A Low-power Real-time Pollution Monitoring System Using ESP LoRa

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Abstract. *Air Quality (AQ) is a very topical issue for many cities and has a direct impact on the environment and health of its citizens. We propose to investigate the air quality at Khon Kaen city in Thailand. We design and realization of 4 sensors (PM2.5-PM10, Pressure, Altitude, Temperature, Humidity and Carbon dioxide) which is defined to operate on Wireless Sensor Network (WSN) form with LoRa technology. The experimental results have been shown the air quality on web application. The proposed of this paper can help the people know the historical and real-time data of air quality through a web browser.*

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LoRa, Pollution Monitoring, Wireless Sensor Networks, Air quality, Dust, Pressure, Altitude, Temperature, Humidity.

1. Introduction

In recently, air pollution is an important issue in the northeastern region of Thailand, especially in Khon Kaen province. In the year 2018, the amount of particulate matter exceeded the standard of 37 times [1]. This problem affects the well-being of the people in the area especially the health effects, economy and tourism. The main cause of air pollution in Khon Kaen city include particulate matter (PM) built by human activities, for example, burning activity in the open incineration of agricultural residues, waste incineration and including nitrogen dioxide, carbon monoxide, carbon dioxide and PM 2.5, which is all seriously affect human health. The best solutions to the problem of air pollution are we can know pollution values and identify the source of each pollution discharge accurately and rapidly.

At present, air pollution monitoring in Thailand depends on the large national monitoring stations, which can provide high-precision monitoring data, which is not installed in every critical area because of large operating and high maintenance costs. Hence, the air quality detector has only installed one point in Khon Kaen city which not enough to acquire the monitoring data from the critical area.

Therefore, in this paper is focused on design and develop a real-time pollution monitoring system which consists of 4 sensors for detecting PM2.5, PM10, atmospheric pressure, altitude, temperature, humidity and carbon dioxide by collecting and recording data from wireless sensors networks based on LoRa technology. Then, all the data sent via a wireless network to record all the data in database, and shown air quality on web application.

2. System Architecture and Wireless Sensor Networks

Air quality (AQ) is a unique problem for many cities and countries and has a direct impact on the environment and public health. Such problems are many causes, whether it is pollution caused by various industries, transportation, and pollution from the agricultural industry, human’s activities, etc. As a result of the problem, many research studies on air quality monitoring by using wireless communication technology to help monitor air quality. WSN is widely used in many works such as healthcare, military and environmental quality monitoring due to the low-cost, long-range transmission and can transmit data via the internet to the server [2-4]. From literature studies, to monitor the greenhouse gas leakage from industries, the data displayed on a webpage, is called “Monitoring of Green House Gases Using Wireless Sensor Networks with Arduino Board” [5]. Another research on greenhouse gases is called “On-line Monitoring of Green House gases Storage and Leakage Using Wireless Sensor Network” .This system implemented using X-bee Digi modules and Arduino platform which displayed greenhouse gases data online that users can be easy to access data [6].

2.1 System Architecture

The main core of proposed system is composed of 2 parts, the first part is software, it includes a software platform based on the browser/server framework, and second part is hardware which consists of sensor nodes and microcontrollers (see Fig. 1). The microcontroller will receive and convert all the data from sensors in digital signal form, and then, all the data will be sent to gateway with LoRaWAN protocol. After that, the gateway will send these data to the database via Wi-Fi communication.

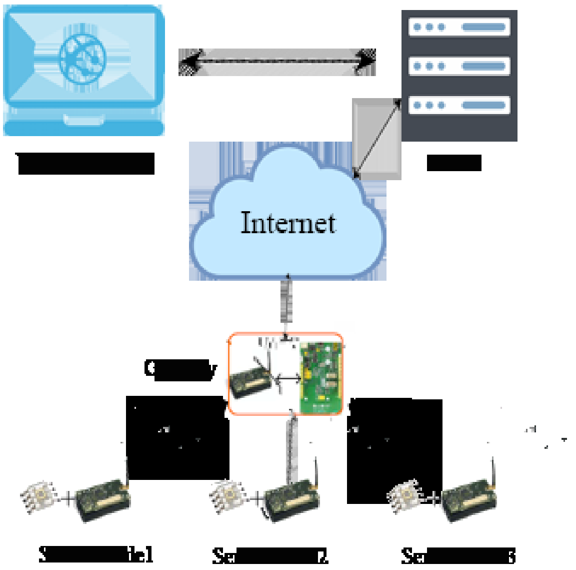

Fig. 1: The System Architecture

2.2 Wireless Communication (LoRa)

Long Range technology (LoRa) is used in the Internet of Things (IoT) applications, which is a low power communication device and link that can communicate remotely with CSS modulation (Chirp Spread Spectrum). The frequency supported by this network is around 433MHz, 868MHz or 956MHz. This type of network uses the frequency shifting keying and has a small error rate. Moreover, LoRa has the advantage that it is a platform for long-distance communication and another factor is that it has a long-term battery performance. LoRa can create a communication network using LoRaWAN for communication between LoRa gateways [7].

Therefore, this technology is an important technology for the IoT application to connect sensors and controllers to the internet instead of using WiFi or mobile phone networks. At present, many popular wireless sensor network technologies, such as LoRa, ZigBee, WiFi, Bluetooth, SIGFOX and NB-IoT is compared with LoRa as shown in Table 1. The proposed system based on LoRa technology has several more features such as low cost, long distance, high coverage, long device battery lifetime [8-9].

2.3 Microcontroller

The system uses the LoRaWAN ESP32 LoRa SX1278 433MHz protocol chip produced by Semtech. The chip has a bandwidth of frequency between 7.8 kHz and 500 kHz and the spreading factor range is between 6 to 12. The available frequency is 137 Up to 525 MHz.These devices also support high-performance radio frequency and significantly lower current consumption, it optimal for any application requiring long range or robustness [10].

Wireless Technology					
Technology	**Frequency**	**Data rate**	**Range**	**Power**	**Cost**
LoRa	< 1 GHz	<50 kb/s	2-5 km	Low	Low
ZigBee	2.4 GHz	250 kb/s	100 m	Low	Medium
WiFi(11f/h)	2.4,5<1 GHz	0.1-1 Mb/s	Several km	Medium	Low
Bluetooth	2.4 GHz	1,2.1,3 Mb/s	100 m	Low	Low
SIGFOX	< 1 GHz	Very Low	Several km	Low	Medium
NB-IoT	Cellular bands	0.1-1 Mb/s	Several km	Medium	High

Table 1 popular wireless sensor network technologies: LoRa, ZigBee, WiFi, Bluetooth, SIGFOX and NB-IoT compared with LoRa

2.4 Smart Sensors

We have selected the sensors based on the performance parameters, such as accuracy and low power consumption. We use the 4 smart sensors are Plantower PMS3003 for detection PM10, PM2.5, MQ-135 for detection carbon dioxide (CO2), DHT22 for detection temperature and humidity and BMP180 for detection pressure and altitude. The smart sensor air pollution monitoring is shown in Fig. 2 Air quality sensors devices.

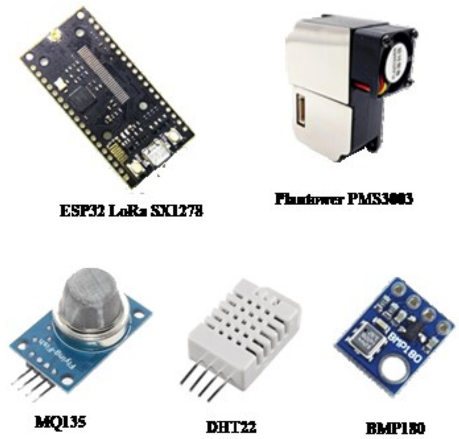

Fig. 2: Air quality sensors devices

Firstly, the particulate matter sensor is effective to detect very fine particle dust in the air and can also detect particle PM2.5 and PM10. This model is Plantower PMS3003 that working with the principle of laser scattering [11-12]. Secondly, gas sensor or cabon dioxide (CO2) sensor that detecting scope fast response and high sensitivity. This model is MQ-135 is suitable for detecting CO2, NH3, NOx, alcohol, Benzene, and smoke. The maximum sensitivity of CO2 sensor module is range 0 to 10000 ppm [13]. Thirdly, in Fig.2 shows the temperature and humidity sensor module. This model is DHT22 that output calibrated digital signal and small size, low consumption, long transmission distance (100m) [12]. Finally, fourth, barometric pressure sensor for measuring pressure and altitude. This model is BMP180 offers superior performance, ultra-low power, low voltage electronics. Pressure sensing range: 300-1100 hPa (9000 m to -500 m above sea level).

3. System Design

In this section, we describe the WSN monitor system designs, which consisted of sensor node design and web application design.

3.1 Sensor Node Design

The sensor node is consisted of ESP32 LoRa SX1278, which is connected with 4 main sensors for detecting PM2.5, PM10, temperature, humidity, altitude and carbon dioxide. The DC power supply is powered by rechargeable battery (3.7 V 5000 mA), and are charged by solar cells, which is able to support long-term, as shown in Fig. 3

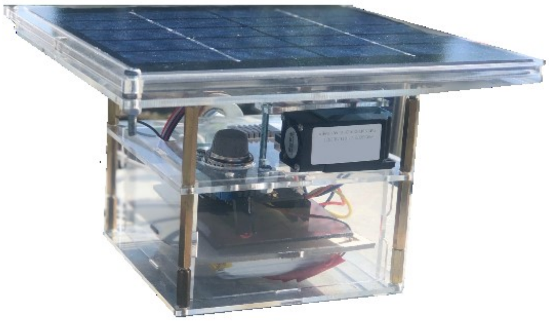

Fig. 3: Proposed sensor node

3.2 Web Application Design

For web application design, we divided into 2 parts. Firstly, when the sensor node sends data to the server side which data are received and stored into the MySQL database. Secondly, the webpage designed and constructed based on HTML and JavaScript. This webpage has a role to query and demonstrated result real-time pollution data on the webpage as graphs and data tables shown as Fig. 4.

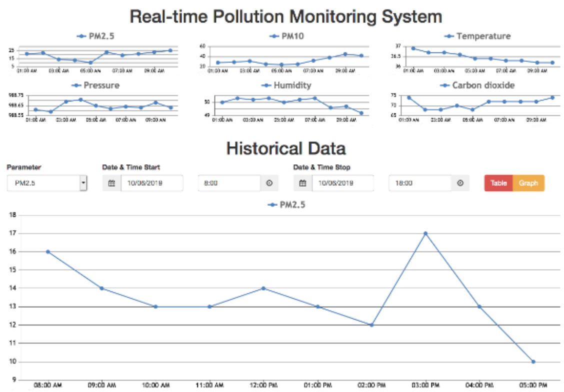

Fig. 4: Real-time pollution monitoring system

4. Experimental Results

To test the system and the accuracy of the collected data. We have installed system devices three areas to consist of (1) Building in front of the university (2) Faculty of Engineering area and (3) Physical education building area at Rajamangala University of Technology Isan Khon Kaen Campus shown in Fig. 5.

Fig. 5: Location of the monitoring nodes in the University

4.1 Application Stability

The results of the data were collected using 3 stations during the 7 days from 6 to 12 June in the year 2019. The results of the measurements, we just present example only the 10th data shown in the Fig. 6-7. The measurement of PM2.5 and PM10 according to the AQI standard, the average continuous 24 hours of PM2.5 must not exceed 25 ug/m3 and PM10 not more than 50 ug/m3. According to results in 7 days, PM2.5 and PM10 values are at a good level according to AQI standard [14]. For the results of temperature, pressure, and humidity are corresponding with the report of the Meteorological Department [15]. In the result, the graphs are shown in Fig. 8.

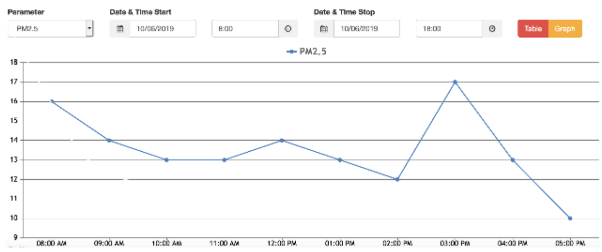

Fig. 6: PM2.5 concentration

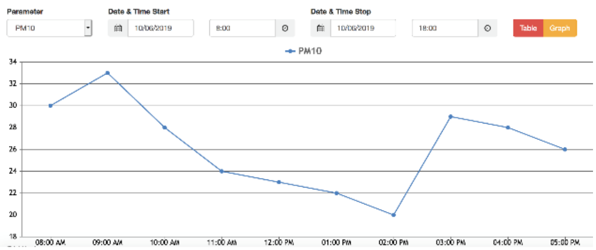

Fig. 7: PM10 concentration

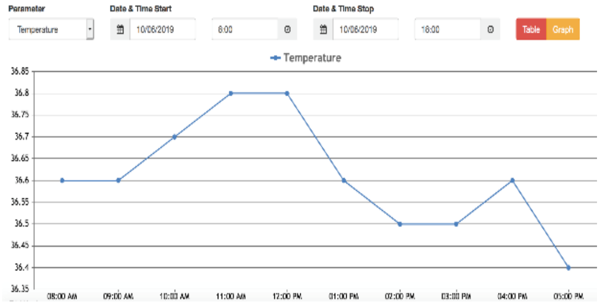

Fig. 8: Temperature

4.2 Sensor Calibration

In this paper, we divided the calibration into 2 parts: 1 calibrated particulate matter compared with the results of the Pollution Control Department [16], which uses the Beta Ray method attenuation equivalent method. In Fig. 9, shown the point of installing of sensor node at the air quality monitoring station in Khon Kaen. In Parts: 2 calibrations of temperature, air pressure, and humidity, we compared their results with the report of the Thai Meteorological Department Automatic Weather System [15].

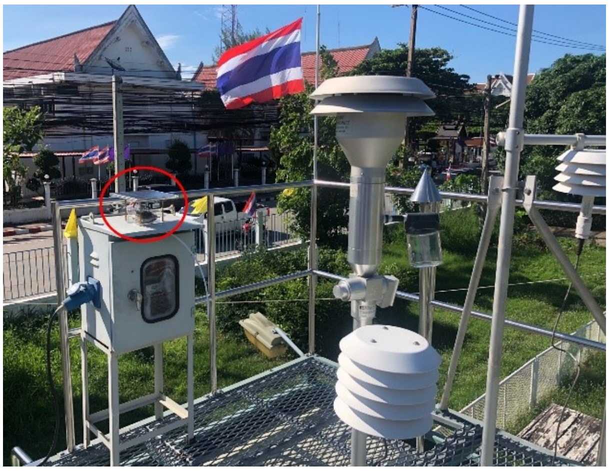

Fig. 9: Installation point of sensor node at the air quality monitoring station

In part: 1 the comparison results from the average particulate matter on an hourly basis shown that the values of PM2.5 and PM10 are in the same direction as the results of PCD shown in Fig. 10-11.

In part: 2 The comparison results of the average daily temperature, air pressure, and humidity shown that the values of the temperature, air pressure, and humidity are in the same direction results of TMD as shown in Fig. 12-14.

From both parts of the examination, it's clearly seen that the trend of both data sets is similar to government agencies and have a small error. Therefore, the air quality data obtained from the proposed system can meet both accuracy and reliability.

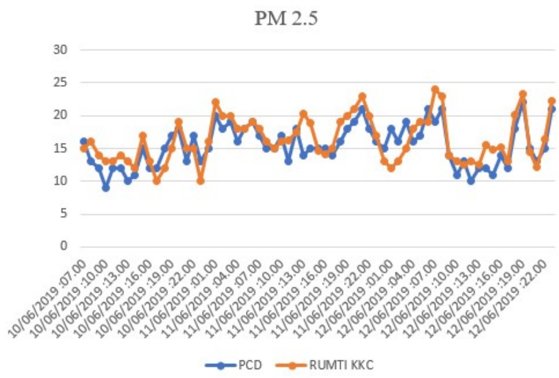

Fig. 10: Comparison between the measured and reference data on PM2.5 concentration

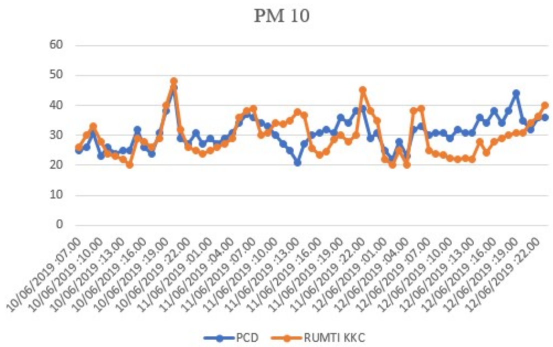

Fig. 11: Comparison between the measured and reference data on PM10 concentration

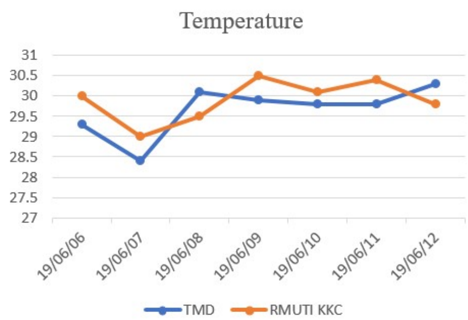

Fig. 12: Comparison between the measured and reference data on temperature

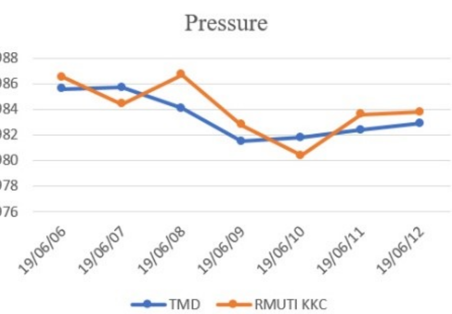

Fig. 13: Comparison between the measured and reference data on pressure

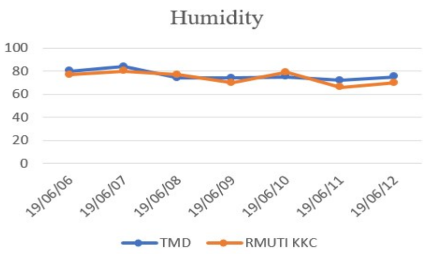

Fig. 14: Comparison between the measured and reference data on humidity

5. Conclusion

In this paper, we proposed a low-power, real-time pollution monitoring system using ESP LoRa for investigating air pollutant and offering information on a web application. Using LoRa can sending data long range distance, low-power consumption, the power supply is powered by battery which is charged by solar cells. Moreover, the sensor node that measures air quality and meteorological conditions which are a concentration of pollutants in the same direction as standards measurement instruments with accuracy. For the smart city of KhonKaen, we believe that air monitoring can help understand and identify the source of each type of pollution to solve air pollution problems. Therefore, future work we will be storing air pollution data in long times period and using data analysis method for the relationship and predict the future of air pollution.

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Biographies

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