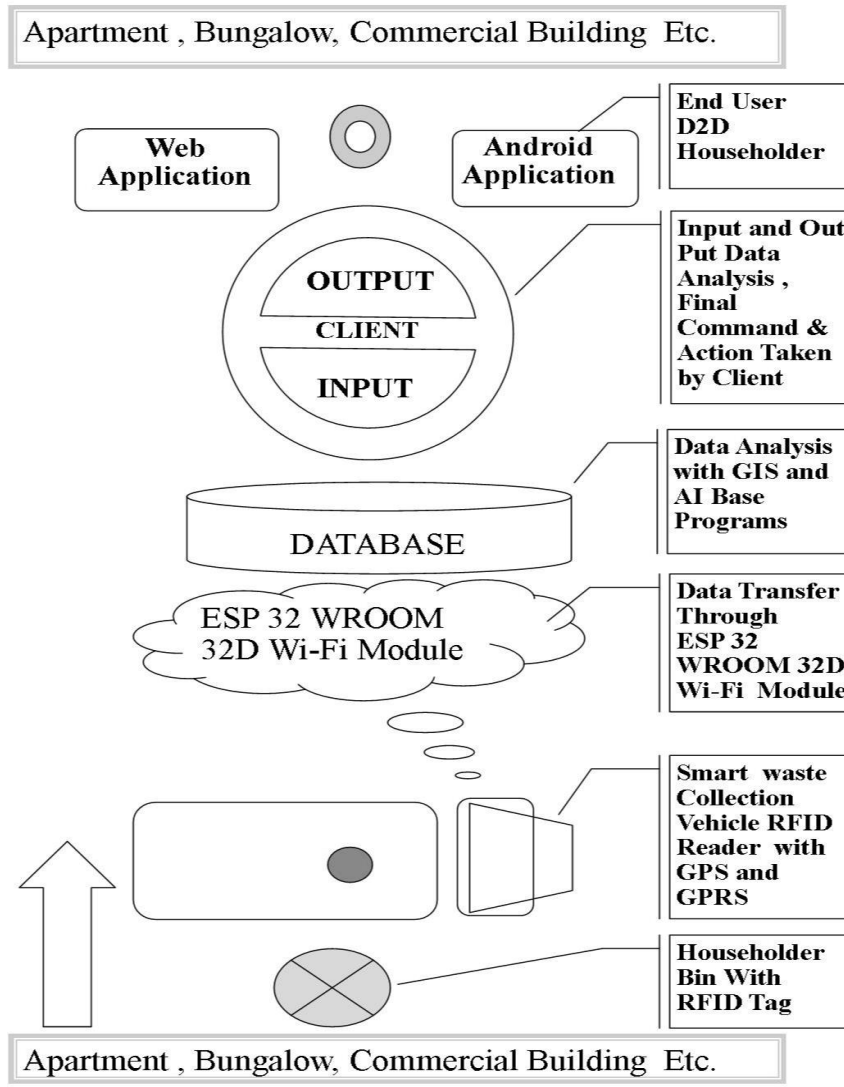

Fig. 5: Architecture of smart, solid waste management system.

3. RFID Reader sends all information through ESP 32 Wi-Fi module to the data center
4. All collected information is saved in the cloud at the data center
5. Datacenter analysis Input data as per the given command
6. All information is shown by the user interface Android and Web Application

Proposed System Architecture

The proposed method of the intelligent and environmentally responsible solid waste collection system is divided into two Infrastructure sections. Firstly, the hardware and software modules achieve 100% door-to-door (D2D) coverage of the separate solid waste collection. In the hardware module, using technologies such as GIS, GPS, RFID, and ESP 32 Wi-Fi module, the software module, covers two versions, one using Android Applications for home users, Waste Pickers, etc., and the other version will be a Web application for overall control of Administration.

Hardware Module of the System

The hardware module consists of ESP 32 WROOM 32D Wi-Fi module that connects with an RFID reader, an Ultrasonic sensor, GPS Module, a 5v DC power supply, and LCD.

The hardware module works on a Wi-Fi Internet network. The RFID reader is used to read and write waste bin RFID tags. When RFID passive tag contacts the RFID reader, the RFID reader reads all information with GPS coordinates that is sent to the data center through a Wi-Fi network.

Software Module of the System

The software module consists of two versions android application and a web application of a smart solid waste collection system. In that system android application is used for all user interfaces for easy communication and aces all information at the user end, such as first user household, second Waste Picker, Driver, and Transfer station. Other user interfaces are web interfaces used as the administrative department and admin section (Wu et al. 2022)

Primary Waste Collection User Interface

The role of the waste picker is a collection of different types of waste. The waste picker roller plays a major role in the daily waste collection on time. However, the door-to-door collection is not carried out properly due to insufficient monitoring of the waste collection process. There is no way for the waste picker to monitor every household physically. This point of view is not achieved correctly. Collecting, sorting, and selling recyclable materials enhance the lives of waste pickers. They play a vital role in primary stage sustainable solid waste management (Municipal Corporation of Pune 2011, Pal 2020, Dhawale et al. 2022).

1. Wet waste
2. Dry waste
3. Mix waste
4. Biomedical waste
5. Construction and demolition waste
6. Garden waste
7. Hazardous waste
8. E-waste

Secondary waste collection from a small waste picker collection is empty in a large van.

SOC Analysis of Its Base Waste Technology and Discussion

Strength

1. 100% Door to door waste collection Properly
2. User fees will be collection done properly
3. Waste collection regularly on time
4. Waste collection record maintains proper
5. No need to keep a record physically 100 % of waste should be segregated at the source
6. Decentralize waste

Opportunities

1. Awareness of the scientific handling of MSW
2. Development of IT solutions for 100% door-to-door collection
3. Decentralize waste management at the ward level
4. Development of integrated solid waste management
5. Management of Rag-Pickers daily on time
6. Uniformity in User fee collection of weight
7. Reliability of collection vehicle in terms of breakdowns, timing, and of route

Challenges

1. The primary collection of data
2. Registration of each Householder
3. Analysis of data
4. Taking action on householders
5. Proper execution
6. Heath issues of rag–picker Training and Education of rag-pickers management at the ward level

Scope of Work

1. Decentralized process of solid waste management at wards
2. Zero waste generation at the ward
3. 100% Coverage of Household door to door
4. Smart Collection, segregation
5. MSW Separation
6. Scientific Disposal
7. MSW Recovery
8. Cost Recovery
9. User charges collection Efficiency
10. Complaint Redressed

CONCLUSION

The Smart City agenda entails improving the citizens' quality of life and strengthening and diversifying the economy while prioritizing environmental sustainability by adopting smart solutions.

Collection can be enhanced by implementing soft computing tools for the collection and a different methodology for waste segregation and providing a processing plant at the ward level. The study reflects the current stage and future scope of methodologies. Encourage citizen participation in the waste management system.

The study was covered over one year and included field visits to 7 transfer stations and 15 ward officers' interviews with various factors involved in 100% Door to door coverage and collection of segregated Municipal solid waste current challenges and sustainable solutions to solve the above problem.

This paper reviews the modern waste collection technology available in some countries and cities to collect door-to-door solid waste effectively and optimize the process of handling waste from primary to secondary transportation.

Solving the above problem by using RFID and IoT base IT solution has the potential to achieve 100% door-to-door waste collection of municipal solid waste.

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