LOCATION BASED GARBAGE MANAGEMENT SYSTEM WITH IOT FOR SMART CITY

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Declaration

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ABSTRACT

Smart cities integrate multiple ICT and IOT solutions to build a comfortable human habitation. One of these solutions is to provide an environmentally friendly, efficient and effective garbage management system. The current garbage collection system includes routine garbage trucks doing rounds daily or weekly, which not only doesn't cover every zone of the city, but is a complete inefficient use of government resources. Purpose of this research area is by using android application and feedback analytical system provide efficient service to citizen and omitting above problems. Since android is currently the fastest growing mobile platform, It's provide a plethora of value-added capabilities, apart from the conventional phone call and message exchange. Also they are able to turn every user into a data gathering agent, since information can be collected from both the environment outside of the device, as well as be retrieved from the digital world. Although smart phones have become an indispensable gadget in data gathering and telecommunication, the features that they provide can also be taken advantage for improving the living conditions of people around the world. By using above features author develop android application which users can easily manage their garbage management in day to day life. Android application provide Location Based Service (LBS) which provide detail map about garbage bins which locate in city. Also it provides calculated route for selected bin. Feedback system include data analytical system which use for provide efficient service to citizen in city.

Acknowledgement

Real-Time Indoor Proximity and Geo-Fence Based Digital Signage Advertising Research was carried out as my 4th year research in Sri Lanka Institute of Information Technology. The completed final project is the result of combining all the hard work of the group members and the encouragement, support and guidance given by many others. Therefore this is my duty to express my gratitude to all who gave me the support to complete this major task.

I deeply indebted to my supervisor Ms. Shashika Lokuliyana and my co-supervisor Mr. Anuradha Jayakody, lecturers of Sri Lanka Institute of Information Technology whose suggestions, constant encouragement and support in development of this project.

I also wish to thank all my colleagues and friends for all their help, support, interest and valuable advices. Finally, I would like to thank all others whose names are not listed particularly but have given their support in many ways and encouraged me to make this a success.

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LIST OF ABBREVIATIONS

SNFS	SMS notification and feedback system
HAL	hardware abstraction layer
CTS	compatibility test suite
IOT	Internet Of Things
Author	Project members
LRU	Last recently Use
HTTP	Hypertext Transfer Protocol
CSS	Cascading Style Sheets
PHP	Personal Home Page
UI	User Interface

1 INTRODUCTION

1.1 Background

Proper waste management is a basic requirement in any kind of an environment. Usually cleaning in these environments are done in the morning and the afternoon. If you take an urban city like Colombo usually there are about 1,200,000 to 1,500,000 [4] employees heading for their workstations every morning. For all those people, there are just not enough garbage bins available. On the streets of urban cities hundreds of people are passing the same location around one minute. Around 95% [5] of people are carrying food covers, polythene bags and plastic bottles. If they dispose all them at once, the bins will be filled in several minutes. When they fill up people just litter their trash around the garbage bins because there is nowhere else to put them. The obvious solution to this is for the cleaning staff to stay near garbage bins everyday till they fill up to clean them. This is not a real solution. It takes way more cleaning staff and costs a lot of money. So, it is impractical. The same scenario is happening in workstations. For instance, a bank or a government office cafeteria usually has about five to six garbage bins to serve hundreds of employees. This is simply not enough. There are some notable negative effects when considering the garbage bins always being full. One of the main effects is the surrounding area starting to smell and be very unpleasant. When the garbage bins are full people put their trash on sides of the garbage bins. When this is done for some time, first it starts to smell bad. So, others who come later tend not to go close and throw their trash in the direction of the garbage bins. If there are any leftover food items, throwing it causes them to spill. This attracts animals like cats, dogs and flies. And these animals spill them even more. Another negative effect is the diseases that spread. It’s not just the garbage that spread them, but the animals also can be a source.

1.2 Literature Survey

1.2.1 Smart Bin Implementation for Smart Cities (2015) [7]

This research is focused on creating optimal changes in the conventional methodology of waste collection. This is done by creating a smart bin that will upload the fill levels via SMS. SMS received from the GSM modules of the dustbin is taken in the form of text files. The text file is connected to the excel sheets. The updated values of the dustbin level are taken to form a real time smart bin status. The excel application designed creates a real-time dashboard along with a time series graph which shows the current trend as well as the historical trend of waste level in that particular smart bin. The data collected is then analyzed to gain insights.

These are the hardware components they used demonstrated on table 1.4.1.1.

Table 1.2.1.1: Hardware Components for Smart bins

Hardware Components and Specifications	
Components	Specifications
Microcontroller	PIC-16F73
Ultrasonic Sensor	HC-SR04
GSM Module	SIM-900A, IMEI-865904022247974
Motor	60 rpm DC Motor
LCD	16X2 (JHD162A)
Motor Driving IC	L293D
Voltage Regulator	7805
Resistor	10kohm
Capacitor	100uf,22pf
Oscillator	Crystal Oscillator

1.2.2 Cruisers: A Public Automotive Sensing Platform for Smart Cities (2016) [9]

This research introduces Cruisers, an automotive sensing platform for smart cities, which is developed based on the following ideas.

- Garbage collecting trucks are used as host automobiles to accommodate sensors
- 3G cellular communication network is used to wirelessly deliver sensed data directly to servers
- Proxy servers are adopted to convert the format of sensed data to required ones.

The technology consists of a collection of sensor nodes installed into the same number of garbage collecting trucks, one proxy server and one data server. Java program is developed to control the sensor nodes. An iOS application is also developed to demonstrate the sensing process and the covered area.

1.2.3 IoT Based Solid Waste Management System A conceptual approach with an architectural solution as a smart city application (2016) [10]

This paper aims at providing an IoT based solution to solve the problems faced by the present solid waste management system. By building an IoT based system, solid waste can be tracked, collected, and managed easily by automating and monitoring. Sensor data collected from the garbage bins can be sent to a gateway using LoRa technology. Data from various garbage bins are collected by the gateway and sent to the cloud over the Internet using the MQTT (Message Queue Telemetry Transport) protocol. The main advantage of this system is the use of LoRa technology for data communication which enables long distance data transmission along with low power consumption.

Four garbage bins were taken to implement the prototype. Each bin was fitted with the sensors, microcontroller and the communication module. Atmel’s ATmega328p microcontroller was chosen as the development board.

1.2.4 Top–k Query based Dynamic Scheduling for IoT-enabled Smart City Waste Collection (2015) [8]

This paper proposes a system architecture to achieve dynamic waste collection and delivery to processing plants. This is done using a top-k query based dynamic scheduling model. In implementation the Smart City is divided into multiple sectors which cover the entire city area. Each sector contains a number of multiple intermediate waste depots, which are temporary waste storage areas. Further waste processing is done on garbage tips located at the edge of the city. Low capacity garbage trucks are used to collect garbage from bins and store them in waste depots. High capacity garbage trucks are used to transfer the garbage from garbage depots to garbage tips. Cloud middleware collects sensor data and provide them to the system. Dynamic scheduling algorithm(Figure 1.4.4.1) is used to locate the first available truck which can load waste from the filled bins. A route for the truck is created according to the gathered information using top-k query.

. Figure 1.2.4.1: Dynamic Scheduling Algorithm

TABLE I. DYNAMIC SCHEDULING ALGORITHM

Input: *Bins*
Output: *k*
While (*true*) **Do**
    k = top−*k* query from relation *Bins*
    /*Select *k red* bins to load*/
End While

1.2.5 Cloud Computing Based Smart Garbage Monitoring System (2016) [13]

In this paper, a Smart Bin is proposed with a network of dustbins which integrates the idea of IoT with Wireless Sensor Networks. Thealso proposes a concept of a network of smart garbage bins based on the Stack Based Front End approach of integrating Wireless Sensor Network with the Cloud computing and discuss how Machine Learning techniques like Decision Forest Regression can be applied to the sensor data leveraged by the system to gain useful insights to improve the efficiency of the garbage monitoring. The system overview(Figure 1.4.5.1) is displayed below.

- Hardware used:
- WSN Motes
- IRIS
- Ultrasonic sensors

Software used:

- TinyOs-2.1.2
- NesC
- Azure IOT Hub

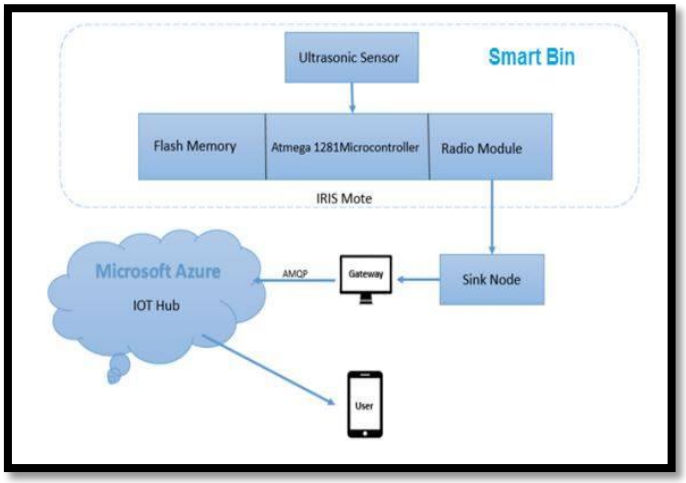

Figure 1.2.5.1: System Overview

Their windows app is coded by C#. It consists of two modes, User and Admin. The admin can add new devices, monitor fill levels and get reports about failures. The user can only view all the bins that has been deployed in the area by entering the area code that has been set up by the admin. They are using Bing Maps API to show the geographical location of the bin. The Admin can also get the shortest path comprising of all the filled bins and can redirect garbage vans.

1.2.6 IOT Based Smart Garbage alert system using Arduino UNO (2016) [14]

This paper proposes a smart alert system for garbage clearance by giving an alert signal to the municipal web server for instant cleaning of dustbin with proper verification based on level of garbage filling. The development board used is an Arduino UNO. The process involved is ultrasonic sensors checking garbage bin levels and sending it to the municipal council. After cleaning the dustbin, the driver confirms that the task is complete using a RFID Tag. After the cleaning is verified, the information is sent to the server.

An Android application is developed and linked to a web server to send the alerts and remote monitor worker progress. The notifications are sent to the Android application using Wi-Fi module.

The e-monitoring system has two parts:

• Embedded system: It comprises of an RFID reader, a microcontroller, a Liquid Crystal Display (LCD) and a GPRS segment.

• Web based software system Interface: It comprises of a GPRS module, a Central Server, a Database Server and a Web server. The Figure reveals the block diagram of the web centered software system.

The overall flow diagram of the proposed model is shown in Figure 1.2.6.1

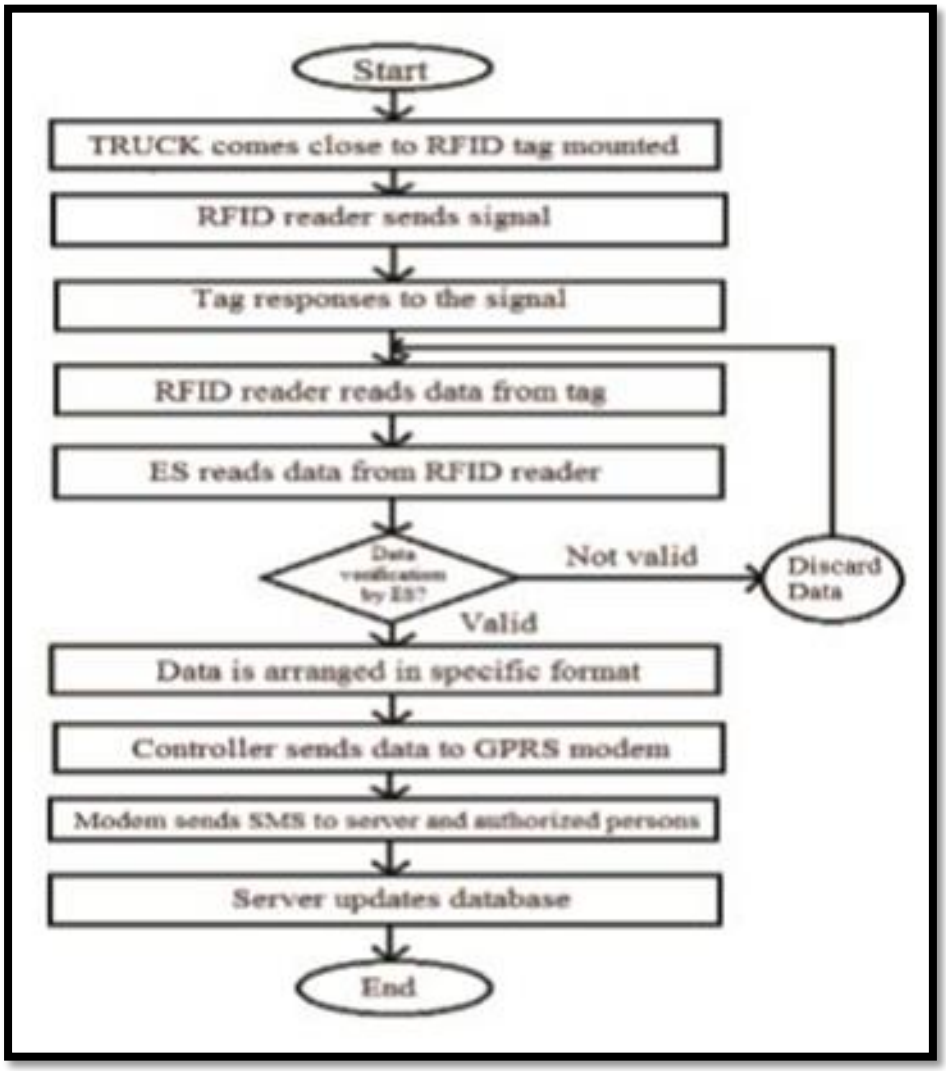

Figure 1.4.6.1: System Structure

1.2.7 Solid Waste Management Architecture using Wireless Sensor Network Technology (2012) [1]

This paper is focused on the on-site handling and storage processes and on the transfer process, with the main topic at developing a smart solid waste management system capable to ensure the public health with costs reduction and quality improvement. In order to enhance the efficiency of solid wastes on-site collection and transfer, an innovative solution for the monitoring and management system has been proposed. A Wireless Sensor Network (WSN) has been developed to improve the garbage bins monitoring process.

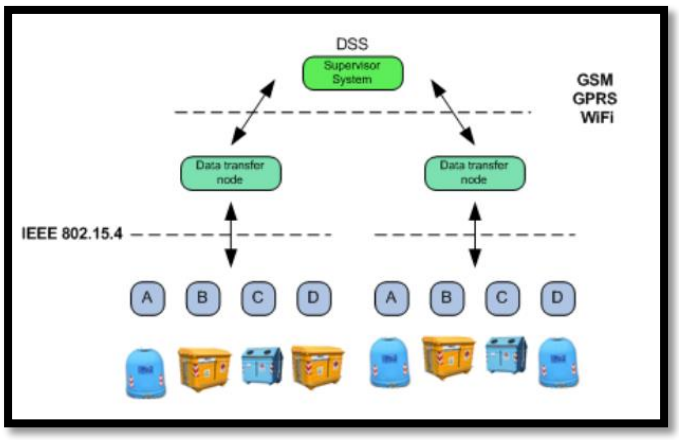

Figure 1.2.7.1: SEA project system architecture

The main components of the developed architecture on the SEA project(Figure 1.4.7.1) are decomposed into three layers. Starting from the bottom, the garbage bins reside at the first one, the DTNs at the second one and the supervisor system at the third one.

- The first layer is composed by sensor nodes, which need for the filling monitoring and provide short-range transmissions through RF technology.
- The second layer is composed by communication modules, which provide long-range transmission through GSM/GPRS.

- The third layer is composed by servers, which provide data storage and supervisor modules.

1.3 Research gap

Most research papers have implemented android application or windows application for user. Also there are few feedback system which they implement. But they lack several key features.

IOT Based Smart Garbage alert system using Arduino UNO has used an android application developed and linked to a web server to send the alerts and remote monitor worker progress. The notifications are sent to the Android application using Wi-Fi module.

In this research paper they are use android application only for get notification. Since android have many other features. Also no need of external wifi module author can host android application in server and get all notification via internet.

Different research papers have used different methods to get feedbacks and connect application with there databases.

- Smart Bin Implementation for Smart Cities has used GSM technology [7].
- Cruisers: A Public Automotive Sensing Platform for Smart Cities has used GSM technology [9].
- IoT Based Solid Waste Management System A conceptual approach with an architectural solution as a smart city application has used LORA technology [10].
- IOT Based Smart Garbage alert system using Arduino UNO has used wifi
- Solid Waste Management Architecture using Wireless Sensor Network technology has used RF and GSM technology

Most of these papers has used GSM technology. When using GSM there is the hassle of through registering to a subscriber and has to pay for the services. For this project wifi was chosen due to the fact that in a smart city everything would be connected through wifi. So android application can easily integrate with the existing communication system.

In Addition to the technologies mentioned, this proposed system will contain these following functions:

- A user interaction interfaces which can collect feedback from users via android application
- A LSB system which will show all available bins in map
- Real time bin level visualizer
- Feedback analytical system to provide better service to user

After the sensor data has been transferred different papers have used different methods to manipulate data,

Smart Bin Implementation for Smart Cities [7] has used an Excel application, which has some weaknesses such as

- Vulnerable to fraud
- Susceptible to trivial human errors
- Difficult to troubleshoot or test
- Obstructive to regulatory compliance
- Not designed for collaborative work

Most of the other papers has used cloud based systems to analyze and monitor data. Author fined no error in doing so as this is the best method to do this currently. So we have also

taken the cloud based approach. Without developing windows application author embedded all features to android application. In cloud based system there is no user interaction part in android application, but in our application there is user interaction system which user can communicate with our management.

Cloud Computing Based Smart Garbage Monitoring System [7], Smart Bin Implementation for Smart Cities [7] has used an android application to notify cleaners, a Cloud Computing Based Smart Garbage Monitoring System [13] has used windows application and some uses only SMS notifications. This project improves upon this to give notifications through the android application and SMS notifications for better efficiency.

1.4 Research Problem

At present, solid waste management in Sri Lanka is not at an adequate level. Municipal councils of urban cities only collect a small portion of the total waste generated. Referring to the National Solid Waste Management Report for 2007 of the Japan International Cooperation Agency [6], the total amount of garbage collected in 311 local authorities was 2838 metric tons per day [6], which amounts to an annual garbage collection of 1.04 million metric tons per year. This is only 23% [7] of the total garbage generated Colombo District. This means that nearly ¾ of the garbage generated leads to surface and groundwater pollution.

With this much waste generated and no way of collecting them, garbage bins fill up instantly. This leads to people turning to open waste dumping. Open waste dumping is the main source of all of the below mentioned problems.

- Increase of acidic levels of ground water, which is water pollution.
- Buildup of greenhouse gases such as methane and carbon dioxide, leading to air pollution and climate change.
- Loss of wetland habitats
- Spread of diseases such as Dengue fever, malaria, etc.
- Attraction of wild animals

In spite of the statistics mentioned above, Sri Lankan government spends a substantial amount of money on solid waste management. An estimation made in 2004 revealed that solid waste management expenditure ranges from a high Rs. 2000 per metric ton in a Municipal Council to a low Rs. 1,200 per metric ton in an Urban Council. So, it could be estimated that Sri Lankan government spends an amount between 1.2 to 2 billion rupees [7] on daily collection and disposal of garbage.

1.5 Research Objectives

1.5.1 Main objectives

In this project ultimate goal is to build green city. To do this author has to achieve many tasks. Developing end user application and feedback analytical system author can achieve many objectives. Since most of people using mobile devices author providing android application to user which has many function. Providing user friendly functions author can keep connection with users and give updates to users. By doing this main goal of ensuring higher customer satisfaction, on the other hand goal is to provide cost effective system and increase customer engagement with our system.

1.5.2 Specific Objectives

- Maintain all the registered customer details with PRESTO application, customer preference details and customer feedback details for value-added services.
- Provide user friendly dashboard to manage all value-added services based on advertising campaign of the organization.
- Provide a communication interface to initiate a communication by mobile application and to supply required details to fulfill the features in mobile application in order to provide customer services.
- Generate intelligence feedback analytical system to provide better service to users.

2 Methodology

The proposed location based garbage management system has two types of users. These users are workforce staff and end users. The proposed location based garbage management system provide a workforce application and end user application. This paper focus on end user application with route calculation and user feedback analytical system.

2.1 End user application

Author will develop mobile application that can be operated minimum hardware requirement with more feature. To run end user android application will be needed minimum android KitKat 4.4.4 (API level 19) operating system or higher version. Therefore, run this application should be include following requirements in mobile device that are minimum 512 MB RAM (2GB recommended) and 1 GHz or higher processor. To connect Wi-Fi, mobile devices should support IEEE 802.11 b/g/n.[15][16]

The workforce android application includes three main features.

1. Real time bin level and bin location visualizer
2. Feedback system
3. Route calculation

Since this application is develop for users, author provide interface to registration. This will be the source that system will collect information about user. After registration user can access to function which it provide(Figure 2.1.1: Registration UI, Figure 2.1.2: Login UI)

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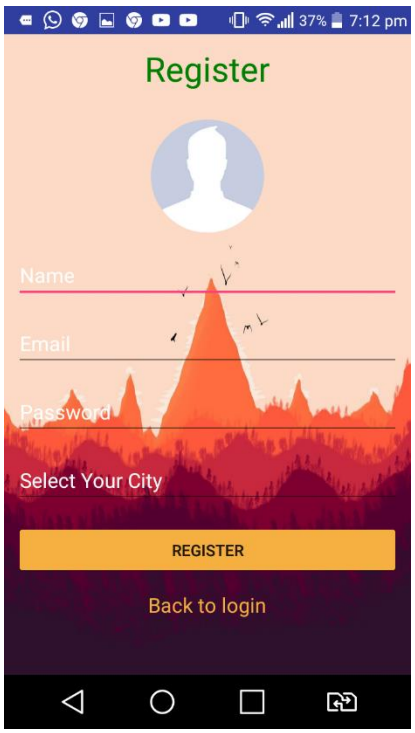


Figure 2.1.1: Registration UI

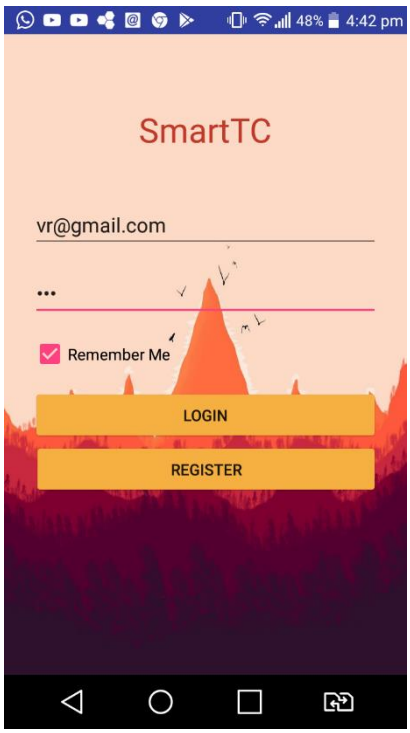


Figure 2.1.2: Login UI

2.1.1 Real time bin level and bin location visualizer

The map shows all the bins that are placed throughout the city. The user can access each bin to get all the specific information about the bin like real time level and other details.(Figure 2.1.1.1: Bin map , Figure 2.1.1.2: Bin detail)

User can see location of all bins in the smart city through bin location map interface

There are four type of garbage bins at one location.

1. Paper (PA)

2. Glass (GL)
3. Plastic (PL)
4. Biodegradable (BI)

Using all bin location interface, cleaner can see all type of bins each location, it's bin ID (Ex- MLB-10-BI) and current bin level status. The bin ID is created using area or zone number and putting garbage type. The current bin level status can be identified using google map location maker color. There are two types of makers. [17]

1. Orange marker - Garbage filled level is 80% or high.
2. Green marker – Garbage filled level is less than 80%.

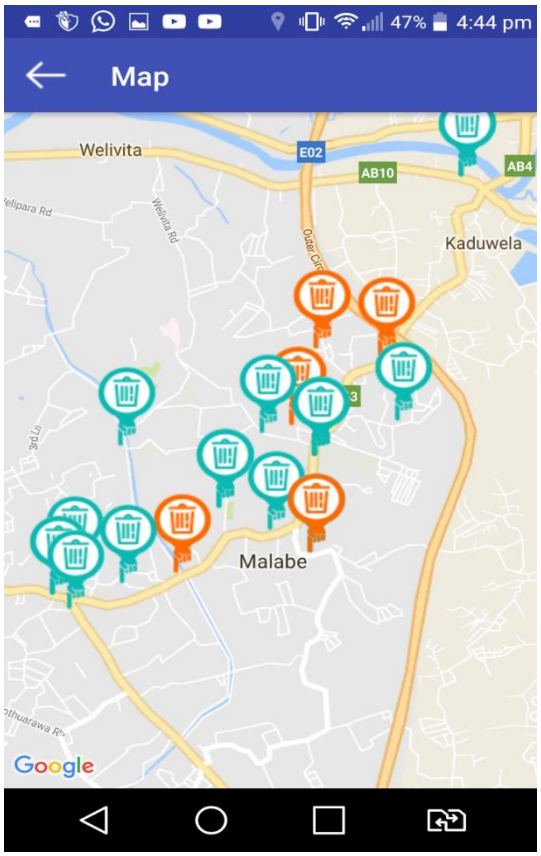


Figure 2.1.1.1: Bin map

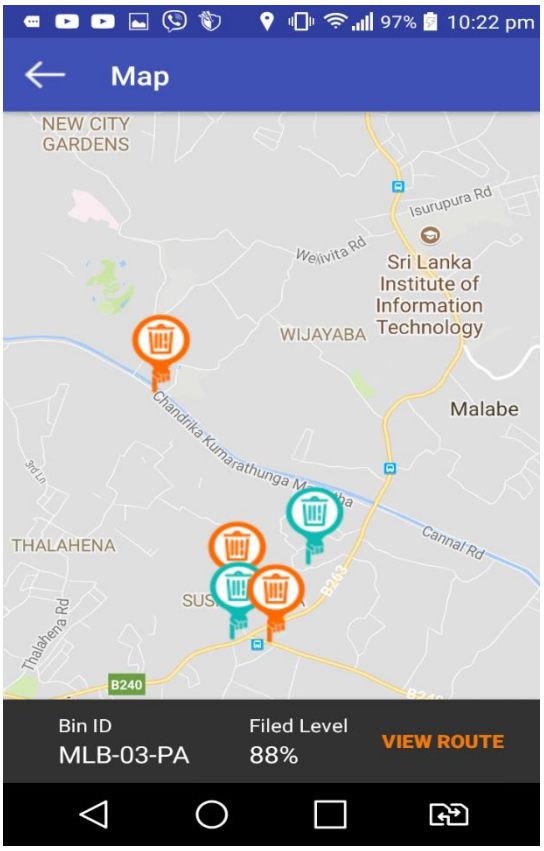


Figure 2.1.1.2: Bin detail

2.1.2 Feedback system

In feedback system there is several type of feedbacks that user can send to our management.

- Bin maintain
- Bin request
- Cleaning issue
- other

When the bin is malfunctioning, user can let our system know that bin is not working properly by sending feedback.(Figure 2.1..2.1: Feedback SMS) When user send feedback using android application, this feedback will come to database and also it will notify the maintain staff by reserving SMS to their mobile number.

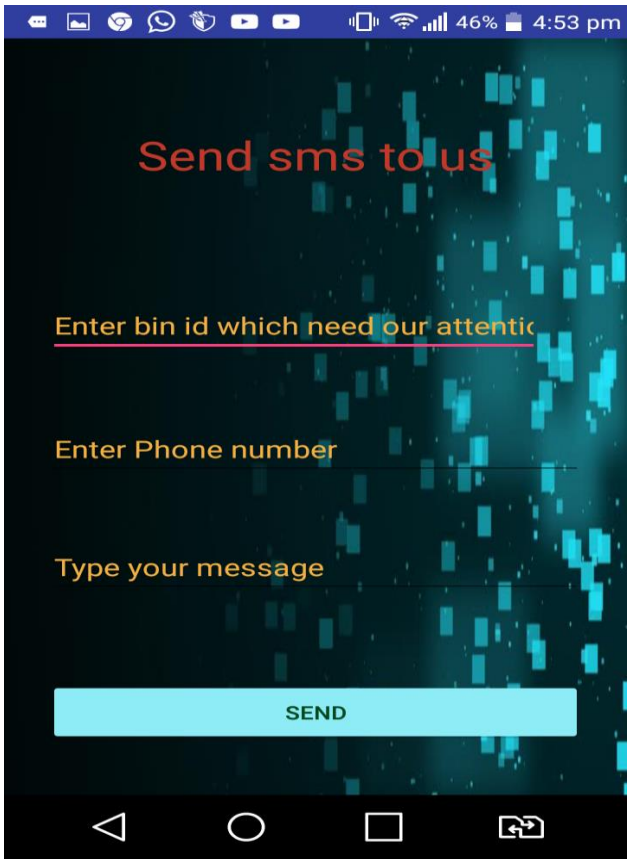


Figure 2.1..2.1: Feedback SMS

Author provide another UI for user to send other three type of feedbacks.(Figure 2.1.2.2: Feedback, Figure 2.1..2.3: Other Feedback)

User can select those feedback and send relevant feedback to our management. These feedbacks are collect in our database to do analytical calculation.

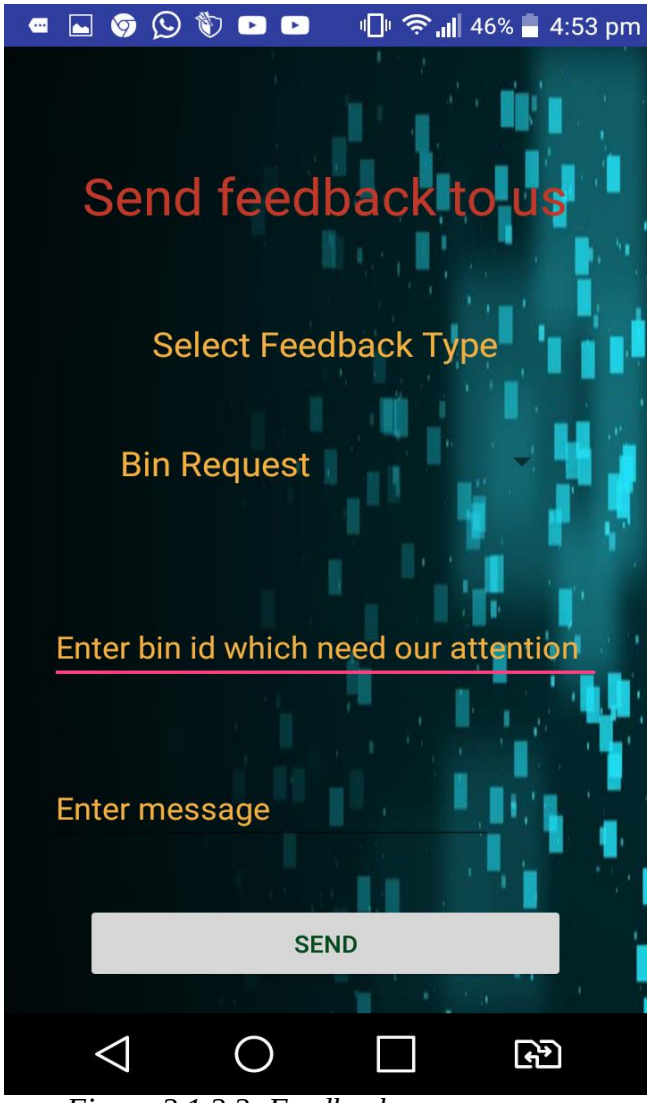


Figure 2.1.2.2: Feedback

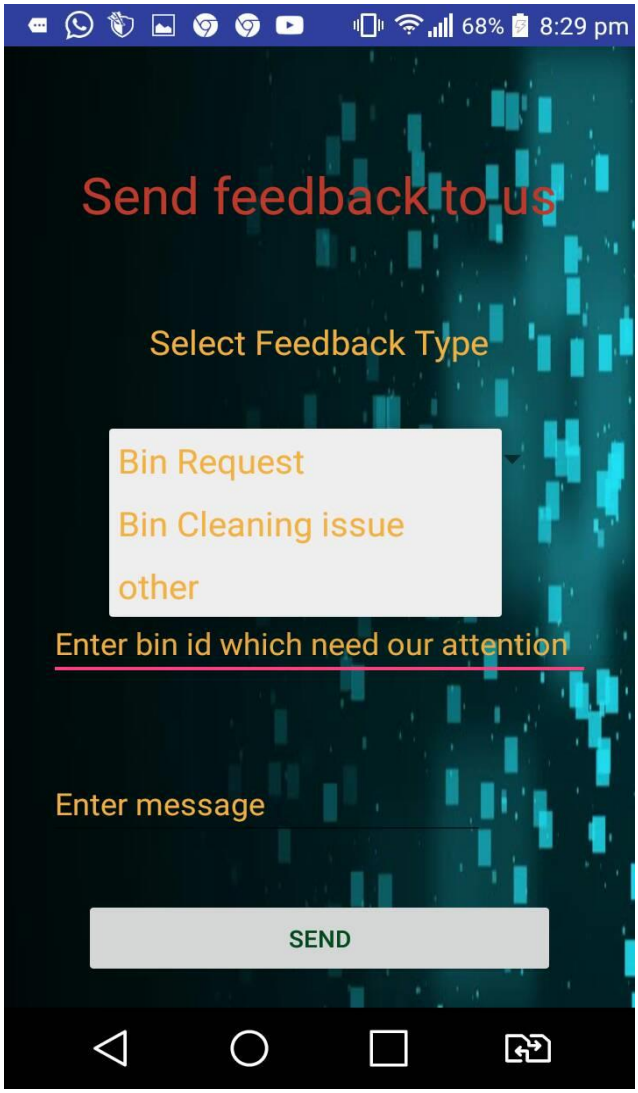


Figure 2.1.2.3: Other Feedback

2.1.3 Route calculation

End user application provide the map which indicate all the bins. Also this map will show the current location of the user. User can see all the bin which near to his current location.

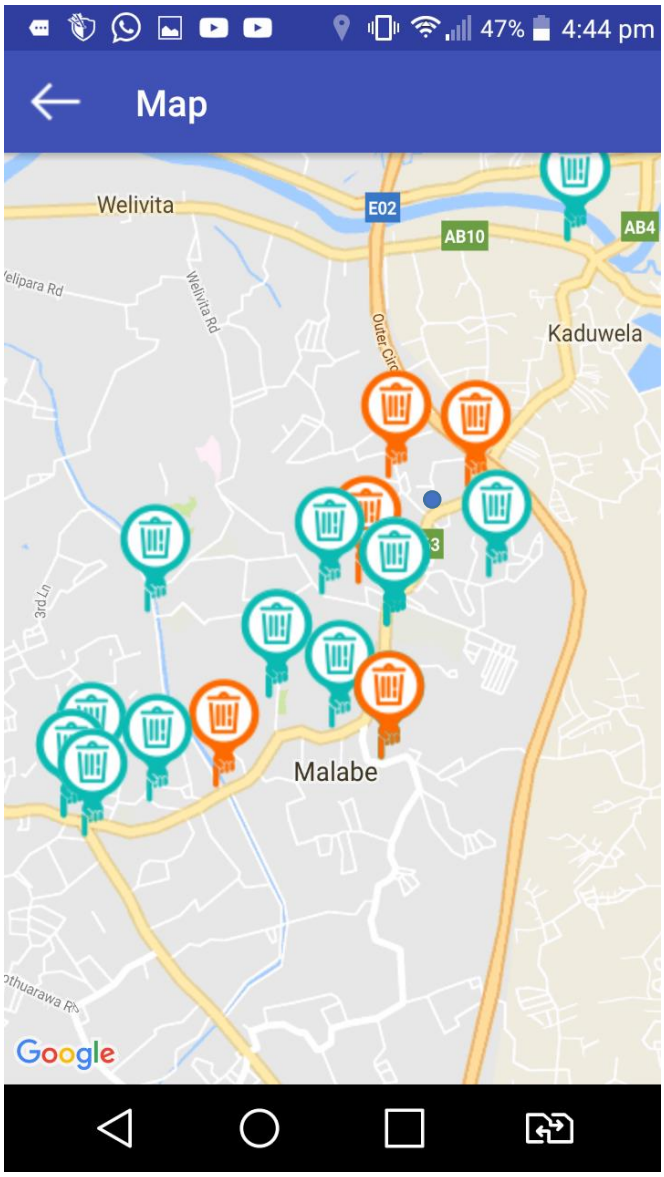


Figure 2.1.3.1: Current location with bins

Use can select the bin which has fill level less than 80% and view the all details about that bin. (Figure 2.1.3.2: Bin details)After user select bin, map provide view route button to get the nearest route from users current location to selected bin. (Figure 2.1.3.3: Best route)

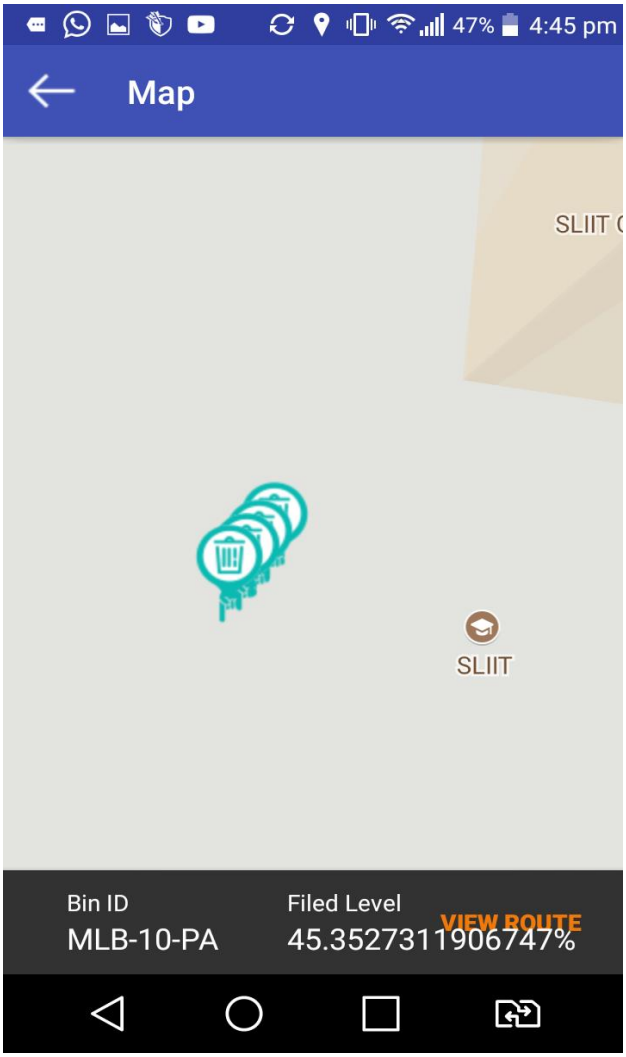


Figure 2.1.3.2: Bin details

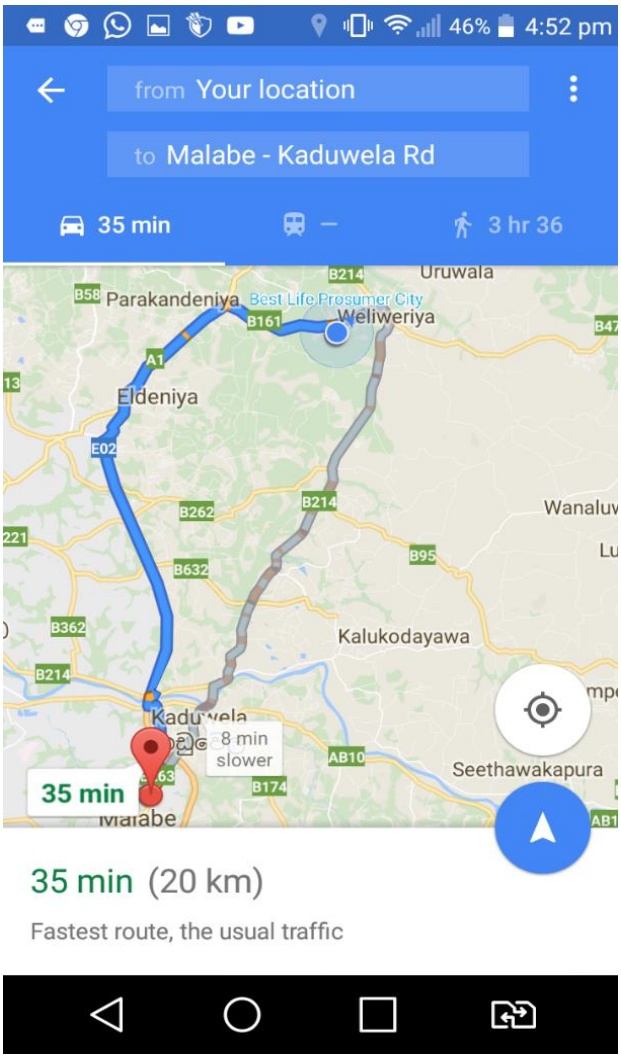


Figure 2.1.3.3: Best route

End user application overall diagram

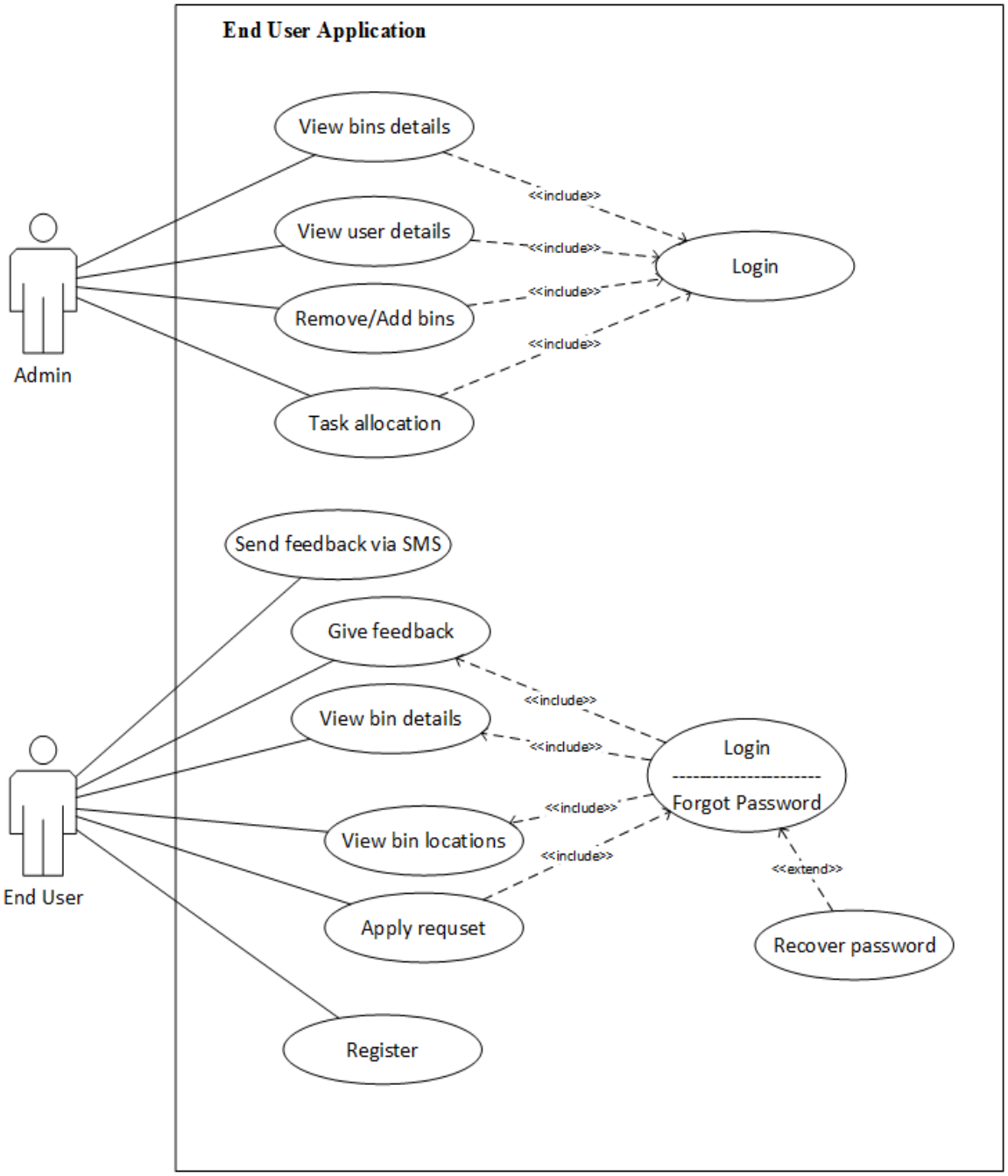


Figure 2.1.3.4: Use Case

2.2 Feedback Analytical system

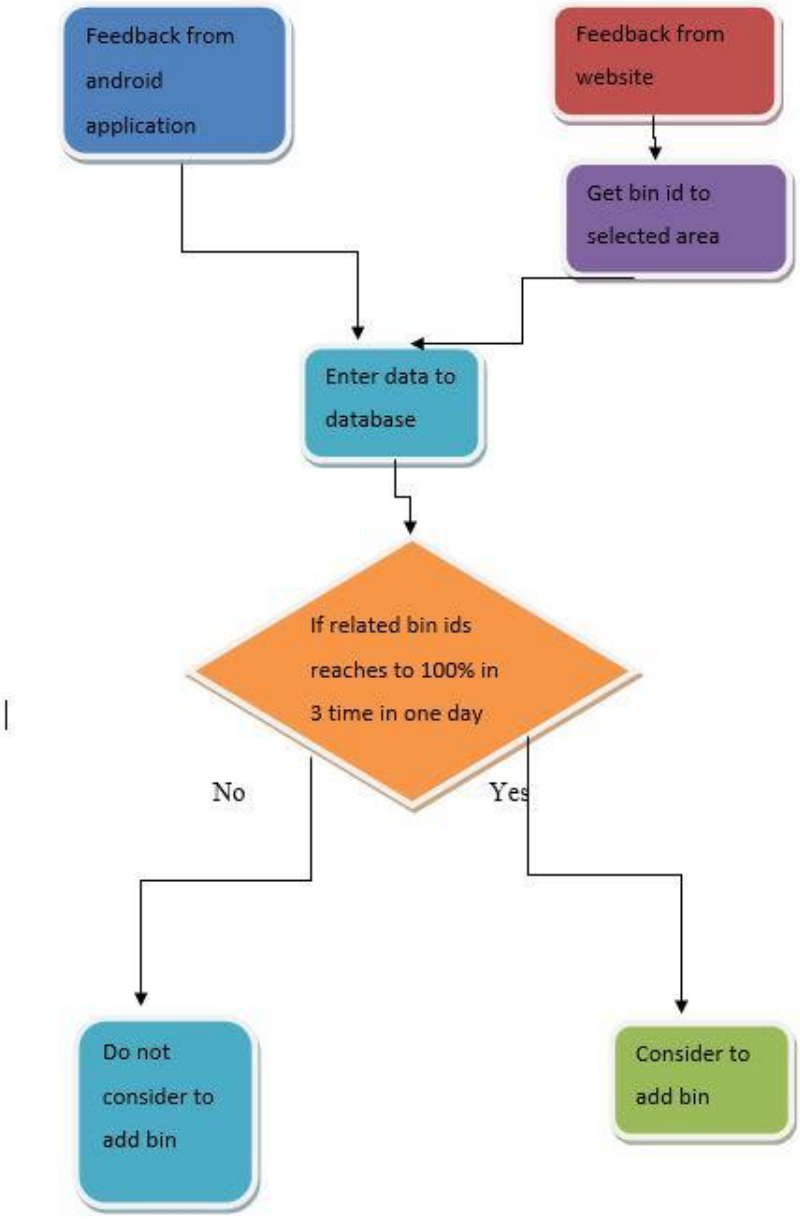
In feedback analytical system author will mainly focus on the bin requesting feedbacks. Users can request bins in two ways. One is using android application. In here users can request bin which bins are already implemented but those bins are not enough for current usages. Other request method is requesting bin using web site. In here user can select position on map and request bin to that selected location. When the user select some point on map author will get the most nearest bins ids for that location. Those bin ids are send to database for analyzing.[13]

In analytical system author will analyze information which in database and provide efficient solution. Following flow chart will explain further. (*Figure 2.2.1: analytical diagram)*

There is another analytical part which is author will provide statically count the bins which need for 'X' number of populated city. In here author will get the one city which is currently successfully implemented our system. As example if we implement our system for kaduwela city by analyzing our data in database author can tell how many bins author use for kaduwela city. According to this value author can generate value for bins which need for 100 people.

When the author going to implement system for new city, author can suggest how many bin need for that city. For this author will get the previously calculated valued and current population of that city.

Figure 2.2.1: analytical diagram



2.3 Testing and Implementations

The end user android application was tested through each function according to the expected output, and tested to ensure that the system was error free. User acceptance testing was done by users. Since performance is a high priority concerned area in a networked application.

A performance test is conducted under the network connectivity of both WIFI network bandwidth (802.11 standards) and under mobile network bandwidth HSPA (H). The conducted test yield, following the results for each method exposed in the web API under mobile network bandwidth connectivity speed of HSPA and WIFI.

To do the testing following test case are using

Table 2.3:1: Test case 01

Test case 01	End user registration
Description	User should be able to Register to system
Pre-condition	End user application must install in users smart phone
Primary user	Citizen
Main flow of events	1. Open application 2. Fill the form by providing details

Table 2.3:1 Test case 02

Test case 02	View map detail/ view bin location
Description	User should be able to view all available bins within his area and bin location
Pre-condition	Users must be login to system
Primary user	citizen
Main flow of events	1. login to system 2. Request available bin within area by clicking view map detail button

Table 2.3:2: Test case 03

Test case 03	Give feedback
Description	Give feedback about custom service and vulnerabilities of system
Pre-condition	Login to android application or web site
Primary user	Citizen
Main flow of events	1. login to android application or website 2. go to feedback section 3. write feedback

Table 2.3:3 Test case 04

Test case 04	Send SMS
Description	User must send feedback and any immediate changes that need to done
Pre-condition	User must have mobile phone which can send SMS to our service number
Primary user	Citizen
Main flow of events	Send SMS via mobile phone

2.4 Assumptions

One assumption about the product is that the GPS components in all Android smartphones work in the similar manner. Another assumption about the product is that it will always be used on mobile phones that have enough performance. The smart phones should enable GPS. Smart city must have Wi-Fi enable all the time. Another main assumption is database server up and running 100%. The application is operating system dependent and should be running only on Android (Minimum Android 4.4.4 KitKat) powered Smart Phones.

3 Result and Discussion

The research produced a usable, functional product that allows peoples to do their work easily. Android application must have user friendly UI and values it provide must be reliable values. When user need to throw their garbage, user will refer the map. The filling levels and other values which map show to user must be real time values otherwise when user reach to selected bin it will be filled with garbage and user has to fine another bin gain.(*Figure 3:2:1: Bin Details)* Also route calculation part must be the same. The route system provide must be most efficient route.

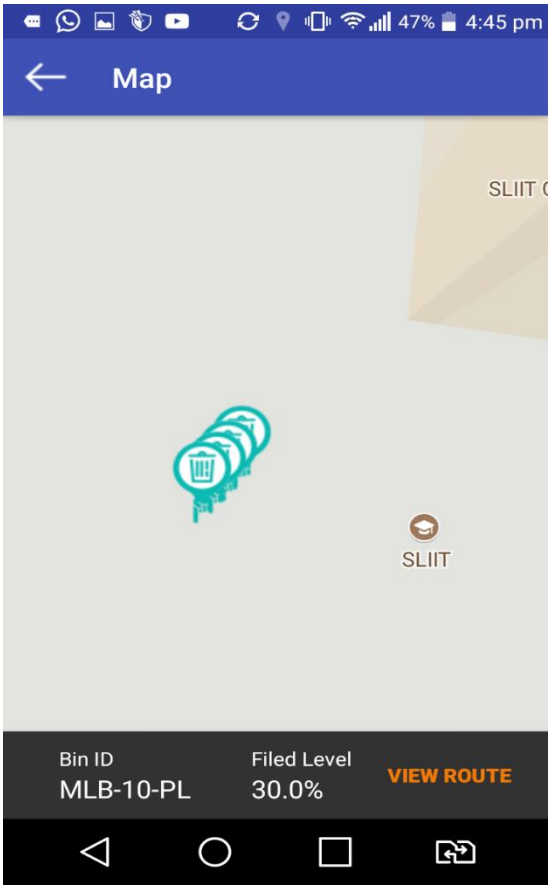


Figure 3:2:1: Bin Details

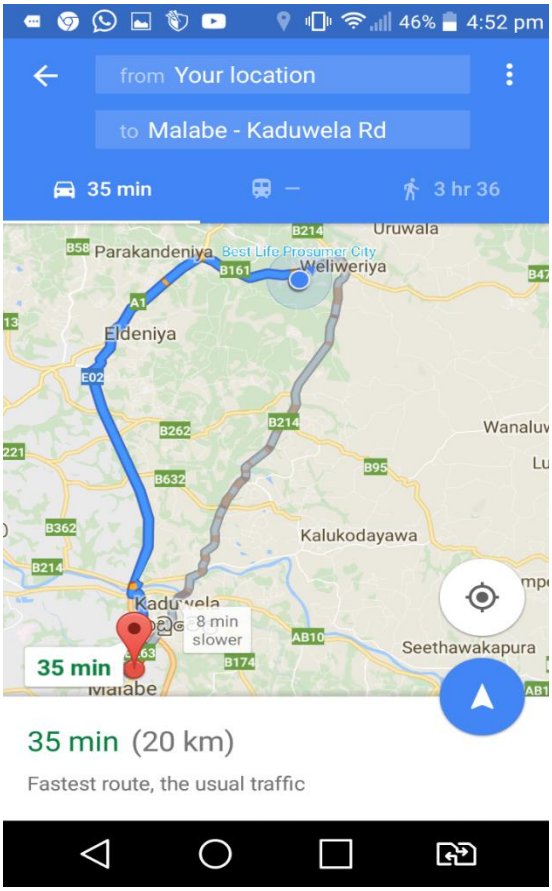


Figure 3:2:2: route

The feedback which get from android application and web site must be analyze fairly. Citizen can give their feedback as they wish like citizen can request any number of bins but author has to analyze those data and must give fair output which will be common to all citizen in city.

3.1 Research Findings

At the very early stages of the research, something that was noted was that there were some studies conducted in the field of the 'Location Based Garbage Management System with IOT for Smart City'. There were research papers even related to the individual research components of the group members. But the main notable point was that this research was unique, in the sense that there were no researches which integrated all of the research components that was integrated into this system. So more in-depth research studies were conducted, some professors were consulted and based on some good research components from different studies, the research components of this project was finalized. Then it was time for the components. Initially an Arduino board was selected as the development board, but then switched to Raspberry Pie Zero due to the lack of parallel processing in the Arduino board. An Infrared sensor was considered to measure distance, but some incompatibilities arose due to the fact that the Raspberry Pie Zero board did not contain any analog pins, and the Infrared sensor operated on analog signals. An analog signal contains infinite number of levels, the digital signal contains only two levels, so when an analog to digital converter was used a base voltage has to be given; the IR signal is checked against this base voltage to see if the signal is higher or lower. The problem arises when different types of garbage is used, the base value has to be changed when the garbage type changes. This cannot be done. So the switch to an ultrasonic sensor was made, since they were digital. A Waterproof ultrasonic sensor was selected, since the bins had to be kept in the open.

4 Conclusion

This research work demonstrated route calculation to all garbage in smart city with feedback analytical system and provide mobile application to workforce users. Analytical system will help to connect users with this system and provide them to better service without vulnerabilities. Android application make citizens day to day if easy. Citizen get their ultimate expectation, benefits on the perspective of garbage management. As well as providing better garbage collection, the government can maintain healthy environment and it will be a foundation to make healthy citizens. This facilitates to initiate, continual improvement and constant garbage management in smart city.

In the future can increase the effectiveness of route calculation to enhance the best route.

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