SMART WASTE MANAGEMENT SYSTEM WITH INTERNET OF THINGS

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SMART WASTE MANAGEMENT SYSTEM WITH INTERNET OF THINGS

by

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LIST OF ABBREVIATIONS

IoT	Internet of Things
GPS	Global Positioning System
PHP	Hypertext Preprocessor
RFID	Radio-frequency Identification
AI	Artificial Intelligence
IR	Infrared
MQTT	Message Queuing Telemetry Transport
GSM	Global System for Mobile Communication
SMS	Short Message Service
OS	Operating System
LED	Light Emitting Diode
CSS	Cascading Style Sheets
IP	Internet Protocol
WPAN	Wireless Personal Area Network
WLAN	Wireless Local Area Network
WNAN	Wireless Neighbourhood Area Network
LPWAN	Low Power Wide Area Networks
UDP	User Datagram Protocol
HTTP	Hyper Text Transfer Protocol
CoAP	Constrained Application Protocol
GCP	Google Cloud Platform

TCP	Transmission Control Protocol
URI	Universal Resource Identifier
DTLS	Datagram Transport Layer Security
SQL	Structured Query Language
DML	Data Manipulation Language
DDL	Data Definition Language
DCL	Data Control Language
DBSM	Database Management System
USB	Universal Serial Bus
GPIO	General Purpose Input and Output
API	Application Programming Interface
RAM	Random-access Memory
SDRAM	Synchronous Dynamic Random-access Memory
BLE	Bluetooth Low Energy
UTC	Coordinated Universal Time
SSH	Secure Shell
VNC	Virtual Network Computing
URL	Uniform Resource Locator
iOS	iPhone Operating System

SMART GARBAGE MANAGEMENT WITH IOT SYSTEM

ABSTRACT

Garbage collection is a process of gathering or taking away domestic waste from neighbourhood or town by the authority in charge. The traditional way of collecting garbage is by moving a truck from house to house to take away the household disposal. The collection is usually scheduled in a daily basis or twice a week. However, problem arises when some of the family do not have any domestic waste to be collected or the dustbin still has a sufficient space for garbage dumping. With the traditional method, the garbage collecting truck will move on to collect domestic waste from residential areas as usual without considering the necessity of the process. Therefore, it can cause wastage of man power and fuel. Apart from that, the traditional waste collection cannot ensure the cleanliness of a city or town to be kept all the time. This is because the garbage collecting process only happens in accordance to the schedule. Highly trafficked areas face a situation where the dustbins are filled up quickly and cause overflow. Increased urbanization comes around with higher garbage disposal rate. Hence, the fixed schedule for collection is less efficient. This project presents a waste management system with Internet of Things (IoT) technique. Authority in charge of garbage collection is able to monitor the level of garbage filling through website and smartphone application. When the capacity of the dustbin reaches a certain level and about to overflow, the webpage and smartphone application show an indication to the users and they will be notified that garbage collection is required. The location of the dustbins is shown on Google Map in the webpage. Hence, the authority can view the optimized path for garbage collection. Analysis is done to determine the suitable IoT protocol and hardware for the project. In this system, ultrasonic sensor and weight sensor are implemented to detect the garbage filling of dustbin and Global Positioning System (GPS) module is used to obtain the location of the dustbin. Raspberry Pi 3 acts as the microprocessor and central control unit. Android application is developed by using MIT App Inventor while Python script is employed to program the Raspberry Pi 3 and configure IoT protocol. PHP, HTML, CSS and Javascript are used to perform webpage design. Overall, Internet of Things technique is applied to the system and tested.

PENGURUSAN PELUPUSAN DENGAN "INTERNET OF THINGS"

ABSTRAK

Pelupusan sampah merupakan satu proses yang melibatkan pengutipan sampah dari kawasan perumahan atau kawasan bandaran oleh pihak berkuasa. Cara tradisional pengutipan sampah oleh pihak berkuasa adalah dengan menghantar lori dari rumah ke rumah untuk mengambil sampah sarap yang dibuang. Pengutipan sampah oleh pihak berkuasa selalunya berlaku sekali atau dua kali dalam seminggu. Namun, masalah ditimba apabila wujudnya keluarga yang tidak mempunyai sampah untuk dikutip atau tong sampah mereka masih mempunyai banyak ruang. Dengan cara pengutipan tradisional, lori pengutipan sampah akan bergerak ke kawasan yang sudah ditetapkan untuk mengutip sampah tidak mengambil kira keperluan tindakan itu. Oleh itu, pembaziran tenaga kerja dan bahan api akan berlaku. Selain itu, cara pengutipan tradisional tidak dapat memastikan kebersihan bandar dapat dijaga sepanjang masa. Hal ini kerana lori pengutipan sampah hanya akan bertindak mengikuti jadual masa yang telah ditetapkan. Kawasan yang sesak akan menghadapi masalah iaitu tong sampah akan dipenuhi dengan cepat dan akan berlaku limpahan. Justeru, cara pengutipan tradisional kurang efektif. Projek ini menyampaikan pengurusan pelupusan dengan teknik "Internet of Things (IoT)". Pihak berkuasa boleh mengawas keadaan pengisian tong sampah melalui laman web dan aplikasi telefon pintar. Apabila isi kandungan tong sampah sampai sesuatu tahap, laman web atau aplikasi telefon pintar tersebut akan menunjukkan satu amaran dan pengguna sistem ini akan sedar bahawa pengutipan sampah diperlukan. Lokasi tong sampah akan ditunjakkan. Oleh itu, pihak berkuasa boleh mendapatkan lorong yang paling optimum untuk membuat pengutipan. Analisis telah dibuat untuk menentukan IoT protokol dan alatan yang paling sesuai untuk projek. Dalam sistem ini, ultrasonik sensor dan sensor keberatan akan diguna untuk mengesan tahap kandungan dalam tong sampah dan "Global Positioning System" (GPS) modul akan digunakan untuk mendapat lokasi tong sampah. Raspberry Pi 3 memainkan peranan sebagai satu mikropemproses. Aplikasi Android akan dicipta dengan MIT App Inventor. Bahasa Python akan diguna untuk memprogramkan Raspberry Pi 3 dan mengkonfigurasi IoT protokol. Bahasa PHP, HTML, CSS dan Javascript akan diguna untuk mereka laman web. Kesimpulannya, teknik "Internet of Things" akan diguna dalam sistem dan akan diperiksa.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Overflowing garbage bins are causing serious impact to us in a lot of ways and have become a severe issue which need to be dealt with. According to an article published in October 2016, overflowing garbage bins have become a common sight in a number of areas in certain countries [1]. This is the situation arises when the current garbage clearance mechanism is inefficient. This ultimately lead to a potentially hazardous health situation in the countries with inefficient garbage clearance mechanism [1]. Other than causing an eyesore to the residents, the overflowing garbage bins also come along with unbearable stench. This unsightly occurrence has also creating more breeding sites for bacteria carrying pests such as mosquitoes and rats. Furthermore, the overflow of garbage in garbage bins has also attracted dozens of stray dogs which thrive solely around the garbage bins and this endangers the residents in that area [1].

Under the Waste Management Act 1996, local authorities are responsible to arrange the schedule for waste collection from residential areas and town [2]. The garbage clearance system employed are usually based on the traditional method which is by scheduling trucks to move around to each individual house to collect the waste [3]. This method is straight forward and efficient only to certain extend depending on the frequency or the activeness of the process. There are other waste collecting mechanisms such as collection from the community bins placed in the locality, users leaving their rubbish directly outside their homes and waste generators deliver their garbage directly to landfill area [3].

However, these methods are found to be less effective and have brought up the concern where people feel that there are a lot of wastage in terms of man power and petrol consumption. This is because there are occasions where the dustbins are not being filled up to a level which requires collection of garbage or the dustbin is not being used and left empty. Therefore, when the garbage collection truck goes to collect garbage from those dustbins, energy is said to be wasted as the collection is not required. Extra petrol is spent for the truck to move to those unnecessary places which do not require garbage collection.

The traditional ways of garbage collection cannot ensure the cleanliness of town with high population rate. The garbage bins in the highly trafficked areas will be filled up quickly and start to overflow onto the pavement [4]. If the schedule for garbage collection in these areas is less frequent, the places become an unhygienic eyesore to the residents and causes troubles due to the overflow of garbage in garbage bins [4]. The inefficiency of traditional garbage collection has been visualized when the public waste bins are filling up real fast and many of the bins end up overflowing before the collection of garbage can be done [5].

The untreated overflow of garbage in garbage bins will allow bacteria, insects and pests to breed vigorously as overflowing waste bins are the ideal breeding spot for them [5]. Animals that thrive from garbage such as stray dogs also face a raise in population and cause troubles to the residential area. Air pollution and respiratory disease are also the inevitable impacts from overflowing garbage bins as garbage gives out stench and the bacteria come along with the foul smell of the rubbish [5]. The foul smell emanating from those overflew dustbins often causes difficulties and discomfort for people to pass through [6]. Inefficient waste control is also bad for municipal wellbeing [5]. Overflowing garbage will cause an eyesore to both the residents and visitors. The city becomes dirty and tourism as well as investments from outsiders are expected to decrease. Ultimately, cities lose money and job opportunities will be affected as well [5].

1.2 Problem Statement

Many smart garbage bins have been developed and proposed in the last decade to cope the problem of overflowed dustbins. These smart dustbins make use of the advanced technology with different approaches to prevent overflow of garbage in dustbins. An IoT based smart garbage alert system which implement ultrasonic sensor and radio-frequency identification (RFID) technology proposed by Dr. N.Sathish Kumar [7] to perform remote monitoring of the capacity of dustbins through municipal webpage and Android application. From their proposed system, RFID reader will be used to confirm the task of emptying the garbage bins is being done by scanning the RFID tags equipped on the dustbins. This system is not efficient as the verification of the cleaning process is being done is less important as the ultrasonic sensor can show real time status of the level of garbage filling of the dustbins. Besides that, this system is not able to tell the authorities the whereabouts of the dustbins merely by using RFID. This is because the dustbins might be moved to other place and the system is designed statically which cannot track the location of the dustbins.

Another smart waste management system proposed by Gopal Kirshna Shyam [8] uses Internet of Things and Artificial Intelligence (AI) techniques to detect and at the same time forecasting the waste levels of dustbins for the future. The system learns how to select daily waste bins to be emptied based on historical data through artificial intelligence algorithm. Even though AI is a technology which grants the system intelligence, its accuracy for this system still need to be improved by continuous data training. Hence, this system is less effective in terms of path optimization accuracy.

Abhay Shankar Bharadwaj [9] had proposed another IoT based solid waste management system. His system implements infrared (IR) sensors to detect the level of garbage filling of garbage bins and load cell to obtain the weight of the bins. The design of his waste management system is a combination of 5 garbage bins in different colour for different types of waste disposal. The GPS location of the garbage bins are hard coded to the processor and he also added gas sensor as well as temperature and humidity sensor to obtain the condition of the surroundings of the garbage bins. The information read by the sensors are sent to the controller through LoRa module and the controller will send data to the web through Message Queuing Telemetry Transport (MQTT) platform. This system is excellent in terms of features, but it is way too costly as it involves a huge number of sensors and microprocessors to be installed to the garbage bins.

Krishna Nirde [10] had come out with another IoT based solid waste management system with different approach. The system implements global system for mobile communication (GSM) module to send short message service (SMS) to notify the user when the garbage filling has reached its threshold level. However, GSM module can encounter transmission interference as multiple users are sharing the same bandwidth. The notification might not be able to send to respective user or the receiving of the notification might be delayed.

Last but not the least, all the limitations of the 4 reviewed solutions are being considered in this project. This project comes out with a solution which can cope with overflow of garbage in dustbins and avoid the limitations mentioned. Thus, a monitoring system which can provide real time status of dustbin will be designed. This is because a dynamic system is more reliable, and user can track the changes applied to the location of garbage cans. In other words, the system is able to detect location of dustbins and does not affect the efficiency of garbage collection. Besides that, the system is designed in a way that it can detect the level of garbage filling accurately and the results will be sent to user's monitoring interface so that user is able to monitor the condition of garbage cans all the time. This further enhances the system's efficiency as user or authority can respond to the condition of trash cans based on accurate detection of the level of garbage filling by using ultrasonic sensor and weight sensor. Other than that, the design of the smart waste management system prioritizes on low cost designing. The system will only spend a reasonable amount of money to achieve its features. This is to ensure that the system is affordable and worth to invest on. Lastly, the system employs Internet of Things protocol as messaging and monitoring platform instead of using GSM module. IoT protocol can provide real-time communication as well as low latency in data transmission. Upon comparing to GSM messaging service, IoT is a better solution in terms of data transmission. User can receive information of the level of garbage filling through the internet anytime anywhere.

1.3 Research Objectives

Based on the problems mentioned above, the objectives of this project are:

1. To design an IoT based smart waste management system which can detect the level of garbage filling of a garbage bin.
2. To design an IoT based smart waste management system which can identify the location of dustbin.
3. To develop real time monitoring of garbage bin capacity.

1.4 Research Scopes

In this project, Raspberry Pi is used as a microprocessor to interface with sensors and act as an apache server. The operating system (OS) used in Raspberry Pi is Raspbian Jessie. There are two main function for the system, one is to notify user when the level of garbage filling has reached its threshold level. The second function is to tell the user the location of the garbage bin which need to be cleaned.

For the first function, ultrasonic sensor and weight sensor are employed to detect the level of garbage filling of the dustbin. The ultrasonic sensor functions by measuring the distance between itself and the obstacles. The measured distance is displayed on a designed webpage in graphical form. The weight sensor is added to aid the trash level detection process. It functions by measuring the total weight of garbage dumped to the dustbin. Once the threshold levels of distance and weight are exceeded, the Raspberry Pi triggers a signal and make a change to the designed webpage which will be noticed by the user.

The second function is done by implementing GPS module to determine the location of the garbage bin. GPS module gives the latitude and longitude of the garbage bin and the information is displayed on Google Map.

The scope of this project focuses on the alarm system through internet and the location of the garbage bin to be cleaned. This project does not focus on the speed of data transmission through the internet protocol. The platform of communication through the internet is less focused.

1.5 Thesis Structure

This thesis consists of five chapters which will describe and explain the details of the project. Chapter 1 of the thesis is the introduction of the project. In this chapter, the research background, problem statement, research objectives and research scopes are discussed.

Chapter 2 presents the literature review of the project. Previous works and journal regarding this project are studied and the fundamental knowledge related to this project are researched. Summary of the past works and approaches to the solution of this project are presented as well. Comparison of Internet of Things protocol and different hardware have been done and explained in this chapter.

Chapter 3 presents the methodology or solution to this project. The methods used to accomplish this project is discussed in detail. The design of prototype, installation of hardware and usage of software are clarified. After all, the flow of software and interface with hardware is visualized clearly and the programme flow to operate the whole system is discussed.

Chapter 4 presents the results and discussion of the project. The data and output obtained from the methodology of the project is recorded and explanations are given in details. The results and discussion for comparison of IoT protocol, GPS sensing, trash level sensing, and webpage as well as smartphone monitoring are written. All the results obtained for the project is summarized as well.

Chapter 5 is the last chapter of the thesis and it covers the conclusion of the project. Inferences and findings of the project are listed. The achievement of the objectives is discussed, and the subject of the project is restated. Besides that, limitations and future works of the project are identified.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter covers the study, analysis and interpretation of previous work. Relevant fundamental knowledge and concept about this project are discussed. The drawbacks, limitations and advantages of previous work are identified as well. Section 2.2 discusses the different approaches and solutions used by engineers and designers for smart waste management and monitoring system. Section 2.3 presents the overview of Internet of Things. Section 2.4 consists of the IoT approaches and protocols usable for IoT solutions. Section 2.5 presents the different type of database used to work along with IoT technique. Lastly, section 2.6 is the summary of the literature review.

2.2 Smart Waste Management and Monitoring System

Without the aid of blooming technology and innovation, people frequently encounters cases of overflowing garbage bins. This is due to the inefficient of garbage collection mechanism which had been employed by most of the country in the world. In fact, despite having advanced technology, most country are still applying the basic yet traditional mechanism in collecting waste. By having limited awareness on the condition and trash filling level of the garbage bins, the traditional method of collecting waste is not able to prevent overflow of garbage in waste bins. The vision to keep the city clean will be a difficult attempt if the mechanism used in collecting waste persists. Therefore, engineers and designers had proposed a lot of solution to cope and overcome the limitations from the traditional mechanism in collecting waste.

The famous yet functional technology, radio-frequency identification (RFID) had been proposed by Dr. N.Sathish Kumar [7] to be implemented on the trash bin monitoring. RFID is a small electronic device that consists of an antenna and a small chip which carries information [11]. The device has similar function with the barcode and it operates with both RFID reader and RFID tag. The RFID reader need to scan the RFID tag in order to retrieve the information from the tag [11]. In their proposed system, RFID used as a computing technology for verification purpose [7]. RFID tag is installed on garbage bins located over the town and residential area. With the help of ultrasonic sensors, the authority will be aware of the level of garbage filling of the dustbins around the town.

When the garbage filling reaches a certain level, the authority sends trucks to collect and clear the dustbins. Upon completion of such act, authority uses their RFID reader to scan the tag installed on trash cans to signify the system. The RFID tags installed on dustbins contain the information of the location of dustbins so that the authority will know which dustbins need to be cleared. However, this proposed solution is less effective in terms of accuracy of location of dustbins. This is due to the statically design of the solution where it assumes the dustbins are located on the same spot throughout the time as the locations are being hardcoded to the RFID tag. In fact, the garbage bins might be moved around or shifted to other places and this causes inaccurate data from the database.

Bharadwaj B [12] had proposed another solution to solve overflowing garbage bins. In his solution, ultrasonic sensors are applied to indicate the level of garbage in the bin. The cover of the bin is closed automatically if the level of garbage reaches 80% by automatic rotation of conveyor belt. The dustbins will be moved to the underground through conveyor belt and cleared its content to the underground bin. Internet of Things (IoT) technique is applied to monitor the system and store information on database. However, this system is very hard to implement as it requires a huge cost in installation and it need to create space for underground bin. Besides that, the system requires an A.C. input of 230V in order to operate and it consumes a lot of power.

The infrared (IR) sensor has also been suggested in the smart waste management system. IR sensor consists of light emitting diode (LED) which emits infrared light continuously. When obstacle is encountered by the IR sensor, the infrared light is reflected, and obstacles detection can be achieved [13]. Trushali S. Vasagade had proposed a solution for dynamic solid waste collection and management which implements IR sensor to detect the garbage level inside the garbage bin as well as to detect garbage outside of the bin [13]. A GSM module is used to send a message through mobile phone to notify authorities about the need to clear the garbage bin content. The system also has an automatic moving shaft to clean the rubbish if rubbish is detected outside of the garbage bin. Besides that, an alarm will be triggered when garbage is detected outside of the bin. However, IR sensor is found to be less accurate when compared to ultrasonic sensor. In fact, most of the IR sensor has a shorter measuring distance. For example, according to datasheet, the model GP2Y0A21YK0F IR sensor has an operating distance of 10cm to 80cm only. As compared to ultrasonic sensor, the model HC-SR04 provides

an operating distance of 2cm to 400cm. Hence, the system proposed by Trushali S. Vasagade [13] might be facing a drawback in terms of accuracy.

The Artificial Intelligence (AI) is a theory in which a computer or a system is able to perform tasks with human intelligence or in short, giving human intelligence to machines. Gopal Kirshna Shyam [8] had suggested a method in which AI will be implemented in smart waste monitoring system. The system is able to detect and at the same time forecasting the waste levels of dustbins for the future. With AI, the system can predict the rate of filling of dustbins and determine the schedule of collecting waste by the authorities. As a matter of fact, artificial intelligence is still under the researching state and most of the applications with artificial intelligence still cannot provide 100% accuracy for output. The data for AI need to be trained continuously and there will be cases which are not predictable and cannot be handled by AI.

The smart waste management system proposed by Ankitha S had implemented ultrasonic sensor as garbage level detection, GSM module as notifier and GPS module as location detector [14]. For this system, each dustbin will be assigned a unique identification (ID) and the ID will be sent to the GSM. The GSM sends it to the server. The ID is identified by using GPS system so that the location of the dustbin can be known.

Balamurugan S [15] had proposed a solution in which ultrasonic sensor and gas sensor are to be used to monitor the garbage filling and decomposition of trash. Upon filling up or decomposed gas is detected, the GSM module triggers an event to send a SMS to the authority. Besides that, a servo motor is installed to the trash can. The servo motor acts as a lock to the cover of the trash bin. When the level of garbage filling has exceeded the predefined limit, or when decomposed gas is detected, the servo motor will lock the cover of the dustbin. The lock can only be opened by resetting the microprocessor or through serial communication with the processor.

Another research done by Teh Pan Fei [16] has used ultrasonic sensor, GPS module and Arduino to build a smart waste management system. PhpMyAdmin is used to manage database while PHP language is used to develop web pages alongside JavaScript and Cascading Style Sheets (CSS). The web pages are used to monitor the level of garbage filling of dustbins and to display the location of garbage bins as well as the optimized route for garbage collection.

2.3 Overview of Internet of Things

Internet of Things (IoT) is the linkage of sensors and actuators embedded in physical layers through wired or wireless networks that connect to the internet [17]. The concept of IoT starts up from the question "how things can communicate?". Smart devices usually communicate in device-to-device form [18]. The connection for two or more devices is usually through network protocols such as internet protocol (IP), Bluetooth, Z-Wave or ZigBee [18]. The data transmission through these protocols are usually of low data rate. The device-to-cloud communication is also a way of communication for IoT devices. Wired Ethernet or Wi-Fi connection is used to connect the device to the IP network in order to link to the cloud storage [18]. The connection between devices and application-layer gateway to reach the cloud service is known as the device-to-gateway connection. This connection has a high network security and provide feature such as protocol translation [18]. Back-end data sharing is the communication that allows users to export and analyse smart object data from a cloud service [18].

2.3.1 IoT communication layer

Coverage of network is one of the main criteria to group and classify the different types of IoT wireless technology. The Wireless Personal Area Networks (WPAN) provides short range network coverage while Wireless Local Area Network (WLAN) gives short or medium coverage. The medium range coverage is designated as Wireless Neighbourhood Area Network (WNAN) and long range as Low Power Wide Area Networks (LPWAN) [19]. It is important to set up a suitable connection network so that the physical system which is loaded with data and information is able to communicate with other intended devices through a communication protocol [20]. In other words, the communication layer of an IoT system acts as the backbones of the whole system. From the research of Bahaa Eldin El-Shweky [21], communication can be classified into three main categories which are short-distance, medium-distance and long-distance communication. Short distance communication is mostly being applied for local areas to manage data flow between local nodes. For example, Wi-Fi connection and RFID. Medium distance allows connection between multiple gateways through installed wired system [21, 22]. For example, ethernet. By having active supports of satellite networks and supplying mobile phones with Fifth Generation communication protocol, long distance communication is achievable with high communication speed [21]. The communication between electronic devices and Internet through Wi-Fi is an easy and

inexpensive way [23]. A wireless router is used, and it receives the signal and send information to the Internet using Ethernet. The latest version of Wi-Fi is the 802.11ac. It operates in a transmission speed ranging from 433Mbps up to several gigabytes per second. It also provides wide range of bandwidth which is 80MHz and 160MHz [24].

2.4 Internet of Things approach

Application protocols over TCP/IP or User Datagram Protocol (UDP)/IP are required in order to access to Internet [30]. There are a lot of approaches and protocols for Internet of Things solution. For example, Hyper Text Transfer Protocol (HTTP), Constrained Application Protocol (CoAP), Google Cloud Platform (GCP), Message Queuing Telemetry Transport (MQTT), and LoRa.

2.4.1 MQTT protocol

Message Queuing Telemetry Transport (MQTT) is a lightweight messaging protocol that allows distribution of telemetry information. This messaging protocol is introduced by an IBM developer Andy Stanford-Clark in 1993 and was internationally standardized in 2013 [25]. MQTT basically consists of three components, which are subscriber, publisher and broker. Publish and subscribe communication pattern is the concept for MQTT to provide communication between machine-to-machine (M2M) [26]. MQTT uses Transmission Control Protocol (TCP) as transport and it requires an IP [27]. IoT devices can employ MQTT technique to send or publish information about a topic to a server which is functioning as MQTT message broker [26]. Information will be pushed out by the message broker to clients whom had subscribed to the topic. This communication method can be further elaborated to five different actions which are “Connect”, “Disconnect”, “Subscribe”, “Unsubscribe” and “Publish”. “Connect” is the action of connecting to the respective server. “Disconnect” is an action to wait for MQTT to be disconnected from the server. “Subscribe” is the way to follow or keep updated on a certain topic. “Unsubscribe” is not to get any update from certain topic. “Publish” is the act of uploading information or data to a certain topic so that client who has made subscription to that topic will receive the message. There are a lot of platforms for MQTT, such as, mosquito, HiveMQ and paho MQTT [28], [29]. Figure 2.1 shows the architecture of publish and subscribe for MQTT protocol.

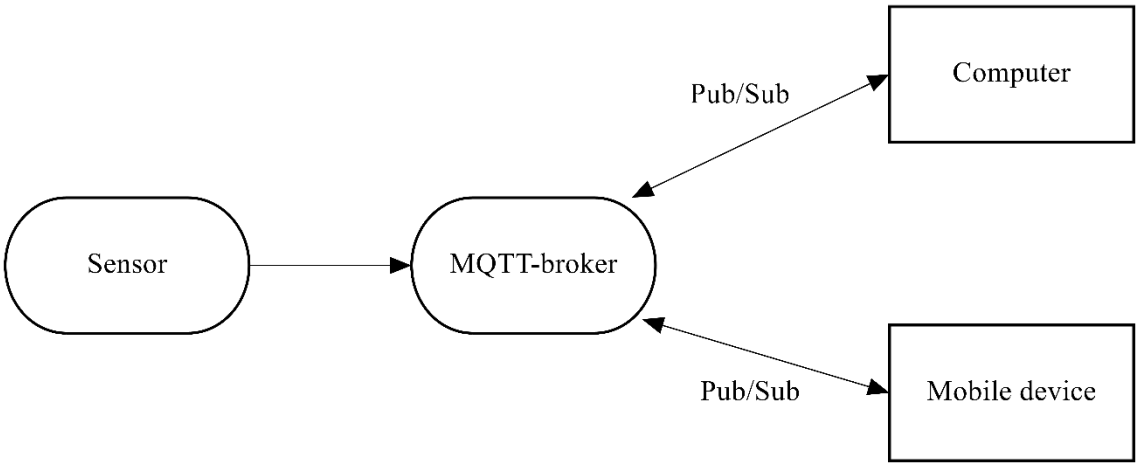

Figure 2.1 Architecture for MQTT Publish and Subscribe

According to the research done by Prarna Dhar [30], MQTT is able to act as an Internet of Things protocol. In his research, he had used Arduino board with an Ethernet shield to act as a microcontroller to develop an intelligent parking cloud services with IoT based. IR sensors are used as detector for parked parking lot. Information will be sent to the cloud through MQTT protocol. User is also able to monitor the availability of car park through webpage. His research had also compared the packet size, power consumption and latency between MQTT and HTTP protocol. From his research, he had found out that HTTP protocol has a larger packet size compared to MQTT. While connecting to Wi-Fi network, HTTP protocol tends to consume more power. Therefore, battery used for creating and maintaining a connection for HTTP is more than MQTT protocol. The delay time in fetching or receiving data for HTTP is slightly longer than MQTT. This is because of the larger packet size on HTTP protocol and it requires longer time to transmit data [30].

2.4.2 HTTP protocol

HTTP is another application protocol used to distribute and collaborate information. It is an asymmetric request-response client-server protocol and it reacts to client request. For instance, the HTTP server will return a response message to the client when the client sends a request message to the server. HTTP can also be known as a pull protocol whereby clients can pull information from the server instead of the server pushes information to client [32]. Figure 2.2 shows the architect of request and response of HTTP protocol.

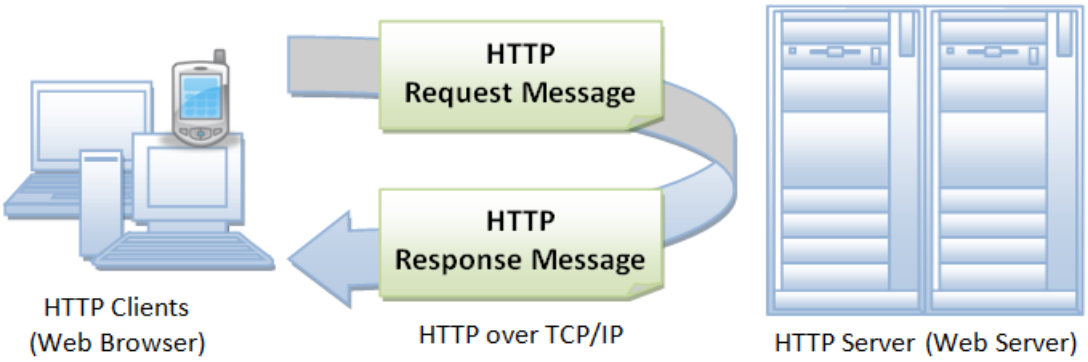

Figure 2.2 Architect of request and response of HTTP protocol [32]

Based on the research done by Tetsuya Yokotani [31], the HTTP must transfer a large number of tiny packets in order to be able to apply for IoT communication. Reliable communication can be achieved since HTTP is operated over TCP/IP. However, communication for IoT can cause serious protocol overhead and consumption and network resources. Therefore, HTTP protocol is less famous in IoT application.

2.4.3 CoAP protocol

CoAP is a lightweight machine-to-machine protocol and it supports both request-response and resource-observer architecture [33]. CoAP is focusing on interoperation with HTTP and the RESTful Web through simple proxies. Universal Resource Identifier (URI) will be used in a form of topic like MQTT protocol [34]. Subscriber has to subscribe to a particular resource indicated by the URL in order to get the new data published by publisher to the URI. CoAP uses UDP as data transmission protocol and Datagram Transport Layer Security (DTLS) for security purpose [35]. CoAP also provides a feature where it uses “confirmable” or “non-confirmable” messages.

Confirmable messages need to be acknowledged by the receiver while non-confirmable messages do not require any acknowledgement [36].

2.5 Database Storage

There are a lot of internet platform provided for database storage. Some of the most famous platform are MySQL, Firebase, and Google Cloud Platform (GCP). Structured Query Language (SQL), is a standard computer language used for relational database management and data manipulation [37]. SQL manipulates and modify data by using query, insert and update function. In fact, most of the relational databases support SQL format. SQL code is classified into four main categories, which are query, data manipulation language (DML), data definition language (DDL) and data control language (DCL). Query is used to "SELECT" statement while DML is used to add, update or delete data. DDL is used to manage tables and index structures while DCL is used to assign and revoke database rights and permissions [37].

Firebase is another platform for storing data. It provides users with a plethora of tools and services to modify their database [38]. Firebase is a real-time database which and it is a cloud-hosted NoSQL database that allows users to store and synchronize data. The retrieving of data from Firebase has been simplified through ordering functions.

The difference between SQL and NoSQL had been discussed in the research done by Sharvari Rautmare [39]. The traditional database management system (DBMS) uses SQL format for database. The non-relational database known as NoSQL is another trend of database format [40]. SQL format focuses on atomicity, consistency, isolation and durability while NoSQL focuses on availability and partitioning of data. The SQL database follows relational data model to store data while NoSQL follows non-relational database model. The SQL database is being used by MySQL, Oracle and SQLServer while the NoSQL database is employed by Firebase, MongoDB and so on [39]. Sharvari Rautmare had used both MySQL and MongoDB databases to compare the performance between SQL and NoSQL. The comparison was done by obtaining results of time taken to execute "Select" and "Insert" queries. The latency and stability of both SQL and NoSQL databases were compared as well. It was to be found that MongoDB requires shorter time for query while MySQL has higher stability in terms of response.

2.6 Microcontroller

Microcontroller is a device or gateway used to control the performance and behaviour of a system. It can be known as the brain of the whole system. There are a lot of choices for microcontroller in the market, such as, Arduino, Raspberry Pi, 8051 microcontroller and so on. An Arduino is a microcontroller motherboard which act as a simple computer which can run one program at a time [41]. Arduino board provides both digital and analogue pins. These pins can be configured to either input or output mode depending on the sketch of program. Besides that, Arduino also allows communication with other devices through its serial ports. Arduino's environment has built-in serial monitor to allow communication with Arduino [42]. Basically, Arduino can communicate with other device through Bluetooth, Wi-Fi, Ethernet, USB and so on by providing suitable communication modules. Figure 2.3 shows the image of an Arduino Uno board.

Figure 2.3: Arduino Uno microcontroller [43]

Raspberry Pi is also one of the most widely used microcontroller in system designing. A Raspberry Pi is a general-purpose computer, which can run multiple programs at a time. The operating system for Raspberry Pi is usually Linux based [44]. Similar to Arduino, Raspberry Pi provides general purpose input and output (GPIO) pins which allow users to interface it with other hardware. However, Raspberry Pi has a drawback in terms of GPIO pins as it does not provide analogue pins. In other words, Raspberry Pi requires extra setup in order to read analogue inputs. Raspberry Pi can function as a mini-computer with its own audio port and display. Besides that, the latest Raspberry Pi 3 also provides built-in Wi-Fi module which allows it to connect to Wi-Fi easily. The Raspberry Pi board also contains Ethernet port and a few Universal Serial Bus (USB) ports. Figure 2.4 shows the image of a Raspberry Pi 3 board.

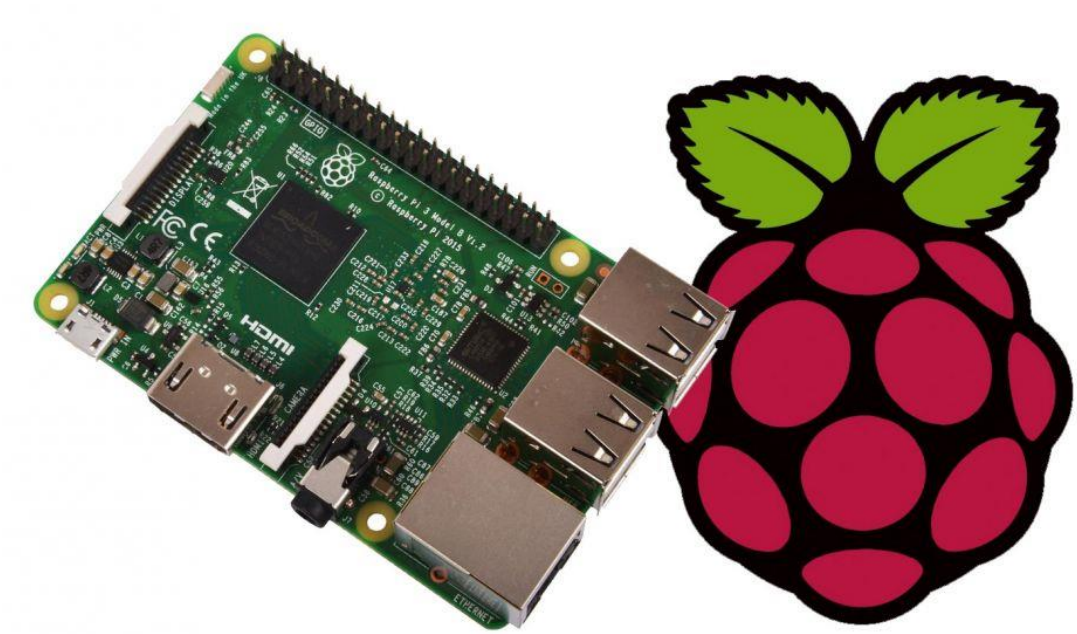

Figure 2.4: Raspberry Pi 3 microcontroller [45]

2.7 Summary

There are a lot of smart waste management system which implement Internet of Things technology to help to cope the problem of overflowing garbage bins. Different approaches had been proposed by engineers and designers in their system design. The technology used include RFID, GSM, GPS, AI, and so on with the aid of different sensors. Based on the review, each approach has its own pros and cons upon implementation to the smart waste management system. Besides that, different protocols or platforms for Internet of Things had also been explored and used by engineers throughout the world to provide IoT solution. Some of the most famous protocols are HTTP, MQTT, CoAP and GCP. The suitable platform for our design will be chosen based on the performance of protocol in terms of power consumption, latency, stability, availability, accuracy and durability. On the other hand, the advantages and disadvantages of different types of database format are also studied. It is important to choose the correct format for the database of our system as it affects the functionality of the whole system. Last but not the least, the types of hardware being implemented are reviewed. In case of microcontroller choice, even though Arduino board is the most famous and widely used controller, Raspberry Pi is selected as our processor. This is due to the higher processing speed of Raspberry Pi when compared to Arduino. Besides that, Raspberry Pi provides built in Wi-Fi module and Ethernet port where by these are the most important element as a processor for Internet of Things solution.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discusses and explain the overall project development in detail. The project consists of both software and hardware development. The overall project development is divided into 8 stages, which are development of Raspberry Pi 3, interface of Raspberry Pi 3 with sensors, garbage level detection, GPS detection, usage of Internet of Things, webpage design, Android application development and performance evaluation. Section 3.2 describes the project implementation flow while section 3.3 presents the project requirement. Section 3.4 is going to talk about the overall system design while section 3.5 discusses the fabrication of dustbin with hardware installed. Section 3.6 presents the flow of program of project and usage of Google Map API. Method to perform the comparison of IoT protocol is discussed in Section 3.7. Section 3.8 presents the way of designing webpage while Section 3.9 discusses the development of Android application. Ways to perform project evaluation is discussed under Section 3.10. The last section of chapter 3 is the summary of the chapter.

3.2 Project Implementation Flow

The project is started by first reviewing the journal and article that are related to the project. The project is continued by the implementation of sensors on Raspberry Pi 3. Next, a webpage will be designed to act as a monitoring interface. After that, the analysis of performance among different Internet of Things protocol is to be carried out in order to determine and select the most suitable IoT protocol for the project. Then, an Android application is developed to further enhance the monitoring system. The project will be proceeded by fabricating the dustbin with hardware installed. Lastly, the accuracy of the developed system is to be tested through repetitive experiment. Figure 3.1 shows the overall flow of the project and Figure 3.2 shows the block diagram of overall methodology.

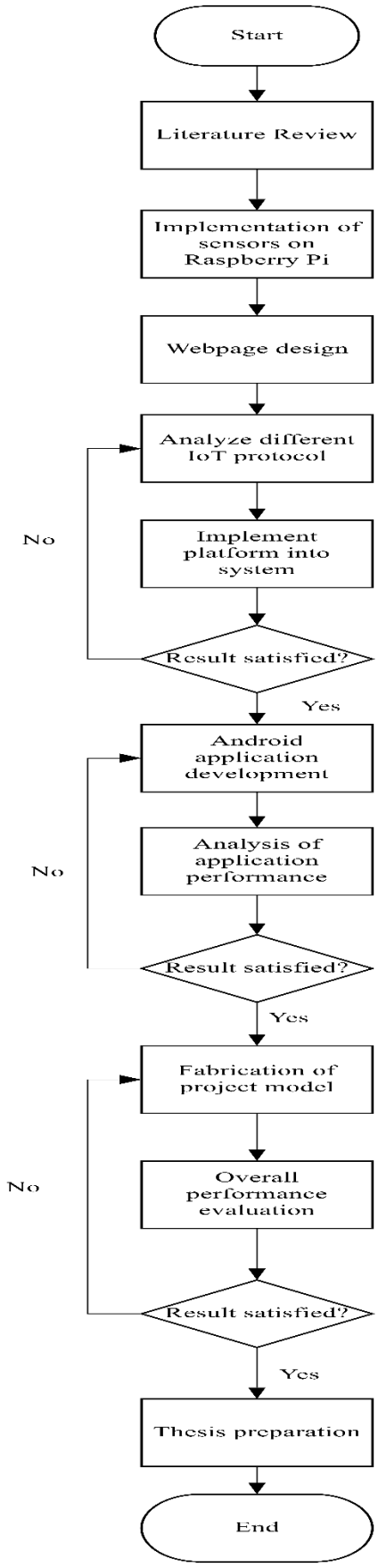

Figure 3.1 Project flowchart

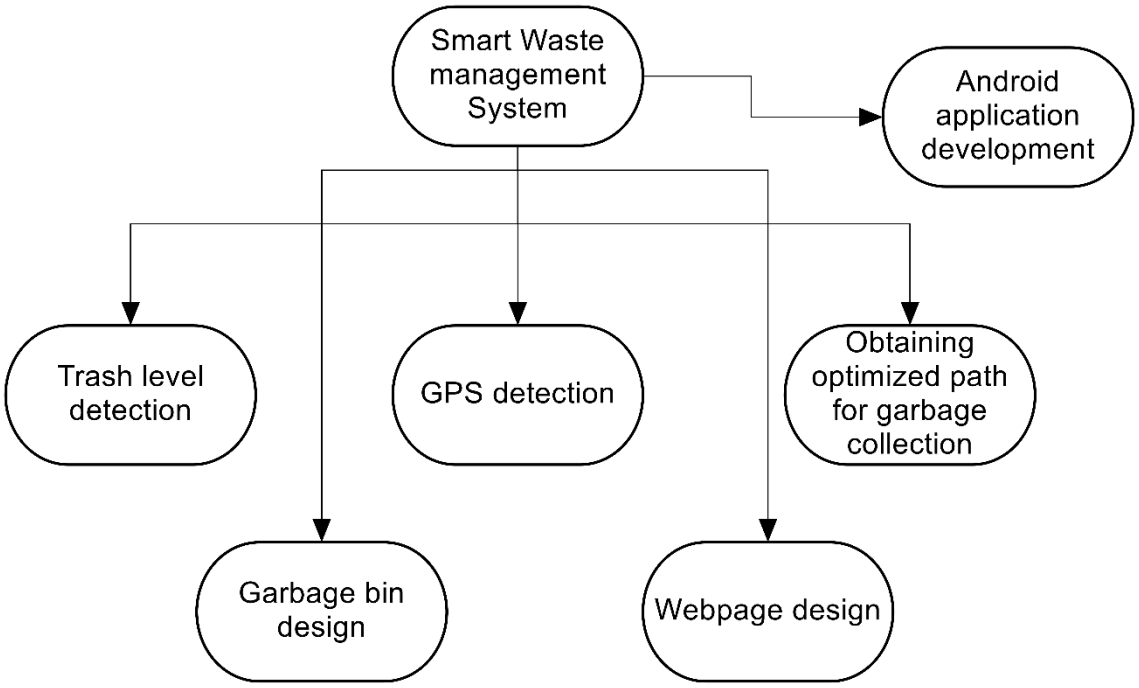

Figure 3.2: Overall block diagram for methodology

Step 1: Literature review

Articles and journals related to smart waste management system are studied and reviewed. By having advanced technology, many solutions to waste management and monitoring had been proposed. The advantages and disadvantages of the proposed mechanisms have been taken into consideration for the feasibility of this project. In addition, articles regarding different Internet of Things protocol and platform are reviewed in order to obtain the suitable protocol with the best performance for the project. Lastly, the choice of microcontrollers and difference between them have been studied and reviewed so that the most suitable yet functional microcontroller can be selected for the project.

Step 2: Implementation of sensors on Raspberry Pi

After reviewing articles on previous work, the hardware for the project has been selected. The sensors are installed to the GPIO pins of the Raspberry Pi. Simple Python script has been written to test the functionality of sensors.

Step 3: Webpage design

After completing literature review, the method to provide monitoring on dustbin has been selected. In this case, a webpage is used broadcast and display the real time condition of the dustbin. PHP, HTML, CSS and Javascript are used as webpage designing language.

Step 4: IoT protocol comparison

A few protocols and platforms for Internet of Things have been chosen to be tested in terms of latency and power consumption.

Step 5: Android application development

Android application is another approach to provide real time monitoring to the condition of dustbin. The application is developed by using MIT App Inventor. The dustbin's condition will be able to read and display on Android smartphone.

Step 6: Overall performance evaluation

The whole system is tested in terms of functionality, stability and latency. Repetitive experiment is done in order to measure every aspect in determining the performance of the system.

3.3 Project Requirements

The project includes implementation of both hardware and software. This section covers the development process for both hardware and software.

3.3.1 Hardware

The hardware for this project includes Raspberry Pi 3, ultrasonic sensor model HC-SR04, SKM53 GPS module, 0-5kg load cell straight bar and HX711 load cell amplifier. In order to provide Internet of Things solution, a microcontroller with valid Wi-Fi connection or Ethernet port is required. In this case, Raspberry Pi 3 is chosen as the main controller of the project as it provides built-in Wi-Fi module and an Ethernet port. The Raspberry Pi 3 is using Quad Core Broadcom BCM2837 64-bit ARMv8 processor with processor speed of up to 1.2GHz [46]. It has a BCM43143 Wi-Fi chip built-in to the board which means it is able to connect to available Wi-Fi network easily. Raspberry Pi 3 also has Bluetooth Low Energy (BLE) ready on the board. The RAM of Raspberry Pi 3 is 1GB of LPDDR2-900 SDRAM. With VideoCore IV GPU at 400MHz available, Raspberry Pi 3 has good graphics capabilities [47]. Raspberry Pi 3 can run with Raspbian Jessie operating system (OS) which is Linux based. For interfacing with ultrasonic sensor, weight sensor, and GPS module, the board also provides 40 GPIO pins which can function as input or output pins to the other components. Figure 3.2 shows the layout of Raspberry Pi 3.

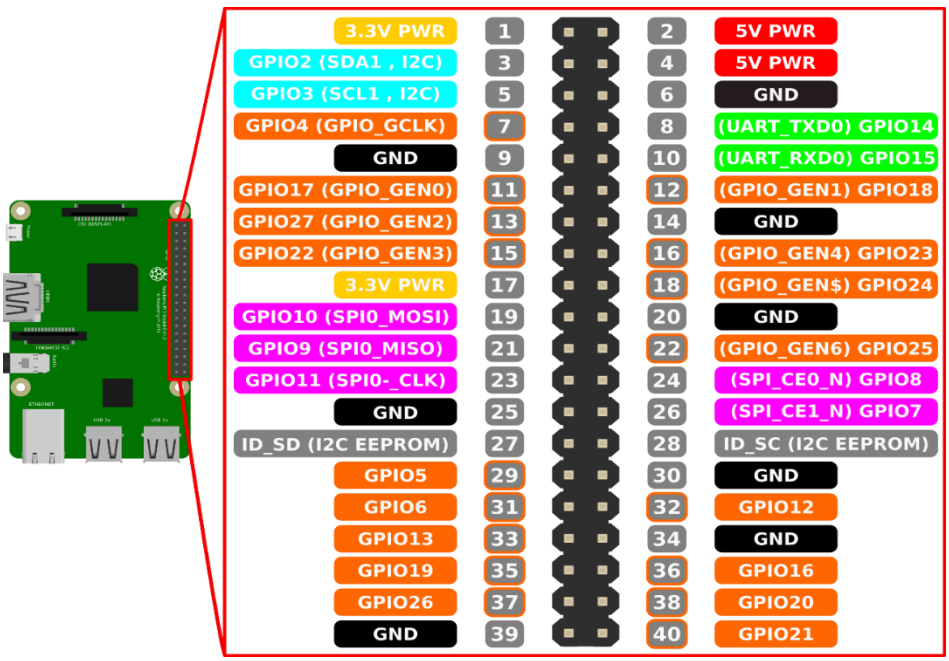

Figure 3.2 Raspberry Pi 3 Layout [47]

The ultrasonic sensor used to detect garbage level is the HC-SR04 model. According to datasheet, HC-SR04 model is able to measure distance from range of 2cm to 400cm which is sufficient for detection of garbage level. The ultrasonic sensor measure distance by emitting short and high frequency sound pulses at regular intervals [48]. These pulses propagate in the air with speed of sound. The pulses will be reflected to the ultrasonic sensor as an echo if the pulse reaches a surface or an obstacle. Then, the sensor can compute the distance based on the time spent in between emission of signal and receiving of echo. Figure 3.3 shows the illustration of ultrasonic sensor working principle.

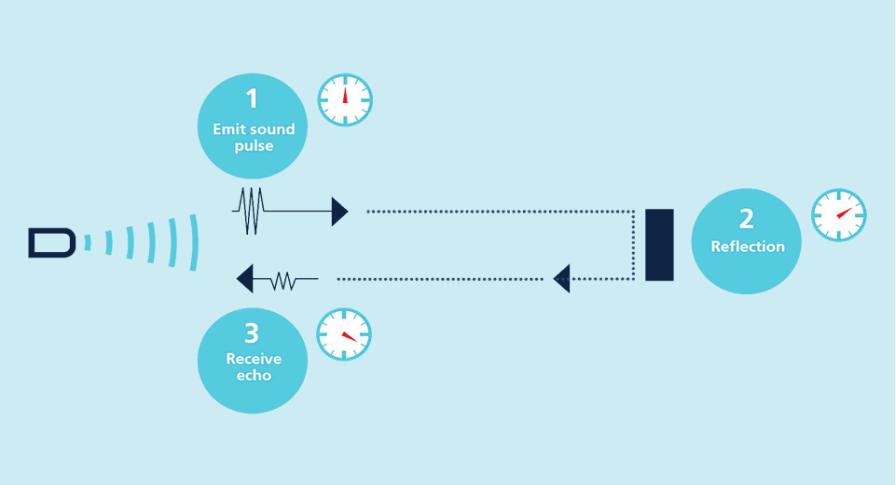

Figure 3.3 Working principle of ultrasonic sensor [48]

The SKM53 GPS module is a device designated for getting the latitude and longitude of the user's current position. The module is embedded with GPS antenna which allows high performance in terms of navigation [49]. Basically, the module provides information on the current date and time based on Coordinated Universal Time (UTC) and current position coordinate. Figure 3.4 shows the overview of SKM53 GPS module.

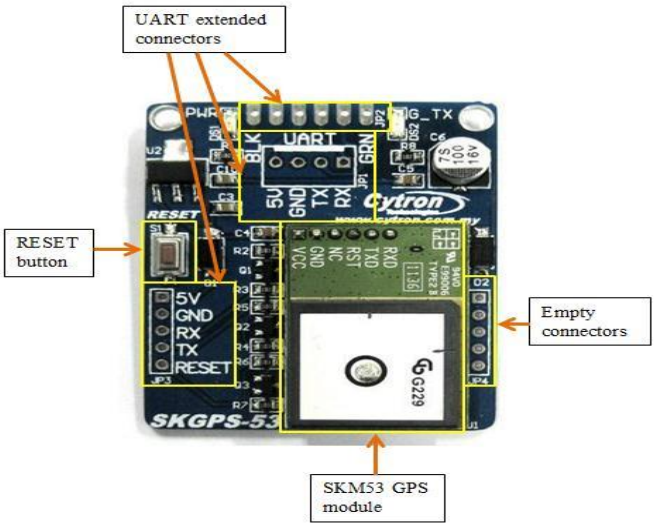

Figure 3.4: SKM53 GPS module overview [49]

The weight sensor or load cell comes with a lot of specifications in terms of measurable weight. For this project, the load cell with the ability to measure weight in between 0 to 5kg is chosen. The load cell consists of 4 pins which are VCC, ground, positive output and negative output. The load cell is made up of 4 strain gauges which form a wheatstone bridge. The change in resistance of the strain gauges eventually causes changes in electrical signal. The changes in electrical signal may be too small for Raspberry Pi to read. Hence, a load cell amplifier, HX711 module is being implemented to amplify the changes of electrical signal provided by the load cell. The amplified output is read by Raspberry Pi and converted to useful information, which in this case, the weight measured. Figure 3.5 shows 5kg load cell strain bar and HX711 amplifier.

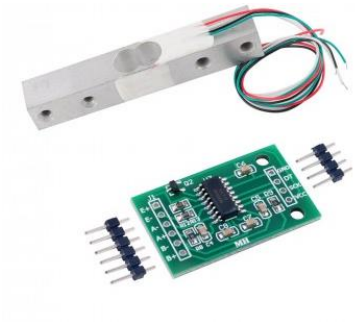

Figure 3.5: Load cell and HX711 amplifier [50]