Implementation of Wireless Sensor Network (WSN) to calculate air pollution index of Samarinda City

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Abstract. Environmental pollution is one of the major problems opened by the world today. The main problem of this pollution, is decreasing air quality. This decrease in air quality is caused by many things, from excessive environmental exploitations, industrial activity, energy use, until the exhaust emissions of vehicles all of which trigger into pollution problems. So far Indonesian government has purchased and use the Air Quality Monitoring Base Station to measure different types of air pollutants. However, field statistics data show that the minimum quality of air quality measuring devices in each city is not commensurate with the minimum recommended amount, ideally one base station is used for 200,000 inhabitants. In this research, we developed an integrated Wireless Sensor Network to monitor the concentration of air pollution. Implemented fifteen sensor nodes which each node contains CO and NOx sensors to sensing from the environment. the collected data will be used to calculate the standard air pollution index of samarinda city. The data is stored in server and we can publish for public to access information through a gadget and thing speak server.

1. Introduction
Air pollution is directly proportional to the rate of economic growth. The growing economic life, more people will use high-tech materials that can cause air pollution such as motorbikes and cars. This contributes greatly to reducing air quality which can disrupt comfort, health and global climate balance. Environmental pollution is one of the major problems opened by the world today. The main problem of this pollution, is decreasing air quality. This decrease in air quality is caused by many things, from excessive environmental exploitations, industrial activity, energy use, until the exhaust emissions of vehicles all of which trigger into pollution problems.

Air pollution index (API) is a value that indicates the quality or level of goodness of air according to the properties of its constituent elements. The air pollution index is calculated based on emissions from two air pollutants, namely Carbon Monoxide (CO) and Nitrogen Oxide (NOx). Both types of pollutants are used as components of the air quality index because of their significant influence on human life.

So far the Indonesian government has purchased and used the Air Quality Monitoring Base Station to measure different types of air pollutants. However, field statistics data show that the minimum quantity of air quality measuring devices in each city is not commensurate with the minimum recommended amount, ideally one Base Station is used for 200,000 inhabitants.
Wireless networks are one of the physical digital networking technologies that are now starting to be found in everyday life. Wireless network technology allows electronic devices to be connected to one another through the medium of air (radio waves). In addition to saving space usage, the wireless network model is easy to install and mobility. With the increasing number of users of this wireless network, the need for reliable and stable wireless networks is increasingly needed [1].

Wireless Sensor Networks (WSNs) is a network system of sensor modules wirelessly and can communicate with each other. Data communication at WSS is used to send information about several physical quantities [2].

Sensor data is collected and sent directly to the server and monitoring site. The sensor network is formed from hundreds or thousands of modules, Sensors that are used in areas that are difficult to access directly. Therefore, the sensor node must be able to communicate, process, and store a lot of data. Sensor networks often employ data processing directly in the network itself. Part of the motivation is the potential for large pools of data being generated by the sensors. By utilizing computation close to the source of the data for trending, averaging, maxima and minima, or out-of-range activities, one is able to reduce the communication throughput that would otherwise be needed. Intrinsic to this is the development of localized algorithms that support global goals; it follows that forms of collaborative signal processing are desired [3].

![Figure 1. Wireless Sensor Network [2]](image)

WSN is a wireless ad-hoc multi-hop network which consists wireless sensor node and sink as the main data receiver like figure 1. Environmental information collected by sensor nodes is routed from the ad hoc network to the sink node, where the data can be analyzed and aggregated [4].

In this research, we developed an integrated Wireless Sensor Network to monitor the concentration of air pollution. Implemented fifteen sensor nodes which each node contains CO and NO$_2$ sensors to sensing from the environment. The collected data will be used to calculate the standard air pollution index of Samarinda city. The data is stored in server and we can publish for public to access information through a gadget and website application.

2. Methods
The design system of the research is divided into two, the first is to build gas sensor nodes (CO and NOx), that are integrated with microcontrollers and NRF as transmitter and receiver antennas. Gas sensor for carbon monoxide using MQ 9 gas sensor and Nitrogen dioxide gas using 4-NO2-20 gas
sensor. Whereas for transmitter and receiver antennas using NRF24L01 PA LNA, the word of LNA is an acronym for Low Noise Amplification and it is used to reduce all types of radio noise in the field.

The second is to build the receiver node as a gateway. Receiver nodes are also built and integrated with microcontrollers and NRFs as antennas. Receiver nodes function as coordinators and data collectors from several gas sensor nodes (transmitter nodes), after which the data will be sent to the server. The process of sending data from the receiver to the server using the HTTP (HyperText Transfer Protocol) protocol by ESP8266.

**Figure 2.** Design System

### 2.1. Hardware Design

The hardware design of the transmitter node, the transmitter node consists of the arduino board as a microcontroller, NRF24L01 as a communication module between nodes using radio waves, MQ 9 as a carbon monoxide gas sensor, and 4-NO2-20 as a nitrogen dioxide gas sensor. Gas data from the sensor is sent to the gateway via the NRF module. Operational voltage from the NRF24L01 module is 3.3 V while the MQ 9 sensor and 4-NO2-20 sensor are 5 V

| Arduino | NRF24L01 | MQ 9 | 4-NO2-20 |
|---------|----------|------|----------|
| Vcc 3/3/5 Volt | Vcc 3.3 V | Vcc 5 V | Vcc 5 V |
| GND | GND | GND | GND |
| Pin 2 | IRQ | - | - |
| Pin 9 | CE | - | - |
| Pin 10 | CSN / CS | - | - |
| Pin 11 | MOSI | - | - |
| Pin 12 | MISO | - | - |
| Pin 13 | SCK | - | - |
| A0 | - | A0 | - |
| A1 | - | - | A1 |

The receiver node consists of the arduino board as a microcontroller, NRF24L01 as the receiving antenna, and the esp8266 board that functions as a wifi client so that the collected carbon monoxide and nitrogen dioxide data can be sent and stored on the server. The esp8266 board with Arduino communicates serially via the Transmitter pin (Tx) and the Receiver pin (Rx) so that a level shifter is
needed to change the voltage. The esp8266 board has an operational voltage of 3.3V while the arduino uno has an operational voltage of 5V so that a level shifter is needed to change the voltage level of the arduino which initially is 5V which will be 3.3V.

Table 2. Wiring Node Receiver

| Arduino   | NRF24L01 | ESP8266 |
|-----------|----------|---------|
| Vcc 3.3/5 Volt | Vcc 3.3V | Vcc 3.3V |
| Vcc 3.3V | Vcc 3.3V | CH PD   |
| GND      | GND      | GND     |
| Pin 2    | IRQ      | -       |
| Pin 9    | CE       | -       |
| Pin 10   | CSN/CS   | -       |
| Pin 11   | MOSI     | -       |
| Pin 12   | MISO     | -       |
| Pin 13   | SCK      | -       |
| Tx       | -        | Rx      |
| Rx       | -        | Tx      |

2.2. Software Design

After the hardware design has been successfully built, the next step is to build a programming infrastructure through the use of open source software. In this study the data acquisition system uses the Atmega328P microcontroller developed by Arduino. Programming is done entirely using the Arduino IDE (Integrated Development Environment). This program is open source so that we can easily download and learn.

Figure 3. Arduino IDE Program

For the server used in this study is to use a free server for internet of things that is using the Thingspeak server, by using Thingspeak we can do sensor data management more easily. Thingspeak
is an API-based webserver application and works to store and visualize data from sensors that have been sent. The thingspeak server has the ability to analyze and be able to work with several communication protocols, thingspeak also has features that can make it easier for users to see and analyze, such as graphics and other supporting tools [5].

Flowchart 1. Sensing and Monitoring Gas Sensor Flowchart
3. Results

The results of this research are divided into 2 parts, the first is testing the signal strength of the NRF to distance, because the position of the sensor nodes must be very clear and able to send data to the gateway node. This test is carried out every 1 meter and to the maximum limit of the NRF.

The results of the NRF distance testing result in a logarithmic graph, and means the physical transmission energy is reduced logarithmic if the distance is further away to communicate.

![Graph 1. Range Test of Signal Strength NRF](image1)

In addition to testing the NRF signal strength, this study also tested the Throughput ability of the NRF. Throughput is expressed as the volume of data being sent successfully in unit time. It is a measure of how fast or how slow the network being studied is. Mathematically, throughput can be expressed as:

\[
Throughput = \frac{\text{number of bytes sent}}{\text{total transmission time (sek)}}
\]

![Graph 2. Throughput Data of NRF](image2)
The second result is measuring carbon monoxide and nitrogen dioxide gas through the ThingsPeak server, the output of ThingsPeak visualization is the air pollution index value. Air pollution can be interpreted as the presence of substances or foreign substances in the air that cause changes in the composition (composition) of air from its normal state [6].

To check the functionality of the devices, the following experiments were made. The Air Pollution Index of CO and NO2 were measured for twelve hours.

4. Discussion

A wireless sensor network for air pollution index monitoring was built and successfully tested in real time where data was successfully captured and displayed on a thingspeak server. The captured data is made available to the user through a graphing application programming interface (API). The network works within the range of 200 meters for optimum performance.
In addition, the main problem of this system is the energy resources of several nodes that are deployed, the energy consumption used is very large so that the battery power used is not enough to cover this system.

5. Conclusions
The conclusion of this research are:
- A wireless sensor network for air pollution index monitoring was built and successfully tested in real time where data was successfully captured and displayed on a thingspeak server.
- Air pollution index can be calculated directly from the arduino program that is used so it no longer needs to be calculated manually
- The energy for the sensor node is rapidly exhausted

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