Location Based Garbage Management System with IOT for Smart City

Project ID : 17-100

Design Document

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

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Declaration

We declare that this is our own work and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of our knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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The supervisor/s should certify the proposal report with the following declaration.
The above candidates are carrying out research for the undergraduate Dissertation under my supervision.

…..... …….....
Signature of the supervisor Date

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1.0 Introduction

1.1 Purpose

This design document gives a detailed description of the system which is going to be develop. It will include functional and non-functional requirements of the system and explain the system interactions with other external applications.

1.2 Scope

“Location Based Garbage Management System with IOT for Smart City” is a concept system developed for smart cities for notifies the cleaning staff whether a garbage bin is full or not. This will motivate people to use garbage bins instead of open dumping. Distance measure sensors and Wifi technology is using for implementing this system in a city.

. Without being a basic garbage container the proposed system integrates the garbage bin with three specific functions.

1. Hand gesture system
2. Garbage level measurement system
3. Security system

This design document is focusing on the garbage bin’s hardware components and its implementation. How to measure the garbage level, send the current garbage level with zero loss and safety measurements for the sensors when garbage bin is in its cleaning process.

1.3 Definitions, Acronyms, and Abbreviations

Table 1.3.1: Definitions, Acronyms, and Abbreviations

Term	Description
IOT	Internet of Things
Wifi	Technology for wireless local area networking with devices based on IEEE 802.11 standards[1]
Raspberry pi zero	Tiny and affordable computer that use to implement garbage functionalities[2]
Python	High level language programming language that can be used to build the code of the system[3]
User	People who using the garbage bin
Workforce	Cleaning Staff
Garbage Level	Trash can filled measurement
GUI	Graphical User Interface
SSH	Secure Shell
CLI	Command Line Interface
GPIO	General Purpose Input Output
GSM	Global System for Mobile
GPS	Global Positioning System
IR	Infrared
Debian	Unix-like computer operating system that is composed entirely of free software

1.4 Overview

Hardware layer of the system will be discussing in this document. This document will show how to make a garbage management system which is always available for users. Without being a basic garbage container the proposed system integrates the garbage bin with three specific functions.

1. Hand gesture system :
   With a simple hand gesture users can open the garbage lid and put their garbage into the bin
2. Garbage level measurement system :
   Bin will be always locked and there will be no bad odors moving around the bin. Garbage level will frequently measure by the sensors and send it to the workforce server via Wifi.
3. Security system :
   Garbage bins' physical security as well as the sensors safetyness when people and cleaning staff using thegarbage bins.

These three main functions contain sub functions for support the main function to achieve its goal. Garbage level measurement system contains how the measured garbage level data pass to the server.

When specifying the users of the system it can divide into two types of users. They are the people who are using garbage bins in their day to day work and the cleaners who are coming to clean the bin.

2.0 Overall Descriptions

Proper waste management is a basic requirement in any kind of an environment. Usually cleaning in these environments is done in the morning and the afternoon. With the current system these problems are identified.

- There are just not enough garbage bins available for serve people. There are one or two bins to serve hundreds of people.
- No method to encourage and inform people: When lid of the bin is covered with dirt no one is like to use that bin.
- Available workforce not utilized properly: Cleaning people are not going for the filled bins they are just going or their daily routine.
- Lots of environmental issues: When Garbage bins are filled bad odors are make unpleasant the area and harmful gases will be created.

Proposed system will build a cost effective garbage management system for the municipal council that will help them keep the city a cleaner place using IOT.

2.1 Productive Perspective

Most research papers have implemented garbage bins, but they are just a bin.
IOT Based Smart Garbage alert system using Arduino UNO has used an arduino board; this poses problems because arduino does not support multi-threaded programming [4]. To avoid this Raspberry pie zero development board is implemented, which is about the same price as the Arduino Uno and supports multithreaded programming.
Most of the papers have used only one level measuring sensor in their bins. This poses a problem because garbage levels can be at different levels at different areas of the bin. To avoid this, four sensors are implemented which will be much more accurate at reading the actual level of the garbage level.

Different research papers have used different methods to transfer data from the bin.

- Smart Bin Implementation for Smart Cities has used GSM technology [5].

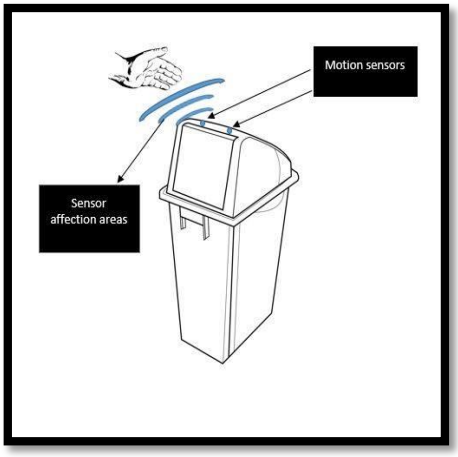
- Cruisers: A Public Automotive Sensing Platform for Smart Cities has used GSM technology [6].
- IoT Based Solid Waste Management System A conceptual approach with an architectural solution as a smart city application has used LORA technology [7].
- IOT Based Smart Garbage alert system using Arduino UNO has used wifi
- Solid Waste Management Architecture using Wireless Sensor Network technology has used RF and GSM technology

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

2.1.1 System Interfaces

Raspberry pi zero uses Raspbian Operating system. It's a free OS based on Debian optimized for the Raspberry Pi hardware.

2.1.2 User Interfaces



Since the system consist of hardware components user interact interface will be a assemble hardware interface. Figure 2.1.2.1 is illustrating the front view of the garbage bin.

Figure 2.1.2.1: Front view of the bin

2.1.3 Hardware Interfaces

- Development Board
- Wifi module
- Distance level measure sensors
- Motion sensors and motors

2.1.4 Software Interfaces

- Python Library
- Putty
- Notepad++

2.1.5 Communication Interface

Wifi technology is used to communicate from Development board to cloud based server. Garbage level will pass via Wifi.

2.1.6 Memory Constraints

- Raspberry pi zero requires 8GB or higher SD card for its operating system [8].
- Raspberry pi zero has a memory (RAM) of a 512MB [8].

2.17 Operations

People have to use a simple hand gesture to open the lid of the garbage bin and the same hand gesture is used to close the garbage bin.

2.1.8 Site Adaption requirements

For power up the garbage bin solar power will be used. Smart city should contains solar energy and that energy will be used for garbage bins.

Garbage bin used Wifi technology to send data to the server. Smart city will have a good Wifi coverage to all the bins to be functional.

2.2 Product Functions

When a user needs to drop garbage into the bin he or she have to walk directly to the garbage bin and using hand gesture open the garbage bin, drop the garbage and use the same hand gesture to close the lid. Hand gesture will be sense by two motion sensors and to open and close the lid servo motor will be used.

While people are using the garbage bin, infrared sensors inside the bin will measure the garbage level and calculate an average garbage level. Calculated garbage level will be send to the server using Wifi module which is integrated to the bin. Wifi module will be connected to the nearest access point and accessing internet to connect to the cloud based server.

Garbage level will be used in prediction algorithm and real time monitoring system located at the server.

2.3 User Characteristics

Specifying the users of the system it can divide into two types of users.

- People who are using garbage bins in their day to day work
- Cleaners who are coming to clean the bin.

2.4 Constraints

- While using the hand gesture system user must need to be in a specific range to detect the hand gesture.
- Garbage level measure sensors doesn't act same on every material type. Becuse of that sensor values may deviate from real values.
- If one garbage level measure sensor defect it will slightly effect to the average garbage level.

2.5 Assumptions and Dependencies

Smart city is consisted with Wifi and solar power.

User should use their hand gesture system to open and close the bin.

2.6 Apportioning of Requirements

If Garbage level measurements configurations getting delayed other functions will be getting affected.

3.0 Specific requirements

This section contains all of the functional and quality requirements of the system. It gives a detailed description of the system and all its features.

3.1 External interface requirements

This section provides a detailed description of all inputs into and outputs from the system. It also gives a description of the hardware, software and communication interfaces and provides basic prototypes of the user interface.

3.1.1 User interfaces

Since the garbage bin doesn't have any designated GUI's, it does not have any direct user interfaces. The hardware connection to the cloud server is managed by the underlying operating system on the web server.

3.1.2 Hardware Interfaces

Embedded hardware devices are being use for assemble a garbage bin. With the help of the embedded devices bins can perform the earlier mention functions. For the proposed bin following hardware devices will be used.

- Development Board
- Wifi module
- Distance level measure sensors
- Motion sensors and motors

Development Board

A microcontroller is use for connect all the other sensor modules. There are many development boards available in the market, and the basic requirements for the system have to be fulfilled by the microcontroller.

The basic requirements:

• Microchip type and the size

• Memory size (RAM)

• Number of I/O pins

• Parallel process availability

• Inbuilt features (Wifi, Bluetooth)

• Price of the board

With the unavailability of the parallel processing in Arduino boards Raspberry boards are clear choice.

Raspberry pi 3 has more memory and inbuilt features than the raspberry pi zero. But the price comparison in Table 3.1.2.1 revealed that is a 1:16 price ratio difference between pi zero and 3. There are pros and cons in both boards according to the comparison in Table 3.1.2.1. For this project the raspberry pi zero will be the most suitable development board to select.

Figure 3.1.2.1: Raspberry pi zero [8]

Table 3.1.2.1: Development Board Comparison [8][9][10]

Requirement	**Arduino UNO**	**Raspberry pi 3**	**Raspberry pi zero**
Microchip type and the size	ATmega328	A 1.2GHz 64-bit quad-core ARMv8 CPU	1GHz ARM11 core
Memory size (RAM)	32 KB (ATmega328P)	1GB RAM	512MB of LPDDR2 SDRAM

Number of I/O pins	26(analog and digital)	40 GPIO pins	40 GPIO pins
Parallel process availability	no	yes	yes
Inbuilt features (Wifi, Bluetooth)	no	WIFI and Bluetooth both	Bluetooth
Ethernet Protocol	_	802.11n Wireless LAN	If there is wifi inbuilt it will support 802.11n Wireless LAN
Price of the board	$50	$80	$5

Distance level measure sensors

Ultrasonic sensors use high-frequency sound pulse to identify the objects by the reflected sound pulse. If the reflection media was rough or damaged, distance calculation of the sensor will be wrong. But using Infrared sensors those error readings will be minimum.

Infrared Sensors:

- Working voltage: DC 3V-12V
- Static power consumption: <0.1mA
- Delay time: 2 seconds
- The blocking time: 2 seconds
- Trigger: Can be repeated
- Working temperature: -20 - + 60 degree
- This module detects the distance 2 ~ 30cm
- detection angle 35 ° [11]

Figure 3.1.2.2: Infrared Sensor

As show in figure 3.1.2.2 the distance can detect potential is adjusted clockwise adjustment potentiometer to detect the distance increases; counterclockwise to adjust the potentiometer to reduce the detection distance

Wifi module

As the transmission media wifi was selected to transfer sensor data. Raspberry pi zero does not possess an onboard wifi chipset, so a wifi module had to be selected. XBEE and ESP8266 were the final modules to be compared in Table 3.1.2.2.

Table 3.1.2.2: WiFi Module Comparison [12]

Wifi Module	**Range**	**Power Consumption**	**Frequency**	**Protocol**	**Price**
XBee	300 Ft	50mA @ 3.3v	2.4GHz	XBee® 802.15.4	$24
ESP8266	250 Ft	< 1.0mW @ 3.3v	2.4GHz	TCP/IP protocol stack	$2.46

According to the comparison on Table 3.2.1.3.1 ESP8266 (Figure 3.2.1.4.2) is the most suitable module to select, since it is the cheapest, provides a much wider range and fulfills the main requirements of the project.

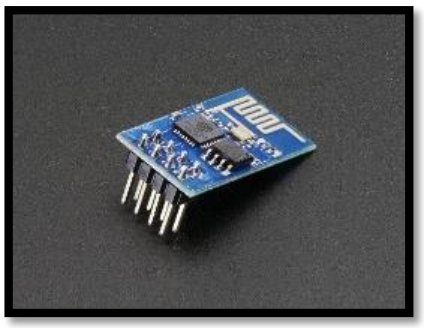


Figure 3.1.2.3: ESP8266 Wifi Module

Motion Sensors and Motors

Two ultrasonic sensors (Figure 3.1.2.4) and a servo motor (Figure 3.1.2.4) will be used for the motion detection of the hand.

Figure 3.1.2.4: Servo Motor

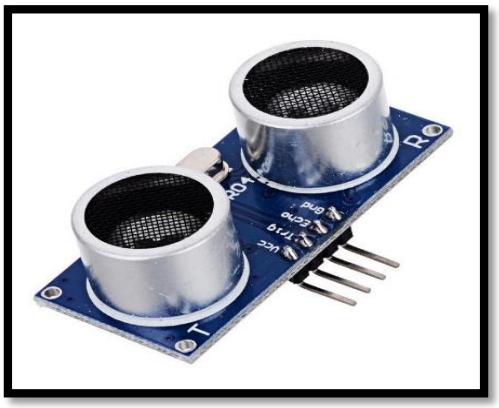


Figure 3.1.2.5: Ultrasonic Sensor

The closing of the lid is done by the servo motor. When the left sensor detects, the servo motor rotates 90° (opening the lid). When the right sensor detects, servo motor rotates back the 90° to 0° (closing the lid).

The locking mechanism takes place when the bin level reaches threshold capacity. During this level the ultrasonic sensors on the hand gesture system is shut down until the bin is cleaned.

3.1.3 Software Interfaces

For develop the proposed system configuring the hardware devices is a must. Configurations of the sensor modules are done in the raspberry pi zero board.

Raspberry boards are configured using python language. To connect the development board and do the modification putty software will be used for SSH connection and the CLI interface (figure 3.1.3.1).

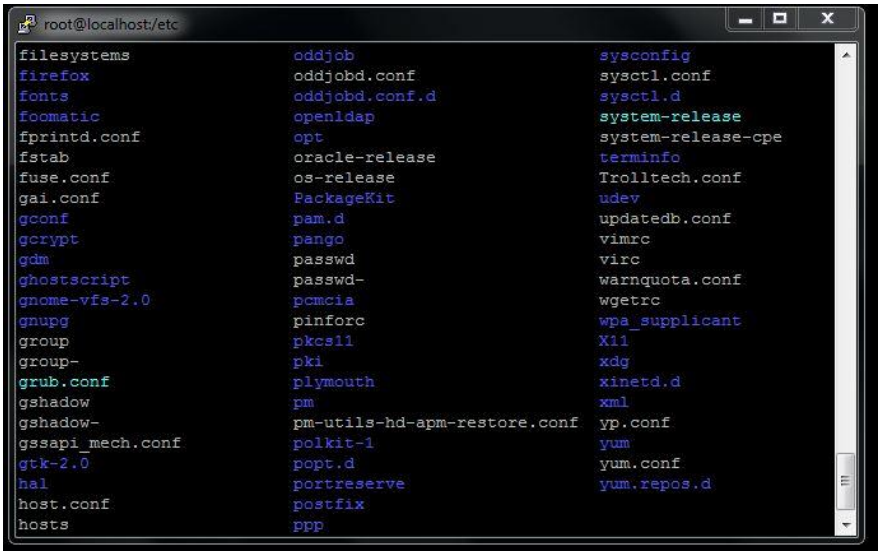


Figure 3.1.3.1: CLI Interface

3.1.4 Communication Interface

Proposed system is working under Wifi technology to pass garbage level to web server. Every Garbage bin (node) is connecting with an access point to communicate with the centralized cloud based server.

For this requirement there should be Wifi access points where the garbage bins can connect and communicate with the server.

3.2 Architectural Design

3.2.1 High level Architectural Design

Below figure 3.2.1.1 is illustrating how the proposed system works.

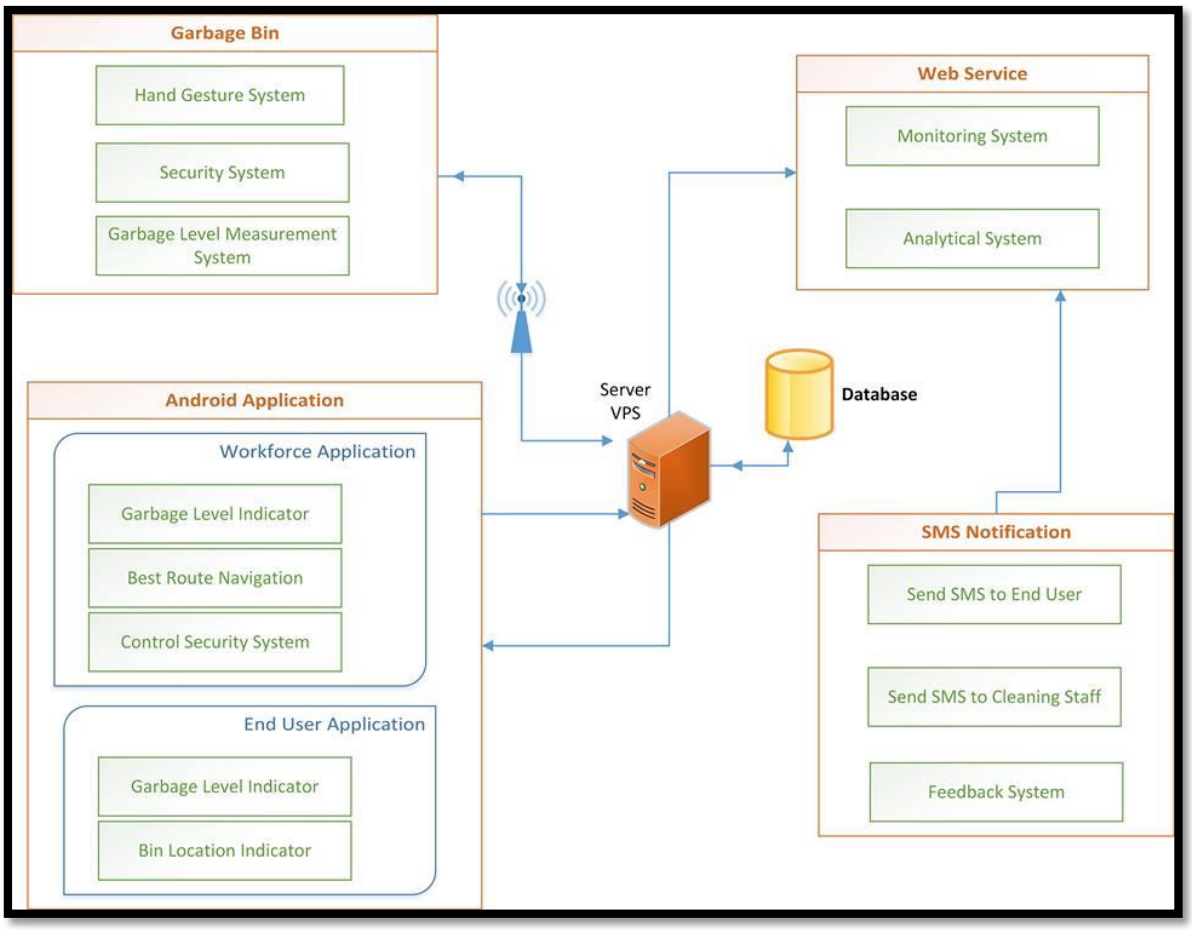


Figure 3.2.1.1: High Level System Architecture

The system architecture can be divided into 3 layers.

- Hardware Layer
- Communication Layer
- Application Layer

Hardware layer includes the component Garbage Bin:

Without being a basic garbage container the proposed system integrates the garbage bin with three specific functions.

Application Layer includes the component Android Application:

Main application will be implementing under two sub applications.

- Workforce Application
- End User Application

Communication Layer includes Web Service and SMS Notification

- Web Service:
  This component includes a monitoring system and an Analytical system.
- SMS Notification:
  This component includes SMS notifications to the End User and the workforce. This also includes a Feedback system.

3.2.2 Hardware and software requirements with justification

Proposed system contains mostly hardware components. Every component is compatible with development board and all the applications in the web server just need the garbage level of the bins. Because of that there won't be any compatibility issues.

3.2.3 Risk Mitigation Plan with alternative solution identification

Garbage level detection will be done by 4 infrared sensors. Garbage level won't be same exact horizontal level. With using 4 sensors an average of the garbage level can be measured. Every bin is sending data to the server periodically. If a bin is malfunctioned it will be inactive for a while. This will identified by the server and workforce will come for the maintenance.

3.2.4 Cost Benefit Analysis for the proposed solution

As this document mentioned earlier raspberry pi 3 and raspberry zero have 16:1 price ratio. Selecting raspberry pi zero will be cost beneficial.

Since the garbage bins are track under its location a GPS module for each bin was required. But without using a GPS module fixing the garbage bin to the floor will cost effective and it brings more safety for the garbage bin.

3.3 Performance requirements

Proposed system have a real time monitoring and a garbage level prediction system which needs the garbage level frequently. For this requirement all the infrared sensors get their readings on each and every second. An average of the readings will be calculated in milliseconds and transfer to the server via Wifi.

When transferring data to the server, data packet contains only the ID of the bin and the garbage level only. This will help to reduce the data traffic on the connection to the access point from the garbage bin.

When garbage bin's lid open for a hand gesture it will open only for 40 seconds only. After the one minute it check whether is anyone still presence, if someone is still using the bin it keep open the lid. If there is no one using the bin it will closed. This method is implement to avoid the keep the bin open by accident.

3.4 Design constraints

- Smart city is consisted with solar power. This green energy will be using to power up the garbage bin. And that power should be supplied without any cutoffs. Otherwise the garbage bin will be switched off.

- With the concept of the Smart city it should have Wifi technology anywhere without any trouble to accessing them. Garbage bins are using Wifi to pass it data their server frequently.

- Implementation And testing of the system will be done under nine months and during testing period garbage bins physical security has to be prioritized.

- Government tax regulations are making the hardware items little bit costly than the international price and shipping items should be delivered on or before the expected date.

3.5 System attributes

3.5.1 Reliability

With the sending garbage level for the server it's been used for systems prediction algorithm. This will gave make the cleaning process more efficient and cost effective. All the systems other functionalities are depend on these garbage level values.

Whenever a person needs to use a garbage bin he or she just needs to walk towards a garbage bin and put their garbage without any problems.

3.5.2 Availability

Proposed system will gives an always available garbage bin with its prediction algorithm. With the implementation of the system people can use any garbage bin without any hesitations.

All the servers are located in cloud services. Because of that there will be no unavailability of the server process. If a data packet is loss in the process of data sharing that data packet will be retransferred because of the TCP/IP protocol.

Even if there is a problem with the server development board can queue up the data to send until the problem get solve.

3.5.3 Security

The Major concern with the security is the physical security of the garbage bin. Every sensor of the bin will be fixed in proper places for avoid any damage by garbage.

There is a specific function for cleaners to use before their cleaning process which will shut down all the sensors and getting rid of passing false data to the server.

Garbage bins will be fixed and no one can ever move the bins here and there.

Bins will be water proofed because when it's raining sensors and the development board will didn't caught any damages.

3.5.4 Maintainability

Garbage bin monitoring system will help to get current status of any bin and it will notify if there is an error in a bin.

This helps to fix the error and keep the system running without any tolerance.

4.0 Supporting Information

4.1 Reference

[1]Wi-Fi- IEEE 802.11 standards [online] Available: https://en.wikipedia.org/wiki/Wi-Fi [Accessed 26-Apr-2017]

[2]Raspberry Pi [online] Available: https://www.raspberrypi.org/ [Accessed 26-Apr-2017]

[3] Python (programming language)[online] Available: https://en.wikipedia.org/wiki/Python_%28programming_language%29 [Accessed 26-Apr-2017]

[4] 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.

[5] 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.

[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] "Raspberry Pi Zero." Raspberry Pi. [Online]. Available: https://www.raspberrypi.org/products/pi-zero/. [Accessed: 25-Jan-2017]

[9] "Raspberry Pi 3." Raspberry Pi. [Online]. Available: https://www.raspberrypi.org/products/pi-3/. [Accessed: 25-Jan-2017]

[10] "Arduino - ArduinoBoardUno." Arduino - ArduinoBoardUno. [Online]. Available: https://www.arduino.cc/en/main/arduinoBoardUno/. [Accessed: 25-Jan-2017]

[11] "Hobbyist.co.nz." Infrared Proximity Sensor | Hobbyist.co.nz. [Online]. Available: http://www.hobbyist.co.nz/?q=infrared_proximity_sensor/. [Accessed: 23-Jan-2017]

[12] What's the difference between RF options (wifi, xbee, NRF24L01) 2013. [Online]. Available: http://arduino.stackexchange.com/questions/3270/whats-the-difference-between-rf-options-wifi-xbee-nrf24l01/. [Accessed: 26-Mar-2017]

4.2 Appendices

Raspberry pi zero specification:

Table 4.2.1: Raspberry pi zero specification

Type	**Model A**	**Zero**
Memory (SDRAM)	256 MB (shared with GPU)	512 MB (shared with GPU)
USB 2.0 ports	1 (direct from BCM2835 chip)	1 Micro-USB (direct from BCM2835 chip)
Video input	15-pin MIPI camera interface (CSI) connector, used with the Raspberry Pi camera or Raspberry Pi NoIR camera	None

Python:

Raspberry Pi Python Code Library

- Adafruit_ADS1x15
- Adafruit_ADXL345
- Adafruit_BMP085
- Adafruit_CharLCD
- Adafruit_DHT_Driver