LOCATION BASED GARBAGE MANAGEMENT SYSTEM WITH IOT FOR SMART CITY

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(Dissertation submitted in partial fulfilment of the requirement for the Degree of Bachelor of Science Special (honors) In Information Technology)

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DECLARATION

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Name: Ms.Shashika Lokuliyana

Signature of the supervisor: Date:

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. This whole process is not monitored, that is the work progress of the workforce or the trucks aren't monitored and the amount of garbage collection is not monitored and recorded.

This study focuses on a web based management and monitoring system for the project which also includes Analysis of municipal solid waste generation. The management and monitoring systems working in conjunction to serve the client and the administrators as a control panel and a monitoring dashboard of the system. The Analysis of municipal solid waste(MSW) generation analyses the data collected from each bin from each region to predict amount of solid waste generated for periods of time. This analysis is also used to make estimates of the profit to be gained by recycling the forecasted MSW.

Keywords – IOT; Smart City; Wi-Fi; Predictive Analytics; Data mining; MSW

ACKNOWLEDGEMENT

I would like to express my special thanks of gratitude to our project supervisor, Ms.Shashika Lokuliyana for her patient guidance, and useful critique of our research work. Her willingness to give her time, so generously has been very much appreciated. Especially mentioning the moral support and the continuous guidance by providing important feedback enabled us to complete our work successfully. I would also like to thank our lecturer-in-charge, Mr. Jayantha Amararachchi for constantly providing us with the guidance and assistance to carry out the research successfully. Also, I would like to thank my research group members as well as all the other friends who supported me and encouraged me throughout this project.

Finally, I would like to express my special thanks to my parents for their support and encouragement throughout my studies.

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LIST OF ABBREVIATIONS

Workforce User	The person who actually uses a particular android application to collect garbage. (Cleaners)
Admin	Administrator of the system
Client	Customer which uses the system
IoT	Internet of Things
Author	Person submitting an article to be reviewed
Bin	Garbage bin
API	Application programming interfaces
MSW	Municipal Solid Waste

1.0 INTRODUCTION

1.1 Background Context

Proper waste management is a basic requirement in any kind of an environment. city Usually cleaning is done in two or three times per day in urban. As an urban city like Colombo usually there are about 1,200,000 to 1,500,000 [1][2] 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 in short time period. most 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. Also considering fill level of garbage bin, all garbage bins are not filled equal time period. Some garbage bin will be filled quickly and some garbage bins will be filled slowly. While collecting garbage by trucks are covered that all type of garbage bin. The obvious solution to this is for the cleaning staff to stay near garbage bins everyday till they fill up to clean them or garbage collecting trucks should go around in the city regularly. These are not effective and efficient solution. It takes way more cleaning staff and costs a lot of money. it is not practical. 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) [4]

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 predict when specific bins gets filled up in the future.

1.2.2 Cruisers: A Public Automotive Sensing Platform for Smart Cities (2016) [6]

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) [7]

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. They use the data collected to analyse and generate reports on the amount of garbage collected and the types of garbage collected

1.2.4 Top–k Query based Dynamic Scheduling for IOT-enabled Smart City Waste Collection (2015) [5]

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 1.2.5.1) 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.

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

Figure 1.2.4.1: Dynamic Scheduling Algorithm

1.2.5 Cloud Computing Based Smart Garbage Monitoring System (2016) [8]

In this paper, a Smart Bin is proposed with a network of dustbins which integrates the idea of IOT with Wireless Sensor Networks. They also propose 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 1.2.6.1) is displayed below.

Hardware used:

- WSN Motes
- IRIS
- Ultrasonic sensors

Software used:

- TinyOs-2.1.2
- NesC
- Azure IOT Hub

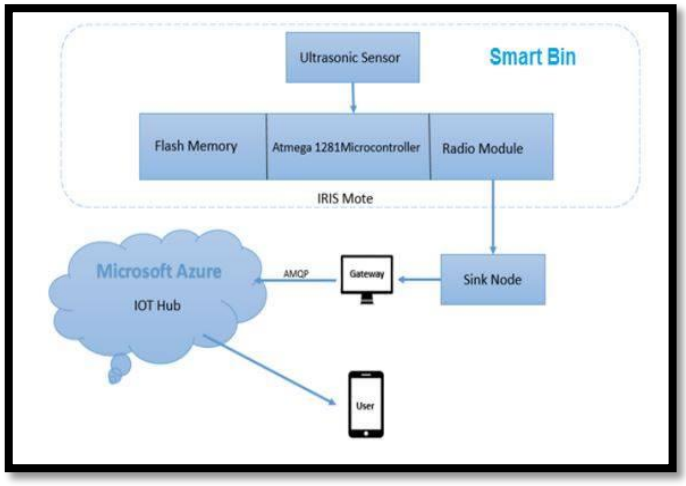

Figure 1.2.5.1: System Overview

This paper uses Azure Machine Learning web service to deploy a trained model as a predictive web service. This system predicts which garbage bins fill up at which points in time.

1.2.6 IOT Based Smart Garbage alert system using Arduino UNO (2016) [9]

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.

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.

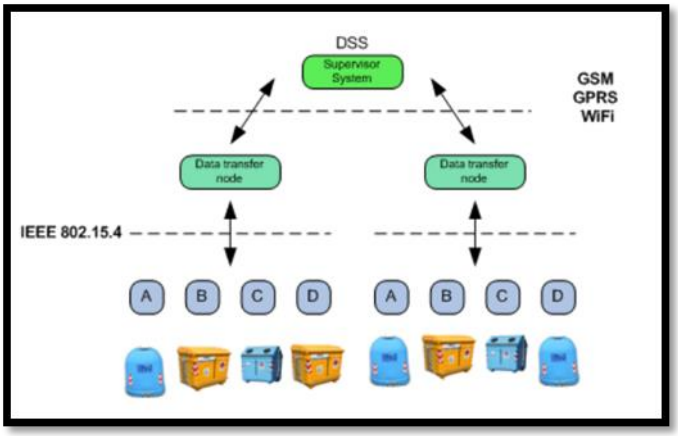

Figure 1.2.7.1: SEA project system architecture

The main components of the developed architecture on the SEA project (Figure 1.2.8.1) 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 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 [3], the total amount of garbage collected in 311 local authorities was 2838 metric tons per day [3], which amounts to an annual garbage collection of 1.04 million metric tons per year. This is only 23% [4] 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 [4] on daily collection and disposal of garbage.

1.4 Research Gap

Different papers have used different methods to manipulate data,

Smart Bin Implementation for Smart Cities [4] has used an Excel application, which has some weaknesses[10] such as

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

This paper only uses the historical data collected to predict when bins are getting filled in the near future.

Cruisers: A Public Automotive Sensing Platform for Smart Cities (2016) [6] uses a SOX server which implements publishing and subscribing functions for sensor data based on XMPP. This paper collect data, but do not use them for analytical purposes.

IoT Based Solid Waste Management System A conceptual approach with an architectural solution as a smart city application (2016) [7] uses the data collected to analyses and generate reports on the amount of garbage collected and the types of garbage collected, but do not use them to forecast future amounts.

Top–k Query based Dynamic Scheduling for IOT-enabled Smart City Waste Collection (2015) [5] paper mainly focuses on optimizing truck routes. It does not look into the garbage level predictions.

Cloud Computing Based Smart Garbage Monitoring System (2016) [8] paper also predicts which bins fill up at which points in time using Azure Machine Learning web service.

IOT Based Smart Garbage alert system using Arduino UNO (2016) uses an Arduino Uno and RFID based system to give real time alerts to the municipal council. This system does not use any predictive algorithms.

The papers mentioned above either does not use analytical algorithms or just predicts future bin levels. This paper not only predicts future bin levels, but forecasts future amounts of solid waste generated for periods of time and estimates profits to be gained by recycling those amounts.

1.5 Research Objective

1.5.1 Main Objectives

- Build a cost-effective garbage management system for the municipal council that will help them keep the city a cleaner place.
- Build a system (Garbage bin/ android application/ website) that will encourage people to use garbage bins instead of littering.

1.5.2 Specific Objectives

The specific objectives are:

- Build a website that inspires clients to use the system, gives proper knowledge on how to use the system and integrate it into their day to day lives.
- Build a user friendly Admin dashboard which can be used by the admin to control the whole system with minimal technical knowledge.
- Give the government an estimate of the profit to be gained from recycling the amount of garbage collected from each region. Give incentive to the government to setup more recycling stations.
- Give the government statistical values of how much of specific types of materials, such as plastic, glass, etc, is being used in each region.
- Give the government the foundation statistics to implement techniques to reduce the use of non-ecofriendly materials like plastic and have a way to test if the implemented techniques are successful.

2.0 METHODOLOGY

2.1 Methodology

2.1.1 Setting up the Server

Amazon AWS was selected to purchase a VPS that suits the specific requirements of the project. The Figure 2.2.2.1 displays the different servers available.

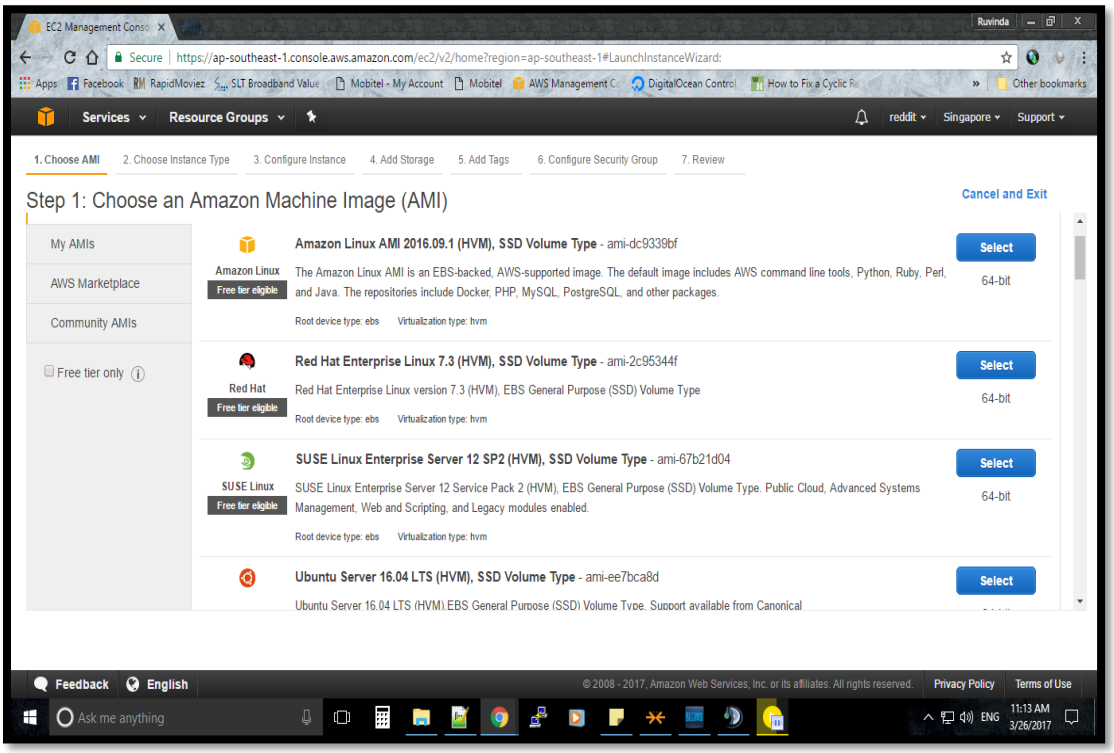

Figure 2.1.1.1: AmazonAWS

Once the VPS was bought these are the software that was used to setup the server and website.

Table 2.1.1.1: Software to be used

Software	Task
Puttygen	To create private key
Putty	To connect to VPS
WinSCP	FTP client to transfer files
LAMP server	Package includes : Apache web server : MySQL database : PHP language

2.1.2 The Website

2.1.2.1 The Home Page

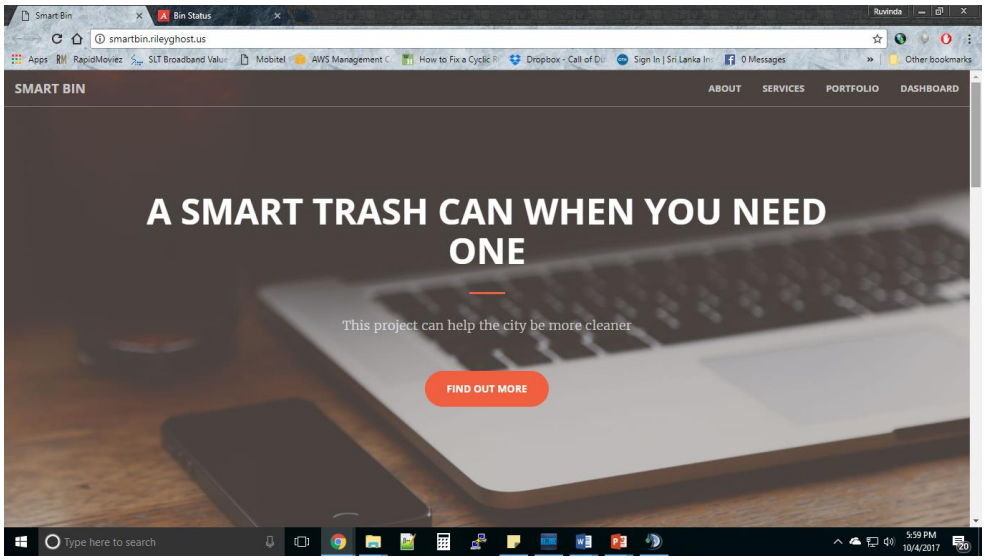

Figure 2.1.2.1.1: Home Page

The home page is where the first page displayed when a user accesses the website, this user can be an Admin or a client.

This page contains a number of sections:

- Find out more

  This section contains information and knowledge needed to inspire a new client to start using the system, as well as information on how the system works.
- Services

  This section provides information about the services provided by the system
- About

  This section contains information on how to get in contact with our system administrators and managers.
- Dashboard

  This section contains the link to the sign-in page for the admins and the clients.

2.1.2.2 The Sign-in Page

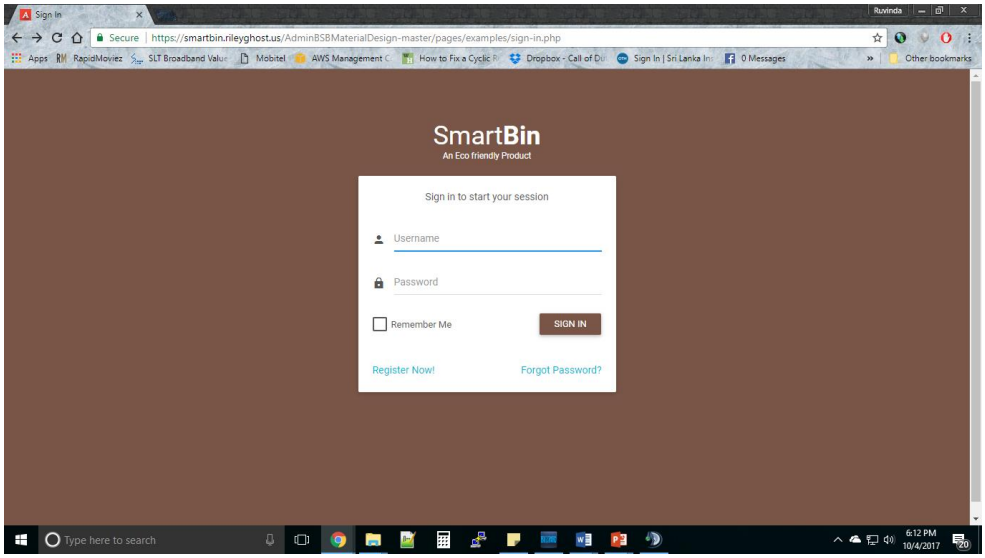

Figure 2.1.2.2.1: Sign-In Page

This page is used by the clients and the admins to login to their respective dashboards. Based on the login credentials provided the user is directed to the Admin dashboard or the Client dashboard.

2.1.2.3 The Sign-up Page

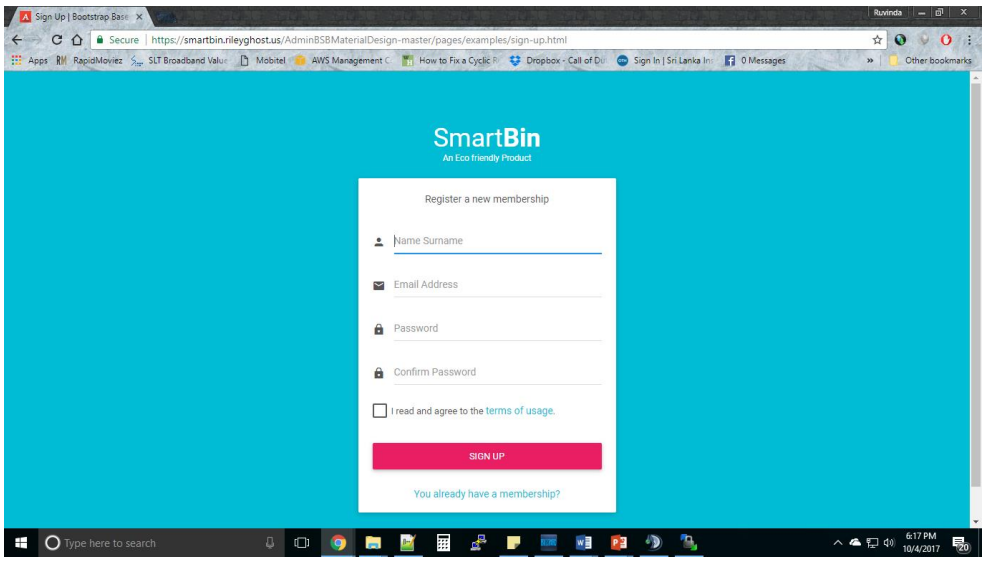

Figure 2.1.2.3.1: Sign-up Page

This page can only be used by new clients to register on the system. This cannot be used to create new administrator account. Only logged in administrators have permission to create new administrator accounts from the Admin dashboard itself.

2.1.2.4 The Admin Dashboard

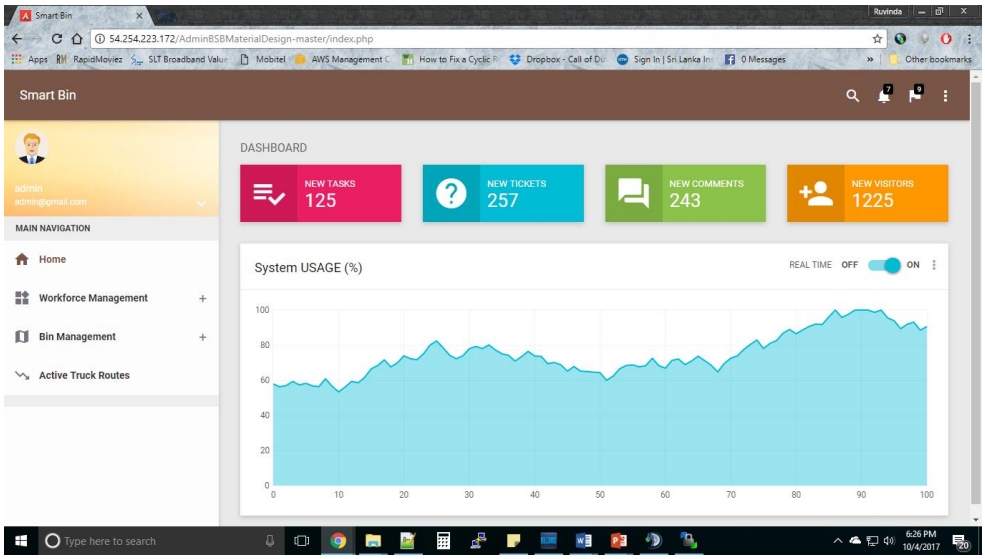

Figure 2.1.2.4.1: Admin Dashboard

This is the dashboard which the admin has to access to gain access to all control functions of the system. The available functions are as follows;

- Add, Delete and manage Administrator accounts

  For security reasons users are not allowed to register themselves as admins. The website signup page can only be used to register new clients. If a new administrator account has to be created, it can only be done by another administrator.
- Add, Delete and manage Workforce user accounts

  Workforce users does not have access to the website, they only have access to the Workforce android application. Since workforce users only has access to manage their profile from the android application an administrator has to create new accounts for workforce users. If a workforce user is no longer in service the administrator has access to remove the account.
- View Active Truck Routes

  The admin has the capability to see the active truck routes in each region
- Status of bins and location

  The admin has the capability to see all the statuses of bins in each region and their locations on a map

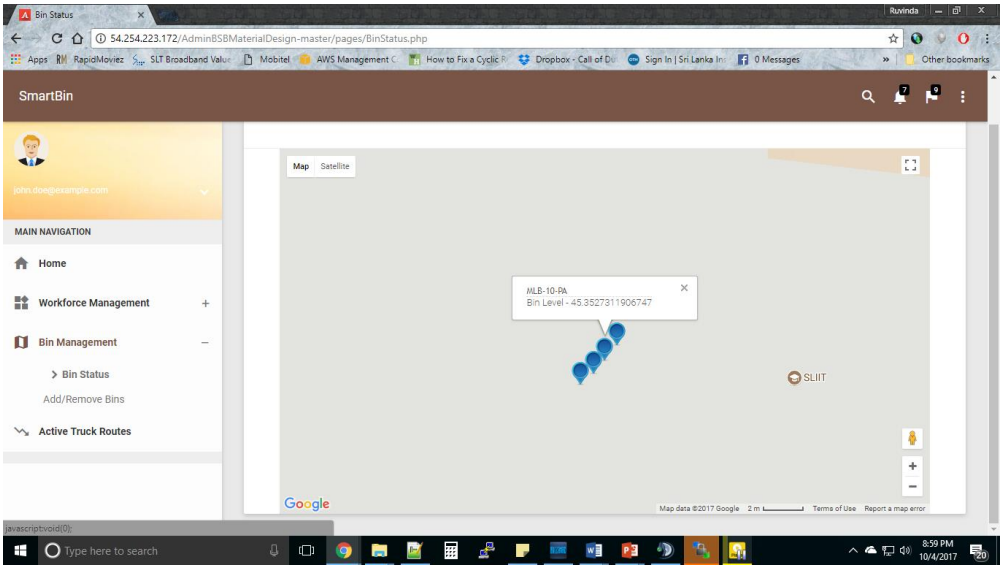

Figure 2.1.2.4.2: Status of bins

- Add, remove bins and change status of bins

  The admin has the capability to manage bins on a map itself. That is add a new bin, remove a current bin or change the status of a bin to ‘Active’ or ‘Inactive’.

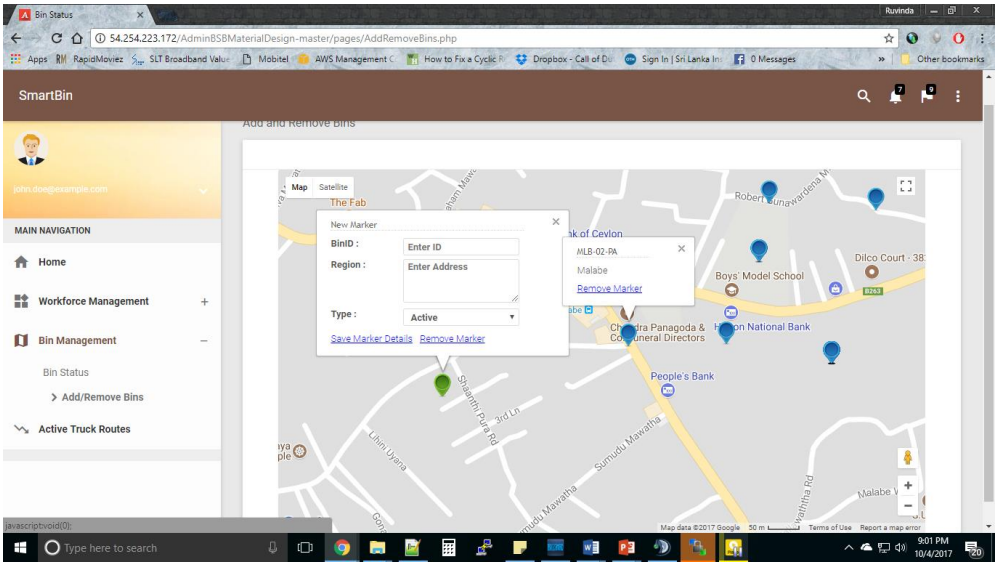

Figure 2.1.2.4.3: Add/Remove Bins

- View client requested bins

  The admin has the capability to view client requested bins and add them if needed from the add bin map.

- View Reports

  The admin has the capability to view different statistical reports generated by the system, such as:

  - Amount of garbage collected in each region from the types biodegradable, plastic, paper and glass.
  - Profit that could be gained by recycling the specific weights of garbage collected from each region.

- Add news and maintenance alerts

  The admin has the capability to add news such as new features added to the system and maintenance updates to the news feed that is shown on the website for clients and the Client android application.

2.1.2.5 The Client Dashboard

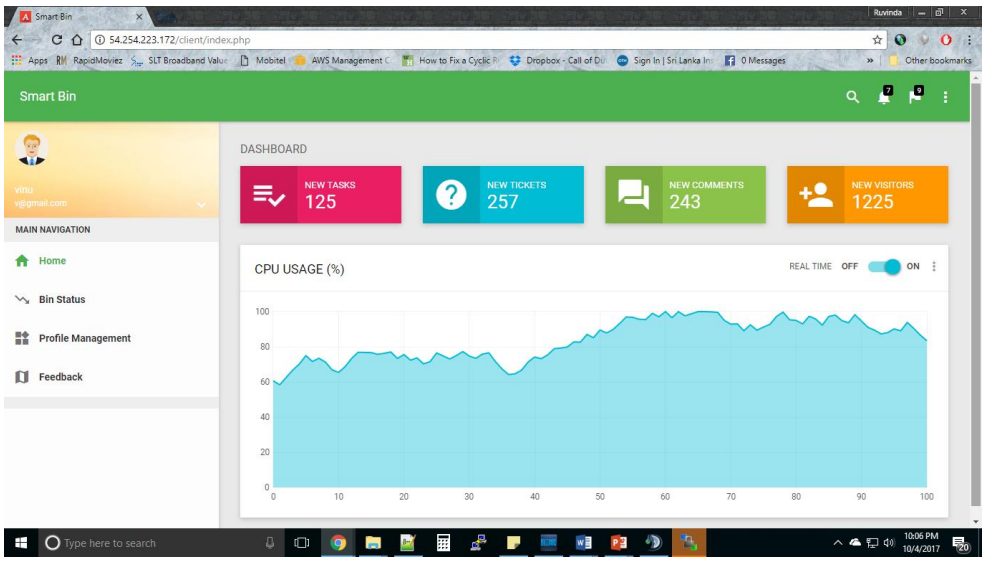

Figure 2.1.2.5.1: Client Dashboard

This is the home page of the client dashboard. The services provided by the system for the client can all be accessed here. The main functionalities are:

- Bin Status

  View bin status and locations of bins in a real time map.

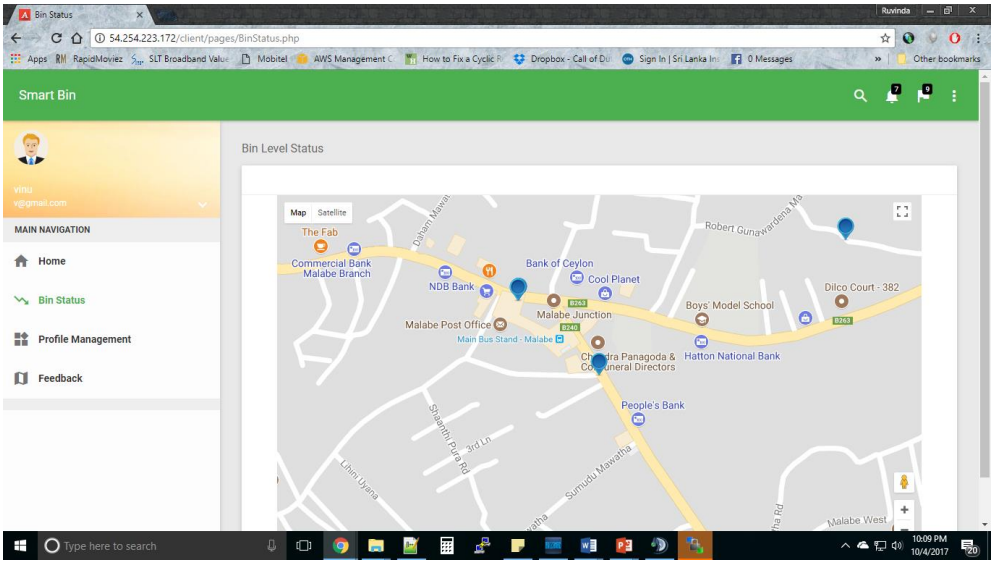

Figure 2.1.2.5.2: Bin Status Client

- Request Bins

  If bins on a certain location is constantly getting filled, or a certain place desperately needs new bins, users can specifically select the location and request a new bin on that location on the map.
- Edit User Profile

  Edit user profile settings like Name, Email, Password and Profile picture.
- Give Feedback

  There are 2 types of feedback which a client can use. They are
  - Bin maintenance request

    If a bin is not working or is not being cleaned properly, clients can lodge a special request to clean or replace the bin in question.
  - Other complains
- Get news and maintenance alerts

  Users get immediate alerts if there are new news alerts or maintenance alerts.

2.1.3 The Analysis of Municipal Solid Waste Generation

This analysis consists of two parts

- Predict amount of solid waste generated for periods of time for each region from each type of garbage.
- Make estimates of the profit to be gained by recycling the predicted municipal solid waste.

The first step to do both of these components is to record the weight of each type of garbage collected from each region. These are the steps used to record the values:

1. Each time a cleaner hits the deactivate bin button to clean a specific bin, the garbage level is uploaded to the server.
2. The level from each bin is converted to weight using the bin's volume.
3. The amount of garbage collected of each type from each region is calculated from the stored amounts on a weekly basis.

4. The weekly values are used to predict the garbage levels in the coming months up to a year in the future.

Each month a report is created detailing the predictions made from the four weeks of the last month. This reported can be used by the government to implement techniques to reduce the use of materials like plastic. After a technique has been implemented, the new reports can be used to check how effective the technique is.

(This part is not complete, some calculations that should be added are not final yet)

2.2 Testing and Implementation

The Webserver and the Website 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 two users. Since performance is a high priority concern area in a webserver, all the components were integrated and tested. The two applications, the bin and the website was run simultaneously to see if the load was too high for the server. The server seemed to work fine under high amount of requests from each component.

2.2.1 Assumptions

- The Amazon AWS server has a 100% uptime
- The users have an internet connection

2.2.2 Test Case

Table 2.2.2.1: Test case 01

Test ID	01
Description	User should be able to login into the system.
Pre-condition	User must load up the website
Actors	Admin/Client
Main Flow Events	1. Load the website 2. Click on ‘Dashboard’ 3. Enter credentials 4. Click login
Input	Correct username and password.
Expected Output	Respective admin or client dashboard loads up
Actual Output	Respective admin or client dashboard loads up successfully

Table 2.2.2.2: Test case 02

Test ID	02
Description	User should be able to monitor all available bin locations and levels.
Pre-condition	User must be logged in to the system
Actors	Admin/Client
Main Flow Events	1.login to system 2. Click view bin detail map
Expected Output	A map with markers loads up.
Actual Output	A map with markers loads up successfully.

Table 2.2.2.3: Test case 03

Test ID	03
Description	Admin should be able to receive different types of progress/review reports
Pre-condition	Admin must be logged in to the system
Actors	Administrator
Main Flow Events	1. login to system 2. Click reports button
Expected Output	The reports page loads up.
Actual Output	The reports page loads up successfully.

Table 2.2.2.4: Test case 04

Test ID	04
Description	Admin should be able to add new bins to required location of the map

Pre-condition	Admin must be logged in to the system
Actors	Administrator
Main Flow Events	1. login to system 2. Click on the monitoring system map to check required locations 3. Add bins from the map
Expected Output	Add bins map loads up.
Actual Output	Add bins map loads up successfully.

Table 2.2.2.5: Test case 05

Test ID	05
Description	Admin should be able to view all the feedback the clients have given regarding the system
Pre-condition	Admin must be logged in to the system.
Actors	Administrator
Main Flow Events	1. login to system 2. Click feedback button
Expected Output	Feedback management page loads up.
Actual Output	Feedback management page loads up successfully.

Table 2.2.2.6: Test case 06

Test ID	06
Description	User should be able to give feedback to the system
Pre-condition	User must be logged in to the system
Actors	Client

Main Flow Events	1. login to system 2. Click on feedback
Expected Output	Feedback page loads up successfully.
Actual Output	Feedback page loads up successfully.

Table 2.2.2.7: Test case 07

Test ID	07
Description	User should be able to request new bins on specific locations
Pre-condition	User must be logged in to the system
Actors	Client
Main Flow Events	1. login to system 2. Click on request bins
Expected Output	A map with to request bins loads up.
Actual Output	A map with request bins up successfully.

2.3 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.

3.0 RESULTS AND DISCUSSION

The system worked well after the testing phase. The research produced a usable, functional product, that allows new client registrations, functional client dashboard and admin dashboard. The system was simple enough to be understood and used by a person who had no technical knowledge of the system.

The system can be improved by adding a component to identify types of garbage from the bin itself, thus removing human segregation. If this is implemented, on a single location instead of four bins for the four different types of garbage, one large bin can be placed which segments the garbage by itself.

Another area which can be improved is instead of each bin connecting to an access point to communicate with the server, bins can communicate with each other and connect to an access point through a main hub. This method may reduce network costs and make the network process more efficient.

4.0 CONCLUSION

This article incorporates IOT solutions to implement a system that provides the municipal council with a system that better equips them to handle the garbage problem in a smart city. Every party is interacting with this system, that is the citizens, the workforce and the admins. Citizens can interact through the android application and the website, workforce through the app and the admins through the website. This

system mainly focuses on the ease of use of the users, and ultimately contributing to a cleaner city.

5.0 REFERENCES

[1] S. Longhi *et al*., "Solid Waste Management Architecture Using Wireless Sensor Network Technology," *2012 5th International Conference on New Technologies, Mobility and Security (NTMS),* Istanbul, 2012, pp. 1-5.

[2] H. Chourabi, T. Nam, S. Walker and others,. "Understanding Smart Cities: An Integrative Framework," In Proc. of the *45th Hawaii International Conference on System Sciences* (2012), pp. 2289–2295.

[3] W. Xie and Y. Chen, "A Cache Management Scheme for Hiding Garbage Collection Latency in Flash-Based Solid State Drives," 2015 IEEE International Conference on Cluster Computing, Chicago, IL, 2015, pp. 486-487.

[4] Narayan Sharma, Nirman Singha, Tanmoy Dutta, Smart Bin Implementation for Smart Cities, International Journal of Scientific & Engineering Research, Volume 6, Issue 9, September-2015, pp. 787- 791.

[5] T. Anagnostopoulos, A. Zaslavsky, A. Medvedev, S. Khoruzhnikov, "Top-k Query based Dynamic Scheduling for IoT-enabled Smart City Waste Collection," In Proc. of the 16th IEEE International Conference on Mobile Data Management (MDM 2015), Pittsburgh, US.

[6] Y. Chen, J. Nakazawa, T. Yonezawa, T. Kawsaki and H. Tokuda, "Cruisers: A Public Automotive Sensing Platform for Smart Cities," *2016 IEEE 36th International Conference on Distributed Computing Systems (ICDCS)*, Nara, 2016, pp. 767-768.

[7] A. S. Bharadwaj, R. Rego and A. Chowdhury, "IoT based solid waste management system: A conceptual approach with an architectural solution as a smart city application," *2016 IEEE Annual India Conference (INDICON),* Bangalore, 2016, pp. 1-6.

[8] J. Joshi *et al*., "Cloud computing based smart garbage monitoring system," *2016 3rd International Conference on Electronic Design (ICED)*, Phuket, 2016, pp. 70-75.

[9] N. S. Kumar, B. Vuayalakshmi, R. J. Prarthana and A. Shankar, "IOT based

smart garbage alert system using Arduino UNO," *2016 IEEE Region 10 Conference (TENCON)*, Singapore, 2016, pp. 1028-1034.

[10] Team, Denizon. "Top 10 Disadvantages of Spreadsheets." Denizon. Denizon, 11 June 2016. [Online]. Available: https://www.denizon.com/spreadsheets/top-10-disadvantages-of-spreadsheets/. [Accessed: 26 Mar. 2017]