Application of a Multi-sensor Network in Monitoring of Air Quality

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Abstract: Air pollution is a condition when air quality becomes damaged and contaminated by harmful substances. Several factors that caused air pollution are increasing infrastructure development, smoke factory, and vehicle exhaust gases. Air quality in an environment needs to be determined with real-time air quality monitoring with affordable and accurate sensors. One of the controls and monitoring systems currently being developed is the Wireless Sensor Network (WSN) which consists of individual nodes that can interact with their environment by sensing, controlling, and communicating physical parameters. In this research, an air quality monitoring system will be designed using multi-sensor network technology, which will then be placed in several locations. This research aimed to measure the parameter of Carbon Monoxide (CO), Carbon Dioxide (CO2), Hydro Carbon (HC), temperature and humidity, and levels of particulates in the air (PM10). It will then be collected and sent to the Raspberry Pi's database server via the internet network. Furthermore, the data will be processed to become information that can be used by users or the general public.

1 INTRODUCTION

Air pollution is a condition when air quality becomes damaged and contaminated by harmful substances. Several factors that caused air pollution are increasing infrastructure development, smoke factory, and vehicle exhaust gases (Anjum et al, 2021); (Newbury et al., 2019); (Sheng et al., 2020); (UNECE, 2021). It can cause various diseases, including eye irritation, upper respiratory tract infection, sore throat, even death (WHO, 1992); (Peng et al., 2019); (Qin et al., 2018); (Handayani et al, 2019).

Based on data from the World Health Organization (WHO), about 4.2 million people died from air pollution or about 5% of the 55 million people who died every year in the world (Anjum et al, 2021); (WHO, 1992). 1500 million people who died prematurely occurred in Asian cities. The morbidity rate resulting from air pollution is much higher (Tarmidi, 2019); (Prihatini et al., 2018); (Kelly and Fussell., 2015); (Health Effects Institute, 2019).

Air quality in an environment needs to be determined with real-time air quality monitoring. The development of technology and information has brought humans to a new generation of affordable and accurate sensors (detection tools). One of the controls and monitoring systems currently being developed is the Wireless Sensor Network (WSN) (Deebak et al, 2020); (Idrees and Zheng, 2020); (Handayani et al, 2020). WSN consists of individual nodes that can interact with their environment by sensing, controlling, and communicating physical parameters (Zervopoulos et al, 2020); (Handayani et al, 2021).

WSN is a network that carries a wireless network as a link between nodes. It can be used for data collection and monitoring a system or environment at the location. WSN consists of several specialized sensor nodes with sensing and computerized capabilities (Sahfutri et al, 2018); (Zakaria et al, 2018). It makes WSN can sensing physical parameters and transmitting the collected data to a central area using wireless communication technology (Handayani et al, 2020); (Yahya et al, 2020). The sensor obtains data in real-time, entered into a database server via an internet network using the Raspberry Pi to access the data in the monitoring system application. It shows that the Raspberry Pi has good complexity and low cost, so it is easy to develop (Jadon et al, 2020). Multi-Sensor Network (MSN) system is a new technology that utilizes multiple sensors and Wireless Sensor Network (WSN) in one

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device. The signal collected from these sensors is transmitted to the monitoring center using a smart device to manage distributed resources and optimize tasks in real-time automatically. This system can produce object data that is detected by sensors automatically (Marques et al, 2019); (Taştan and Gökozan, 2019).

Some of the research was implemented the WSN. In (Sahfutri et al, 2018), WSN was used to find out the parking slots available in the parking area. The monitor serves as a monitoring of the parking slot area to be displayed so that visitors know whether the parking slot is still available or even fully charged. Furthermore, in the research by Xu and Liu (Xu and Liu, 2017), monitoring water quality using parameters of oxygen solubility, water pressure, PH, and temperature by applying the Wireless Sensor Network (WSN).

In this research, an air quality monitoring system will be designed using multi-sensor network technology, which will then be placed in several locations. For example, in parking areas, on roadsides, housing estates, industrial sites, etc. The parameters measured include Carbon Monoxide (CO), Carbon Dioxide (CO2), Hydro Carbon (HC), temperature and humidity, and levels of particulates in the air (PM10). The value of these parameters is obtained from the sensor's sensing process periodically. It will then be collected and sent to the Raspberry Pi's database server via the internet network. This air quality monitoring system has an advantage in applying multi-sensor network technology. More harmful pollutant gases can be measured in real-time to monitor air quality in the environment.

2 ENVIRONMENT MONITORING

2.1 Wireless Sensor Network

Wireless Sensor Network (WSN) is one type of distributed wireless network that utilizes embedded system technology and a collection of sensor nodes to perform sensing processes, monitoring, sending data, and presenting information to users via wireless network communication (Handayani et al, 2019); (Handayani et al, 2018). There are many sensors, including air sensors, temperature sensors, motion sensors, pressure sensors, radiation sensors, position sensors, etc. (Zhou et al, 2021). Each sensor also has software (application, operating system) and hardware, respectively, which will run into a Wireless Sensor Network system (Sahfutri et al, 2018).

Each point in the WSN is equipped with a radio transceiver as a receiving or sending node also other supporting devices. Therefore, WSN is also known as a system consisting of several low-cost sensors small in size and spread over a vast area with one container node to collect the reading process results for other sensor nodes (Zervopoulos et al, 2020).

According to the application, the number of nodes used in a WSN can be in the thousands using low-cost nodes placed in specific locations. Its small size does not rule out weaknesses and limitations on sensor nodes. WSN usually communicates using multi-hop communication, which aims to save power usage. The sensor node data will end at a select node called a sink node. Another communication module or a gateway to another network equipped is usually called a gateway in charge of forwarding to cloud storage or the internet. Sink node processes and computes more complex data, which sensor nodes may not do. It makes sink nodes have enough processors, memory, and energy to properly carry out their tasks. The architecture of the wireless sensor network can be seen in Figure 1.

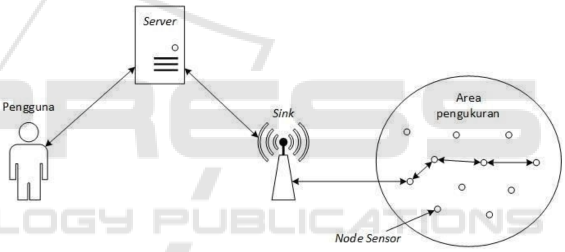

Figure 1: The architecture of the wireless sensor network.

2.2 WSN as Environment Monitoring

Industrial development and construction result in increased pollution in the environment. Industrial pollution consists of waste in water, gas, and solid. In general, this waste is dangerous because most of its components consist of additives and chemicals that are difficult to degrade. These substances harm the environment and threaten the survival of living things (Yahya et al, 2020).

The environment is currently very polluted because of the many factors that support pollution. From industrial waste, environmental pollution also comes from waste from vehicle emissions. Diesel engines are considered the single most significant contributor to environmental pollution caused by exhaust gas emissions, and they are responsible for several health problems (Jadon et al, 2020).

WSN is a distributed autonomous device that uses sensors to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, and movement in different locations. WSN cooperatively passes data through the network to the Base Station. Data can be analyzed in this location and acts as an interface between the user and the network (Handayani et al, 2021).

WSN applications are used in commercial and industrial applications to monitor complicated or expensive data using wired sensors. WSN is spread over an area intended to collect data via its sensor nodes (Handayani et al, 2021).

Currently, the sensor node commonly used is equipped with an onboard processor. The data processing component is used to separate the required data. It is due to many sensor nodes being used and possible that the distance between nodes will be close together. Therefore, multi-hop communication is widely preferred to consume less power than single-hop communication. Multi-hop communication is effectively used to overcome some of the signal propagation effects that often occur in long-distance wireless communications.

2.3 Sensor TGS 2442 as a Carbon Monoxide (CO) Detector

Carbon Monoxide (CO) is a gas that is colorless, odorless, and tasteless. It consists of one carbon atom covalently bonded to one oxygen atom. There are two covalent bonds in this bond and one coordinating covalent bond between the carbon and oxygen atoms. Most of the CO gas comes from combustion and emissions from motor vehicles. CO gas is hazardous if inhaled by humans, especially respiratory problems and can even cause death (Handayani et al, 2018).

Figure 2 shows the CO sensor used in this system is the TGS 2442 sensor. This sensor is a carbon monoxide (CO) gas detector with low power consumption, minimalist size, and high sensitivity. This sensor works at a reference voltage of 5 V connected to the heater (Vh) and Rs. Rs itself is the sensor's resistance connected to pin 2 and pin 3. Apart from being a reference voltage, Rs' value is used for input on the heating element (heater) on pin 1 and pin 2.

2.4 Sensor MG-811 as Carbon Dioxide (CO2) Detector

Carbon Dioxidant (CO2) is a colorless gas with a density about 60% higher than air (1,225 g / L) that is odorless at the concentrations typically encountered. Carbon dioxide consists of a double covalent carbon atom bonded to two oxygen atoms. It occurs naturally

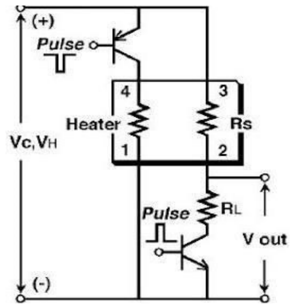

Figure 2: Sensor TGS 2442 (Handayani et al, 2018).

in the Earth's atmosphere as a trace gas at a concentration of about 0.04 percent (400 ppm) by volume.

In general, the ventilation rate should keep the carbon dioxide concentration below 1000 ppm to create indoor air quality conditions that are acceptable to most individuals (Zhou et al, 2021). In this system, CO2 detection uses the MG-811 sensor to detect carbon dioxide gas in the range of 350 - 10000 ppm with a 5V DC circuit power supply. The MG-811 sensor is suitable for indoor air quality monitoring systems, fermentation process control systems, etc.

2.5 Sensor GP2Y1010AU0F as PM10 Detector

Particulate matter (PM) is a term for solid or liquid particles found in the air. Particles that are large or dark enough can be seen as soot or smoke. Simultaneously, tiny particles can be seen with an electron microscope. The particles come from various sources, both mobile and stationary (diesel trucks, woodstoves, power plants, etc.) (Mufid et al, 2020). The PM sensor used in this system is the Sharp GP2Y1010AU0F sensor. The GP2Y1010AU0F sensor is a dust sensor that utilizes light scattering or the so-called optical sensing system. This sensor is equipped with an LED, and a photodiode arranged diagonally.

2.6 Sensor TGS 2611 as Hydro Carbon (HC) Detector

Hydrocarbon (HC) is a gas that is not significantly detrimental to humans, but it is the cause of the mixed smog. The hydrocarbon emission in the exhaust gas is in the form of unburned gasoline. Hydrocarbons are found in fuel evaporation in the tank, carburetor, and gas leaks through the gaps between the crank cylinders commonly called the last gas. For hydrocarbon gas emission limits in Indonesia, based on the Decree of the State Minister for the environment, a maximum HC threshold of 2000 ppm has been set for 2-wheeled and 3-wheeled vehicles. For 4-wheeled vehicles or more than 4 wheels, the maximum HC threshold is 200 ppm (part per million) (Honeycutt et al, 2019). The HC sensor used in this system is the TGS 2611 sensor from Figaro, which has adequate sensitivity and selectivity to methane gas (CH4). This sensor has a resistance value of Rs, which changes when exposed to methane gas, and has a heater that functions to clean the sensor room from outside air contamination. The TGS 2611 sensor requires a source voltage of 5 volts, which is well regulated. This sensor requires two input voltages, namely heating voltage (VH) and circuit voltage (VC).

2.7 DHT-11 Sensor as Temperature and Humidity Detector

Temperature is an energy that can move from a higher to a lower temperature. Environmental temperature is the level of hot air in a place expressed in degrees Celsius (oC). The highest temperature is usually at 01.00 – 14.00 PM, and the lowest is at 04.00 - 05.00 AM.

Humidity is the water vapor content in the air, measured with a hygrometer in units of %. Air humidity changes inversely with air temperature changes, i.e., when the air is cold, the humidity increases, and when the air is hot, the humidity decreases (Honeycutt et al, 2019). The temperature and humidity sensor used in this system is the DHT-11 sensor because it has a wide measurement range, 0 to 100% for humidity and -40 degrees Celsius to 125 degrees Celsius for temperature. This sensor also has a digital output (single-bus) with high accuracy.

3 RESEARCH METHODOLOGY

This study divided the design into two parts, namely hardware design and software design.

3.1 Hardware Design

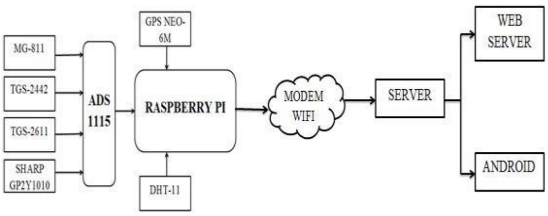

Figure 3: Block Diagram Hardware Systems.

Figure 3, the air quality monitoring system designed using a Raspberry Pi microprocessor equipped with Multisensor Network technology. It consists of several sensors, namely, the Tgs2442 sensor as a CO sensor, the MG811 sensor as a CO2 sensor, the Tgs2611 sensor as a Hydrocarbon sensor, the Sharp GP2Y1010 sensor as a dust sensor, the DHT11 sensor as a temperature and humidity sensor, and the Neo-6M GPS module to detect whereabouts. Each node. The Raspberry Pi can only read the output value in digital form, while each sensor's output value is analogous. An ADC or Analog to Digital Converter module is needed in getting the output value reading, namely ADS1115 as a sensor reading value converter. The Raspberry Pi can process it, which functions as a gateway. The voltage source used in the tool is a 12V battery.

Raspberry Pi acts as a gateway or intermediary to forward data transmission before the database server, which can also be used to store log data. In the Raspberry pi, an interface called Raspbian is installed, which functions as data visualization, and data log storage. The data obtained at the gateway will be forwarded to the server that has been created.

The communication process from the gateway to the database server connects the Raspberry Pi to an available Wi-Fi network, where the SSID and Password have been predetermined. The Raspberry Pi has better network capabilities with a dual-band wireless connection that supports 802.11ac. In this test, the Wi-Fi network uses a Wi-Fi modem as an internet service provider. In this test, sensor nodes will automatically detect air quality levels in a place and send temperature, humidity, and gas content information to the server in real-time while the device is still on. Then the data obtained is entered into a database table that has been prepared. The data is used as a caller to display air quality monitoring data and provide emergency messages about the state of air quality. The air quality conditions are classified into 3, namely, Normal, Moderate, and Hazardous.

The complete series of data reading hardware, data transmission systems, and data storage consists of 3 parts, namely Node 1, Node 2, and Node 3. In general, the overall circuit scheme is shown in the following figure 4.

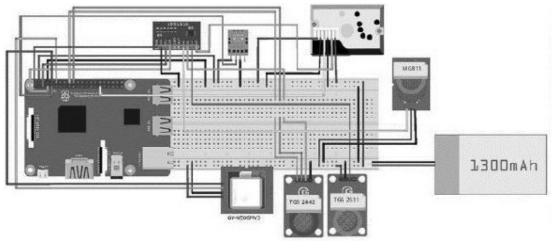

Figure 4: Overall Circuit Design Schematic.

In Figure 4, each Node 1, Node 2, Node 3 has the same circuit scheme and components. The nodes consist of several series, including the TGS-2442 sensor circuit, the TGS-2611 sensor circuit, the MG-811 sensor circuit, the Sharp GP2Y1010 sensor circuit, the DHT-11 sensor circuit, the NEO-6M GPS module series, and the ADC-module series. 1115 as an analog to digital converter.

The TGS-2442 sensor circuit functions to detect and measure levels of CO gas. This sensor produces output in the form of analog data, which is converted into digital data, and calculations are carried out to have output in the format of ppm (parts per million) gas units. The primary sensor circuit consists of Vc (legs 3 and 4) connected to a 5 Volt voltage source on the Raspberry Pi GPIO pin, Vh (legs 1 and 2) connected to the ground. In leg 1, before being connected to the ground, it must first be connected to a resistor (Rl 20K ohm). The sensor output is measured at pin 1 connected to the Analog pin (pin A1) of the ADC and used as input for CO sensor data readings.

MG-811 sensor circuit functions to measure and detect CO2 gas. This sensor produces output in analog data that will later be converted into digital data on the ADC, and calculations are made to produce output in ppm (parts per million) gas units. The MG-811 sensor has 5 pins, namely the VCC, GND, DOUT (Digital Output), AOUT (Analog Output), and TCM (Temp Compensation Output) pins. The VCC pin is given a DC voltage of 5V then the GND pin is connected to the ground pin on the Raspberry Pi. In contrast, the AOUT (Analog Output) pin is connected to the Analog pin (pin A0) ADC (analog to digital converter), which will be used as input for reading CO2 sensor data.

The TGS-2611 sensor circuit functions to measure and detect HC gas. This sensor produces output in analog data that will later be converted into digital data by the ADC (Analog to Digital Converter). The calculation is carried out so that the output is in the form of ppm (parts per million) gas units. The TGS-2611 sensor has 4 pins, including VCC, GND, AOUT (analog output), DOUT (digital output) pins. The VCC pin is given a DC voltage of 5V. Then the GND pin is connected to the Raspberry Pi ground pin. At the same time, the AOUT pin (analog output) is connected to the analog pin (pin A2) of the ADC (analog to digital converter), which is used as input for reading the HC sensor data.

The SHARP GP2Y1010 sensors' series functions to measure and detect dust particulates with an optical sensing system. The LED emits an infrared (IRED) diode, and the photo-transistor is diagonally arranged in this device. This sensor produces output in analog data, which will then be converted into digital data by the ADC (analog to digital converter). The output is PM10 data with the Dust unit (µg / m3). This sensor has 6 pins, namely VCC, V-LED, LED-GND, LED, S-GND, and Vo. The VCC and V-LED pins are combined and given a DC voltage of 5V, then the LED-GND and S-GND pins are also integrated to be connected to the ground pin on the Raspberry Pi. The LED pin is then connected to the GPIO pin 5 Raspberry Pi. The Vo pin is connected to the analog pin (pin A3) of the ADC (analog to digital converter), which will be used to read the PM10 dust particulate sensor data.

DHT-11 sensor circuit functions to measure the temperature and humidity of an environment. This sensor's output data is in digital data where the values of temperature and humidity measurements have units of Celsius (˚C) for temperature and in percent for humidity. This data can be read directly by the Raspberry Pi by connecting it to the GPIO pin on the Raspberry Pi. The DHT-11 sensor has 3 pins, namely the VCC, DATA, and GND (ground) pins. The VCC pin is given a DC voltage of 5V, and then the DATA pin is connected to the GPIO 4 Raspberry Pi pin. The GND pin is connected to the Raspberry Pi's ground pin.

The GPS-NEO 6M sensor functions to provide information in the form of latitude and longitude when the device is on. The GPS-NEO 6M module has 4 pins, including VCC, GND, RX (Receiver), TX (Transmitter). The VCC pin is given a DC voltage of 5V then the GND pin is connected to the ground pin available on the Raspberry Pi. Furthermore, so that the GPS-NEO6M module can communicate with the Raspberry Pi, the RX pin on the module is connected to the TX pin on the Raspberry Pi. The TX pin on the module is connected to the RX pin on the Raspberry Pi so that the GPS-NEO6M module can send coordinate point data in the form of latitude and longitude.

ADS1115 module is a type of ADC with a resolution of 16 bits. It means that ADC has a high level of accuracy in the conversion value than ADC with a little resolution. In this ADC, 4 channels can convert values for 4 sensors at once with bipolar and single differentials. The ADS1115 module has 10 pins, including VCC, GND, SCL, SDA, ADDR, ALRT, and 4 analog pins A0-A3. The VCC pin is given a DC voltage of 3.3V then the GND pin is connected to the ground pin on the Raspberry Pi. The sensor reading data received by the ADS115 will be sent via I2C serial communication by connecting the SDA and SCL pins on the ADS1115 with the SDA and SCL pins on the Raspberry Pi to be processed by Raspberry pi.

The tool in this final project is to put the sensor in the right position so that each sensor can work optimally. The hardware design that will be made is as follows:

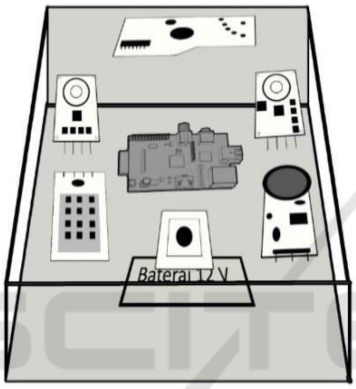

Figure 5: Hardware sensor block design.

(a)

(b)

(c)

Figure 6: (a) Top View Hardware Design (b) Side View Hardware Design (c) Front View Hardware Design.

Figure 6 shows the sensor position in the planned hardware design. This design uses a box made of plastic. This plastic box aims to make the device (hardware) more complex and more comfortable to obtain. The Lippo battery will be arranged alongside the Raspberry Pi in the box. Meanwhile, each sensor will be positioned on the box's surface using a screw to be more robust so that the sensor can read the air quality around it without any obstruction.

3.2 Software Design

The software design will begin with the tool work process starting from the sensors' initialization. Then the sensors will start working on getting air quality data. The data obtained from the sensor readings will be sent to the server to be stored and displayed on the web and Android applications.

3.2.1 Raspberry Pi Configuration

Raspberry Pi uses a Linux operating system called Raspbian. Using the operating system must be flashed first on the SD-card because the Raspberry Pi uses an SD-card as a bootable operating system. After booting for the first time, it is asked to enter ID: pi and Password: raspberry, which is the system's default ID and Password. It can be seen as below,

Figure 7: Login Raspbian.

After logging in, the Raspbian operating system is ready for use, and the command line will appear as follows:

Figure 8: Raspbian Command Line Display.

The Raspberry Pi will be connected to the available internet network and use the SSH protocol to simplify the operation process. It can remote this operating system from other clients who are connected to the same network. After the Raspberry Pi is connected to the internet network, this mini-computer will have a local IP.

It can be entering the command "ifconfig" to find out the local IP, as shown below:

Figure 9: Raspberry Pi's Local IP.

Other clients can remote on this operating system after knowing the Raspberry Pi's local IP using the PuTTY application.

3.2.2 PuTTY Configuration

Ensure the client is connected to the same network as the Raspberry Pi before running the PuTTY application. Next, enter the previously known Raspberry Pi IP address in the Hostname field, then select the SSH type as follows:

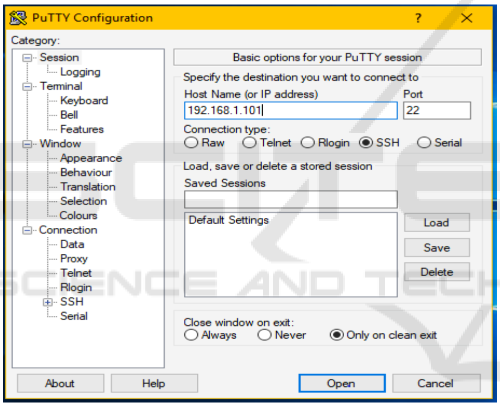

Figure 10: PuTTY Configuration.

If the Host Name is entered and the SSH connection is selected, then clicking the open button and successful, the Raspberry Pi is ready to operate.

4 DESIGN RESULT

4.1 Air Quality Monitoring System Design Results

The system design results are divided into hardware design and monitoring system software. This system is designed using Multisensor Network technology to measure a lot of harmful pollutants. This test's overall system performance will automatically work when the sensor reads the pollutant gas levels and sends the reading data to the server in real-time. Furthermore, the data will be processed to become information that users or the general public can use.

4.1.1 Hardware Design

This air quality monitoring system's hardware is equipped with multi-sensor network technology. This system used the TGS-2442 sensor as a CO (carbon monoxide) gas meter, the TGS-2611 sensor as an HC (hydrocarbon) gas meter, the SHARPGP2Y1010 sensor as a PM10 dust particulate gauge, MG sensor -811 as a CO_2 gas (carbon dioxide) meter, the DHT-11 sensor as a temperature and humidity meter and the Neo-6M GPS module as a provider of information about the coordinates of the points of each node and the ADS-1115 module as an analog to digital converter from sensor readings. The system also equipped with 3 cells 12 volt lithium battery. Raspberry pi 3 module as a microprocessor, and communication between hardware and the server as a database. In the figure below are the results that have been achieved in making hardware :

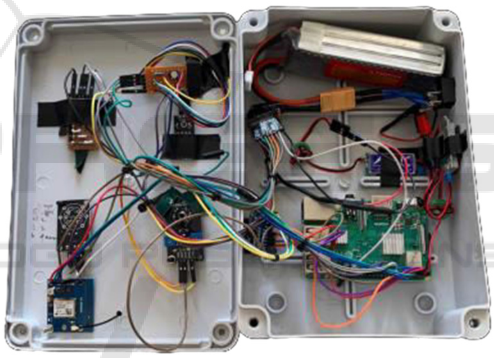

Figure 11: Inside of Hardware Display.

The hardware in this air quality monitoring system is placed in a box to reduce the risk of damage. It continues to work optimally in conditions of the data collection process. It makes it easier to find the location of the tool with location information in latitude and longitude.

4.1.2 Software Design

Air quality monitoring data will be displayed in results from readings of each sensor and information in latitude and longitude. The data obtained from sensor readings are the result of implementing source coding on the hardware, which is displayed as follows:

```python
import sys
import wiringpi
import spidev
from numpy import median
import wiringpi
import Adafruit_DHT
from Fungsi_ads1115 import ads1115
from pm10 import sharpPM10
import time
import math
import Adafruit_ADS1x15
import numpy as np
import matplotlib.pyplot as plt
import requests
import serial
import string
import pynmea2

url = 'https://AdeVpolsri.online/Android/tambahdata.php'



degree_symbol = u"\u00b0"
# print('starting...')
#dht_model = 22
DHT_SENSOR = Adafruit_DHT.DHT11
DHT_PIN = 4
sharp_pin = 21
sharp_channel = 3

tgs2442_channel = 1
circ = 24
heat = 23

def baca_mg811(data_mentah):
    V400 = 0.814
    V40000 = 0.699
    buffer = (V400 - V40000)/(math.log10(400) - math.log10(40000))
    buffer = (data_mentah - V400)/buffer
    buffer = buffer + math.log10(400)
    return pow(10,buffer)

```

Figure 12: Combined Source Coding Hardware.

Figure 12 is the source coding for each sensor. The sensor reading data is sent to the database server using the HTTP post request protocol, which will then be displayed in the monitoring system application that has been provided.

4.2 Test Results

In this tool's testing process, each node is distributed to a predetermined location. The nodes are turned on simultaneously to monitor air quality at the location. It sends the read data to the server to be displayed on the android and webserver interfaces provided in real-time.

4.2.1 Node 1 Air Quality Monitoring Results

Testing for Node 1 was carried out in the KPA parking lot of the State Polytechnic of Sriwijaya. This test is carried out in the morning, afternoon, and evening which is shown as follows:

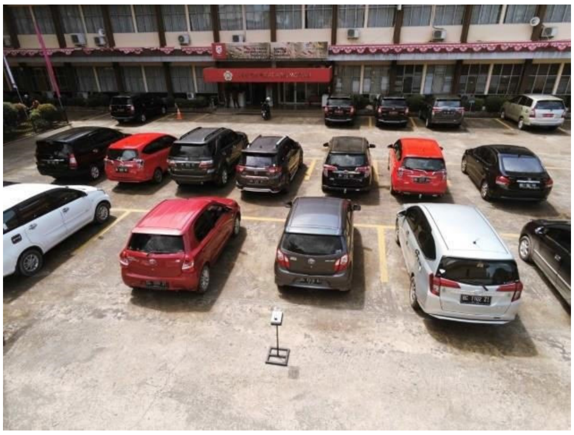

Figure 13: Monitoring Node 1 Location.

The results of the sensor slowly show the decrease in gas levels to normal again with a reading value of 57 ppm of CO, a value of 366-415 ppm of CO_2, and HC value of 275-276 ppm, a value of particulate dust PM10 17-19 µg / m3, a temperature value of 32 - 33ºC and humidity 60% - 64%. This is because the location looks quiet, and there are not many vehicles passing.

4.2.2 Node 2 Air Quality Monitoring Results

Testing for Node 2 was carried out in the Electrical Engineering State Polytechnic Sriwijaya parking lot. This test is carried out in the morning, afternoon, and evening which is shown as follows:

Figure 14: Monitoring Node 2 Location.

Gas levels at the location returned to normal with a CO reading of 44 - 45 ppm, a CO_2 value of 331 - 336 ppm, an HC value of 365 - 370 ppm, a dust particulate value PM10 9 - 15 µg / m3, a temperature value of 32 - 33 ºC and a humidity of 65 % - 66%. This situation is due to the location that looks deserted, and there are not many vehicles passing.

4.2.3 Node 3 Air Quality Monitoring Results

Testing for Node 3 was carried out in the Management Informatics State Polytechnic Sriwijaya parking lot. This test is carried out in the morning, afternoon, and evening which is shown as follows:

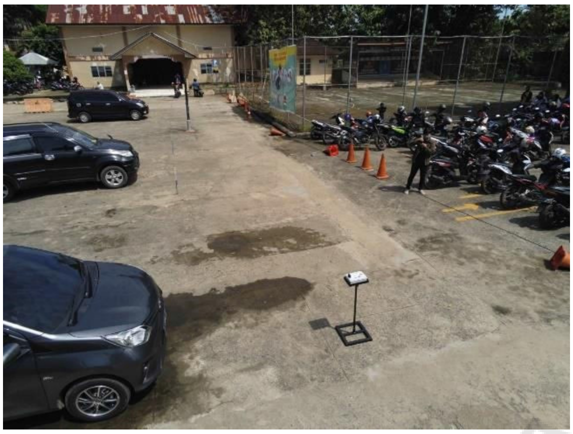

Figure 15: Monitoring Node 3 Location.

Gas levels at the Node 3 location returned to normal with a reading value of CO 52 - 53 ppm, a CO2 value of 298 - 304 ppm, an HC value of 295 - 298 ppm, a dust particulate value PM10 14-15 µg / m3, a temperature value of 32 ºC and humidity 62 %-63%. This condition is due to the location that looks deserted, and there are not many vehicles passing.

4.3 Air Quality Monitoring System Performance Analysis

Overall, the multi-sensor network technology works when the sensor reads pollutant gases' levels in the surrounding environment. In this study, the system automatically detects pollutant gas levels and provides information on each node's location coordinates. The results will then be sent to the server in real-time to be processed to provide air quality information.

The air quality monitoring system has reached 4 parameters in the system testing, i.e., accuracy in reading data, device durability, device integration, and ease of use. This system is integrated with an Android application and a webserver to facilitate the monitoring process. Therefore, it makes public easier to access information about air quality in an area.

The sensor testing results showed that the KPA parking lot air condition at 09.00 AM was still quite normal. This condition caused the lecture system is carrying out online activities due to the Covid-19 pandemic. There was an increase in CO2 gas levels up to 1673 ppm at 12.00 WIB. This condition is caused by an increase of motorized vehicles so that the gas from combustion is detected by the sensor, considering that it is currently a rest time. In the afternoon, which started at 14.00, the measured gas levels looked back to normal because the location was already deserted. There was a change in the value of the gas during the testing process in other gas level measurements, but the difference was not seen significantly and still in normal conditions.

The sensor testing results showed that the air condition at Electrical Engineering parking lot at 09.00 AM was still quite normal. This condition is due to the lecture system is carrying out online activities due to the Covid-19 pandemic. At 12.00 PM, there was an increase in CO2 gas levels up to 647 ppm, but the value of the increase was not as high as KPA parking lot. At 14.00 , the measured gas levels looked back to normal because the location conditions were already deserted. There was a change in the 0gas value during the testing process in other gas level measurements, but the difference was not seen significantly and still in normal conditions. The results of sensor testing showed that the Management Informatics parking lot air condition at 09.00 AM increased CO2 gas with a value of 670 ppm. This condition is caused by chemical engineering students' burning activity while carrying out practical lessons. Furthermore, at 12.00 PM, the air had returned to normal because chemical engineering students' activities had finished. At 14.00 , the measured gas levels still looked normal because the location conditions were already deserted. There was a change in the sensor reading value during the testing process in other gas level measurements. However, the difference was not seen significantly or was still in normal conditions.

5 CONCLUSIONS

Based on the result and discussion from this paper, the air quality monitoring system that has been designed has a good level of accuracy performance in determining the levels of gas measured. Measurement against CO, CO2, HC, PM10, temperature, and humidity is also good resistance. This monitoring system successfully sends an "air quality status" information to the server with an interval of 10-13 seconds. The Raspberry Pi also works well at managing data and sending it to the server in real-time.

Based on the conclusions above, authors recommend developing other sensors such as NO2 sensors, SO2 sensors, and NOx sensors in air quality monitoring systems. More pollutant gas can be measured to increase our awareness of air pollution in the environment.

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