International Journal of Engineering & Technology, 7 [2.29] [2018] 725-729

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper



Smart Waste Bin with Real-Time Monitoring System

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Abstract

This paper presents IoT innovation project of a smart waste bin with real time monitoring system which integrates multiple technologies such as solar system, sensors and wireless communication technologies. The aim of this project is to provide an efficient and cost-effective waste collection management system hence providing clean, healthy and green environment. This study proposed a new framework that enables remote monitoring of solid waste bin in real-time via Wi-Fi connection, to assist the waste management activity. The system framework is based on wireless sensor network [WSN] contains three segments: renewable energy source, WSN and control station. Within this framework there are four developed subsystems: solar power system, smart waste bin, short messaging service [SMS] notification system and real-time monitoring system that are interrelated to each other to perform as an efficient, cost-effective waste management system that yield to a green and healthy living environment.

Keywords: *IoT, solid waste management; wireless sensor network; Arduino, ultrasonic; PIR motion sensor; ESP8266 Wi-Fi module; smart waste bin; GSM/GPRS module, solar*

1. Introduction

Due to the fast pace of urbanization, waste management is becoming a bigger issue each day in each developed and developing countries. In Malaysia, rapid urbanization and industrialization transition have changed the solid waste characteristics [1, 2]. The generation of municipal solid waste [MSW] over the past 10 years has increased by 95 per cent due to rapid development in the urban areas [3]. The waste created from various sources will be lead to environmental pollution arising without an effective and well-organized solid waste management. Besides, this can also bring to serious health hazard and lead to the spread of infectious diseases. An effective solid waste management practices need to be updated to suit the current waste quantity and composition. Municipal waste management in Malaysia has gone through several transitions [4]. This proved that, Malaysia is striving in improving the solid waste management practices towards sustainability.

In the approach of smart city, the objective is to provide a city with basic infrastructure to give a decent quality of life, a clean and sustainable environment through application of some smart solutions. One of the basic infrastructure is sanitation and solid waste management. Internet of Thing [IoT] can play an important role in providing a smart solution for waste management that will reduce costs and increase efficiency.

In Malaysia, many companies concentrates on remote sensing system [5] in waste management system. Alam Flora has started to use Automated Vehicles Locating System [AVLS] to monitor the collection timing and fleet management and FloraCare system to support the company to carry out its operations efficiently [6].

Producing a cost-effective operation is very important to waste management companies. Rather than traversing all the route to clean the waste bin, it is more efficient if the waste management system able to alert the collector only the waste bin requires to be emptied. Thus, this able to optimize collection routing and save time and fuel. A system that able to collect and analyze data are important as a decision support tool to help the local authority or waste management contractor to improve their service. Many researches in waste management focus on the solution implementation rather than how to deliver a product with competitive price with less maintenance cost [5].

This paper proposed a new framework for waste management system. The designed framework comprises of three main parts: solar power system, smart waste bin and control station with SMS notification system and real-time monitoring system. Smart waste bin uses WSNs to collect waste bin status and transmit waste bin information wirelessly to the control station. Control station receives the waste bin information and stores it in the database. SMS notification system is a daemon program to automatically identify the full waste bin and help to send alert notification to garbage collector in real-time, then updates the waste bin status. After the waste bin has been emptied the smart waste bin will update the waste bin status and transmit the information again to the control station. A web-based application is developed to monitor the waste bin status and collection activity. This proposed system able to reduce the development cost since the component used are cheap.

2. Literature Review

Several solutions for waste management equipped with IoT facilities have been proposed and invented in the literature to help solid waste management authorities improve the quality of service delivery.

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Researchers in [7, 8] designed a solid management system uses WSN integrating two different wireless technologies. Waspmote [9] from Libeum has been used as sensor node. The mote encompasses ATmega1281 microcontroller with built-in accelerometer sensor. Multiple type of sensors such as level, weight, humidity and temperature sensors applied at the sensor node using mart Metering v2.0 board also from Libeum. All data read from sensor node are transmitted to receiver segment by going through Zigbee and GPRS communications using Meshlium [10] as a middle gateway. Receiver segment stored all collected data in database and displayed it using a developed web application. Thus, solid waste bin and its real time status can be monitor by using the developed automated system.

Smart Waste Management System [SWMS] developed by [5] manipulates geospatial technology and intelligence sensor such as ultrasonic sensor via IoT technology [9] for reliable Smart City and M2M solution. A pilot study is conducted by locating the SWMS at districts of Sepang and Kuala Langat and limited to apartment and condominium. SWMS application as a tool for local authority to monitor waste collection operator to ensure waste collection services is deliver per contract by the service provider. Application of geographic information system [GIS] also done by [2] as a decision support tool for planning waste management. The proposed system attempts to provide solution of problems like proper allocation and relocation of waste bin, check for unsuitability and proximity convenience to the users and future suggestions.

Another work by [11] provides a Smart Garbage Monitoring System specifically to apartment, condominium or flat type residency that has trash chute. This proof of concept system uses ultrasonic to measure the waste level and Arduino Uno as microcontroller. Ultrasonic sensor will continuously measure the waste level and notify the residence and garbage collector regarding the waste status. This system send notification through SMS to collector whenever waste bin is almost or already full. Indicator can be put at each level of the resident to alert the residencies to minimize or stop dispose waste.

Some researches exploit the power of RFID as a way to improve and enhance the waste management efficiency especially in monitoring the waste collection activities [12-14]. It also may reduce the workload of truck driver in recording the collection process and the surrounding area. Not only that, scattered waste around the dustbin also monitored using IR sensor in [15] and low-cost camera by [13] to maintain the cleanliness and hygiene of city.

3. Methodology

As a guidelines for proposing the new framework for waste management system, several problems in waste management will be considered [12-14]:

1) Lack of information about the collecting time and area.
2) Lack of proper system to monitor the trucks and trash bins that have been collected in real time.
3) There is no estimation to the amount of solid waste inside the bin and the surrounding area due to the scattering of waste.
4) There is no quick response to urgent cases like truck accident, breakdown, longtime idling.
5) There is no quick way to response to client's complaints about uncollected waste.
6) There is no analysis of finding best route path of collecting waste.

The proposed confirmed able to provide solutions to all above problems. In this paper the framework is used to develop modules for problems 1, 2, 3 and 5. Figure 1 shows the proposed system framework. This framework consists of three segments namely the solar power system, smart waste bin and control station. Each part is facilitates with subsystems that will execute different tasks. All these segments and subsystems will be further described in the following section.

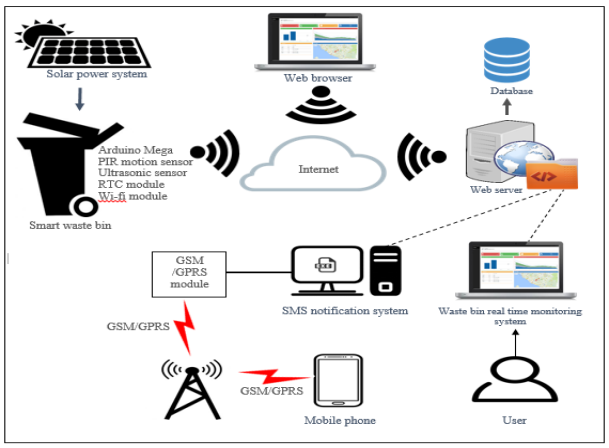


Fig. 1: System framework

3.1 Renewable Energy Source

In this segment, a solar power system is built by assembling three components: solar panel, solar charger controller and rechargeable battery. Solar panel absorbs the solar energy and converts it into electricity energy. The SR-HM solar charger controller is placed between a solar panel and a PROLiNK 12V 1.8AH rechargeable battery to regulate the amount of charge coming from the panel that flows into the deep cycle battery bank to avoid the battery being overcharged. The solar charger controller also provides a direct connection to the sensor system, while continuing to recharge the battery. Solar energy is the cleanest and most available renewable energy source. Figure 2 shows the block diagram of implemented solar power system.

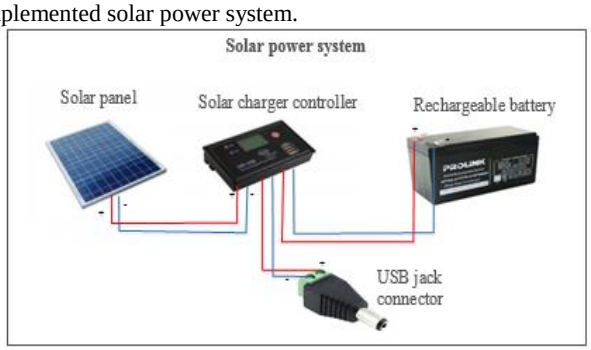


Fig. 2: Solar power system

3.2. Wireless Sensor Network

The smart waste bin in Figure 3 implements WSN technology interfaces with a microcontroller which are fixed in the waste bin. Arduino Mega is the microcontroller used in this subsystem. To yield a real time data from waste bin, PIR motion sensor will worked continuously in keeping track the presence of new garbage in the waste bin. When garbage is present, microcontroller instructed ultrasonic sensor to measure the fill-level inside the waste bin and read timestamp from the DS1302 Real Time Clock [RTC] module. Liquid Crystal display [LCD] is used to display the output from the microcontroller. Two indicators are initialized by this subsystem which are waste bin status indicator and SMS notification indicator. To know whether the waste bin is full or empty, waste bin status indicator will automatically set according to the fill-level in the waste bin as described in Table 1. Table 2 shows another important indicator that will automatically initialize by the smart waste bin which is the SMS notification indicator. SMS notification indicator is used later in the SMS notification system. The combination of these two indicators state three difference conditions for the waste bin as described in Table 3. The initial condition of waste bin is always condition 1. Data from smart waste bin which comprise of the waste bin id, fill-level measurement, timestamp, status and SMS were then transmitted to the control station through ESP8266 Wi-fi module as a wireless communication technology. The smart waste bin is not able to

work without a power supply. In this framework, solar power system is used as an environmentally friendly way of producing electricity for the smart waste bin.

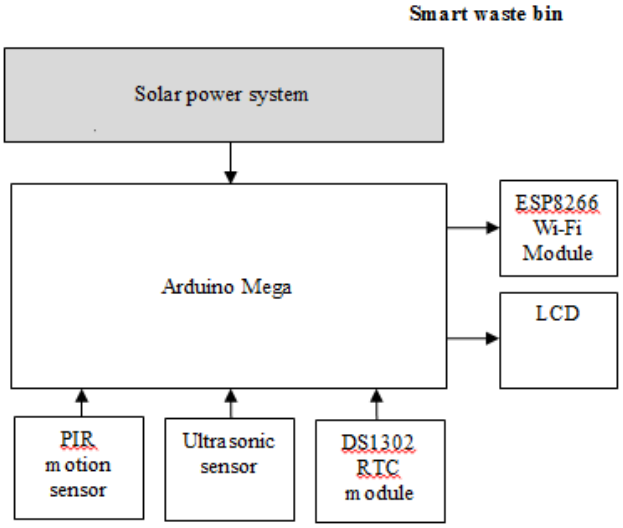


Fig. 3: Smart waste bin block diagram

Table 1: Waste bin fill-level indicators.

Indicator	Threshold	Value	Description
Status	0%	0	Empty/Not full
	>= 80%	1	Full

Table 2: Waste bin SMS notification indicators.

Indicator	Value	Description
sms	NS	SMS not sent
	S	SMS is sent

Table 3: Waste bin conditions.

Condition	Indicator		Description
	status	sms	
1	0	S	Initial or empty
2	1	NS	Full and notified
3	1	S	Full and not notified

3.2. Control station

The control station contains the central server which hosts the web server, database, SMS notification system in Figure 4 and a web-based waste bin real time monitoring system in Figure 5. The data sent by the smart waste bin is received by the control station and stored in the database server. Control station runs two systems which handle different jobs. The systems are SMS notification system and web-based was bin monitoring system.

3.2.1. SMS Notification System

This is a remote application that is developed in JAVA. To do its job, this application requires a computer that is directly connected to external GSM/GPRS SIM900A module. SMS notification system is daemon program which is configured to continuously query for waste bin with condition 2 together with garbage collector information [user id, name and mobile phone number] for every 1 seconds, send SMS to the respective garbage collector then update the waste bin data to condition 3.

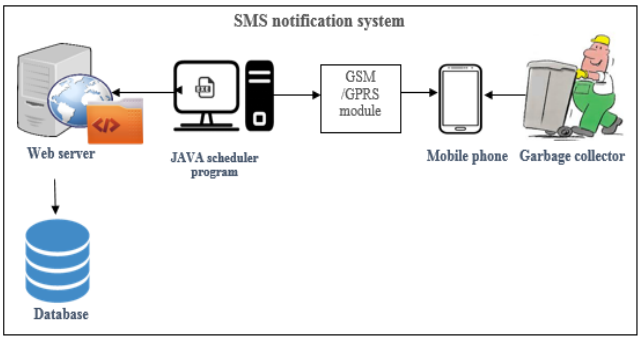


Fig. 4: Architecture of SMS notification system.

3.2.1. Real time monitoring system

The web-based real time monitoring system provides a GUI for displaying the waste bin data so that user can monitor the waste bin status and collection activities using web browser from any devices. This monitoring system is developed using Bootstrap 3 Admin and Dashboard open source template and morris.js dashboard API. The location of waste bin [latitude and longitude] is retrieved from database server and marked on the map by using Google Map API.

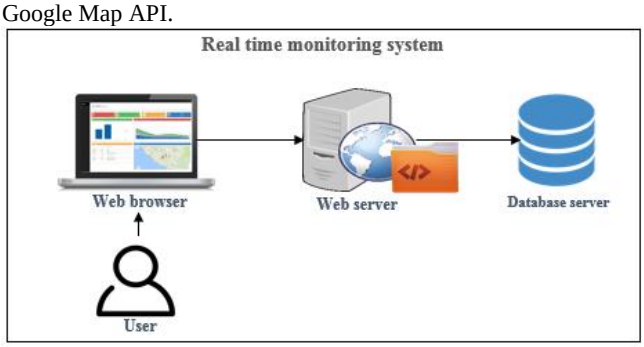


Fig. 5: Architecture of real time monitoring system.

4. Results and Findings

The system has been tested to ensure its proper functionality. Figure 6 shows the overall prototype.

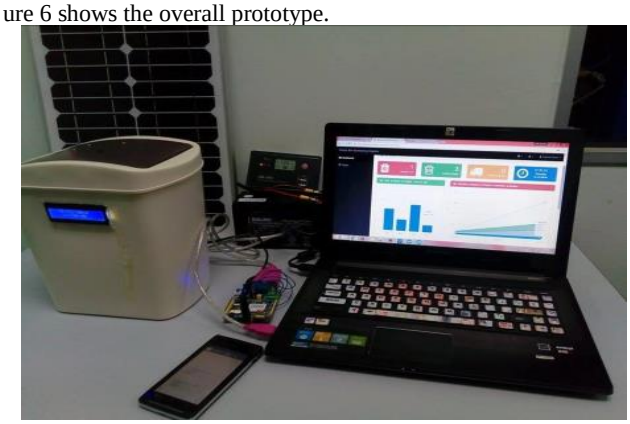


Fig. 6: Smart waste bin and real time monitoring system.

The smart waste bin only works with Internet connection in order to send waste bin data to the control station. Therefore the ESP8266 Wi-fi module was used in this project for portability reason. ESP 8266 Wi-fi module provides a small, low-cost and effective way to get the Arduino to connect to the Internet wirelessly. WifiEsp library is used to allow the Wi-fi connection in the Arduino. The WifiEsp library are fully compatible with the standard library of Arduino Wi-fi shield which is expensive. Waste bin data is send to the control station using the below code fragment:

```
char server[] = "greenhomestay.com.my";
int s = 0; //0 - empty, 1 - full
String data = "ID_Bin=" + String[id] + "&level=" + String[level]
```

```
   + "&timestamp=" + String[rtc[]] + "&sms=S&status=" +
String[s];
WiFiEspClient client;
if [client.connect[server, 80]] {
    client.println["Connected..."];

    client.println["POST /add.php HTTP/1.1"];
    client.print["Host: "];
    client.println[server];
    client.println["Content-Type:application/x-www-form-
urlencoded"];
    client.print["Content-Length: "];
    client.println[data.length[]];
    client.println[];
    client.print[data];
    client.stop[];
   }
```

Figure 7 shows the PIR motion sensor and ultrasonic are placed under the waste bin lid. Therefore, when someone open the lid to throw garbage, the movement is detected by PIR motion sensor and the input is send to Arduino. After Arduino received the input, it will output a message "Motion Detected" at the LCD. In the Arduino program a 5 seconds delay is set for user to close the lid back before Arduino triggers the ultrasonic sensor to measure the fill-level in the waste bin and read current timestamp from the RTC module. A delay of 5 seconds is set as a relevant epoch for user to close the lid back after throwing the garbage. If the lid is not close an error message will be displayed at the LCD.



Fig. 7: Sensors attached at the waste bin lid.

To get the current timestamp the DS1307RTC.h and Time.h libraries were used in this project. The DS1307 RTC module need to be synchronized first with the development machine's system time to get the current timestamp. Below is the fragment of code snippet to synchronize and get timestamp in RTC module:

```
setSyncProvider[RTC.get];
if [timeStatus[] == timeSet]
   time_t timestamp = now[];
```

SMS notification system is installed and runs in a computer that is connected to GSM/GPRS module through a serial communication port. A subscriber identity module [SIM] card need to be inserted to the GSM/GPRS module to provide a mobile communication network. In this project a USB to RS232 converter cable is used since the computer does not have serial port. A comm.jar library is used in the JAVA program to establish communication with the GSM/GPRS module. AT commands are used to send SMS.

Real time monitoring system is a web-based application illustrated in Figure 9 which provides a graphical user interface [GUI] for the user to monitor the waste bin and collection status. The GUI layout is divided into several divisions. Division 1 shows three icons which represent three waste bin condition in Table 3. Division 2 displays a bar chart showing the current fill-level in the waste bins. Division 3 displays a line and area chart showing the monthly analysis of total number of waste collection made for each waste bin for recent year. Division 4 displays a table showing twenty recent waste management activities and lastly division 4 showing the actual location of all waste bin.

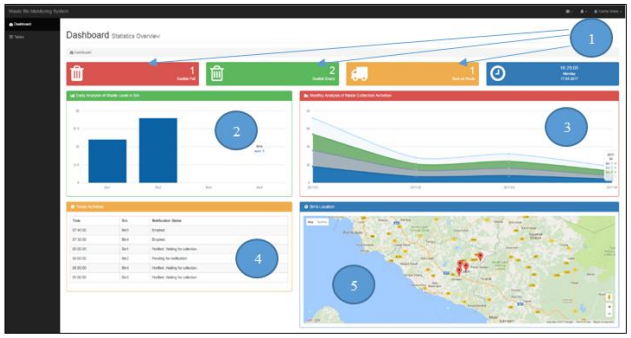


Fig. 9: Waste bin real time monitoring system.

5. Conclusion

This paper presents a framework of IoT innovation project for waste management system. This novel solution able to enrich the efficiency of waste bin collection activities and cost reduction. The implemented system on top of this framework can be further improve to perform real-time, reliable and efficient waste management system. For future works, a customer complaints module will be added and integrates with the SMS notification system to perform fast response. The map showing the waste bin actual coordinates stored in the database can be further leverage by integration with GPS technology to give the current waste bin location. Alert message can be produce if the waste bin has been reposition to other place or fall down. Other than that, to solve problem 6, the map can be used to show only full waste bin together with shortest route to help reduce operation costs and GhG emission. We also found several limitation in this implemented system. Firstly, the smart waste bin should work more intelligently to detect the waste bin lid is in close or open position. Due to that, in the future a hall effect sensor can be implemented as in [7, 8] so that the ultrasonic sensor can give correct reading at any time required. This implemented system also requires strong Wi-Fi connection to make it functioning. External Wifi-Extender device could be used to improve the Wi-Fi signal [16]. Local authority can use this type of system and monitor the waste collection status in real-time and based on the recorded information they able to measure their operational performance, predict future operation requirements and plan for better service to deliver.

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