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A Design and performance analysis of a telemetry system for remote monitoring of turbidity of water during the COVID-19 pandemic

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ABSTRACT

A turbidity telemetry system for COVID-19 pandemic situations using nRF24L01+transceiver and SEN0189 water turbidity sensor-based microcontroller has been successfuly developed.. The method used to characterize the sensor is by comparing sensor output voltages with the value of water turbidity. Turbid water used was created by adding distilled water with a concentration of sediment obtained from the filtered sediment with less than 60 µm in diameter. Data transmission performance for various transmit power was done by calculating the error percentages by comparing the number of messages sent by transmitter and received by receiver. The transmit power settings were 0, -6, -12, and 18 dBm and variations in the distance of data transmission from 10 to 80 m. The test results show that the water turbidity sensor has a good measurement range in measuring turbidity of water from 1.873 to 3500 NTU. Higher concentrations of sediment and turbidity of the water made the sensor output voltage decrease. There was a decrease in output voltage in the value, namely -0.0006 in turbidity sensor sensitivity. The results also show an increase in error percentages as the distance of data transmission increases, while the bigger the transmit power is used for data transmission, the smaller the percentage of errors occurs.

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1. INTRODUCTION

A Telemetry system is a method or process of measuring physical quantities over long distances and the measurement results can be moved to another place through the process of sending data using a cable or without using a cable (wireless) (Akyildiz *et al.*, 2002). Thus, this device is very suitable to be used during the COVID-19 pandemic. In a remote scoring system, sending data without using cables is more beneficial because the assessment will be wider, can be accessed from several points apart from where the measurements are made (D'Amico *et al.*, 2002).

Researches on telemetry systems can be applied to various measurements, among others, is the measurement of water quality, especially in water turbidity. Research on the telemetry system has been carried out using various communication modules to obtain the best performance. Hasanah *et al.* (2018) conducted a research simulation by shortening the path using the Decision-Tree-Based Multi-Hop Routing system and using the Dijkstra algorithm to save energy used by communication module devices to send and receive data. Meanwhile, Pule *et al.* (2017) undertook research by studying and analyzing various water quality monitoring methods that use telemetry systems based on Wireless Sensor Network (WSN) taking into account the measurement range, energy consumption used and security systems used as the main problems studied.

Water turbidity is a reduction in transparency of fluids caused by the presence of non-dissolved material such as suspensions due to inorganic material such as sediments or organic matter such as small organisms in the liquid (Davies-Colley & Smith, 2001). Based on the standard procedure for operation and maintenance of water treatment plant package units in 2008, measurements of water turbidity were carried out by using sampling schedules from turbid water and manual recording by each worker who was on guard at each scheduled time (Yogi, 2020). These measurement techniques can cause problems because water turbidity data cannot be identified at any time and at several different points. Measurement of water turbidity can be applied using a telemetry system so that the reading of data can be accessed from several points apart from where the measurements will be made. Research that has been carried out on remote measurement using a telemetry system has one advantage, namely measurement and reading of data can be done automatically and reduce human involvement in detecting water turbidity. The advantages of the telemetry system are also not spared from deficiencies that must be considered in building a telemetry system so that the system can run properly. One factor that must be considered is the disturbance in data transmission by the transmitter (data sending device) towards the receiver (data receiving device) (Haq & Zainuddin, 2017). In this study, a turbidity telemetry system has been built using the SEN0189 water turbidity sensor as a detector used to detect turbidity of water. The turbidity of water detected is a type of turbidity caused by suspended sediments. The sensor is controlled to measure turbidity of water by an Arduino microcontroller. After water turbidity data have been obtained, the data are sent to the receiver (receiving device) so that the data can be displayed in a LCD panel. The module used for communication between the transmitter (sending device) to the receiving device uses the nRF24l01+PA+LNA transceiver module. By making the telemetry system for measuring turbidity of water, the measurement of turbidity of water can be done at several points and can reduce the need of human workers as has been done using conventional methods. The problem of measuring turbidity of water can be solved in an effective inspection system

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by using digital technology for data acquisition in real time, so that several important factors regarding water conditions can be easily analyzed so that water quality maintenance can be carried out and far from many human interventions because the entire the measurement and data storage system has been carried out by the entire turbidity monitoring system (Amruta & Satish, 2013).

2. MATERIALS AND METHODS

2.1. Background

Isotropic antenna is known as the isotropic radiator which is a theoretical point source of electromagnetic waves or flares that emit the same intensity of radiation in all directions and do not have a certain direction of radiation in the sphere coordinate centralized at the source. An isotropic radiator is used as a reference radiator compared to other antenna sources. When an antenna sends information to another antenna as a receiver it will produce a transmit power or it can be called a power density. In an isotropic radiator system power density can be explained using the following equation (Rahmatullah, 2017).

$$P_{Di} = \frac{P_S}{4\pi d^2} \quad (1)$$

From equation (1), it can be known that P_{Di}, which is the antenna transmit power, has a relationship with P_S (the input power on an isotropic radiator) and d (the distance). This equation is illustrated using **Figure 1**. If the source of power input on an isotropic radiator has a constant value, the transmit power of the antenna can be affected by the distance between the sending antenna and the receiving antenna. The farther the distance used to send the data packet, the smaller the transmit power of the antenna.

Interference in data communication is a disturbance which will result in the loss of data packets sent through the sending device to the receiving device. The loss of the data package is the percentage of the number of data packets lost in a network caused by the obstruction of the data at the time of delivery.

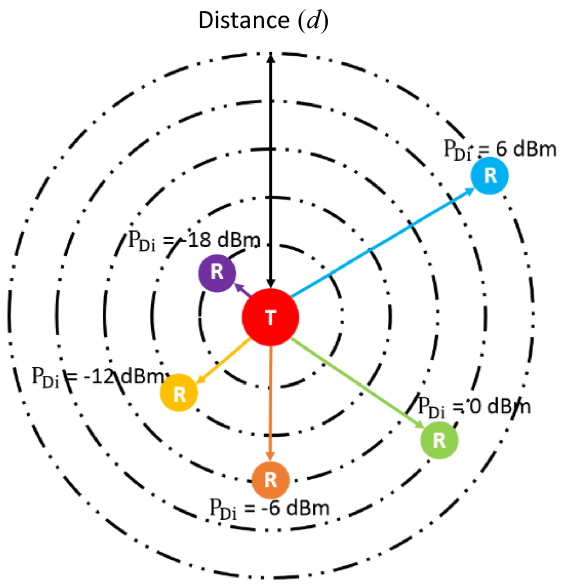

Figure 1. Illustration of the relationship between the transmit power of the antenna and the distance between the transmitter and receiver.

To find out how much data is lost, equation (2) is used to compute the percentage of errors in data communication by comparing the exact value, namely the number of messages sent by the transmitter device, with an uncertain value, namely the number of messages received by the receiving device.

$$\text{Error}\ (\%) = \left(\frac{\text{data sent} - \text{data received}}{\text{data sent}}\right) \times 100(\%) \quad (2)$$

2.2. Material.

In this study, the telemetry system hardware for measuring turbidity of the water is developed using electronic hardware and materials as shown in **Table 1**.

In addition to hardware components, software for data acquisition, storage, and logging is required. The software used is the Parallax Data Acquisition tool (PLX-DAQ). This software is integrated with Microsoft Excel and can be connected to the microcontroller so that by microcontroller program, data obtained from the sensor can be stored directly to Microsoft Excel. The software also supports real-time data retrieval and plotting.

2.3. Methods

This study was conducted using descriptive method and experimental methods. The descriptive method includes studying literature to find references of measurements using turbidity water sensors and learn about digital communication along with the physics concepts that occur in sensors and digital communications. The experimental method was used to design and make a water turbidity telemetry system which begins with the design and manufacture of hardware and software, water turbidity sample preparation, testing of the characteristics of the turbidity water sensor SEN0189, and testing of transmit power on the telemetry system.

2.4. Design of Data Sending System

The data sender system is designed using an Arduino nano microcontroller as a command processor. In the data sender circuit there is a sensor SEN0189 which will detect the turbidity value of water and the value can be directly sent using the nRF24L01 + transceiver module. There are two senders of water turbidity data with a similar design as shown in **Figure 2**, a significant difference is in the program, namely in addressing data. During the process of testing data transmission, turbidity data that are sent will be stored in Microsoft Excel using the PLX-DAQ application so that data processing can be done in real time. Configuration of electronic component pins is shown in **Table 2**.

The software design is done by making a flow chart in the form of steps to program the turbidity data delivery system. The programming flow chart is shown in **Figure 3**.

Data receiver systems are designed using Arduino Uno microcontrollers as program processors that have been designed in software. When the data sender has sent measurement data to the data receiver systems, the receiver system will classify the data based on the address that is owned by the data that come. The data will be displayed in an LCD screen to display the

Table 1. Hardware tools and materials

Electronic Components	Specification	Amount
Arduino nano	ATmega328P	2 pieces
Arduino uno	ATmega328P	1 piece
Water turbidity sensor module	SEN0189	2 pieces
Transceiver module nrf24l01+	2,4 GHz	3 pieces
LCD I2C Module		1 piece
DC to DC Step Down Module	LM2596	2 pieces
Power supply switching module	12 V – 3 A	2 pieces
nRF24L01+ Adapter		3 pieces

value of water turbidity detected by the data sender system. The LCD display will contain two turbidity data that are detected by two sensors that allow an observer to be able to read two data obtained simultaneously. In the testing phase, the transmit power of the transceiver module nRF24L01+ to LCD screen is not used because the data will be stored directly into Microsoft Excel using the PLX-DAQ application so that data processing can be done in real time.

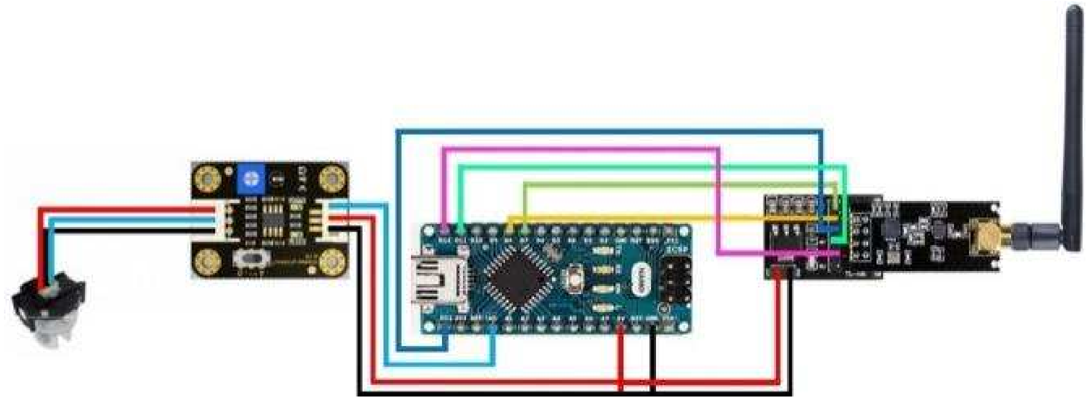

Figure 2. Schematic series of water turbidity data transmitter

Table 2. Configuration of electronic component pins with microcontroller for the transmitter

Component	Pin component	Pin Arduino Nano	Component	Pin component	Pin Arduino Nano
Turbidity Water Sensor	VCC	5V	nRF24L0+	CE	D7
(SEN0189)	GND	GND	PA+LNA	CSN	D8
	Output	A0		MOSI	D11
nRF24L01+	VCC	5V		MISO	D12
PA+LNA	GND	GND		SCK	D13

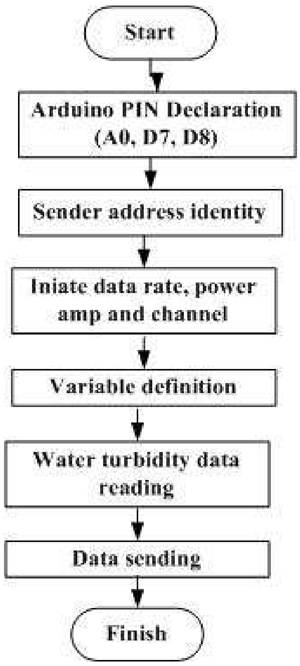

Figure 3. Flow chart for turbidity data transmitter

Table 3 shows the pin configuration of each component from the results of hardware design in **Figure 4**. After designing the hardware, it is time to proceed with designing software for data receiving systems. Software design is done by making a flow diagram in the form of programming steps for receiving turbidity water data. The programming flow chart is shown in **Figure 5**

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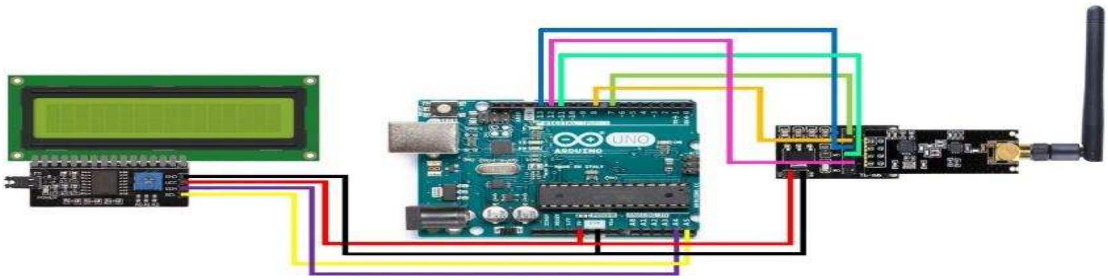

Figure 4. Schematic receiver for turbidity data

Table 3. Configuration of electronic component pins with microcontroller for the receiver

Electronic Components	Specification	Amount
Arduino nano	ATmega328P	2 pieces
Arduino uno	ATmega328P	1 piece
Water turbidity sensor module	SEN0189	2 pieces
Transceiver module nrf24l01+	2,4 GHz	3 pieces
LCD I2C Module		1 piece
DC to DC Step Down Module	LM2596	2 pieces
Power supply switching module	12 V – 3 A	2 pieces
nRF24L01+ Adapter		3 pieces

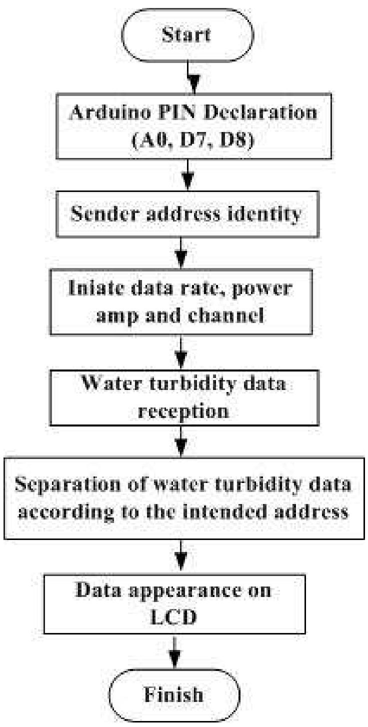

Figure 5. Flow chart for turbidity data receiver

3. RESULTS AND DISCUSSION

After testing the frequency at the point of sending and receiving data, the process of testing the transmit power can be done because a channel that can be used well for communication between the sending and receiving devices of the data is known. The testing process was done by comparing the number of messages sent through data sending devices with data receiving devices for varying distances *d* communication paths between devices. Measurements were done 5 times with 1 min interval so that messages were received by the recipient of the data in 5-min duration. The test was carried out by using a variation of the amplitude of the transmit power that can be used, namely the amplification of transmit power P_{Di} of 0, -6, -12, and -18 dBm. Comparison results of data in the form of the number of messages sent and the number of messages received on each transmit power are shown in **Tables 4-7**.

From **Table 4**, it can be seen that when data communication was carried out using transmit power P_{Di} of -18 dBm, it has a bad error percentage because the reception of data sent is not perfect even from a distance *d* of 10 m. The error percentage increases as the distance increases.

In **Table 5**, data communication was carried out using the transmission power of -12 dBm. From the test results, the error percentage is better than when using lower transmit power. The biggest percentage of errors obtained when using transmit power P_{Di} of -12 dBm is 48.17% at measurement distance 80 m. It indicates a lower error percentage value compared to when using the transmit power of -18 dBm, which has an 81.67% error percentage at similar distances as shown in **Table 4**.

Table 6 shows the test results of sending data using transmit power P_{Di} of -6 dBm. The results show that the error percentage is 0% for 10-30 mof distance (*d*). This is better than when using transmit power P_{Di} of -12 dBm where 0% error percentage only occurs when data transmission is carried out at a distance of only 10 m.

The test results in **Table 7** are shown to be better than those of testing using transmit power P_{Di} of -18, -12, and -6 dBm, indicated by the lowest percentage error of all previous measurement. It can also be seen that 0% error percentage is achieved at distances up to 40 m.

Table 4. The results of the data delivery performance test on the distance of data reception with a transmit power of -18 dBm

Distance (*d*) (m)	Number of data packets sent in 5 min	The number of data packets received in 5 min	Error percentage (%)
10	600	591	1.50
20	600	587	2.17
30	600	549	8.50
40	600	454	24.33
50	600	321	46.50
60	600	251	58.17
70	600	280	53.33
80	600	110	81.67

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From all the test results, it can be seen that the transmit power of the nRF24L01 + transceiver module is better for the performance of sending and receiving data using maximum transmit power of 0 dBm if the distance for sending data to the receiver is less than 80 m. The increase in the error is caused by attenuation events that decrease the transmit power when the distance between sender and receiver increases. The transmit power used will affect the good reception of the data because according to the equation (1), where $P_{Di} \sim 1/d^2$, the transmit antenna power P_{Di} is inversely proportional to the square of distance as d^2.

Table 5. Data delivery performance test on the distance of data reception with a transmit power of -12 dBm.

Distance (*d*) (m)	Number of data packets sent in 5 min	The number of data packets received in 5 min	Error percentage (%)
10	600	600	0
20	600	598	0.33
30	600	593	1.17
40	600	590	1.67
50	600	588	2
60	600	440	26.67
70	600	340	43.33
80	600	311	48.17

Table 6. The results of the data delivery performance test on the distance of data reception with a transmit power of -6 dBm

Distance (*d*) (m)	Number of data packets sent in 5 min	The number of data packets received in 5 min	Error percentage (%)
10	600	600	0
20	600	600	0
30	600	600	0
40	600	597	0.50
50	600	589	1.83
60	600	543	9.50
70	600	542	9.67
80	600	404	32.67

Table 7. The results of the data delivery performance test on the distance of data reception with a transmit power of 0 dBm.

Distance (d) (m)	Number of data packets sent in 5 min	The number of data packets received in 5 min	Error percentage (%)
10	600	600	0
20	600	600	0
30	600	600	0
40	600	600	0
50	600	598	0.33
60	600	597	0.50
70	600	596	0.67
80	600	566	5.67

4. CONCLUSION

The data transmission performance of telemetry system for measuring water turbidity show that higher error percentages occur when the distance between the sender and the receiver gets farther away. This is caused by attenuation where the value of antenna transmit power is inversely proportional to the square of the distance of data transmission. After testing the transmit power of the transceiver module nRF24L01+, the results show that the transmit power of 0 dBm is better than the transmit power of -6, -12, and -18 dBm. This is because the error percentage in testing data transmission for various distance *d* is smaller at 0 dBm than the other variation of transmit power.

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6. AUTHORS' NOTE

The author(s) declare(s) that there is no conflict of interest regarding the publication of this article. The authors confirm that the data and the paper are free of plagiarism.

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