An Intelligent Solid Waste Management System using Internet of Things (IoT)

Pramod Mathew Jacob, Rasha Kabeer, Negha Nair, Sony V Saji, Meenakshi, Renju Rachel Varghese

Abstract*: Waste Management is one of the hectic and troublesome tasks which require much man power. The traditional waste management system is time consuming and not cost effective. In this scenario, we are designing an intelligent system for solid waste management using Internet of Things. Our proposed system consists of an intelligent smart bin and a mobile application. The smart bin consists of a unique identifier (RFID tag) and an ultra-sonic sensor to determine the waste level of the bin. The mobile application is intended for two user categories: Normal user and Garbage collector. The normal user can locate the nearby dustbins whereas the garbage collector can remotely assess the bin level. When the bin is full, an alert message is sent to the garbage collector and also displays the shortest route to the bin location. It uses genetic algorithm for finding the optimized path from the user to smart bin. The entire connected components and communication is managed by a central coordinator. Our implementation and evaluation results claims that this model can be used as an alternative for the traditional waste management system. This system also ensures cost effectiveness and less time consumption.

***Index Terms*: Internet of things (IoT), Smart waste management, Android application, Smart bin**

I. INTRODUCTION

Waste management is one of the challenges exist in any country or industry. Various sources of waste include home, industry, organization, restaurants and wherever there is human living. It will exist as a part of everyday activities till life exists. Waste management is a developing issue in both global and local levels. Waste management consists of various processes and activities for managing and disposing wastes effectively. The waste management process includes

phases like collection of garbage, transporting from source to treatment plant and the proper disposal.

The traditional waste management system consists of various bins placed at different locations. People used to deposit their garbage in the bins. Some garbage collecting person empties the bin by collecting the wastes and transport it to the treatment plant. The treatment plant either disposes or recycles the garbage. The disadvantage of this system is that the person needs to wander here and there to locate a waste bin to deposit the garbage. Also when the waste collector travelled all the distance from the treatment plant to the bin location for collection, there may be a chance that the bin may not be full or even empty. This may not be economical (fuel cost is high) and is a total waste of time. Another challenge is the chance of occurring health problems due to the improper management of waste.

So our proposed model aims to answer the following queries.

Q1: How a user can identify the nearest waste bin?

Q2: How to manage the transport of waste in an efficient and economical manner?

Q3: How can we remotely monitor the level of waste in a particular bin?

We have studied and evaluated various existing waste management systems. The summary of these studies are provided in the next section. Our proposed system uses an efficient and economical model for solid waste management. The proposed system framework is shown in Figure 1. Our system consists of a Passive Infrared (PIR) motion sensor to detect the presence of a human (user), and automatically opens the lid of the dustbin.

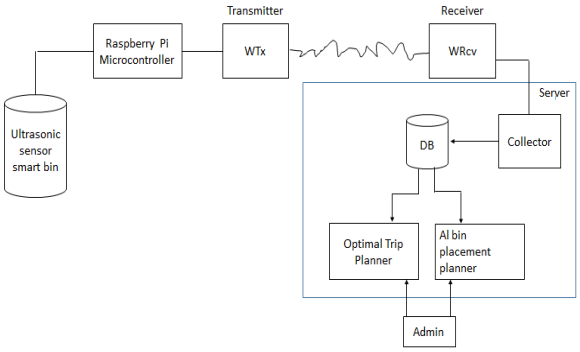

Figure 1: Proposed System Framework

Our mobile application will help the user to identify the locations (GPS coordinates)

Revised Manuscript Received on July 05, 2019.

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of the nearby dust bins. An ultrasonic sensor is used to measure the bin level. When the waste in the bin reaches a particular threshold, an alert message is sent to the garbage collector. The optimized path from the garbage collector to the dust bin and from dust bin to the treatment plan is generated. Thus our proposed system is an automated system model or architecture for detecting, monitoring and management of solid waste to the server side using GSM in an efficient way.

II. RELATED WORKS

We have analyzed about 20 related works in this area and the summary of all is provided below. The analytical and detailed study shows that there exist a lot of gap between the theoretical models and real time models.

Sahil Mirchandani et al [1] proposed an IOT enabled waste bin. Here they use the RFID tags for tracking the wastes and it connected with web based online system and based on the weight of the waste the status of the bin is updated and gives notification when the dustbin is full. And also provide an optimal path for the collection of wastes. Harshita Chugh et al [2] proposed an IOT based smart waste bin which can monitor the waste through sensors. The sensors from different places are connected through internet. The sensors would measure and calculated the amount waste. Also with the help of an android app both the user and authority could got the status of the bins.

Chandradeep Tiwari et al [3] developed a smart solar bin. Here they use two bins one for crush the bio degradable waste and the other for store the bottles and tins. And a wireless technology is used to find the status of the bin, send notifications and route optimization. The modules crushed the waste and compressed them to reduce the volume so thereby that provide space for larger amount of wastes and reduce the number of service for the waste collection. S.Karthikeyan et al [4] proposed a ZigBee network and MQTT (Message Queue Telemetry Transport) protocol for find the status of the bin. The main aim of the proposed system was to find the status of the waste bin and send these data through a wireless ZigBee network. With the help of MQTT a connection link was established between the node and server. Also the travelling salesman algorithm was used to find the optimal distance. And telegramming messaging application was used to find the trucks.

B.S.Malapur et al [5] proposed an automated consist of four modules bin addition, view bin status, collection planning and log. An ultrasonic sensor was used to calculate the status of the bin. Also an optimal path was used for the collection of waste. Ravale et al [6] proposed a solid waste management system which forwards the waste to various biodegradation plants based on waste categories. It alerts the administrator when the bin is full and thereby avoids overflow.

Jayalakshmi et al [7] proposed a novel approach for food waste management through measuring and displaying the amount of food wasted and recycling the wasted food using embedded systems to make fertilizers at planting. The system uses three infrared sensors and also a weight sensor to detect the amount of garbage in the dustbin. Communication takes place through a Wi- Fi module. Ghadage et al [8] review various solid waste management techniques and proposed a system which will take proper care of processing of garbage. The proposed system uses GSM module and ultrasonic sensors to sense the level of garbage in the bin, flame sensor to detect the fire and moisture sensor to separate out wet and dry garbage.

Aleyadeh et al [9] suggests an IoT system for monitoring waste volume as well as routing and scheduling of waste collection trucks based on bin locations. The system uses ultrasonic sensing device to detect the bin level and a humidity sensor to detect the dryness level of the bin content. Abhimanyu Singh et al [10] proposed an IoT garbage management system which uses infrared sensors to detect waste level at a particular period of time. The communication is initiated using Raspberry PI which acts as central coordinator.

Anupama et al [11] suggests a model to measure and sense the water quality level of contaminated water using pH sensor. The model is good for environmental friendly regions. Mustafa et al [12] suggests a model for municipal waste collectors to remotely sense the garbage content in a particular bin. The garbage level in the bin is measured using ultrasonic sensor and an ARM microcontroller. Every modules are connected to ThingSpeak. Cyril et al [13] proposes an intelligent bin which alerts the authorities only when the bin content is full. It provides the optimized route map to the truck drivers by covering only the route where the bin is full. Neetha et al [14] also proposed a similar system; when the garbage level in bin reaches the threshold value, the bin status is alerted to the authorities by updating it in a cloud database. This can be accessed by the authorities and can take suitable disposal measures in an efficient and economic manner.

Medvedev et al [15] proposed a smart city waste collection using Top-k query based dynamic scheduling algorithm. It analyses the water contamination level and alerts the administrators when it reaches a threshold. Aazam et al [16] suggests an intelligent IoT system for waste handling. It includes various sensors to capture the real time data and is updated oin the central cloud database. The bin status updation is sent to the administrator whenever the bin content reaches a threshold value. The separate values based on waste category are provided in this system which may efficiently enact the waste disposal.

Fariha Irfan Khan et al [17] proposed a system that shuts the lid of the bin when the bin gets completely filled. Ultrasonic distance calculation sensors are been used for checking bin status. When the lid is shut, a message is been send to the server side and the remaining process is been carried out by them. A database of the truck driver is been maintained that contains the information of the truck's location. Location of the truck driver can be identified through the GPS installed on the truck. Once the bin gets filled, alert message will be sent to truck drivers. If another bin which is also gets filled, and produce an alert message which is nearer to the truck driver, he should collect that waste also. Therefore, larger trucks are been used for collecting waste

from several bins. When a truck gets fully filled, then no more alert messages will be sent to that truck driver even though the bin is nearer to that truck.

Poddar et al [18] proposed a smart bin which automatically opens its lid when a human presence is detected in front of it. The ultrasonic sensor senses the bin level and updates the real time bin fill rate to the waste collector. It also provides the optimized path for the waste collector the filled bins. This system is more efficient and economical as it uses optimized path. Wijaya et al [19] uses load calibration method to measure the bin waste and thereby estimates the waste content in the smart bin. Thus it doesn't require any external devices or components to measure the bin level. Upadhyay et al [20] proposed an integrated cloud based IoT system for waste management in smart cities. It measures humidity, temperature, fire detection using suitable sensors and update the same to the central processor. Communication protocols include TCP/IP and GSM/GPRS. The waste content in the bin is sensed using ultrasonic sensors. The collected information is updated in the cloud which is constantly monitored by the authorities. It is an economical efficient model for smart cities.

Most of the above mentioned work uses similar model for waste management. Ultrasonic sensor is used in most systems to measure the bin content level. But the problem of locating unfilled dust bins nearby for a user is not implemented in most systems.

III. PROPOSED SYSTEM

Our proposed system consists of three modules as shown in Figure 2: A smart dustbin, a central coordinator and an Android application. The smart bin comprises of a GSM module, ultrasonic sensor, PIR sensor and a servo motor integrated to a central coordinator system. These components acts as the server side of our proposed system. The key purpose of ultrasonic sensor is to estimate the waste level inside bin by calculating the distance from the bin top to the waste level. The sensed value is read by the central coordinator and calculates the equivalent distances in centimeters. When the garbage level in the bin reaches a threshold, an alert message will be sent to the garbage collector using Android application. The application also provides the shortest optimal path from the dust pin to the current location of the garbage collector using genetic algorithm. The smart bin produces a buzzer alarm when it is full and thereby controls the overflow. The central coordinator module consists of user module and waste collector module.

A. Android Application

The Android App has two modes: A User mode and a Garbage Collector mode. In user mode, the end user can search for the nearby dustbin which is free to put the garbage. It provides the shortest route to the bin from the user's current location. In the Garbage collector mode, it alerts the garbage collector by initiating an alarm message when the garbage level reaches a threshold. The application tracks the current location of garbage collector and shows the optimized route to all the dust bins which attained its threshold. The application also provides facility to the garbage collector to remotely check the bin status whenever required. GSM module inserted with a sim is used for the communication.

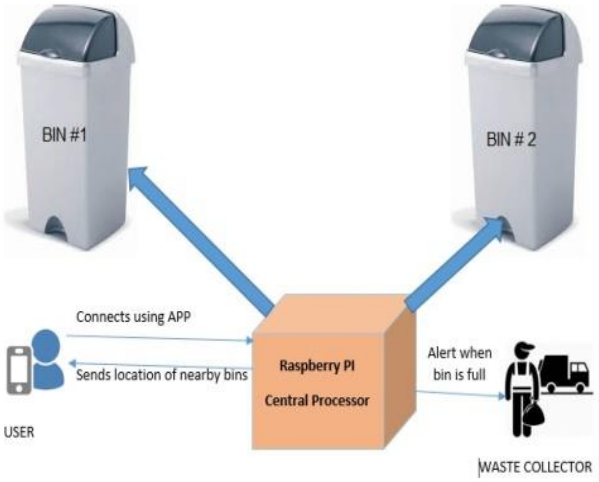

Figure 2: Proposed System Architecture

B. Smart dust bin

An ultrasonic sensor is fixed at the top of the smart dust bin. The sensor produces sound pulses of high frequency which will hit on the garbage and echo back. The time taken to reflect back is analyzed and converted to the equivalent distance in centimeters. If Total_Bin_distance denotes the height of the bin and Empty_distance represents the free space in the bin then the Garbage_level can be estimated as follows:

$$Garbage\_level = Total\_Bin\_distance - Empty\_distance \quad (1)$$

The percentage of garbage in the smart bin can be calculated using the following equation.

$$Filled\_percentage = \frac{Total\_Bin\_distance - Garbage\_level}{Total\ Bin\ distance} * 100 \quad (2)$$

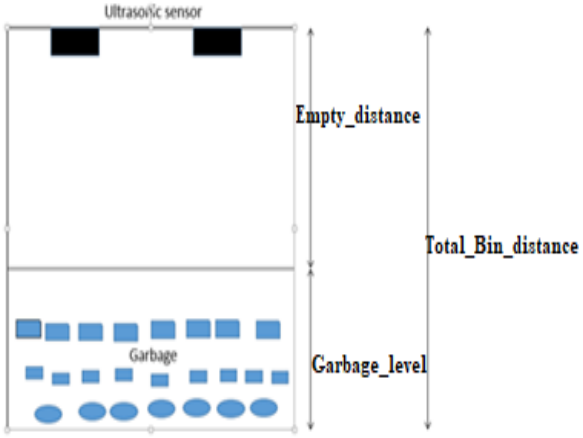

Figure 3: Smart Bin

C. Central coordinator

The central coordinator is a Arduino system [21] which has powerful processing capability as well as having Wi-Fi module and interfaces. The central coordinator controls and coordinates all the activities in this project. The smart bin is automatically operated with control of Arduino. The

sensed bin level is fed to the central processor. When the central processor [22] exceeds a threshold value, it alerts the waste collector through email / SMS. Central coordinator acts as server side; all the data collected and stored in the database. It also consists of an optimal trip planner and bin placement planner using Travelling Salesman Algorithm is provided below.

Optimized Path using Travelling salesman algorithm:
Input: Latitude, Longitude and Bin id
Output: Optimal path
Steps:

1. Read the latitude, longitude and bin id.
2. Initialize the latitude, longitude and id of the bins
3. Check whether if the latitude and longitude is empty, if so,
   i. Then TSP cannot load the location
4. Otherwise compare filled bin latitude and longitude with the initialized
5. If both the latitude and longitude are same
   i. Return 0
6. Next Create TSP node and calculate its cost.
7. TSP starts from first bin location, i.e., node 0
8. Initialize cost, vertex, level, reduced matrix, new matrix
9. For cost calculation, perform the following
   i. Perform row reduction and column reduction
   ii. Total expected cost is the sum of all the reductions.
10. Create a priority queue to store live nodes of the search tree
11. Find a bin location with least estimated cost
12. Store the current bin location number
13. Repeat steps 9-12.
14. If all bin locations are visited, then
    i. Return to starting city.
    ii. Print list of cities visited.
    iii. Return optimal cost, path and location

The system work flow from both client side and server side is illustrated in Figure 4.

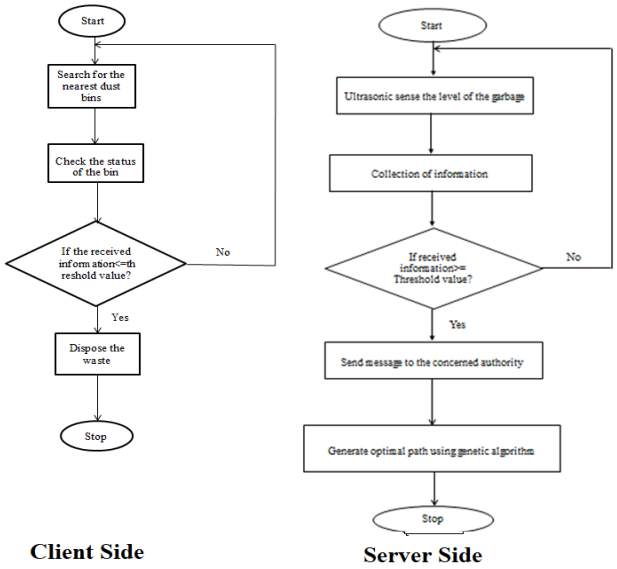

Figure 4: Client side and server side flow chart

IV. RESULTS & DISCUSSIONS

We have implemented the proposed system using Arduino Uno and an Android app. The dustbin is converted to a smart dustbin as shown in Figure 5. Arduino microcontroller is used as the central coordinator of our system. The Arduino microcontroller will give a pulse width modulation signal to the servo motor connected in the lid. Based on the pulse width modulation the shaft of the servo motor rotates in counter clockwise and clockwise directions and lid will automatically open and close.

Figure 5: Smart bin with automatic lid open

The ultrasonic sensor will detect the human presence and the servomotor attached in the bottom actuates the automatic opening of lid. The ultrasonic sensors placed at the top of the lid will evaluate the dustbin content. When the waste content in the bin reaches a threshold an alert message is sent to the garbage collector which is shown in Figure 6.

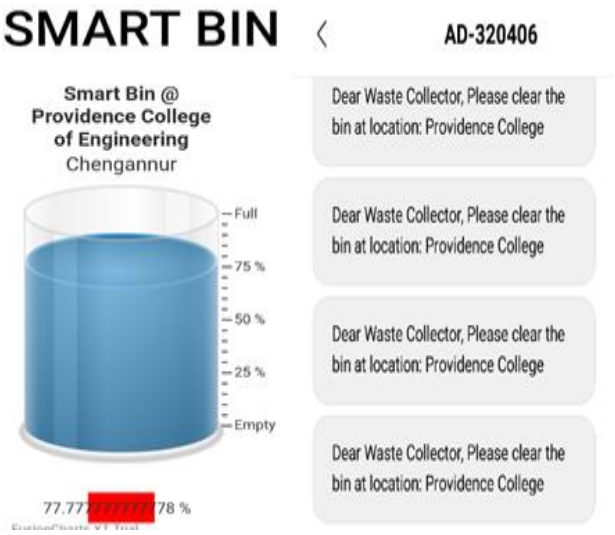

Figure 6: Android application – Bin level notification

The Android app is installed the user mobile. When the user searches for the nearby bins, the application searches for the nearby bin locations and identifies the GPS coordinates of bin locations. With the help of Google map, the application provides the route towards the bin in the user's mobile as

shown in the left part of Figure 7. Travelling Salesman algorithm is used to generate the optimal path from the garbage collector to the dust bin. Product is validated using various testing strategies [23].

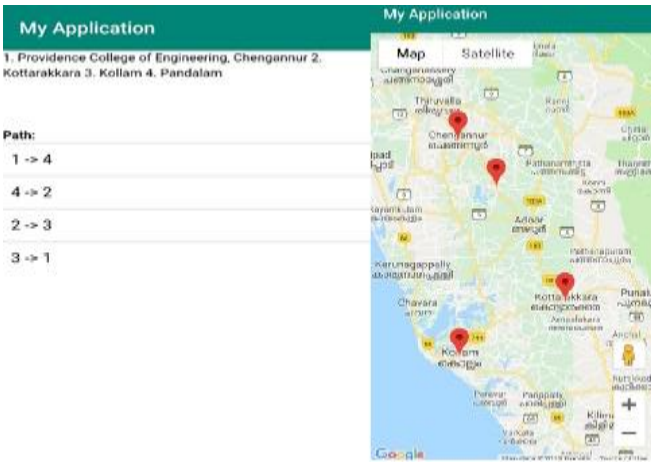

Figure 7: Optimal path to bin locations

The advantages of our proposed system are:

- More user friendly and easier to locate nearby bins.
- Average time spent by each garbage collection vehicle during a time period can be minimized.
- Average route covered by each garbage collection vehicle an be improved.
- Auto alerting about the bin condition to the waste collector.
- More economical and optimum utilization of resources.
- Dynamic routing enhances efficiency.

V. CONCLUSIONS

Our proposed smart waste management system consists of a smart bin and a mobile application controlled by a central coordinator. The mobile application helps the user to identify the nearby bin locations. Travelling Salesman algorithm is used to find the optimal path for the same. The sensors incorporated in the bin identify the bin status and alerts the garbage collector when the bin level reaches a threshold value. Thus our smart waste management system helps the authorities to save time as well as cost. It also reduces human effort and manages wastes in a healthier way. Our future work aims to address the automation of waste treatment plant in an efficient and economical manner.

ACKNOWLEDGMENT

We express our sincere gratitude to Providence College of Engineering, Chengannur, Kerala for the support provided. We are thankful to Mr. Sreejith P and Ms. Jisha Elizabeth Mammen for the technical support provided in executing test cases in the laboratory.

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