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Internet of Things (IoT) Based for Landfill Gas Monitoring System

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Abstract: Landfills are the most common method of waste disposal used all over the world. Gasses that are produced at the landfills can harm the workers and community. To identify the presence of harmful gasses at the landfill, an Internet of Things (IoT) based landfill gas monitoring system is suggested. The proposed solution allows for the evaluation of an application that can notify the authorities. This prototype performs in long-range data transfer by long-range wide area network (LoRaWAN) transceiver and Global System for Mobile communications (GSM), sensor node utilized the sensor gas to detect the landfill gas, Arduino Uno as a gateway equipped with GSM, LoRaWAN transceiver (transmit) and monitoring system in Favoriot IoT platform for graphical user interface (GUI) and apps. Results obtained show that the prototype able to detect four (4) types of gas such as methane, carbon dioxide, ammonia and hydrogen sulphide. Hence, it proves this prototype can be further expanded for real implementation in landfill gas research projects.

Keywords: Internet of Things (IoT), Landfill Gas Monitoring, Low-Power Wide-Area Network (LoRaWAN), Favoriot

1. Introduction

Every year, around 62 million tons of solid waste are generated and by 2030, it is expected to reach 165 million tons. From the 62 million tons, 43 million tons are collected, only 12 million tons are treated. It means the remaining 32 million tons are untreated and dumped into landfill sites [1]. Landfills have been the most common method used to organise waste disposal around the world. Because of that, landfill gas is created by the action of microorganisms when bacteria break down organic waste within a landfill. In general, a landfill can continue to produce gases for more than 50 years [2].

Landfill gas contains many different gases, including the evaporation of volatile organic compounds, chemical reactions between waste components, and microbial action that emitted 40%-60% methane. The rest is carbon dioxide, making up 90% to 98% of landfill gas. The remaining 2% to

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10% includes nitrogen, oxygen, ammonia, sulphides, hydrogen, and other gase. However, humans can detect hydrogen sulphide and ammonia odours at very low levels in the air, generally below levels that would cause health effects. Nevertheless, these harmful gases in the air can still affect human health like vomiting, headaches, nausea, stress, anxiety, frustration and restriction in outdoor activities. However, some methods in implementing landfill gas methods as shows previous research.

In [3], a robot is used to enter the sanitary landfill area to detect the gas produced in the landfill site. The robotic system is high-cost if compared with IoT based system implementation. In [4], a smart compost system is proposed. Several sensors such as temperature, gas, humidity and moisture are monitored by this system, which is controlled by Arduino. The system implemented only had a monitoring system and no alert notification system or other types of notification through GSM from a long range. Greenhouse gas emissions and groundwater leachate leakage monitoring of sanitary landfills is executed in [5]. This research aims to implement a system that monitors different environmental parameters of a sanitary landfill. This research project uses the IoT concept to monitor greenhouse gas emissions and groundwater leachate leakage in a sanitary landfill. This concept same as an IoT based landfill gas monitoring system. In [4], smart compose system using IoT is proposed. This research is an improvement from the research work in [6] as the IoT component is integrated in the system. By having an IoT platform, the compost system can provide alert SMS system to notify the workers in [7]. The aim of this research is to monitor the composition of the biogas that naturally emanates from the landfill and has been continuously analyzed by an intelligent system. The operating system uses four (4) type of sensors gas which is (MQ-4, MQ-7, MQ-135 and MQ-2) to detect landfill gas. The system has alert notification via SMS that can notify workers regarding detection of biogas in the landfill site.

IoT based landfill gas monitoring system should be proposed. Landfill gas monitoring system can identify and measures the gasses produced in real-time. Other than that, by having this system, an exact location of the gas produced can be identified by sensing node zone location. Online monitoring application can immediately notify the authorities for further action.

2. Methodology

2.1 Proposed system

The execution of this project involves three (3) main processes; node to node data transfer, gateway, and online monitoring system as shown in Figure 1.

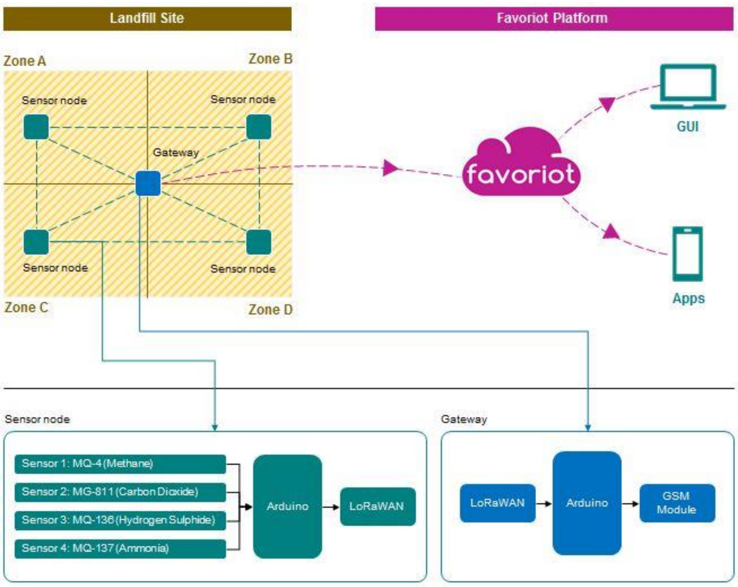


Figure 1: Overall structure of the system

To establish node to node data transfer, the following processes will be involved.

i. Every node comprising specific types of gas sensors (MQ-4, MG811, MQ137 and MQ136), microcontroller Arduino Uno and long-range wide area network (LoRaWAN) transceiver. Four (4) sensor nodes are located in a specific area at the landfill.
ii. If any of the nodes detect the presence of harmful gasses, Arduino Uno will process the data from the sensors before it is being transmitted by the LoRaWAN that has cellular network coverage.

Global system for mobile communications (GSM) at the gateway acts to receive the data from the nearest node. The information is processed on Arduino Uno before being sent to the Favoriot IoT platform through the GSM module. The data received from the Favoriot platform will be visualized using graphical user interface (GUI) for the monitoring system. The alert notification of the presence of harmful gasses will be notified via Telegram. The overall real implementation of prototype as shown in Figure 2 (a) – (c).

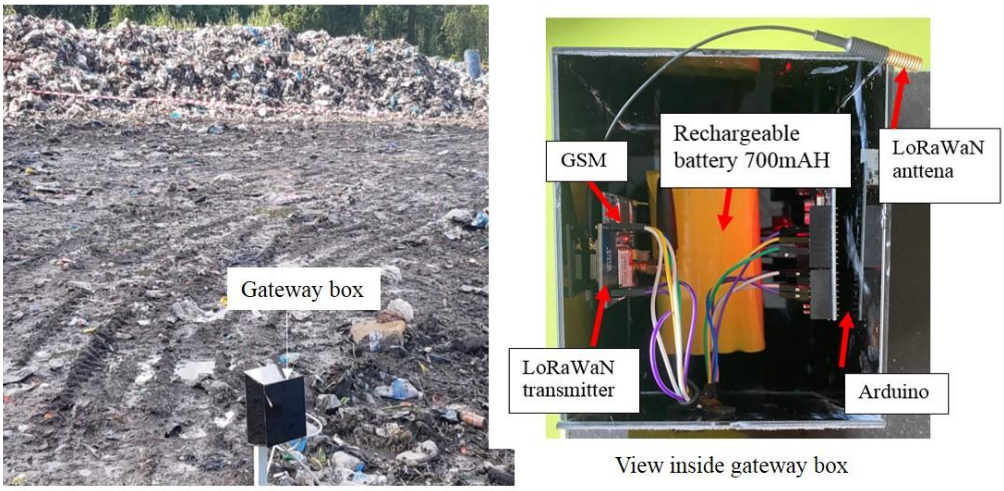
Table 1 shows the input, process, output and data transmission. This table shows some detail of the important hardware used in term of implementation in this project prototype to function. The real prototype setup to analysis the result of gas reading, online monitoring process and to notify the workers.

Table 1: Detail of the input, data transmission, process and output

Input	Data transmission	Process	Output
Sensor Gas: MQ-4, MG-811, MQ-137 and MQ-136	GSM and LoRaWAN	Arduino Uno	Application: Telegram Website: Favoriot platform

The real prototype setup as shown in Figure 2.

(a)



(b)

(c)

Figure 2: (a) Sensor node installation location (b) View Gateway box (c) View Monitoring system

The prototypes have been setup at the Pantu landfill. The sensor node prototype that located at the Pantu landfill is as shown in Figure 2(a). There are four (4) sensor node installed with distance of 50cm from the ground. Besides, at the gateway also installed at the landfill with distance five (5) meter from sensor nodes as shown in Figure 3.14. The gateway comprises of several component such as LoRaWAN transmitter, GSM, Arduino and 700mAh battery as shown in Figure 2(b). In the last part, the monitoring system as shown in Figure 2(c) comprises of LoRaWAN receiver, Arduino microcontroller and laptop are setup to receive data from the sensor node for display and notification process.

3. Results and Discussion

To evaluate the proposed prototype, four (4) evaluations have been executed as follows.

i. Ability to detect four (4) types of gas
ii. Ability to notify workers

iii. Ability to store and upload data
iv. Power consumption

3.1 Ability to detect four (4) types of gas

The prototype project is able to detect four (4) types of gas such as methane, carbon dioxide, ammonia and hydrogen sulphide at Pantu District landfill site. Table 2, Table 3 and Table 4 show the gas reading.

Table 2: Results of Gas reading on 17 December 2021

Gas	Gas detection reading based on times			
	07:30 am	10:30 am	02:30 pm	4:30 pm
Methane $\boldsymbol{CH_4}$	11 ppm	11 ppm	15 ppm	15 ppm
Carbon Dioxide $\boldsymbol{CO_2}$	76 ppm	76 ppm	76 ppm	76 ppm
Ammonia $\boldsymbol{NH_3}$	10 ppm	10 ppm	35 ppm	35 ppm
Hydrogen Sulphide $\boldsymbol{H_2S}$	16 ppm	16 ppm	12 ppm	12 ppm

Table 3: Results of Gas reading on 31 December 2021

Gas	Gas detection reading based on times			
	07:30 am	10:30 am	02:30 pm	4:30 pm
Methane CH_4	×	×	15 ppm	15 ppm
Carbon Dioxide CO_2	×	×	76 ppm	76 ppm
Ammonia NH_3	×	×	35 ppm	35 ppm
Hydrogen Sulphide H_2S	×	×	12 ppm	12 ppm

Table 4: Results of Gas reading on 7 January 2022

Gas	Gas detection reading based on times			
	07:30 am	10:30 am	02:30 pm	4:30 pm
Methane $\boldsymbol{CH_4}$	10.33 ppm	11.50 ppm	10 ppm	14 ppm
Carbon Dioxide $\boldsymbol{CO_2}$	55 ppm	60 ppm	76 ppm	74.58 ppm
Ammonia $\boldsymbol{NH_3}$	10 ppm	10.90 ppm	9 ppm	10.22 ppm
Hydrogen Sulphide $\boldsymbol{H_2S}$	11.10 ppm	12.10 ppm	16 ppm	16.10 ppm

Tables 2, 3, and 4 display the gas data was collected by date and time. To ensure the data is reliable, it will be taken at 7.30 a.m., 10.30 a.m., 2.30 p.m., and 4.30 p.m. for at least three (3) weeks. The selection of the four (4) different times for gas detection to observe the higher gas reading.

There no gas reading at 7.30 a.m. until 10.30 a.m. After retaken the gas reading after 7.30 a.m. but still no gas reading until 10.30 a.m. As the result, no gas reading at morning as shown in Table 3. The reading shows that the prototype success to collect four (4) type of gas data and transmit to IoT platform for notification process. As the result, the gas reading was increase at 4.30 p.m. evening as shown in Table 2, 3, and 4.

3.2 Ability to notify workers

In this project, the process of notifying the workers consists two (2) methods which are through Global Serial Mobile (GSM) and Telegram application. Using the cellular network in GSM, the SMS will be directly sent to the worker's handphone. Figure 3 shows the alert message GSM and Telegram application.

As the result, capable of the prototype success to send alert message through GSM and Telegram Application as shown in Figure 3 shows the alert message GSM and Telegram application.

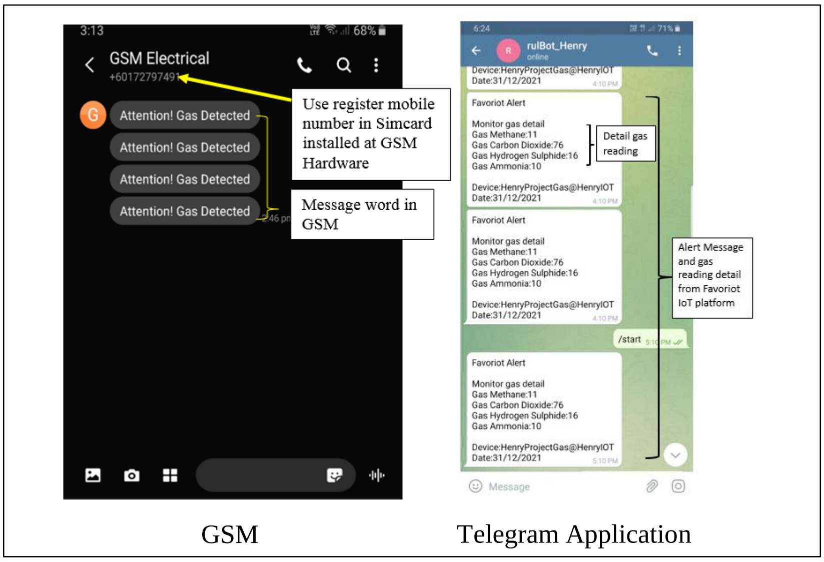


Figure 3: Alert message GSM and Telegram application

3.3 Ability to store and upload data

By using the Favoriot platform, the data was successfully store and stream before send for alert notification. This is very important process in IoT based project implementation. Figure 4 shows the data uploaded and stored in Favoriot IoT platform and Figure 5 shows the dashboard of gas graph.

The data gas success stored in Favoriot IoT platform. The capable of the prototype after send the alert message through GSM. At the same, the data success store in Favoriot account to stream the data before send for alert notification to the worker.

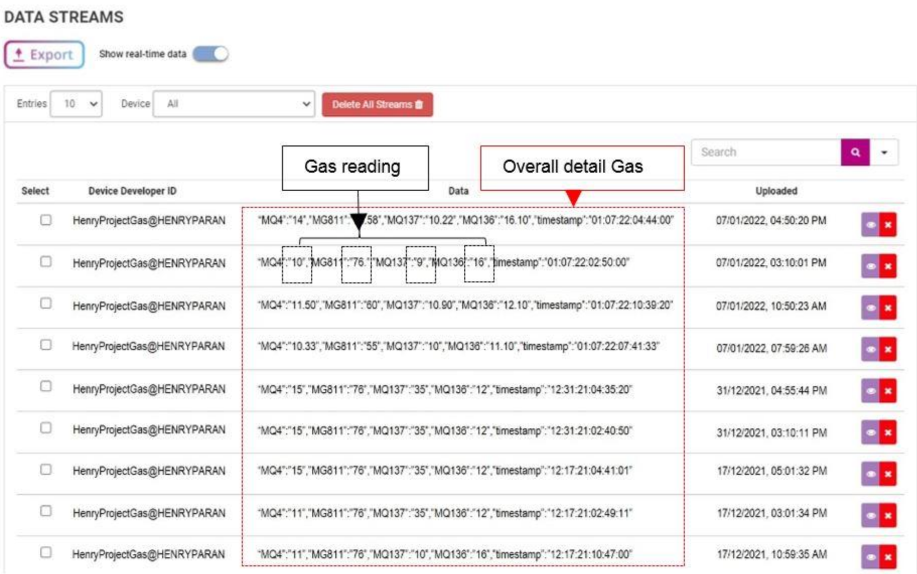


Figure 4: Gas sensor data stored in Favoriot IoT platform

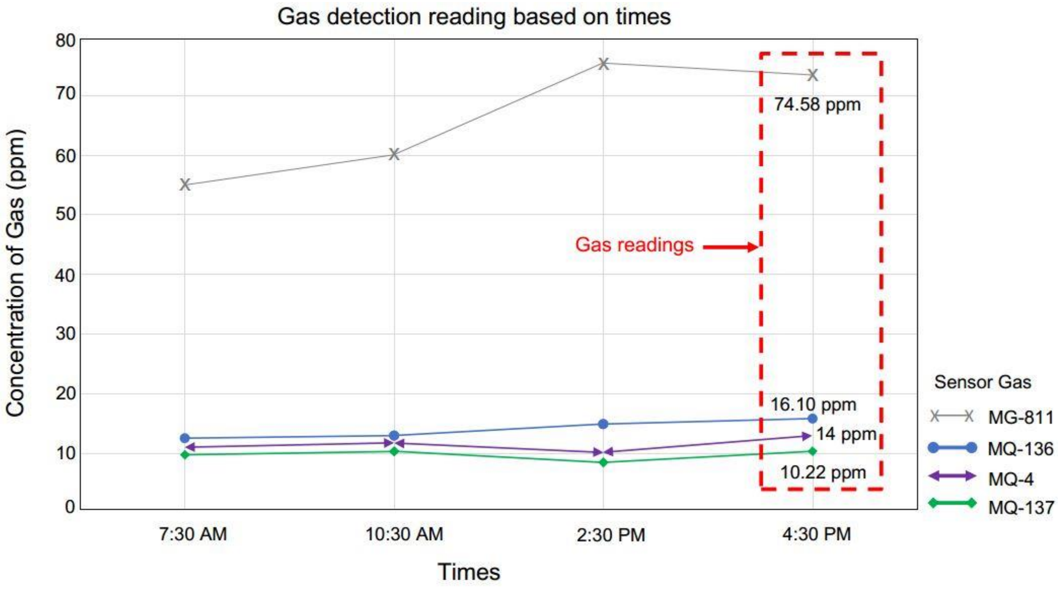


Figure 5: Dashboard of gas graph

3.4 Power consumption

Power consumption is an important parameter to be evaluated for wireless sensor network component such as sensor nodes and gateway. In this research work, the evaluation of power consumption of the proposed prototype is calculated and estimation battery capacity for 24 hours working period is suggested. For example, this project prototype can be long-lasting for 6 hours only. However, the calculation of the overall power battery life of the prototype is given as follows.

i. Sensor Node

MQ-4 (Methane)	=	0.1A
MQ-136 (Carbon Dioxide)	=	0.2A
MQ-811 (Ammonia)	=	0.2A
MG-817 (Hydrogen Sulphide)	=	0.2A
LoRaWan	=	0.2A
Arduino	=	0.5A
Battery	=	700mAH
Total		4800mAH

Currency battery capacity,

$$= \frac{0.14}{0.7}$$
$$= 5\ hors$$
$$= 5 \times 60\ minutes$$
$$= 300\ minutes$$

Battery capacity if needed for 24 hours,

$$= \frac{24 \times 60}{300\ minutes}$$
$$= 4800mAH$$

ii. Gateway

LoRaWan	=	0.2A
Arduino	=	0.5A
GSM	=	0.5A
Battery	=	700mAH
Total		4137mAH

Currency battery capacity,

$$= \frac{0.12}{0.7}$$

$$= 5.8\ hours$$

$$= 5.8 \times 60\ minutes$$

$$= 348\ minutes$$

Battery capacity for 24 hours,

$$= \frac{24 \times 60}{348\ minutes}$$

$$= 4137 mAH$$

Overall the total battery capacity needed in 24 hours is 4000mAH ~ 5000mAH.

4. Conclusion

In conclusion, the objectives proposed in this project have been achieved as the prototype developed is able to detect four (4) types of gas at the landfill. The prototyped also can communicate to IoT platform and has an ability to send notification to workers through SMS and Telegram.

Acknowledgement

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