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Development of Smart Air Pollution Monitoring System Using LoRa Technology

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ABSTRACT

The presence of elevated air pollution levels can lead to respiratory problems and certain cardiovascular conditions among individuals in the surrounding areas. Unfortunately, Malaysia currently lacks an air pollution monitoring system capable of promptly notifying the appropriate authorities. In such instances, it becomes impossible to take preventive measures before the pollution intensifies, exposing people to harmful levels of air pollution. With the current technological advancements, implementing an Internet of Things (IoT) system for monitoring air pollution and alerting authorities is the most effective way to ensure citizens live in a healthy environment. This paper aims to develop a smart air pollution monitoring system capable of detecting levels of Carbon Monoxide (CO), Carbon Dioxide (CO2), and smoke. The system will send a warning notification to the relevant authorities when gas concentrations reach predefined levels. The microcontroller will receive sensor data, undergo necessary processing, and transmit the information to Blynk's cloud using LoRa technology. Simultaneously, the system will automatically store backup data on Google Sheets. Additionally, a notification for Carbon Dioxide (CO2) gas levels will be sent every hour while for Carbon Monoxide (CO) and smoke index, an alert will be triggered when the air pollution level surpasses a moderate range of Air Pollution Index (API) and displaying the current air pollution index. By developing this technology, we aim to measure air pollution based on Malaysia's Air Pollution Index (API) and facilitate easier monitoring by authorities. The system will categorize pollution levels as unhealthy (API 101-200 PPM), very unhealthy (API 201-300 PPM), and beyond. This initiative will raise awareness among relevant authorities about the adverse effects of air pollution on health and prompt timely interventions.

1. Introduction

The rapid industrialization and urban expansion in Malaysia have resulted in a surge in pollutant emissions from diverse sources, including vehicular emissions, and construction activities. Consequently, respiratory illnesses ranked as the second leading cause of death, accounting for 14.8% of fatalities in 2019 in Malaysia [1], [2], [3], [4]. To enhance the well-being of the population and facilitate swift action in response to air pollution, a technology with versatile communication capabilities for data transmission and reception is crucial [5], [6], [7]. The capabilities of the Internet of Things (IoT) have permeated various advanced systems, offered numerous benefits, and

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transformed our interaction with technology [8], [9], [10],[11]. IoT has been commonly used to enhance monitoring systems, with Blynk apps being a well-known IoT platform. Its user-friendly mobile app interface simplifies the creation and management of IoT applications, making it a reference device due to its seamless integration with diverse IoT devices and platforms [12], [13], [14]. With technological advancements, LoRa, or Long-Range technology, represents the latest wireless communication technology based on radio frequency. Its distinguishing features include support for long-range communication and the use of low-power wireless chipsets [15], [16], [17], [18]. Its unique feature lies in its ability to reach far distances with low power consumption and cost-effectiveness, making it suitable for many IoT devices [19], [20]. Therefore, this paper proposes the implementation of a smart air pollution monitoring system using the Internet of Things (IoT) and LoRa technology. By utilizing the Blynk application accessible through mobile phones or various devices, this system can promptly alert authorities when the Air Pollution Index (API) exceeds 100, following Malaysia's standard API, and automatically store backup data in Google Sheets. Leveraging this innovation enables effective monitoring of air pollution levels, including Carbon Monoxide (CO), Carbon Dioxide (CO2), and smoke levels, ensuring a high-quality environment for people.

2. Methodology

The system comprises four inputs: MQ135, MQ2, MQ7, and DHT22, along with three outputs: Blynk apps for notification and monitoring, a Google Sheet for data storage, and LEDs as indicators. The project is divided into two parts: a sensor node and a gateway. On the sensor node part, the microcontroller is connected to sensors, and the LED will turn on when the data is transmitted through the LoRa module every 5 minutes. On the gateway part, the LED will turn on when the LoRa module receives data, and the data will be saved on Blynk's cloud and on Google Sheet. A notification will be sent to the user's device to provide information and alert on the current air quality.

Figure 1 illustrates the block diagram of the sensor node part of the system. The sensor node is interconnected with the gateway, completing the entire system. The input section of the sensor node includes MQ-135, MQ-2, MQ-7, and DHT-22, which detect various types of air pollution. Specifically, the MQ-135 sensor detects Carbon Dioxide (CO2), MQ-2 detects smoke, and MQ-7 detects Carbon Monoxide (CO) in the air. In this part, the Maker UNO functions as the microcontroller, receiving data from the sensors and transmitting it to the gateway through the LoRa module. An LED serves as an output signal, indicating data transmission to the gateway.

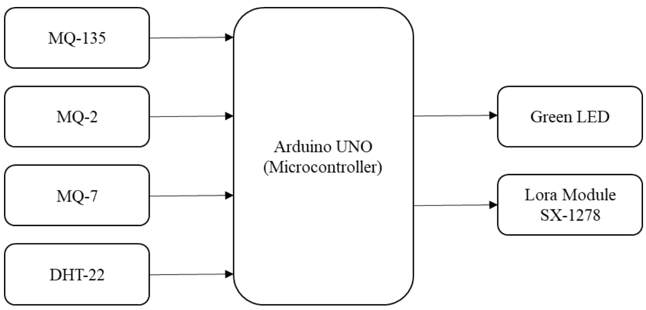


Fig. 1. Sensor node block diagram

Figure 2 illustrates the block diagram of the gateway part of the project. After the sensor node part, the system will continue on the gateway side of the project. In the gateway part, the LoRa module receives data from the sensor node, triggering the LED indicator to illuminate. The NodeMCU ESP32 acts as the microcontroller in this segment, generating a Wi-Fi network used to synchronously send data to cloud for both the Blynk app and Google Sheet, which can be monitored on user devices.

From the received data, the NodeMCU ESP32 will check if the data meet certain conditions, triggering an alert notification on the user devices.

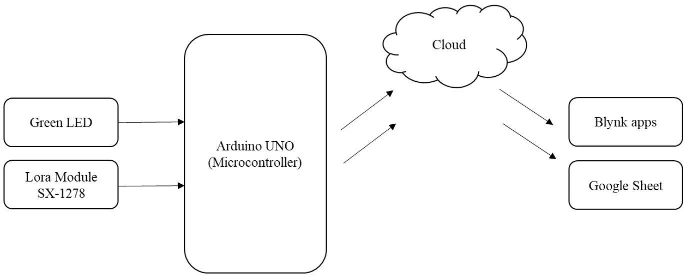
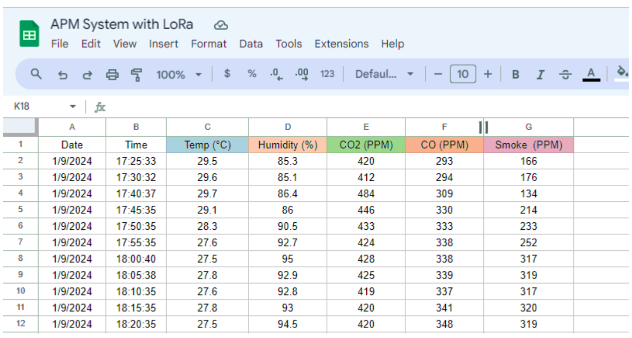


Fig. 2. Gateway block diagram

3. Results and Discussion

The collected data from the outdoor environment underwent thorough analysis. The focus of the analysis centered around the indices of temperature, humidity, CO2, CO, smoke, and the distance between the sensor node and gateway recorded throughout the experiment. The data were collected at 5-minute intervals and analyzed by calculating the average indices for each parameter over a 1-hour period. All received data will be stored on the Blynk app and Google Sheet as a backup platform. Due to limited access on the Blynk app, the data can be monitored for no more than one week. Thus, Google Sheet is used for storing the data, allowing for monitoring over a longer period compared to Blynk. Figure 3 displays data on the Blynk app, while Figure 4 shows the backup data on Google Sheet.

Fig. 3. Data on Blynk apps



	A	B	C	D	E	F	G
1	Date	Time	Temp (°C)	Humidity (%)	CO2 (PPM)	CO (PPM)	Smoke (PPM)
2	1/9/2024	17:25:33	29.5	85.3	420	293	166
3	1/9/2024	17:30:32	29.6	85.1	412	294	176
4	1/9/2024	17:40:37	29.7	86.4	484	309	134
5	1/9/2024	17:45:35	29.1	86	446	330	214
6	1/9/2024	17:50:35	28.3	90.5	433	333	233
7	1/9/2024	17:55:35	27.6	92.7	424	338	252
8	1/9/2024	18:00:40	27.5	95	428	338	317
9	1/9/2024	18:05:38	27.8	92.9	425	339	319
10	1/9/2024	18:10:35	27.6	92.8	419	337	317
11	1/9/2024	18:15:35	27.8	93	420	341	320
12	1/9/2024	18:20:35	27.5	94.5	420	348	319

Fig. 4. Backup data on the Google Sheet

Two experiments were conducted to test the system in outdoor environments. The first experiment took place in a residential area, and the second experiment was conducted at the parking area of UiTM Engineering Towers in UiTM Shah Alam.

For residential area, the sensor node was positioned near the primary road, and data were collected during two specific time intervals: from 12 am to 2 pm and from 5 pm to 7 pm. The objective of collecting data during these periods was to capture environmental conditions during lunch hours and peak traffic times when the road experiences high activity. The distance between the sensor node and the gateway device was maintained at 200 meters. Figure 5 displays the distance between the sensor node and gateway. The sensor node is placed close to the road, and the gateway is inside a house on the first floor. Figure 6 illustrates the locations of the sensor node and gateway, with the sensor node positioned near the road, and the gateway situated inside a house on the first floor.

Fig. 5. Distance between the sensor node and gateway

Fig. 6. Location of sensor node and gateway

Figure 7 shows the average API reading during the afternoon period. Based on the 3-hour experiment, it is evident that the average value of Carbon Monoxide (CO) is higher compared to the smoke index, with a difference of 69 PPM. This can be attributed to peak hours when residents typically engage in duties such as sending their children to school and taking their lunch break. Simultaneously, the Carbon Dioxide index remains within the normal range for outdoor environments, with the highest average amount recorded at 335 PPM.

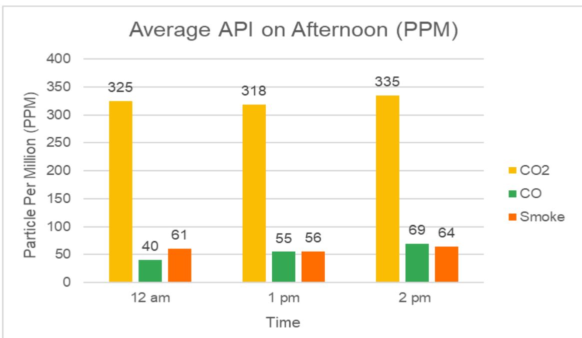


Fig. 7. Average API reading on afternoon period

Figure 8 shows the Carbon Dioxide (CO2) index notification during the period. Carbon Dioxide (CO) notification will be received on user device in every 1 hour.

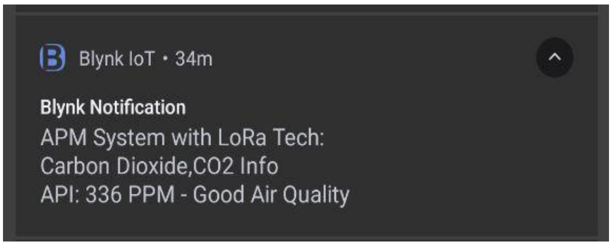


Fig. 8. Carbon dioxide (CO_2) index notification during the period

Figure 9 illustrates the average API reading during the evening period. The experiment was conducted again at the same spot during this timeframe. According to the results, the API indices for all parameters increased compared to the afternoon period. This increase could be attributed to peak hours during the evening, as residents engage in evening duties and people return home after work. At 7 pm, the highest Carbon Monoxide (CO) index recorded was 135 PPM, falling within the range considered unhealthy for at-risk individuals. Within a one-hour period, a Blynk notification was promptly sent to devices, alerting users about the current environmental conditions.

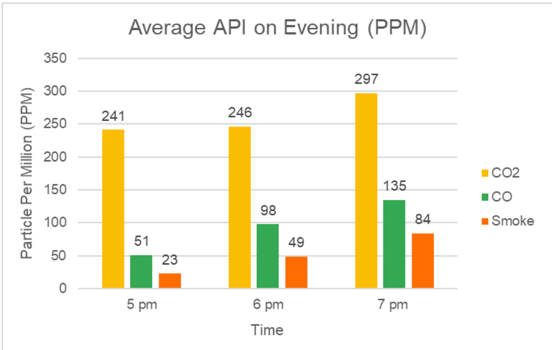


Fig. 9. Average API reading on evening period

Figure 10 displays the alert notification for the Carbon Monoxide (CO) index.

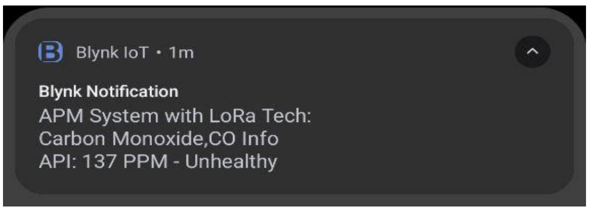


Fig. 10. Alert notification of carbon monoxide (CO) index

Figure 11 presents the graph of the average API between two different periods: afternoon and evening. According to the results, the Carbon Monoxide (CO) API is higher in the evening, attributed to the increased use of vehicles on the road by residents during that time. On the other hand, the Carbon Dioxide (CO2) API shows a decrease in the evening compared to the afternoon, with a reduction of 100 PPM, while the smoke index remains similar between the afternoon and evening periods.

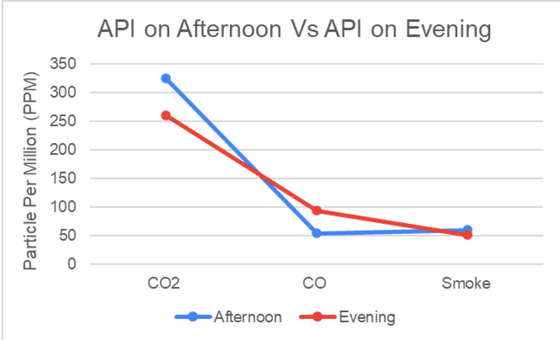


Fig. 11. Graph of average API between two different period

The primary motivation for conducting this experiment stems from the high student population at UiTM Shah Alam who utilize this parking area. The frequent double-parking by students is a common occurrence due to the limited parking spaces and proximity of the nearest parking area. Figure 12 illustrates the distance between the sensor node and gateway, while Figure 13 depicts the locations of the devices.

Fig. 12. The distance between the sensor node and gateway

Fig. 13. Location of the sensor node and gateway

This experiment was conducted during the early morning, from 8 am to 9 pm on weekdays, owing to the high student population utilizing this area. Figure 14 displays the average API readings at the parking area. According to the results, the Carbon Dioxide (CO2) index in this area gradually decreased over 3 hours, from 8 am to 10 am, ranging from the highest at 275 PPM to 267 PPM. Simultaneously, the Carbon Monoxide (CO) index was higher compared to the residential area, ranging from 133 PPM to 139 PPM, while the smoke index showed a significant increase, ranging from 95 PPM to 116 PPM. The elevated smoke index is attributed to the numerous vehicles in the area. Figure 15 exhibits the alert notifications for Carbon Monoxide (CO) and smoke indices.

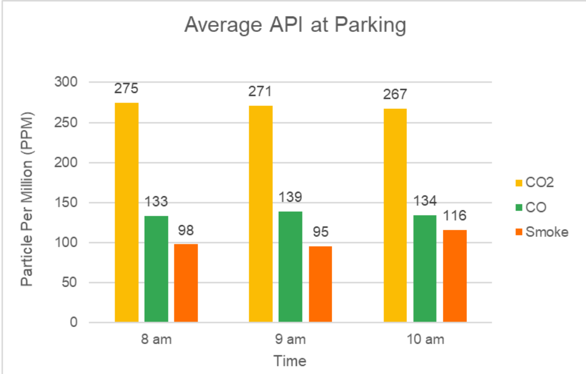


Fig. 14. Average API reading at parking area

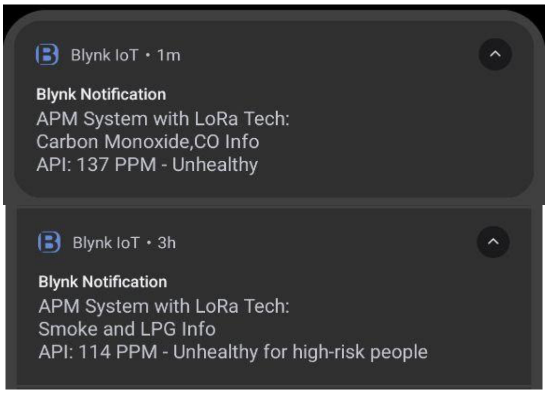


Fig. 15. Alert notification of carbon monoxide (CO) and smoke index

Figure 16 illustrates the graph of the average API in two different locations: the residential area and the public parking API index. The residential area index represents the higher value between the afternoon and evening readings. Based on the results, the API index for Carbon Dioxide (CO2) is higher in the residential area compared to the parking area. Additionally, the Carbon Monoxide (CO) index and smoke index are notably higher in the parking area than in the residential area, likely due to the increased use of vehicles during that time. Consequently, the parking area is more exposed to air pollution compared to the residential area.

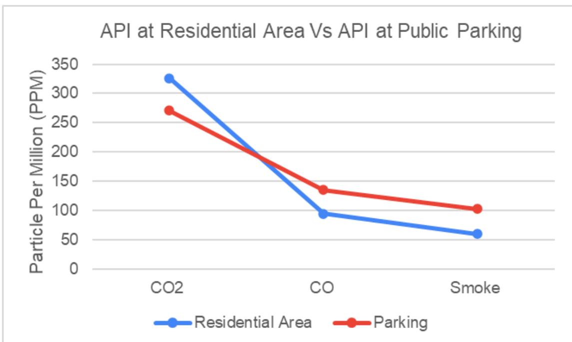


Fig. 16. Graph of average API between two different locations

Humidity and temperature have a significant impact on the air pollution index. Higher humidity and temperature levels in the environment can lead to an increase in the air pollution index. This is because humid air traps pollutants close to the ground, while warmer air can trap cooler air near the surface, preventing the dispersion of pollutants into the atmosphere. An experiment was conducted during a rainy day in a residential area to analyse this factor. Figure 17 displays the average API reading during the rainy day.

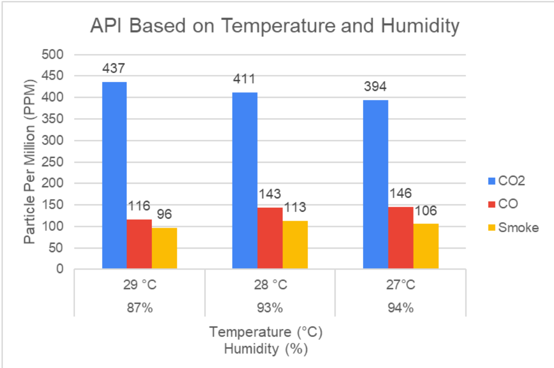


Fig. 17. Average API reading during the raining day

The experiment was conducted over a period of 3 hours, and the results are displayed above. Based on the findings, it is observed that the Carbon Dioxide (CO) index shows a gradual decrease, while the Carbon Monoxide (CO) and smoke indices increase when humidity percentages are higher, and temperatures are lower. Next, Figure 18 presents a comparison of the pollution index during sunny and rainy days. The graph indicates a slightly higher API index on rainy days compared to sunny days. This result underscores the influence of humidity and temperature values on the air pollution index.

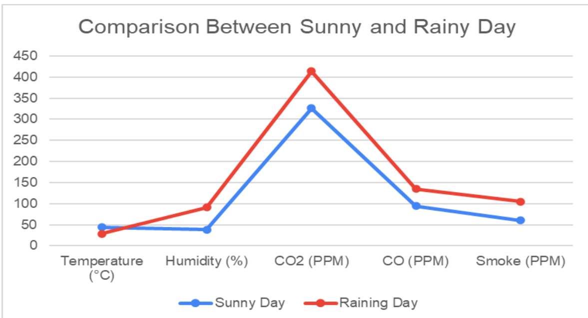


Fig. 18. Graph of comparison of the pollution index during the sunny day and rainy day

An experiment on LoRa performance was conducted at Elmina Temu to study transmission coverage based on distances. The experiment took place on a rainy day, with an average humidity of 100% and a temperature around 25°C. Elmina Temu is a newly developed factory area with minimal road traffic. Figure 19 depicts the locations of the sensor node and gateway.

Fig. 19. Location of the sensor node and gateway

Figure 20 illustrates the route of the LoRa performance test conducted, and Table 1 presents the data updated time at different distances. The experiment commenced at 100m and progressed in increments of 100m, following the electric pole distances along the roadside. Each electric pole spans a distance of 50 meters, serving as an indicator of the distance covered during the experiment. Monitoring of the performance was conducted using the Blynk app to track received data. However, it was observed that the data updates were inconsistent within the 5-minute intervals. This inconsistency and observed delays in packet reception within this distance range may be attributed to unstable internet coverage in the area.

Fig. 20. Route of the LoRa performance test

Table 1
Data of updated time at different distances

Distance (m)	Data updated time on Blynk
100	4.15 pm
200	4.24 pm
300	4.34 pm
400	4.41 pm
500	4.46 pm
600	5.03 pm
700	m5.10

4. Conclusion

In conclusion, this research has successfully met its objectives, as detailed in this paper. The air pollution system, employing LoRa for communication, efficiently alerts users through the Blynk notify feature based on Malaysia's Air Pollution Index (API). The project emphasizes the variation in pollution indices influenced by location and weather, with busier areas generally exhibiting higher indices. Additionally, the LoRa module's performance showed optimal results in wider and more open areas. It is worth noting that delays in data collection, possibly attributed to an unstable internet network at the location, were observed.

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