Real - Time Smart Waste Management System Based on IOT for Smart City

Student Name: A. K. D. Shiroma Weerathunge
Student Reg No: 2016 MIT 085
Supervisor Name: Dr. M. G. N. A. S. Fernando

A dissertation submitted in partial fulfillment of the requirements
for the degree of
Master of Information Technology

31st May 2019

Abstract

In many places, it can be seen that the Municipal garbage bins are overflowing and they are not cleaned regularly. Waste have become one of the crucial universal problems at present and has become a cause for the environment as well as a reason for the diseases like dengue, malaria etc. There should be a system that can monitor the bin and can give the information of filling of the bin to the municipality using IOT technology, so that the bin can be cleaned on time and the environment can be safeguarded. And also the garbage collecting process can be optimized by viewing the collecting vehicle location on the route. Municipal councils has a problem with the monitoring of filling levels of garbage bins efficiently and collecting them by going collecting vehicles on optimized path. The main reason for this problem is having no communication among the customers who has garbage bins and the municipal council. This project is carried out to provide a solution to the mentioned problem. This project suggests a solution to enable the society to automate and optimize waste management process using Internet of Things (IOT) technologies. The system provides a web interface and mobile app to the cleaning authority so that they can monitor and clean the garbage bin. In this project, Arduino and NodeMCU is used as the main boards which are designed based on the ATmega2560 microcontroller architecture and ESP8266 Wi-Fi microchip architecture. Arduino board makes the connection with all distributed sensors placed in the bins and transfer data to the NodeMCU. NodeMCU communicate via Wi-Fi and send all data to the firebase cloud database. The goal of sensors are to collect the parameters like level of the three types of garbage bins. The parameters are collected by the sensors are sends to the NodeMCU module and NodeMCU sends them to the Firebase cloud database. Google Firebase stores collected data in the database and analyzes the stored data. Hence database collects the data over Wi-Fi wireless communication protocol and allow user to monitor the data from a web browser or mobile app. Cleaning authority can collect the garbage on time. And also this project suggests a Global Positioning System (GPS) to the collecting vehicles for an efficient garbage collection, by tracking vehicle location according to the current latitude and longitude of the collecting vehicle provided by the mobile phone of vehicle driver via the app. And each delivery vehicle can be tracked using the GPS/GPRS based data and the location of the vehicle will be updated on the map. This system has ultimately improved the efficiency of the garbage collecting process optimizing the collecting process and emptying the garbage bins on time.

Declaration

The thesis is my original work and has not been submitted previously for a degree at this or any other university/institute.
To the best of my knowledge it does not contain any material published or written by another person, except as acknowledged in the text.

Student's Name: A. K. D. Shiroma Weerathunge
Registration Number: 2016/MIT/085
Index Number: 16550851

_____ _____
Signature: Date:

This is to certify that this thesis is based on the work of Ms**. A. K. D. Shiroma Weerathunge** under my supervision. The thesis has been prepared according to the format stipulated and is of acceptable standard.

Certified by:
Supervisor Name: Dr M.G.N.A.S. Fernando

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Signature: Date:

Acknowledgement

I would like to convey my deepest gratitude to those who helped me to make this masters project a success. I specially thank to Lecturer Dr. M. G. N. A. S. Fernando, University of Colombo who guided me throughout the whole research project and encouraged me by giving necessary instructions to complete this.

Next I would like to express my sincere gratitude to Mr. Harsha Subhasinghe, Public Health Officer, Embilipitiya Urban Council who provided information and support me to make this a success. Furthermore I wish to thank my friends in the electronic engineering field and my students in school robotics students club of Embilipitiya President's College who helped me to design the IOT device which is very important for this project. Further I thank all the delivery personnel from whom I got assistance for my data survey.

Finally I am sincerely grateful to my Husband, son, daughter, parents, and my friends who always encouraged and stood behind me.

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List of Acronyms

ER - Entity Relationship
GUI - Graphical User Interface
HTML - Hypertext Mark-up Language
PDF - Portable Document Format
RAM - Random Access Memory
RUP - Rational Unified Process
SQL - Structured Query Language
UML - Unified Modeling Language
URL - Uniform Resource Locator
RFID – Radio Frequency Identification Uses
GPS – Global Positioning System
UC – Urban Council
LED –Light Emit Diode
LCD – Liquid Crystal Display
IOT – Internet of Things
SMS – Short Message Service
GSM - Global System for Mobile Communications
GPRS - General Packet Radio Services
SDK – Software Development Kit
API – Application Programming Interface
IDE – Integrated Development Environment
HTTP – Hypertext Transfer Protocol
SSID – Service Set Identifier

Chapter 01 – Introduction

1.1 Identification of the Problem

Waste management has become one of the critical universal problem today. The growth in world population, their complex living styles and the growth of urbanization have increased the amount of solid waste produce. According to the World Bank report, [1] Current global MSW generation levels are approximately 1.3 billion tons per year, and are expected to increase to approximately 2.2 billion tons per year by 2025. This represents a major increase in per capital waste generation rates, from 1.2 to 1.42 kg per person per day in the next fifteen years. However, global averages are broad estimates only as rates different considerably by region, country and within cities. It therefore means that every state and local authorities suffer from the problem of effective waste disposal due to the generation of too much waste. The problem is that the today society is driven by a throw-away consumerism with companies and producers motivate to maximize profits by producing one-time use products without prioritizing on 3R that is reuse, recycling or the reducing use of environmentally non-friendly materials.

These waste have become a huge problem for the environment as well as a reason for the diseases like dengue, malaria etc. In Sri Lanka It has become a threat for the people as number of people die annually due to dengue disease. According to the updates of epidemiology unit, ministry of health, Sri Lanka, [2] for the year 2017, 186101 and in the month of May, 2018, 18695 suspected dengue cases were reported to the Epidemiology Unit from all over the island. Approximately 30.4% of dengue cases were reported from the Western province. The highest numbers of dengue cases were reported during the 29th week of 2017.

Having a proper waste management mechanism is a must to manage the situation. Traditionally, litter bins are emptied at certain intervals by relevant authorities. This method has several drawbacks such as some garbage bins fill up faster than the speed of emptying and they are full before the next scheduled time for collection of garbage. This leads to overflowing of garbage bin and poses spread bad smells. There are special periods when certain litter bins are filled up very quickly and there is a need for increased collection intervals. It is a challenge to maintain a clean and pleasant environment.

1.2 Motivation

As a major application field of IoT, waste management systems are much needed for present society. Waste management has become a major issue in the world. The absence of efficient waste management system has caused severe environmental problems and cost issues. In Sri Lanka, there are some recent incidents that happened. People died as there were no proper garbage management process. Related to Sri Lankan body, some urban councils are following manual methods to collect waste. But still they aren't following correct methods to collect garbage as well as many cities are filled with bad smells and people are suffering without proper waste management systems. The latest incident which happened in "Meethotamulla garbage pit" was the fatal incident which showed how the failures about mismanagement of waste. An automated waste management system will resolve many problems which have with manual system. IOT based automated waste management systems are very useful for waste management and still those systems are in under the research level in the world.

Embilipitiya urban council (UC) has taken some steps forward, so that the UC has given a bin for each house to collect their non – bio wastage. And the UC is going to collect them once for three weeks. And also the UC is coming to collect their bio – wastage twice a week. But the people in the area want to give their bio – wastage daily or very often as non – bio wastage become spoil very soon with their bad smell. And also the problem of UC was that they have no more garbage trucks to go to collect waste and they don't have a method to know about the filling status of the garbage bins. Normally they are going to collect garbage according to the houses in the lanes. So there is not fuel efficience when considering about their transportation cost. They want a system which indicates about garbage filling level status and then follow the relevant paths for the garbage collection vehicles to collect them according to the vehicle capacity.

Considering their present situation, proposed a model to send notifications to the UC, indicating garbage filling levels of the bins and manage the waste collection using a web based app is a great opportunity not only for the Embilipitiya UC but also for the whole country. The UC can plan and anticipate for future demand, in advance they can react immediately for any situation in waste management.

1.3 Aims and Objectives

The main aim of the system is increasing the efficiency and effectiveness of collecting waste by optimizing the path and managing the waste properly. To achieve the main objective, following objectives of the project are also hope to achieve.

- **Sending notifications to the authorized parities on the status of waste bins are getting filled.**

  In the present manual system, UC doesn't know about the filling levels of the bins and many times overflow the waste bins. To avoid this, it can set the sensors to the bins to get the bin filling level updates.
- **Collecting garbage by going along suitable path and updating relevant authorities and track the collection vehicle by GPS.**

  After receiving the notifications of bins' filling level, follow the best paths to collect the waste by tracking the waste collection vehicles.
- **Update the trailer capacity by sending notifications to the authorities.**

  While collecting the waste, the authorities will be updated.
- **Suggest guidelines to deliver for the authorized people.**

1.4 Scope

This project suggests a solution to enable the society to automate and optimize waste management process using Internet of Things (IOT) technologies. The proposed solution will notify the users and authorized parties when the waste bins are getting filled. Users can take necessary action based on the status. At first, get the locations of the bins are placed by GPS. Users put garbage in to the bins so that the sensors are detect the filling level of the bins. And also authorities get the notifications from garbage collection tractors' capacity level updates as well. Authorities analyze the notifications and calculate the total garbage filling level of certain paths and calculate trailer capacity level. After that authorities tracks collecting vehicles' locations by GPS and sends

notifications to the relevant vehicles to follow the relevant path by showing it on the map. Collecting vehicles reach to the filled bins and empty the bins and it will automatically updates the authorized parties about waste collected status. Then vehicles are delivered with collected garbage to the collection centers.

The proposed model and the Web App provides detecting filling levels, monitoring environment, track locations, update status, view the path with smart dashboard, analytics, and control center in the system. And the proposed model is going to be created using Arduino - Uno/ Raspberry- Pi, Sonar sensors, GPS Modules, SMS Module, power Supply, LED Panels and some other devices etc. The sensors send data to the cloud database and the control centre analyse those data and calculate shortest paths to follow the collecting vehicles. This model will be used as an example to show garbage collection routine.

1.5 Structure of the Dissertation

Dissertation is the document which contains overall information of the project in chapter wise. The Background chapter will be written to provide an idea about background of implementing the project. Other than that, chapter will provide a review of similar systems, tools and technologies which used in the system implementation. The Methodology chapter will describe about how it made the proposed model. The chapter will includes methodologies, tools and techniques used to design the system. To describe the design, it will use appropriate mechanisms like pseudo codes, suitable diagrams etc. And the implementation environment (hardware/software), tools, and existing software that re-used, etc. will be included. All major code and module structures in the code and also will identify platform dependencies. The evaluation chapter will describe how the system will be tested by using various testing methods. It also will report errors, how to overcome those errors and how to modify the system. This chapter will give the results of the work in the form of tables or graphs. This chapter will provide a discussion evaluating the results pointing out positive and the negative aspects of the work. The Conclusion chapter will be included all the summarized details of the projects and also included findings and lessons learned during the project with further improvements of the project.

Chapter 02 – Background

2.1 . Background Introduction

Waste management is all the activities needed to manage waste from its generation to its final clearence. This includes amongst other things, categorization, collection, transport, treatment and disposal of waste together with monitoring and regulation and it's a discipline which manage waste materials in a way that best addresses the range of public health, conservation, economics, aesthetic, engineering and other environmental factors.

2.2 Organization Background

Embilipitiya urban council collects their garbage twice a week without getting any daily updates about the available garbage collection from houses and many places in the area. When collecting garbage they have their own route plans to follow. They don't know the exact places which have garbage to collect and also they don't have any data on the amount of garbage that collected before leaving the tractors from urban council in relevant days. So they follow their own fixed route plan and collect garbage. As collecting vehicles do not follow predetermined paths, it's a course for a high fuel consumption. They don't have enough garbage collecting vehicles to allocate for the routes. And also they have a challenge as they don't know the places where garbage bins are overflowing. It's a course for spreading bad odour in everywhere and a barrier for the pleasant and safeguard environment. This situation is common not only for Embilipitiya urban council but also for every urban councils in Sri Lanka.

2.3. Review of Similar Systems

Smart waste management system solutions optimizes waste collection routes and schedules based on real-time and historical data, provides predictive analytics to enable decision making ahead of time, and offers consultation on waste bin allocations.

A Portuguese municipality Cascais [3] has taken a significant leap forward in Smart City waste management by deploying SmartBin technology to their underground bins as part of its Smart City initiatives, reducing collection costs and improving waste collection processes. In partnership with Sotkon Waste Systems, from March 2015, the region will monitor their public Sotkon underground recycling bins with SmartBin's remote fill-level sensors, joining a growing list of private and public waste collectors using smart waste management services in Europe. The municipality, that serves over 200,000 inhabitants, have positioned themselves as one of the most forward thinking Smart City advocates, with a history of innovative projects and awards. SmartBin is a provider of intelligent remote monitoring solutions in the waste management and recycling sectors and commenced operations in Australia in July 2014. The Dublin-based solutions provider leverages wireless ultrasonic fill-level sensors and a cutting edge logistics platform called SmartBin Live to revolutionize how companies collect and service their regions. The bins which have ultrasonic fill level sensors idea is good to apply for this project without the underground recycling bin idea.

The Swedish company has an underground waste collection system which collects waste via vacuum tubes, whether outside or indoors. The underground tanks have sensors that notify waste collection when the tank is full and ready to be serviced. The waste is then collected away from residential areas by a truck and then transported to a waste management facility.

South Korea's capital city, Seoul, is one of the world's largest metropolitan areas by population. The government was facing a challenge with regular waste management, collection and

overspill issues. Founded in 2011, Ecube Labs has its headquarters in Seoul. The company is a manufacturer of smart and connected waste bins and solar-powered portable waste compactors [4].

Ecube Lab's garbage containers are equipped with sensors capable of monitoring their fill-level and bin status. This allows duty crew to reduce operating costs through lowering collection frequency.

The firm's portfolio includes Clean Cube, a waste compaction bin powered entirely by solar energy. This product includes embedded sensors which measure the bin fill-level in real-time and triggers automated compaction of waste, effectively increasing the bin capacity by 500% – 700%. The sensors send real-time data to Ecube Labs' online network, allowing remote monitoring of bin status and fill-levels. The Clean Cube boasts optional features such as Wi-Fi hotspot capability, LED back-lit advertisement panels, and motion-activated sound players. It's a good idea to measure the bin fill level with embed sensors. This system is using wi-fi facilities. But it's not a good idea for the project because in any case of power failure, it's unable to start the system to work when power back and it need to restart the system if use the wi-fi facility to send the data to the cloud.

In the paper "Smartbin: Smart Waste Management System" by Fachmin Folianto, Yong Sheng Low & Wai Leong Yeow, presented the Smart bin system that identifies fullness of litter bin in 2015 [5]. This system is designed to collect data and to deliver the data through wireless mesh network. The system also employs duty cycle technique to reduce power consumption and to increase operational time. The Smartbin system was tested in an outdoor environment. Through the testbed, they have collected data and applied sense-making methods to obtain litter bin utilization and litter bin daily seasonality information. The idea of employs duty cycle technique to reduce power consumption is best to apply for the project. Then it may start and stop the system according to the allocated employees and reduce power consumption. Because power source has an impact on run the system and it may be good to have some intervals to run the system.

The paper "RFID-based Real-time Smart Waste Management System" by Belal Chowdhury & Morshed U. Chowdhury in 2007, discussed about RFID and sensor model for developing RFID and sensor based Real-time waste management systems [6]. There, the use of RFID (Radio Frequency Identification) and load cell sensor technology can be employed for not only bringing down waste management costs, but also to facilitate automating and streamlining waste (e.g., garbage, recycling, and green) identification and weight measuring processes for designing smart waste management systems. In this paper, they have outline a RFID and sensor model for designing a system in real-time waste management. An app of the architecture is described in the area of RFID and sensor based Waste Identity, Weight, and Stolen Bins Identification System (WIWSBIS). RFID waste identity system is good to identify the bins as well as identifying the location via longitude and latitude of google map to track the location.

In the paper "Smart Waste Collection System Based on Location Intelligence" by Jose M. Gutierreza, Michael Jensenb, Morten Heniusa and Tahir Riazc proposed waste collection system is based on waste level data from trashcans in a metropolitan area in 2016. The data collected by sensors is sent over the Internet to a server where it is stored and processed. The collected data is then used for monitoring and optimizing the daily selection of trashcans to be collected, calculating the routes accordingly [7]. Every day, the workers receive the newly calculated routes in their navigation devices. The key feature of this system is that it is designed to learn from experience and to make decisions not only on the daily waste level status but also on future state forecast, traffic congestion, balanced cost-efficiency functions, and other affecting factors that a priori humans cannot foresee. The rate at which trashcans are being filled can be analyzed based on historical data and the overflow predicted before it occurs. The optimized selection of trashcans to be collected is

expected to reduce costs, improve collection efficiency or both, depending on predefined economic requirements. This is a best idea for the project as it gives the notifications on path should go by calculating the trash cans in the morning and forecast the filling levels according to the historical data and traffic congestion and optimizing daily selection. So it may reduce the fuel cost and time saving.

The paper “Smart Waste Management Using WSN and IoT” by Sivasankari, Bhanu Shri and Y.Bevish Jinila did a scheme on smart waste management using Wireless Sensor Networks (WSN) and IoT (Internet of Things) is proposed in 2017 [8]. The garbage bins are deployed with sensors and are networked together using WSN. The sensors deployed in the garbage bins collect the data for every determined interval. Once the threshold is reached, it raises a request to the GCA (Garbage Collector Agent). This agent collects the requests of all the filled vehicles and communicate using IoT framework. The experimental simulation is done in proteus tool. A hardware prototype is developed for the proposed framework. Analysis of the proposed scheme provides better results in waste management.

The paper “IOT Based Smart Waste Management System using Wireless Sensor Network and Embedded Linux Board” by Kusum Lata and Shri S. K. Singh has proposed a Smart waste management system that identifies fullness of the bin using a wireless sensor network (WSN) and embedded Linux board and inform the authorized person for the cleaning of the bin [9]. The system provides a web interface to the cleaning authority so that they can monitor and clean the garbage bin. In this paper, Raspberry Pi is used as an embedded Linux board which is designed based on the arm 11 microcontroller architecture. Embedded Linux board makes the communication with all distributed sensor nodes placed in the tested area through ZigBee protocol and itself act as a coordinated node in the wireless sensor network. The goal of coordinator node is to collect the parameters like level of the bin and odor wirelessly. Each sensor node consists of level sensor and gas sensors and one ZigBee RF antenna device for communication with the coordinator node. Raspberry Pi stores collected data in the database and analyzes the stored data. The board has an Ethernet interface and runs the simple data web server. Hence coordinator collects the data over ZigBee wireless communication protocol and allow user to monitor the data from a web browser. Cleaning authority can collect the garbage on time. It’s good that above system using odor sensors to measure the odor level of the bins as it’s good for pleasant environment.

The Paper “IoT Based Smart Waste Management System for Smart City” by Sneha Pati, Snehal Mohite, Aishwarya Patil and Dr. S.D.Joshi has proposed a solution [10] that gives prior information of the filling of the bin that alerts the municipality so that they can clean the bin on time and safeguard the environment. According to them, there needs to be system that gives prior information of the filling of the bin that alerts the municipality so that they can clean the bin on time and safeguard the environment. To avoid all such situations they intend to propose a solution for this problem "Smart Garbage Bin", which will alarm and inform the authorized person when the garbage bin is about to fill. Then message will be send to the authorized person to collect the garbage from the particular area. The authorized person will sends the message from his web application to the garbage collectors by sending a SMS .This system maintain a dry waste and a wet waste separately. This will help to reduce the overflow of the garbage bin and thus keeping the environment clean. The above sensor models have some good features to apply for the project like sending alerts to the authorized persons when garbage bins are about to fill.

The PickMe software is a platform that facilitates a real time connection between the taxi passenger and the taxi driver, enabling mutual engagement for the receipt and delivery of a seamless service [11]. PickMe is one of largest transportation company which runs using mobile app

technology in Sri Lanka. When a customer planned a trip marking the pick-up and drop –off locations using the app, it automatically tracks the locations via Google map. PickMe finds the nearest driver and will go to pick-up the customer. Then the customer Knows his driver's location and estimated time of arrival in real-time.

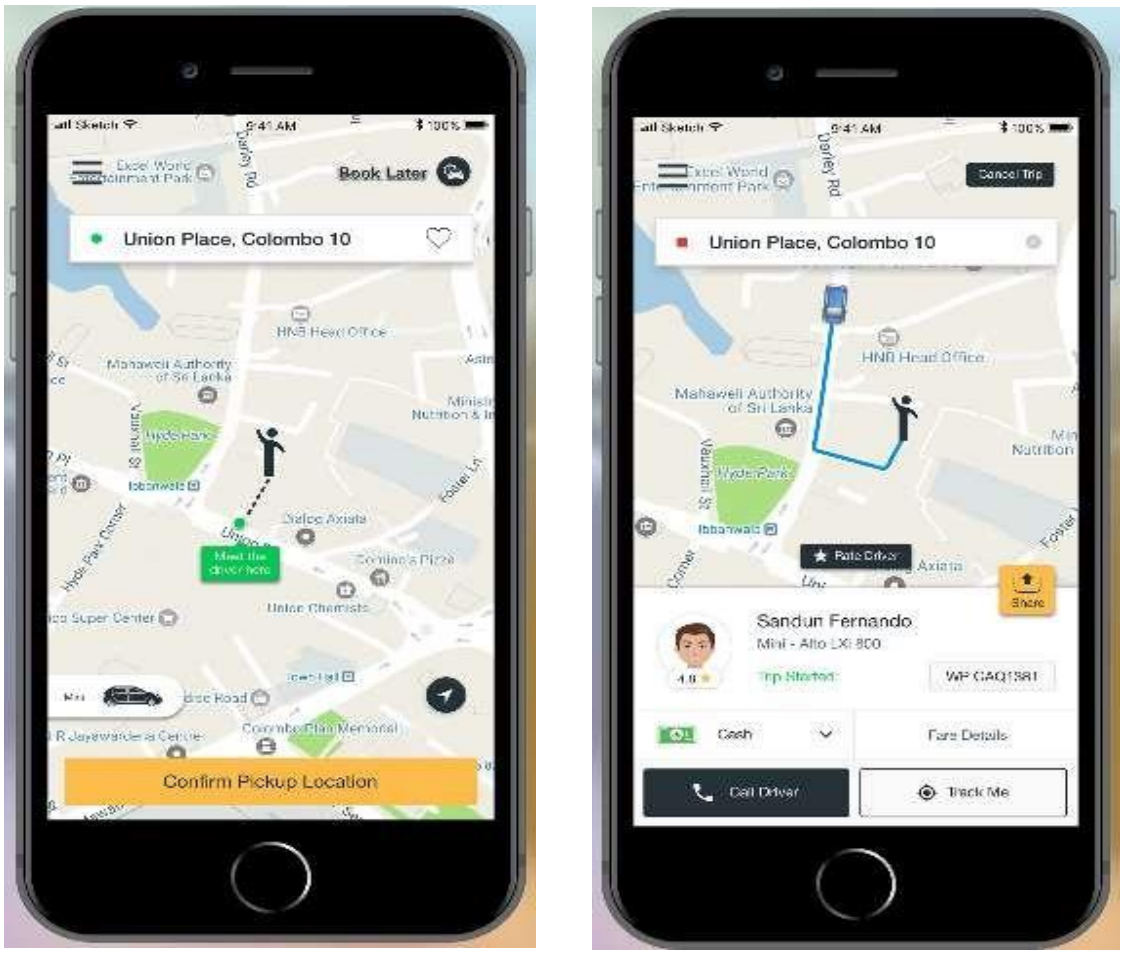

Figure 2.1 : Examples for find locations

When we consider the above solutions, it can see some advances and drawbacks which can be criticized. Many options in PickMe app can be used when track the garbage filling levels from many locations like a customer made a plan from pick-up location. When it shows the bins' filling threshold level in locations, the garbage vehicle drivers can see the locations and paths to go as same as taxi driver followed the pick-up location using the Google map. It can get this system as an example for path optimization.

2.4. Alternative design strategies

This project describes how the sensors send data of filling levels of bins to the cloud server and track those locations by GPS and collecting those garbage bins according the path. For this it makes a model with sensors to send data to the cloud database. Once the cloud data base gets notifications from the model, it can monitor the filling levels of bins in each locations via a dashboard and it can see the path to go to collect the garbage with web based mobile application.

Proposed system will be deployed web – based system with mobile application and cloud based technology. The proposed system architecture will be multi-tier architecture. The multi-layered sensor based waste management system architecture, namely, physical layer, process

layer, data access layer and user interface layer. The physical layer consists of the actual Arduino - mega hardware components that include sonar sensors, GPS activated mobile.

The Process Layer drives waste management services to deploy sensor based waste management system processes that provide real-time integration into their existing systems. This layer enables data mapping, formatting and service interactions with databases. The data access layer is formed of a No SQL Database and applications that allow waste management service providers to create sensors “events”.

And the user interface layer is comprised of an extensible graphical user interface, which allows sensors in a uniform, user-friendly way to work seamlessly in a mobile application environment.

Proposed IOT based waste management system avoids the difficulties has raised by the traditional waste collection methods and available waste collection automation systems introduced by many communities. It’s very hard job to keeping a track of the status of the bin filling levels manually. This introduced IoT system can also be applied to create a new concept and wide development space for smart cities and homes to provide intelligence, comfort and to improve the quality of life. Customers can view their bin filling levels by the app and as well as via the LCD screen. And also they no need of waiting until it comes the municipals to collect garbage as authorities are update automatically via this system. The customer bin system sends data to the main server with 5 minute intervals, only if the bin levels are change. It can see the time when database is updated. And also it breaks the issues face by the municipals when collecting garbage than other systems. The collecting vehicle driver doesn’t know how much level filled of the vehicle trailer while collecting. And also municipal also doesn’t know it. But using this waste management system municipals can update the trailer filling levels to the controlling center via the waste bin sensor models. Short interval is execute for the garbage trailer bins. And also before start the daily ride, the municipals can view the route where the garbage bins are getting filled. So this system is a best example than the other waste collection systems.

Chapter 3 – Methodology

3.1. Introduction

This chapter gives an overview of system analysis and system design. Requirements gathering and analysis are a significant practice for a successful project. The main processes of this phase includes domain understanding, requirements collection, classification, structuring, prioritization and validation. Appropriate methods and processes were engaged to carry out the analysis phase in an effective way.

Software design phase is an iterative process in which requirements gathered in analysis are translated into a "blueprint" in building the system. The output of the design phase is the system specification.

3.2. Analysis

User Personas and characteristics

Authorities – These users can monitor the garbage collecting vehicle with the details coming from the vehicle GPS/ GPRS based data login device attached to the garbage collecting vehicles. This device is developed to switch on when a ride is started, so that the authorities can monitor the collecting vehicle during the drive. GPS/ GPRS based data login device sends GPS data to the web server after each 5 minutes. And also the collecting vehicles has three partitions to collect categorized garbage and it has connected three ultrasonic sensors for that three partitions to measure the garbage filling level. Then Wi-Fi based data login device sends those filling level details to the web server and automatically updates the trailer capacity of collecting vehicle so that authorities can monitor the trailer capacity status via the web app. The Wi-Fi based data login device sends trailer capacity levels to the web server after each 5 minutes.

These users have their own registered customers in the organization and these authorities have predefined geographical area to monitor the status. So they can monitor the garbage bin filling level of each registered customer in the area. It can monitor the customers' bin filling levels and locations via the dash board of the web app.

Customers – These users who are in the predefined area has installed the garbage filling level measuring system in their residencies and places etc. They have their own three bins to put garbage by categorizing them. It has connected three ultrasonic sensors for each bin with microcontroller and Wi-Fi based data login device sends the garbage filling level of bins with the bin location to the web server. The Wi-Fi based data login device sends garbage filling levels and bin locations to the web server after each 1 minute. The customers in the suburb areas can install GSM module in their systems to send their bin filling data to the cloud.

3.3. Requirement Gathering

Several kinds of techniques were engaged here to capture requirements from different stakeholder perspectives. The main approaches used for requirement gathering process were; interview, observation and scenarios.

Both open ended and close ended interviews were conducted for prompt existing and also to identify new problems. Current garbage collecting system were analyzed and studied. Captured facts were represented using scenarios. Use case diagram was designed to get clear picture of the gathered requirements.

3.4. Requirements of the proposed system

3.4.1. Functional Requirements

This section has specifies all the major functions of the system with respect to the customer supplied specifications.

- Switch on the GPS/ GPRS based data login device of vehicle.
- Switch on the Wi-Fi based data login device of customers.
- Update the position of the garbage collecting vehicle position in 20 second interval, to the web server.
- Send notifications on garbage filling level of each customer locations.
- Update the trailer capacity.
- Send notifications to the collecting vehicle driver when the trailer capacity comes to the filling level.
- Using the GPS data provided by the GPS/ GPRS based data login device attached to the garbage collecting vehicle, draw the root of the vehicle on google map.
- According to the customers bin filling locations, show the path to go for collecting vehicle driver on google map.
- Empty the bin levels after emptying them.
- Add new collecting vehicles to the system.
- Add new bin locations to the system.
- All the devices should work without any hardware failures

3.4.2. Non-Functional Requirements

Non-functional requirements are the requirements which are not directly affected with the exact basic functions delivered by the system. But, failing to meet non- functional system requirements may make the whole system unusable. Non-functional requirements are relevant with quality attributes, quality of service requirements and non-behavioral requirements. The non-functional requirements of the system are listed below.

- The system should provide a user friendly environment including flexible interfaces,
- Person who has average computer skills can work with the system with a short period of training.
- The system should be accurate and consistent, in proper way and displaying correct information.
- The system should keep up security and reliability, because the system handles important data.
- Occasionally backups should be taken to maintain reliability and necessary security measures.
- The system should be reusable and maintainable.
- It should be able to adopt future implementations to the system.

3.5. Proposed Architecture for the system

Proposed system will be deployed web – based system with mobile application and cloud based technology. The proposed system architecture will be multi-tier architecture. The multi-layered sensor based waste management system architecture, namely, physical layer, process layer, data access layer and user interface layer. The physical layer consists of the actual Raspberry pi/ Arduino - Mega and NodeMCU hardware components that include ultrasonic sensors, GPS Module and LCD display.

The Process Layer drives waste management services to deploy sensor based waste management system processes that provide real-time integration into their existing systems. This layer enables data mapping, formatting and service interactions with databases. The data access layer is formed of a Relational Database Management System and applications that allow waste management service providers to create sensors "events". For this it is used google firebase as an IOT platform.

And the user interface layer is comprised of an extensible graphical user interface, which allows sensors in a uniform, user-friendly way to work seamlessly in a mobile application environment. The figure 3.1 shows the proposed architecture of the system.

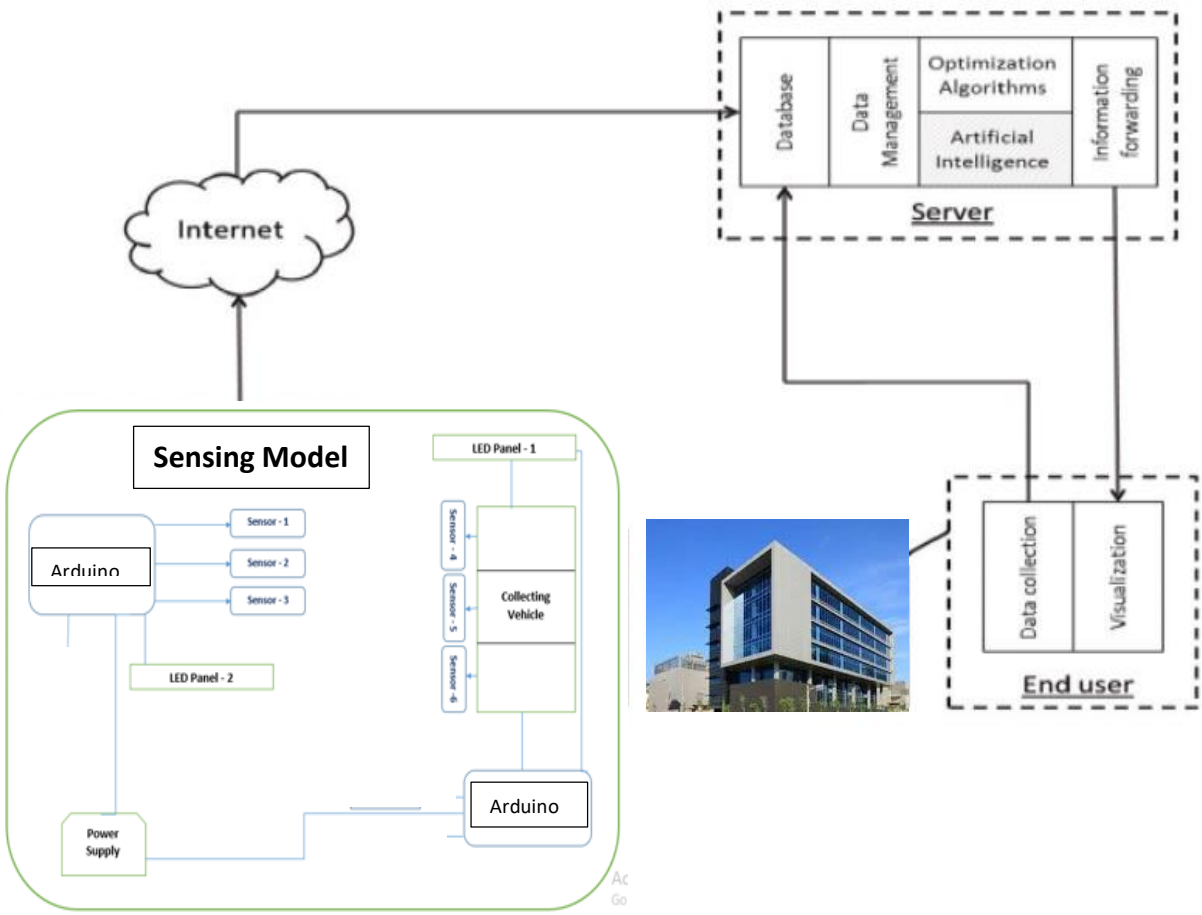

Figure 3.1: Proposed Architecture

3.6. Design

3.6.1. Methods and Techniques

Design techniques are the techniques that use to model the system. There are different design techniques such as Modern Structured design, Rapid application development, and prototyping. The proposed system will adopt a prototype model of system development method. The prototyping model is a system development method in which a prototype is built, tested, and then reworked as necessary until an acceptable prototype is finally achieved [12].

After making the model of proposed system, it should be tested weather the model sends data to the cloud database. Once the cloud data base gets notifications from the model it can be develop the designed system with web based mobile application and test it. And then rework as necessary until an acceptable prototype of web app. The *figure 3.2* presents the phases of prototyping model [complextester.wordpress.com, *Prototype Design and Development*]. The research worked carried out accordingly.

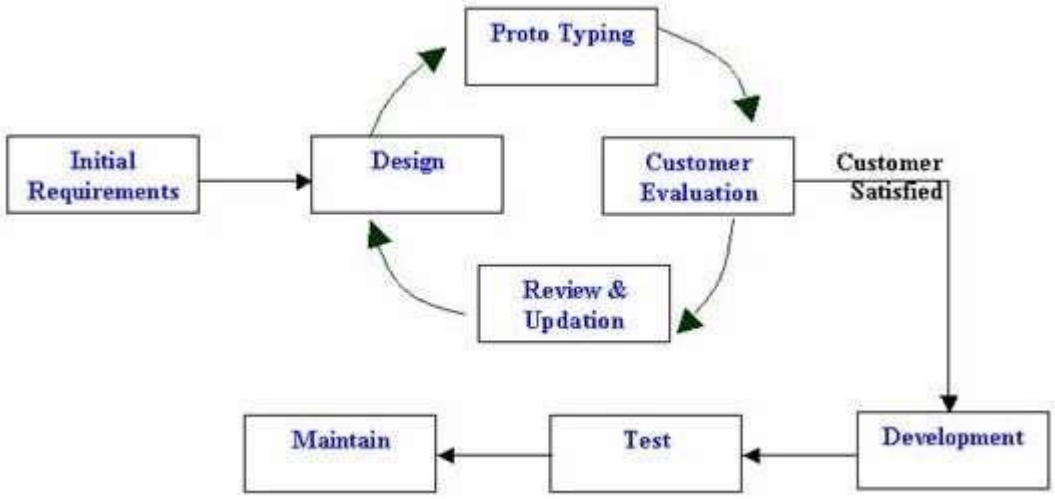

Figure 3.2: Prototyping Model

3.6.2. Proposed system design

Use case diagrams are consisting in Unified Modeling Language (UML). Graphically describes who will use the system and in what ways the user expects to interact with the system. The proposed system has two main actors such as authority and customer/ customer Bins. Diagram in Figure 3.3 depicts the overall high level Use-Case of the proposed system.

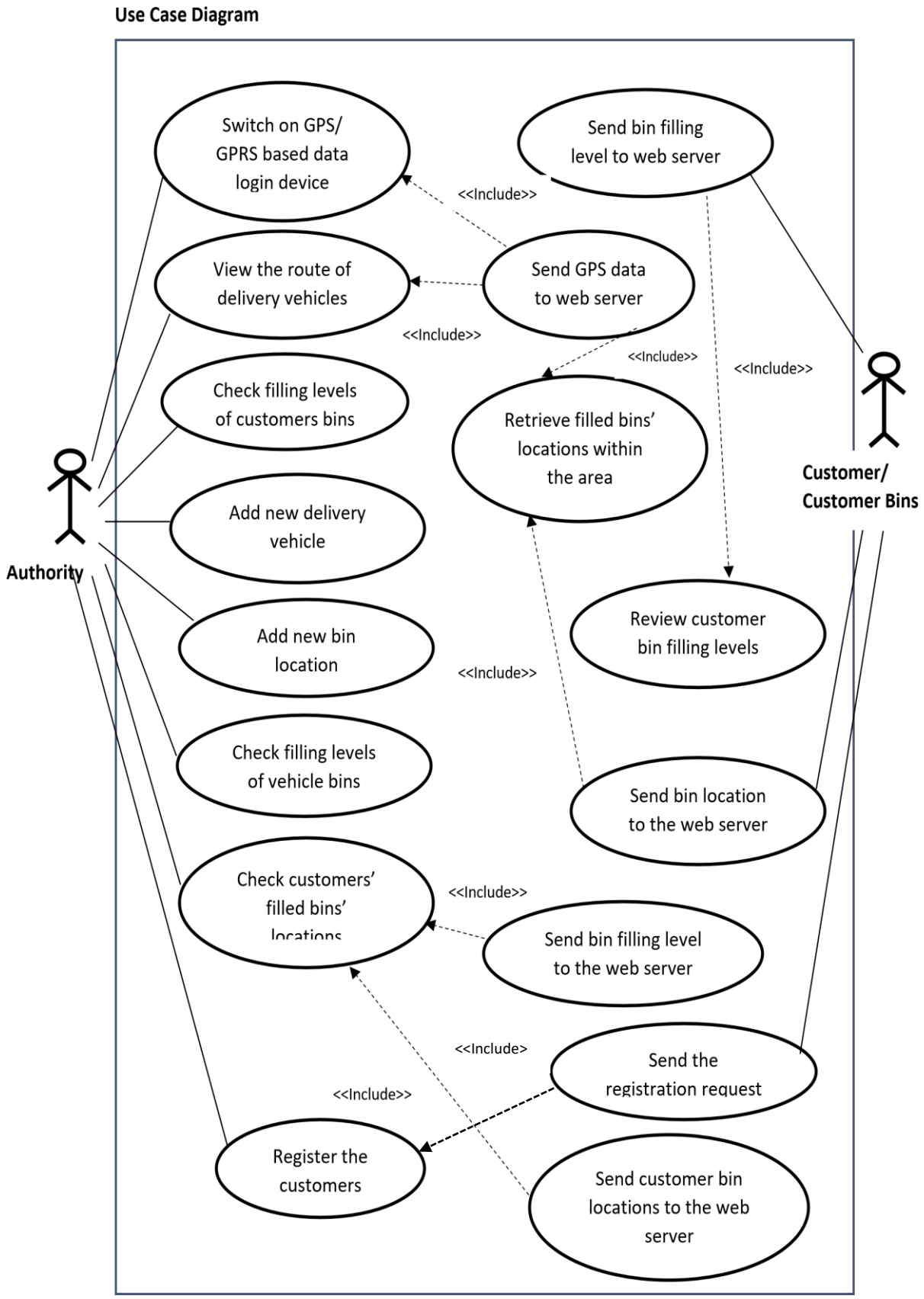

Figure 3.3: Use Case Diagram of the System

3.6.2.1 Use Case Narratives

Use case narratives are text based description of a use cases. Descriptions should be written in natural language and it is very useful communication tool between developer and the users. Use case narratives for the developed system is shown in table 3.1, 3.2, 3.3 3.4.

Use Case	View filling levels of Customer Bins
Description	Admin can view the filling levels of customer bins when login to the system
Primary Actor	Admin
Secondary Actor	None
Pre-Conditions	
1. Admin should login to the system. 2. The sensor model should work properly by sending data to the cloud	
Flow of Event	
1. Login to the system as admin. 2. Enters to the filling levels view interface 3. View the bin filling levels of a customer's bins	
Post Condition	
Go to the dashboard	

Table 3.1. Use Case Narrative for View filling levels of Customer Bins

Use Case	Send the registration Request
Description	Customers should register to the system for access the functions.
Primary Actor	Customer
Secondary Actor	Author
Pre-Conditions	
1. Required to have email address	
Flow of Event	
1. Users must provide initial details to register with the system. 2. Users must provide password and confirm password.	
Post Condition	
Fill he registration details	

Table 3.2. Use Case Narrative for Send the registration Request

Use Case	View customers' bins filled locations
Description	Admin can view the filling levels of customer bins in any location when login to the system
Primary Actor	Admin
Secondary Actor	None
Pre-Conditions	
1. Admin should login to the system. 2. The login device should connect to the internet	
Flow of Event	
1. Login to the system as admin. 2. Enters to the google map view interface 3. View the filled bins' locations	
Post Condition	
View the google map	

Table 3.3. Use Case Narrative for View customers' bins filled locations

Use Case	Register the customers
Description	Admin should confirm the customers registration requests and register the customers
Primary Actor	Admin
Secondary Actor	None
Pre-Conditions	
Admins should get a request from customers	
Flow of Event	
1. Login to the system 2. View the registration requests 3. Confirm the requests	
Post Condition	
Accept customers' requests	

Table 3.4. Use Case Narrative for Register the customers

3.6.3. Database Design

Database design is completed through data modelling. Database design is used to specify the structure of business objects used in the client/server system. The database tables were normalized to 3rd normal form to avoid redundancies. The following Entity Relationship diagram in Figure 3.4 depicts the structure of the relational database configuration of the system.

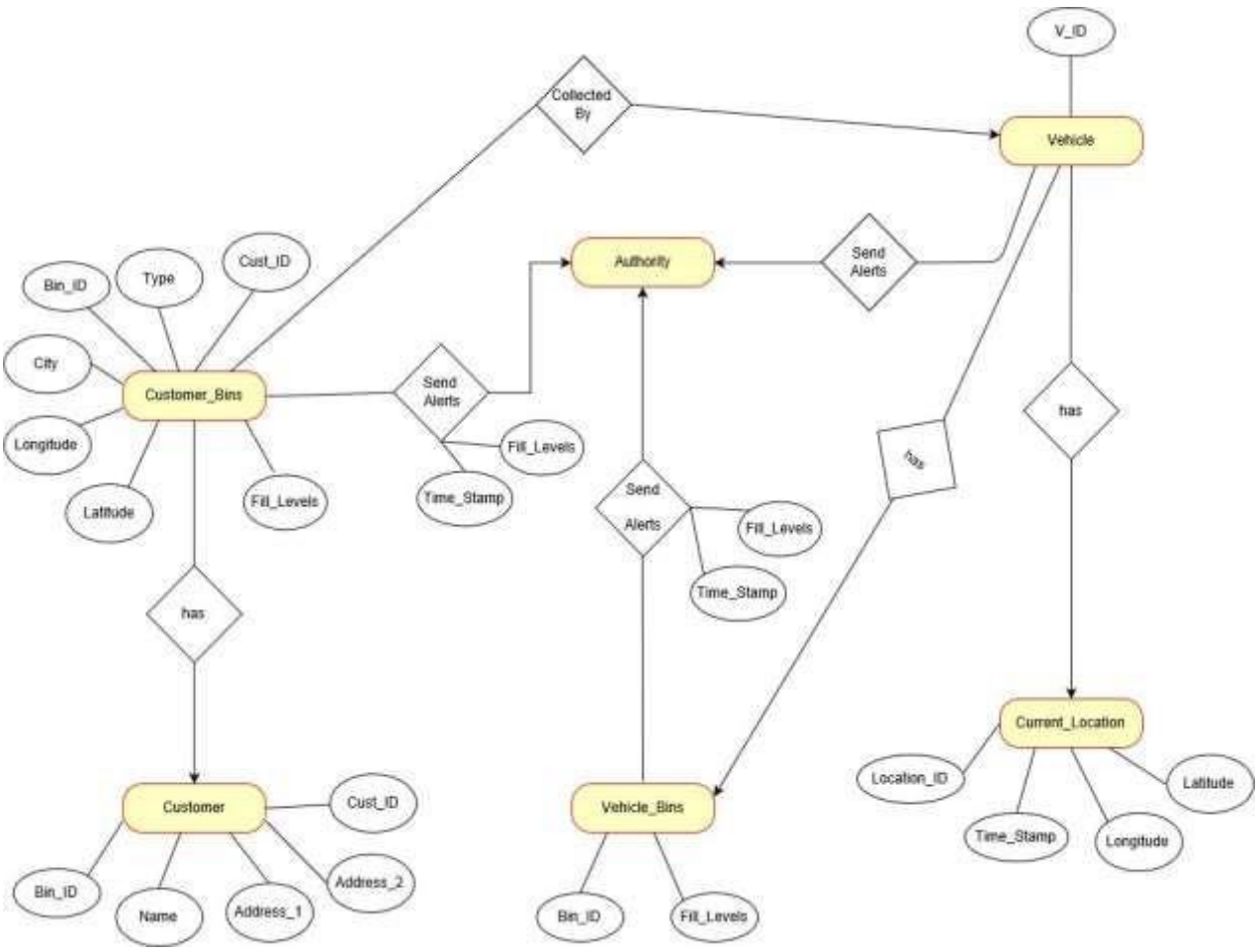

Figure 3.4: ER Diagram of the System

3.6.4. High Level Design

This project is intended to enhance the waste management in easy way for the authorities and as well as to enhance the customer satisfaction. The suggested system, has two IOT devices for authorized organization side and customer side. In the authority side it has a system attached to the collecting vehicle for tracking the collecting vehicle's location and to receive the updates of trailer capacity. In the customer side it has another system to send their waste bins' filling levels to the authorized organization.

Main functional blocks and their interactions are shown by this high level block diagram **(***Figure 3.5*) and each block and its functions are described below.

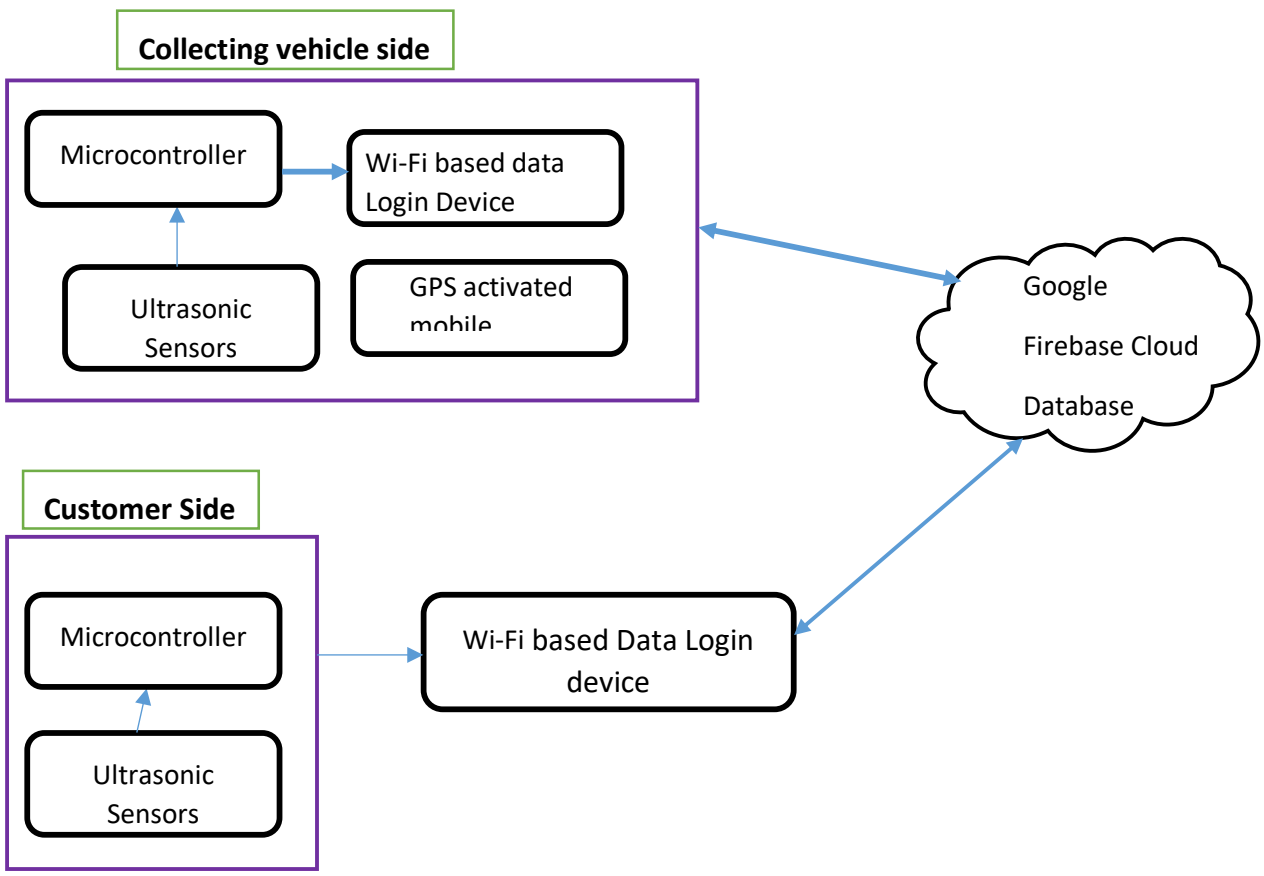

Figure 3.5: Functional Block Diagram

The proposed system, "Real - Time Smart Waste Management System Based on IOT for smart city" is consists of main three components.

- GPS/ GPRS based Data Login device
  - Microcontroller
  - GPS tracker using mobile

- Wi-Fi based Data Login device
  - Microcontroller
  - Wi-Fi Module
  - Ultrasonic sensors
  - LCD display

- System Application
  - Server side application
  - Client Application

GPS/ GPRS based Data login device

1. Microcontroller

This integrated circuit (IC) is a programmable device which is used to control the functions of entire system according to the written program. The Arduino Mega 2560 Microcontroller Rev3 [13] is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-toDC adapter or battery to get started. Arduino Mega development platform is chosen for this design. Firmware is written using Arduino language and complied using Arduino IDE 1.8.4. version. Microcontroller access the GPS/ GPRS module and Wi-Fi module through asynchronous serial interface with 9600 BUAD rate. It gives instructions commonly known as "AT commands".

Figure 3.6: Arduino Mega Microcontroller

Wi-Fi based Data Login Device

2. Wi-Fi Module

The ESP8266 is a low-cost Wi-Fi microchip with full TCP/IP stack and microcontroller capability produced by Shanghai-based Chinese manufacturer Espressif Systems. This small module allows microcontrollers to connect to a Wi-Fi network and make simple TCP/IP connections using Hayes-style commands [14]. English-language documentation on the chip and the commands it accepted. The very low price and the fact that there were very few external components on the module.

Figure 3.7: ESP8266 Wi-Fi microchip

3. Ultrasonic Sensor Module

The commonly available low-cost ultrasonic sensor is Hc-SR04. Its working principal is sensor sends sound pulses towards the object and receives echo signals reflect back from it. During the time period from transmitting sound waves to receive the echo, ultrasonic sensor gives a high-level signal to Data Acquisition Unit. Using timer Data Acquisition Unit counts the time span signal remains high. By dividing timer output result with two times of exact speed of sound, it will find the object distance. Distance = (high level time × velocity of sound (340M/S) / 2

4. LCD Display

An LCD is an electronic display module which uses liquid crystal to produce a visible image. The 16×2 LCD display is a very basic module commonly used in circuits. The 16×2 translates a display 16 characters per line in 2 such lines. In this project display module can be used near garbage bins so that users can see the garbage filling levels of the bins.

System Application

The app is activate with internet connection, when the delivery vehicle started. When starting a ride, the driver can see the path should go through his mobile after calculating the garbage bin levels of customers which can put to the collecting vehicle. And in each 20 seconds a string generated by the GPS tracking app will be sent to the server application which is hosted in google firebase. The device of the vehicle driver is connects to the internet using the mobile data. Then admin can view the vehicle id, device time, latitude, longitude, heading direction details. The bin system installed in the collecting vehicle, have separate bin ID and sends it's filling levels to the database.

The client application gets the updates from the database and using google map API, the live updates of the delivery vehicle are displayed on the google map. The client application is running on a

personal computer in the head office. When the delivery vehicle is moving, the customer bins within the defined area are shown on the map and at the same time customer bins filling levels and collecting vehicle bins filling levels will be sent to the server side application.

3.7. Implementation

3.7.1. Introduction

Implementation process use to convert system specifications to executable system. In this phase convert design to user friendly views with front end interfaces and back end systematic logics for perform functionalities. A comfortable language and suitable tools were selected in the process of coding and development. The codes were written and arranged in a readable format. Comments added for special logics to help for future implementations.

3.7.1.1 Implementation environment

Server side environment and client side environment were consider in implementation process. These environment requirements basically divide in to software requirements and hardware requirements. These requirements are described below.

Server environment

System hosted location and client server architecture operators are considering in this environment. Google firebase cloud storage used as server environment and is used to host developed system, which can handles all the data processing activities. Server should be a Mid-upper range server with 12 GB RAM and 300 GB Storage.

Client environment

Client software run in between the user and server be responsible for a user interface for user to cooperate with the server, for example mobile app act as client software. System is rich with latest technologies and tools, so updated android compatible smart device should use to avoid app compatible issues. System is capable of working with different hardware and software requirements, minimum system requirements are listed below.

Software Requirements

- Software needed in designing & implementing the system
  - Android Software Development Kit (android ADK): Software development kit for applications on the Android platform.
  - Android Studio Latest version
  - Arduino IDE
  - Arduino Libraries (Liquid Crystol_I2C, New Ping, Firebase Arduino Master, Arduino RTC Library, Wire)
  - Google Firebase

Hardware Requirements

- Desktop PC/ Laptop
- Android Mobile Phone/ Tablet (Minimum SDK: API 19: Android 4.4 (Kit Kat))

Client Hardware and Software Requirements

- Android Mobile Phone/ any android support device
- Desktop PC/ Laptop

For the database design and server side software configurations it used google firebase cloud store. Google Cloud Storage is a restful online file storage web service for storing and accessing data on Google Cloud Platform infrastructure. For the waste bin model, it is used Arduino IDE for development.

Waste Bin Model Requirements

- Arduino Mega 2560
- NodeMCU board
- 3 Ultrasonic sensors
- 16 * 2 LCD Display Module with I2C Module
- LM 2596 DC-DC switch mode power supply
- 12V Battery
- Bread Board

3.7.2. Development tools and techniques

Below described the tools and technologies that were used to develop the system.

3.7.2.1. Tools

- Android Studio - Android Studio is the official integrated development environment for Google's Android operating system, built on JetBrains' IntelliJ IDEA software and designed specifically for Android development. It is available for download on Windows, macOS and Linux based operating systems. It is a replacement for the Eclipse Android Development Tools as the primary IDE for native Android application development.

- Arduino IDE - The Arduino integrated development environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in the programming language Java. It is used to write and upload programs to Arduino compatible boards, but also, with the help of 3rd party cores, other vendor development boards. The source code for the IDE is released under the GNU General Public License, version 2 [15]. Arduino language is just a set of C/C++ functions that can be called from your code.

- Google Firebase Realtime Database- Firebase provides a realtime database and backend as a service. The service provides application developers an API that allows application data to be synchronized across clients and stored on Firebase's cloud. The company provides client libraries that enable integration with Android, iOS, JavaScript, Java, Objective-C, Swift and Node.js applications. The database is also accessible through a REST API and bindings for several JavaScript frameworks such

as AngularJS, React, Ember.js and Backbone.js. The REST API uses the Server-Sent Events protocol, which is an API for creating HTTP connections for receiving push notifications from a server. Developers using the realtime database can secure their data by using the company's server-side-enforced security rules [16].

3.7.2.2. Technologies

- C as development language - Arduino is the hardware platform used to teach the C programming language as Arduino boards are available worldwide and contain the popular AVR microcontrollers from Atmel. Atmel Studio is used as the development environment for writing C programs for AVR microcontrollers. It is a full-featured integrated development environment (IDE) that uses the GCC C software tools for AVR microcontrollers and is free to download [17].

3.7.2 Implementing

Assembling the hardware model for waste bins is the first thing need to do. The figure 3.8, shows how to assemble the required devices.

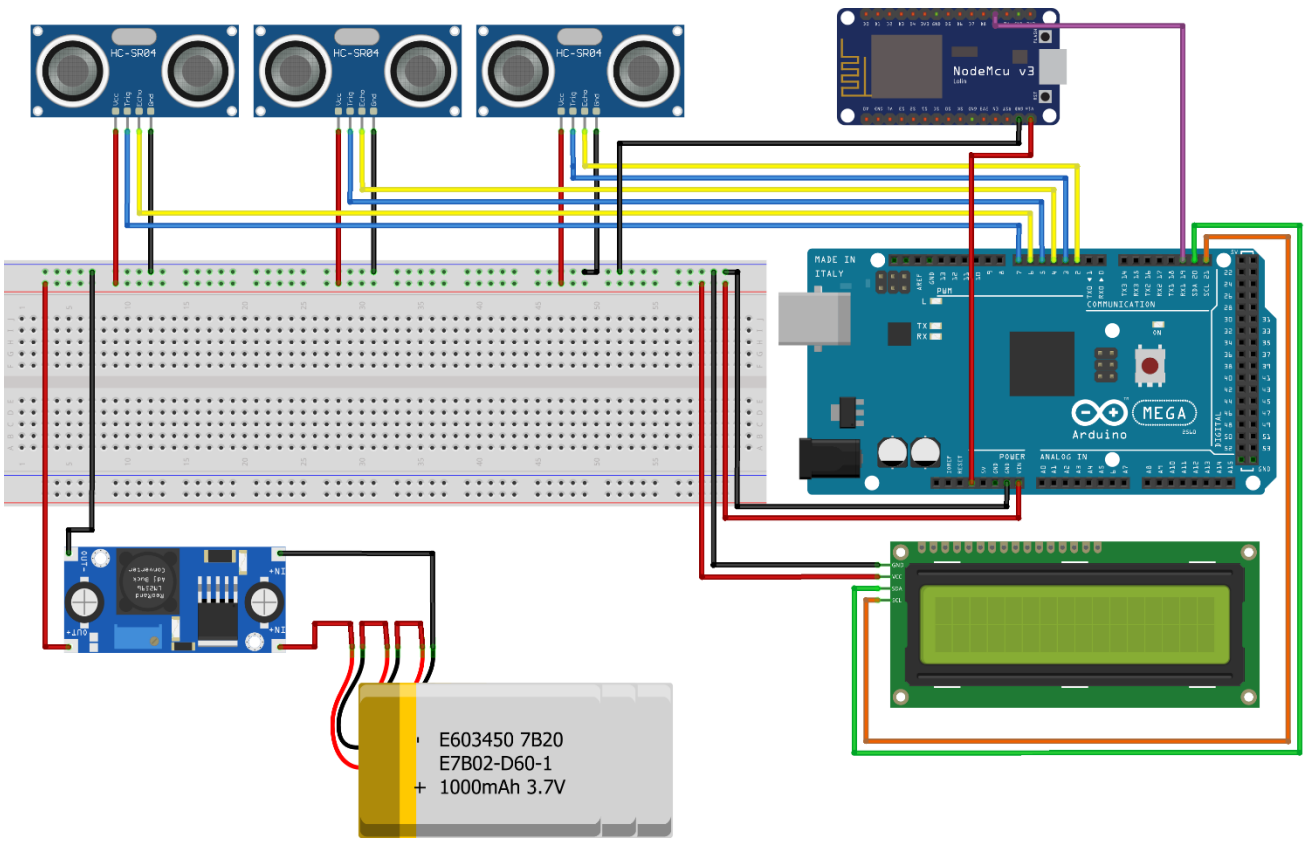

Figure 3.8: Circuit Diagram to assemble the bin model

Backend of the hardware model is developed using C++ programming language using the Arduino software. In the data layer, Firebase real-time database management system is used to save the hardware model data send to the cloud and google Firebase server is used to manage data in it.

Frontend is developed using Android Studio. And google map API is used to do the map implementations.

```
void ReadData(){
  if(Serial.available()>0){
    String str = Serial.readStringUntil('\n');
    int x = Serial.parseInt();
    if(str == "A"){
      Serial.print("A : ");
      readDataVal[0] = x;
    }else if(str == "B"){
      Serial.print("B : ");
      readDataVal[1] = x;
    }else if(str == "C"){
      Serial.print("C : ");
      readDataVal[2] = x;
    }
    Serial.println(x);
  }
}

void SendData(){
  for(int i = 0; i < 3; i++){
    String string = "CU815012780V/Bin" + String(i+1);
    if(readDataVal[i] != sentDataVal[i]){
      Firebase.pushInt(string, readDataVal[i]);
      delay(100);
      sentDataVal[i] = readDataVal[i];
      Serial.println("Data Sent");
    }
    else{
      Serial.println("Data Not Change");
    }
```

Figure 3.9: Code

The code segment shows in figure 3.9 shows, how to read the sensor data getting from sensor model and push bin filling levels to the firebase real-time data base when it changed bin filling levels.

3.8. Main User Interfaces

The below section of the document provides only a few main user interfaces in order to show system interface structure.

Sign Up

Below interface (Figure 3. 10) allows the user to sign up before login to the system with his email and password.

Figure 3. 10: Sign Up Page Interface

Login Page

This interface (Figure 3. 11) allows the user to log in to access the system with correct user name.

Figure 3. 11: Login Page Interface

Vehicle Registration

The system have to register the garbage trucks. Figure 3.12 shows the sample form module.

Figure 3. 12: Vehicle Registration

Customer Registration

The system have to register the customers with customer's data. Figure 3.13 shows the sample form module.

Figure 3. 13: Customer Registration

3.9. Testing

One of the important phases of software development lifecycle is testing and evaluation. In here following techniques are used for testing and evaluation of the system.

- Unit Testing

Unit testing is used as the first testing method. The main goal of the unit testing is to isolate each part of the program and to check the correctness of the code. The system is tested with the developed model. In the model there are three bins and one collection vehicle, So that it can be test whether the model sends data to the cloud. In this model there should be many bin locations and some collecting vehicles. But model provides only one bin location and one collecting vehicle. So that it needs changing the IDs with the coding of the model and send those data to the cloud by making bin locations virtually. Then it is created a map with virtual bin locations and few collection vehicles. Then it can be tested showing the bins and collecting vehicles in different locations.

- Integration Testing

Integration testing is done by combining all the individual modules of the garbage collection system. Here it is focused all the modules of the system.

- System Testing

The system testing is mainly done on the whole integrated system to make sure that the project that has been developed meets all the requirements. Each use case and functions will executed using data.

Chapter 4 – Evaluation

4.1 Introduction

Software testing is a critical component of software quality assurance that represents the ultimate analysis of specification, design, and code generation of software product. The testing method is basically combine with Verification and Validation. Validation refers to testing whether the system satisfies the requirements while verification refers to whether the system implements the specified functions properly. Basic goals of test evaluation is determining whether the promises about the invention by the supplier and the requirements of the customer are met on an acceptable level.

4.2 Testing Procedure

Software testing and implementation are iterative processes. Most of the time both stages work as simultaneous system components. The propose system was tested while the development was ongoing. At first it was tested weather Arduino module works correctly with the ultrasonic sensors. For this it used Arduino serial monitor and LCD display to check weather ultrasonic sensors working with showing bin filling levels. And then it tested weather waste bin model sends data to the cloud database via NodeMCU module. It could see the way of real time database updating when sends bin filling levels to the cloud.

After building the bin model tested the system while developing the mobile app. Structural testing techniques were followed in this phase including “white box” testing which tests “how a program/system does something”. Functional testing techniques were used, which includes “black box” testing which tests the behavior of a system or program. These techniques were exploited in different testing levels like unit testing.

Individual operations associated with objects were tested initially, followed by testing individual classes and clusters of objects, and finally test the system as whole. User acceptance testing was completed in client site, participation of few people.

4.3 Test Plan and Test Cases

Testing begins with the implementation, code is reviewed while developing stage for testing. Test plan is included all phases of testing and also used as a guide for the overall testing process. Before the system implementation, the test plan was designed. A test plan includes: test objectives, schedule and logistics, test strategies and especially test cases.

Test cases were created according to the designed test plan. That contains data, procedure, and expected result and represents which use to system or part of the system run. To reduce complexity of the testing process test cases were designed for each module independently.

Manual testing method and procedures are used for testing rather than automation tools and technologies.

Below tables tabulate some test cases for test basic functions.

4.3.1. User Registration module

Test Case Id		01	
Tested Component		Register a user	
Module Name		Customer Registration	
Test Case		Add customer details	
Expected Output		Empty fields are highlighted in yellow fields with the relevant error messages.	
Test Case Description			
No	**Test Case**	**Actual Output**	**Status**
1	Click Submit button after all fields correctly completed.	Redirect to Add Bin details screen	Pass
2	Click Submit button without filling fields	Display relevant error message	Pass
4	Click submit button without filling required fields.	Empty fields are highlighted in yellow fields with the relevant error message	Pass

Table 4.1. Test case for user registration module

4.3.2. User login module

Test Case Id		02	
Tested Component		Login	
Module Name		Login Module	
Test Case		Login Screen	
Expected Output		User friendly view. When invalid login occur display red colour with the relevant error message	
Test Case Description			
No	**Test Case**	**Actual Output**	**Status**
1	Click login button after all fields completed.(Positive)	Enter valid username and password. Validate and redirect to correct user home page	Pass
2	Click login button with incorrect details. (Negative)	Enter invalid username and password. Error message display with reason	Pass

Table 4.2. Test case for user login module

4.3.3. Signup module

Test Case Id	03	
Tested Component	Signup	
Module Name	Signup Module	
Test Case	Signup Screen	
Expected Output	Redirect to login screen	
Test Case Description		
No	**Test Case**	**Actual Output**	**Status**
1	Click Signup button without filling fields	Display relevant error message.	Pass
2	Enter Password less than required characters	Display relevant message.	Pass
3	Click Signup button after all fields correctly completed.	Redirect to login screen	Pass

Table 4.3. Test case for signup module

4.3.4. Waste bin model

Test Case Id	04	
Tested Component	Waste bin model sensors	
Module Name	Sensor module	
Test Case	LCD Display	
Expected Output	Display the bin filling level status while filling the bins	
Test Case Description		
No	**Test Case**	**Actual Output**	**Status**
1	Put some litters in to the bin model	Display filling level as a percentage	Pass
2	Keep the bins empty	Display filling level as zero cDis : 10 Bin No: 0 binV : 0 cDis : 10 Bin No: 1 binV : 0 cDis : 10 Bin No: 2 binV : 0 A 0 B 0 C 0	Pass
3	Put some litters by changing their types (paper, pebbles etc.)	Display filling levels as a percentage cDis : 9 Bin No: 0 binV : 10 cDis : 9 Bin No: 1 binV : 10 cDis : 5 Bin No: 2 binV : 50 A 10 B 10 C 50	Pass
4	Put some litters by changing their types while changing the environmental factors like wind, noise etc.	Display filling levels as a percentage	Pass
5	Keep the bins empty and change the environmental factors.	Display filling level as zero	Pass

Table 4.4. Test case for waste bin model sensors

4.3.5. Cloud Fire store database

Test Case Id	05	
Tested Component	Fire store database	
Module Name	Database module	
Test Case	Update the fire store database	
Expected Output	Display records of bin filling levels as documents with time stamp	
Test Case Description		
No	**Test Case**	**Actual Output**	**Status**
1	Put some litters into three bins while switch on Wi-Fi network	Create a document in fire store database with time stamp	Pass
2	Keep the bins empty	Create a document in fire store database with time stamp	Pass
3	Sends bin filling levels with time intervals	Sends data to the fire store database and create documents with relevant time intervals	Pass
4	Put some litters into three bins while switch off Wi-Fi network	It doesn't create the document's in the fire store database	Pass

Table 4.5. Test case for cloud fire store database

4.4 Summery

After full testing cycle user can comment system was developed successfully and according to positive user reactions shows they accepted the system. When consider user acceptance test results all the functional requirements given by the client were fulfilled and the users can carry out their tasks effectively and efficiently with new system. Few minor modifications were made to the system according to the user feedback.

Chapter 05 - Conclusion

5.1. Problems Encountered

This last chapter discuss about the objectives archived and the future encasements of the developed system. Initially, the problem that was found is the customer satisfaction with the existing manual waste collecting system is very weak due to the main reason of communication problem with the urban council and also as no proper method to collect peoples' waste. As a solution to the above problem, this system was suggested. At the beginning of this project, the aim was to increase the customer satisfaction through introducing a GPS based monitoring with alert system. According the plan it decided to use SMS module to send bin level alerts to the urban council. But it didn't allowed to execute some AT commands as Telecommunications Regulatory Commission in Sri Lanka has banned of executing. So it was unable to identify users' bin locations. So it could eliminate those problems by giving a bin number for the users and selecting the location by their mobile devices when register user bins. And also assigned those numbers to the Arduino module.

According to the needs of proper waste management, suggested system has achieved the main aim. System introduced to viewing the garbage filling levels of system users and urban councils or authorities can view the correct path to collect waste with path optimization. So it increases the customer satisfaction towards emptying waste bins with proper intervals and keep the environment in pleasant way. So it is clear that by the proper communication with the customer from sending notifications on garbage filling levels, increases effective waste management of urban councils.

5.2. Lessons Learnt

The knowledge added throughout the project was actually valuable. Starting from the feasibility studies, to the end of development this process gave incomparable experience in many ways. This project gave a chance to test and implement most important theories and technologies learnt so far. It also facilitated to learn very interesting new and updated technologies (Firebase Cloud Store, No SQL databases) in order to improve the system performance. Moreover, special efforts were taken to learn the Arduino programming and assembling Arduino, NodeMCU modules and related sensors.

Furthermore working on the project encourage me to improve technical skills as well as intellectual skills by collaborating with many individuals from collective fields. Proper time management and planning is very important aspects learn out during this project should carry out the work according to the schedule.

5.3. Future Work

As an extended version of the application, the application system can be developed as an e-business model. It can be develop for the other services which need to do with users and urban councils. Urban council will be able to improve their public services via that developed app. And also hope to develop the system with payment gateway which the customers can order waste bins with Arduino modules and fertilizers net online and pay on line. The system implementation team of this waste management team, should have to assemble and install the hardware model. So they have to configure it with customer details and locations. To protect the system, hope to restrict the code editing using a keypad and then any authorized persons who haven't computer knowledge too can install the module.

In the main microcontrollers it is using Arduino and wi-fi modules. So there may be a threat for finding microcontrollers in the future market with some commercial rules in some other countries and Sri Lanka. So it is planning to build a custom circuit to protect the copyright of the system and to implement the system uniquely. And also plan to apply for the patent license for the system.

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Appendix

System User Manual

Developed system has built for several users which are admin, Vehicle Driver and customer, the system offers wide variety of functionalities for these users. This manual is guidance for users how to use system features which helps to adhere management expectations.

Administrator has all the rights to operate all the modules. Explain all the module functions in the system, the documentation is compiled for the user who holds administrative privileges.

This documentation provides guidelines prior to the setup of the system. This is to assist the administrators and managers to install the system in customers' waste bins and Servers. As this system needs to assemble a sensor model, according to that it should get the devices needed and assemble them.

Getting familiar with the system

In order to install the system, the chosen device should meet the following requirements of Hardware and Software.

Hardware

Hardware	**Recommended Requirements**
Sensor Model (both Customer and collecting vehicles need 2 models)	Arduino Mega 2560
	NodeMCU board
	3 Ultrasonic sensors
	16 * 2 LCD Display Module with I2C Module
	LM 2596 DC-DC switch mode power supply
	12V Battery, Bread Board
Processor	Intel Core i3 processor 2.3GHz
Memory	2GB RAM or more
Internet	Minimum 512kbps wi-fi connection for the module Minimum
Disk Space	2 gigabytes (GB)

Table A.1: Hardware

Software

Operating System	Microsoft Windows 7 Or above.
Code editor	Arduino IDE
Database	Google Firebase Real-time database
Web browser	Internet explorer/Fire Fox/Google Chrome

Table A.2: Software

- Install above mentioned software in a suitable hardware installed PC.
- Assemble the waste bin model for customer with above hardware devices.

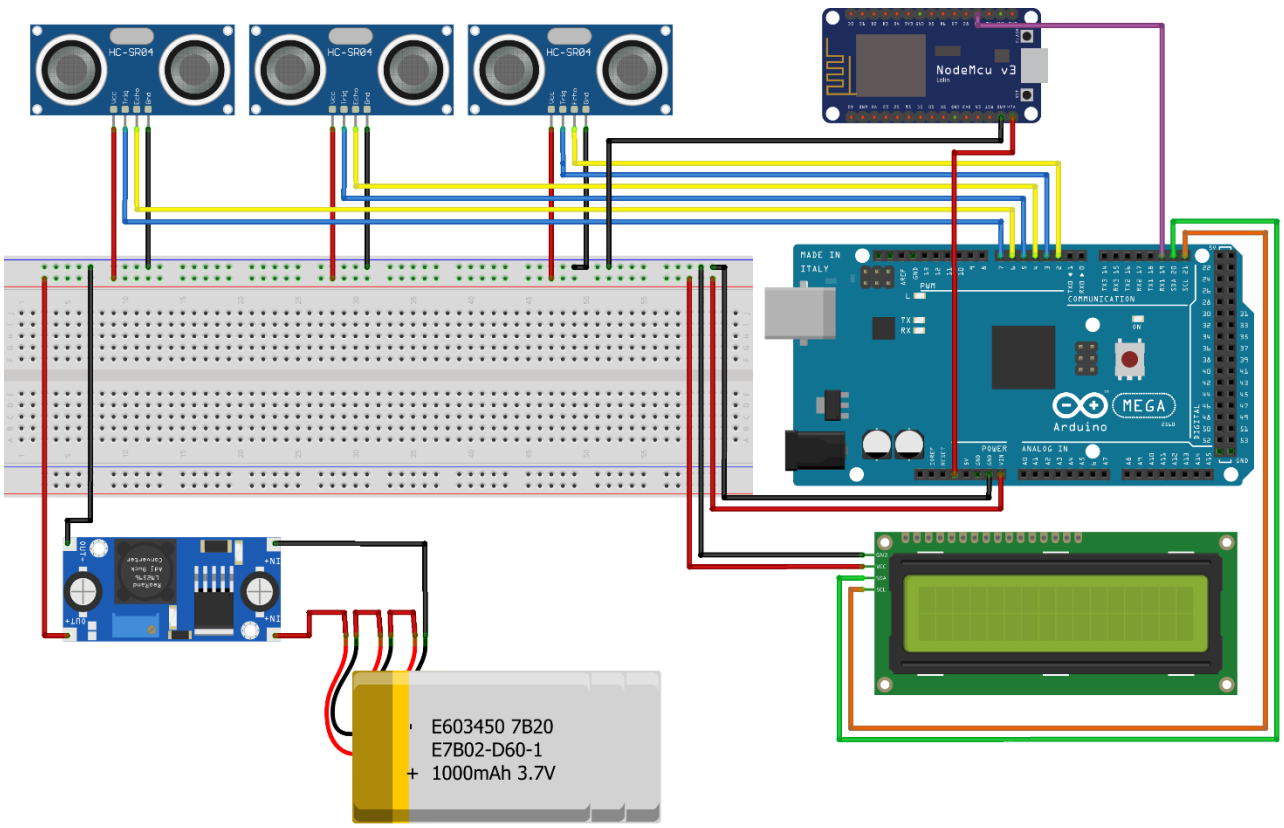

Figure A.1 : Circuit Diagram to assemble the bin model

- Assemble the waste bin model for vehicle truck with above hardware devices too.
- Configure a Google firebase real-time database
- Write codes for the above models with Ardino IDE and install the developed program in to the bin models.
- Provide the customer's wi-fi key with SSID, Password and Urban council firebase database's HOST and AUTH to connect the bin model to the cloud.

```
#include <ESP8266WiFi.h>
#include <FirebaseArduino.h>

#include <TaskScheduler.h>

#define FIREBASE_HOST "smart-waste-management-4e6c1.firebaseio.com"
#define FIREBASE_AUTH "TipHY43G1DhBg78RPOlnvoW1vxgiInKA26Lnm60Q"
#define WIFI_SSID "SLT-LTE-WiFi-FB5D"
#define WIFI_PASSWORD "44EGJDGDMRR"

int readDataVal[3] = {0,0,0};

int sentDataVal[3] = {0,0,0};
```

Figure A.2: Add Customer's wi-fi login details

- Set the time interval to send filling level updates to the database (5 mns – you can change this interval according to the urban council needs.

```
  runner.addTask(task1);
  Serial.println("added task1");

  runner.addTask(task2);
  Serial.println("added task2");

  delay(300000);

  task1.enable();
  Serial.println("Enabled task1");
  task2.enable();
  Serial.println("Enabled task2");
}
```

Figure A.3: Time delay to push data to the cloud

- Same time interval or different interval can set for the grabage collecting vehicle bins too according to the urban council needs.
- Open Google firebase console and check whether the bin model is working

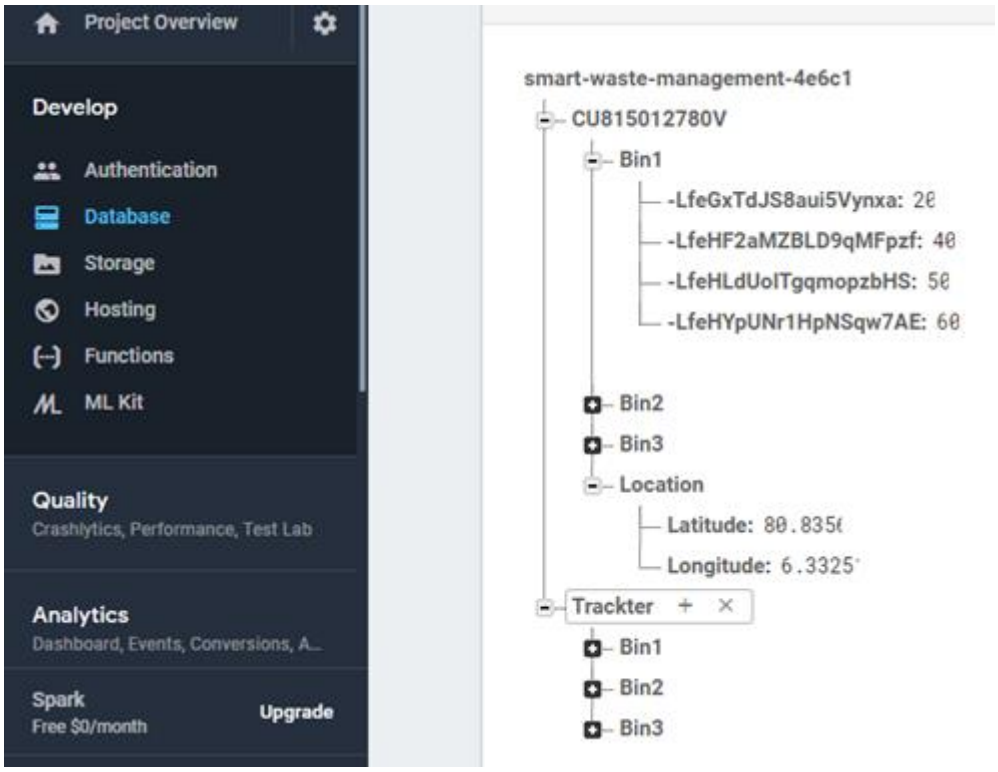

Figure A.4: Checking the filling levels of waste bins

- Add the customer's bin location to the database
- Do the same for garbage tractor bin model too
- Open the web app on your device
- Press login to access, by providing correct username and password.
- See the customers bin filling levels and locations via the app.

Glossary

HOST - A **host** is a type of Web server that stores, serves and manages websites and Web-based applications and services.
AUTH - **Firebase Authentication** is necessary to provide read or write privileges to server users via security rules.
GPS - **GPS** stands for Global Positioning System by which anyone can always obtain the position information anywhere in the world. It is possible to calculate the position of the **GPS** receiver from distance from the **GPS** receiver to three satellites [18].