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LoRa and IoT-based Heart Rate and Temperature Monitoring Tool Using MQTT Protocol

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ABSTRACT

Heart rate is one of the most important organs in the human body as it plays a role in the circulatory system. Body temperature is the result of the body's metabolic processes and is influenced by external and internal factors. In this research, we design a monitoring tool that uses LoRa and IoT technology to monitor heart rate and human body temperature. This tool aims to provide real-time health monitoring and can communicate remotely. MQTT allows efficient data transmission between connected devices in the network. Pulse heart rate sensor and temperature sensor MLX90614 The data obtained from these two sensors is sent through the LoRa network to the LoRa gateway. The LoRa gateway functions as a link between the monitoring device and the MQTT server. The gateway receives data from the monitoring device via the LoRa network and forwards it to the MQTT server via an internet connection. The MQTT server sends the data to an application that can be accessed via a smartphone. The test results show that the RSSI value of -72.5 dBm is obtained when the minimum distance is 5 metres. The lowest value for RSSI, which is -93.5 dBm, is obtained at the maximum testing distance of about 55 metres. For the results of the packet loss value is 0% occurs at a closer distance, but at a distance of 50m (5%) and at a distance of 55m (20%) indicates that the signal begins to weaken or experience interference at a greater distance.

1. INTRODUCTION

Technology in the health sector has progressed rapidly in line with the development of science and technology in general. There are a number of factors that influence the development of health technology, such as increased demand for effective and efficient treatment, as well as increased research and development of IoT (Internet of Things) based technology for monitoring and controlling human health conditions [1]. IoT (Internet of

Things) is a concept that describes the connection between electronic devices or machines connected to the internet network and able to communicate and share data [2].

The heart is an organ that has a vital role in the human body. In the context of health, a person's heart rate is also a very important factor [3]. Heart rate monitoring devices use the unit of measurement beats per minute (BPM), which refers to the number of heartbeats in one minute. Standard heart rate measurements in adults range from 60 to 100 bpm [4]. The heart is one of the most important organs in the human body, which plays a role in the human circulatory system [5].

Human body temperature is the temperature measured inside the human body or -on the surface of the skin, which can provide information about the internal temperature of the body. Normal human body temperature is between 35.5oC to 37oC under normal conditions. Human body temperature is the temperature measured inside the human body or on the surface of the skin, which can provide information about the internal temperature of the body [6]. However, a person's body temperature may vary within acceptable limits depending on the time of day, physical activity and ambient temperature. If the body temperature rises above 38oC, it indicates an infection or other illness and is called a fever. At the same time, a person's low body temperature below 34oC may indicate hypothermia[7].

Body temperature and heart rate are one of the important factors in determining the right treatment steps in a hospital environment. In reality, monitoring the temperature and heart rate of patients in this hospital can only be seen from their respective rooms [8]. However, the diagnosis process related to the patient's health condition takes a long time [9]. This is because to know the patient's condition in real-time, the nurse must visit the patient's room directly. However, this approach has the potential to cause delays in obtaining information about the patient's emergency condition [10]. Therefore, a device is needed that can provide real-time patient physical condition information to nurses without the need to visit the patient's room directly [11].

Several studies have been conducted in designing a telemedicine device system that allows nurses to monitor patient conditions in real-time. In previous research conducted by [12] which has discussed a heart rate monitoring system using NodeMCU and MQTT. In addition, research conducted by [13] discusses the LoRa-based heart rate monitoring system. Furthermore, in research conducted by [14], a heart disease detection device has been designed using the IoT (Internet of Things) based Fuzzy Logic Algorithm technique.

In this study, researchers designed a telemedicine device system that uses pulse heart rate sensor, mlx90614 temperature sensor, arduino nano, LoRa, NodeMCU ESP 8266, LCD, and Buzzer. This system allows patient monitoring through the LoRa communication module. The advantage of this system is that sensor devices connected in the hospital do not need to always be connected to the internet because they can communicate locally through the LoRa network. For data transmission through the server, the system uses the

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MQTT protocol, the selection of the MQTT protocol allows more efficient data transmission between connected devices in the network.

2. RESEARCH METHOD

This research was conducted through a series of implementation stages, starting from component selection and hardware design, device assembly, overall device design, to testing the designed device. The framework of this research is illustrated in Figure 1.

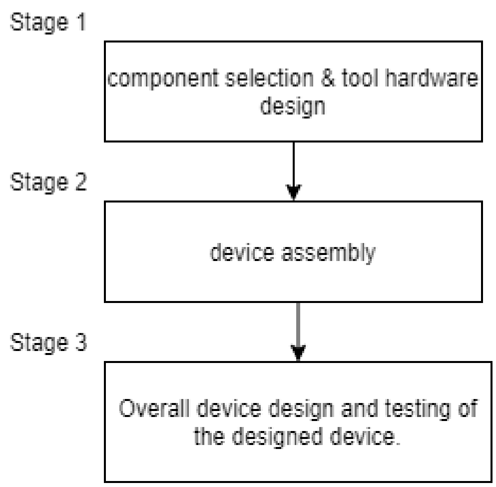

Figure 1 Overall Research Stages

2.1 Hardware Design

At this stage, hardware design is carried out for LoRa and IoT-based human heart rate and body temperature monitoring tools using the Message Queuing Telemetry Transport (MQTT) protocol. In the Hardware Design process, components are needed to create a monitoring device.

2.1.1 Long Range (LoRa)

LoRa (Long Range) is a wireless technology specifically designed for Internet of Things (IoT) applications with long range and low power consumption. LoRa is a process that converts periodic waves into signals that carry information. The frequency range used by LoRa is in the range of 300 - 3000 MHz, known as UHF (Ultra High Frequency). The frequency values used by LoRa may vary depending on the geographical area. For example, in Asia the frequency used is 433 MHz, in Europe the frequency used is 868 MHz, and in North America the frequency used is 915 MHz [15].

2.1.2 Sensor Heart Rate

Pulse Sensor Heart Rate is a sensor used to non-invasively measure human heart rate. The heart rate sensor, functions to detect the pulse rate through the use of a fingertip or wrist. The pulse data collected by the sensor will be connected to the programme running

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on the Arduino Nano microcontroller, to calculate the heart rate value in units of Beats Per Minute (BPM) [16].

2.1.3 Sensor MLX90614

The MLX90614 sensor is a non-contact temperature sensor that uses infrared technology to measure the temperature of an object without having to make physical contact with the object. It uses an infrared sensor to detect the infrared radiation emitted by the object and convert it into an electrical signal. This signal is then processed by the sensor to produce an accurate temperature value [17].

2.1.4 Arduino Nano

Arduino Nano is a microcontroller development board that has a small size, complete with all the necessary components, and supports the use of breadboards. It uses an Atmega328 or Atmega168 microcontroller. One difference is that the Arduino Nano does not come with a Barrel Jack-type DC connector, and instead uses a USB Mini-B connection to connect to a computer. The Arduino Nano is designed and manufactured by a company called Gravitech [18].

2.2 Device Assembly

At this stage, after collecting all the components needed for the device, the assembly process is carried out to assemble the components into a heart rate and body temperature monitoring device.

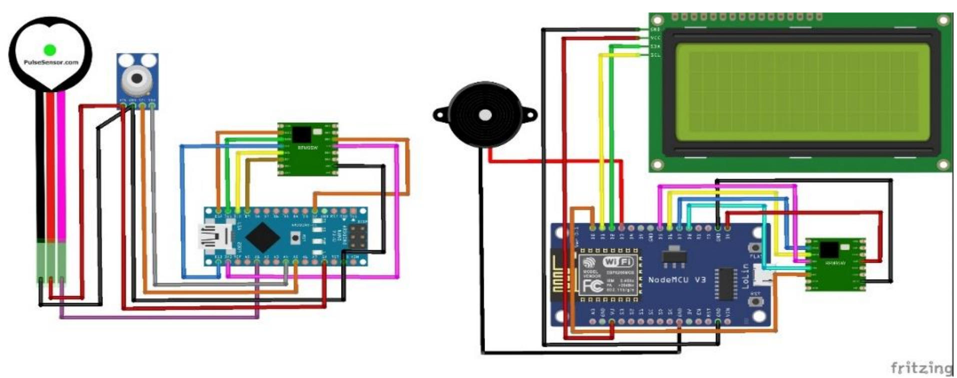

Figure 2 Overall circuit schematic

Figure 2 shows the overall circuit scheme that has been planned using various hardware components. These components include various types of sensors, Heart rate sensor (heart rate), serves to take readings in units of BPM (Bit Per Minute). MLX90614 temperature sensor functions to read the temperature value. Arduino Nano functions to process the reading data from the sensor so that the reading data can be sent via LoRa. The LoRa module acts as a transmitter that sends sensor data to the gateway. The LoRa gateway functions as

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a receiver, while the ESP8266 module is used to forward the data received by LoRa and send it to the server to be published. The LCD is used as a local display to show the readings, while the buzzer serves as an indicator in case of abnormal conditions, such as too high a temperature or a significant increase in heart rate.

2.3 Overall Device Design

After completing the device assembly process, the next step is to proceed with designing the device. The device will be designed to be fingertip- or wrist-mounted with a complex size, aiming to increase the efficiency and effectiveness of its use.

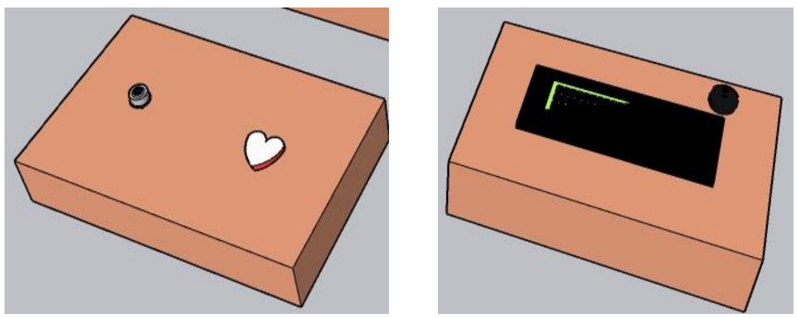
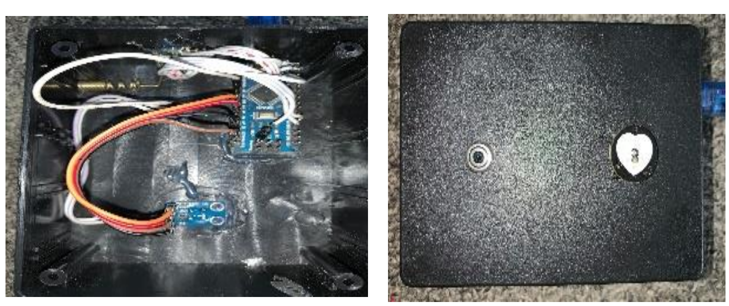


Figure 3 Device Design

Figure 3 shows the sensor placement in the design The design uses a plastic box. The use of the box aims to provide complexity and order to the hardware, and the box is easy to obtain. In the box, the Arduino Nano node and LoRa module will be placed inside for security, while the heart rate sensor and MLX90614 sensor will be placed on the surface of the box. For the ESP8266 NodeMCU Gateway box, the LoRa module, and buzzer will be placed inside the box for security, while the Liquid Crystal Display (LCD) will be placed on the surface of the box. and can be seen the overall device design in Figure 4.



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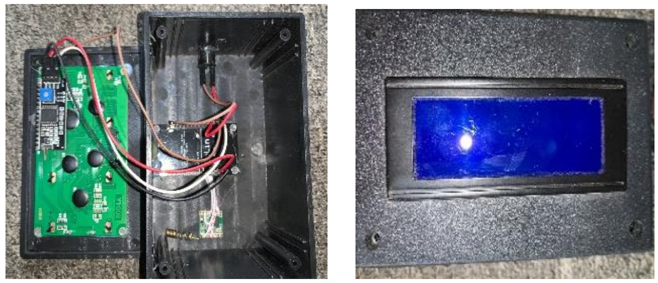

Figure 4 hardware results that have been designed

3. RESULTS AND DISCUSSION

3.1. Hardware Testing Results

Figure 5 Comparison of Standard Tools and Result Tools

In this stage, researchers test the hardware and software that has been integrated and connected as a whole. In this test, the hardware is connected to a computer that has been installed with Arduino software. This research was conducted on the 2nd floor area (two) in the classroom of the Electrical Engineering Lecture Building at the Sriwijaya State Polytechnic Campus starting with a distance of 5 metres. The purpose of this research is to test the range of LoRa and find out at what distance to produce the maximum range of LoRa. The parameters tested in this research are RSSI, Packet Loss, and Delay. As for what you want to test, namely the results of testing the tool.

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Figure 6 Hardware Testing

RSSI testing is a way to measure signal strength. The greater the distance between the transmitting devices, the weaker the received signal will be, which in turn can cause delays in data transmission. This signal strength measurement usually uses dBm (decibel milliwatt) units. The following are the Received Signal Strength Indicator (RSSI) test results:

Table 1 RSSI Testing Results

Distance (m)	Min	Max	RSSI Average Value (dBm)
5 meter	-77	-68	-72,5
10 meter	-80	-68	-74
15 meter	-76	-73	-74,5
20 meter	-80	-77	-78,5
25 meter	-83	-73	-78
30 meter	-84	-77	-80,5
35 meter	-85	-78	-81,5
40 meter	-88	-76	-82
45 meter	-88	-86	-87
50 meter	-95	-85	-90
55 meter	-97	-90	-93,5

Based on Table 1, it can be concluded that the Received Signal Strength Indicator (RSSI) value is in the range of -72.5 dBm to -93.5 dBm. The test results show that the highest value for RSSI of -72.5 dBm is obtained when the minimum distance is 5 metres. Meanwhile, the lowest value for RSSI, which is -93.5 dBm, is obtained when the maximum test distance is about 55 metres. The graph of RSSI test results can be seen in Figure 2.4.

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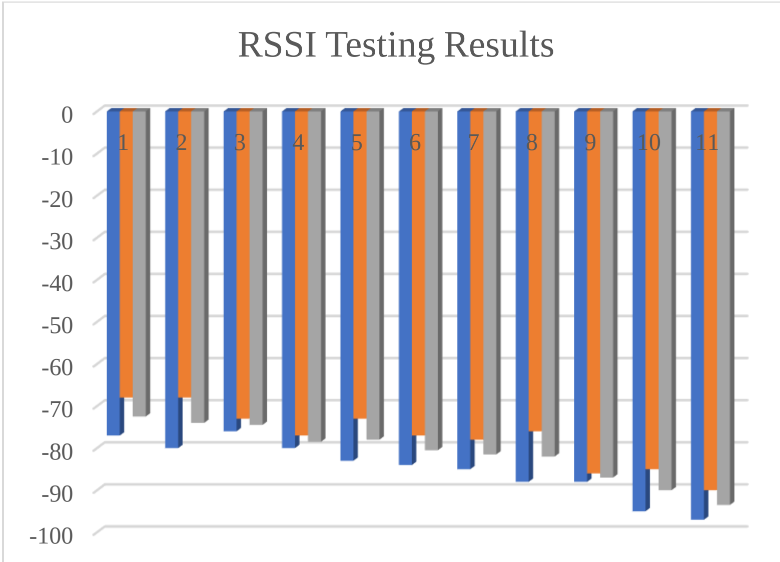

Figure 7 RSSI Testing Results

Packet Loss testing is a method for measuring the percentage of data packets that are lost or do not successfully reach their destination when communicating over a network. This test is used to observe the quality of the communication link by calculating the number of data packets that do not successfully reach their destination during the packet transmission process.

Table 2 Packet Loss Testing Results

No	Distance (m)	Average Packet Loss Value (%)
1	5 meter	0%
2	10 meter	0%
3	15 meter	0%
4	20 meter	0%
5	25 meter	0%
6	30 meter	0%
7	35 meter	0%
8	40 meter	0%
9	45 meter	0%
10	50 meter	5%
11	55 meter	15%

Based on the calculation, test data, it can be concluded that the test distance greatly affects the measurement results. The further the measurement distance, the higher the packet loss value generated. It can be seen that a low packet loss rate or 0% occurs at closer distances, indicating excellent communication quality. However, packet loss starts to appear at a distance of 50 metres (5%) and increases at a distance of 55 metres (15%), indicating that the signal starts to weaken or experience interference at longer distances.

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The result of delay testing is a measurement of the time or duration required by the programme or part of the programme to delay execution for a certain period of time. Delay test results can be expressed in certain time units, such as seconds or milliseconds (ms).

Table 3 Delay Testing Results

No	Jarak (m)	Average Delay Value (ms)
1	5 meter	202,4
2	10 meter	265,6
3	15 meter	318,2
4	20 meter	306
5	25 meter	283,6
6	30 meter	296,8
7	35 meter	306,4
8	40 meter	341,6
9	45 meter	390,4
10	50 meter	398,6
11	55 meter	431,8

Table 3 shows the results of delay testing at various distances. The test results show the average value of delay in milliseconds (ms) when communicating or transmitting data at certain distances. At a distance of 5 metres, the average value of delay is 202.4 ms, while at a distance of 55 metres, the average value of delay increases to 431.8 ms. This indicates that when the communication distance increases from 5 metres to 55 metres, the delay time increases by 229.4 ms.

Table 4 Tool Comparison Test Results

No	Name	Results Standardised tools		Tool Design Results	
		Heart Rate (bpm)	Body Temperature (^{o}C)	*Heart Rate* (bpm)	Body Temperature (^{o}C)
1	Ajik	82	36,7	80	37,51
2	Salsa	78	36,6	79	37,23
3	Tamara	87	36,6	88	36,75
4	qila	87	36,7	83	36,51
5	ulin	85	36,5	80	37,43

In table 4 data testing is carried out referring to the reading results of each sensor used consisting of pulse heart rate sensors and MLX90614 sensors. For oximeter sensor readings and heart rate sensors, the reading results on the device compared to standard oximeter measuring instruments produce relatively accurate readings with a difference in values ranging from 0-6 numbers. MLX90614 sensor testing gets readings in the form of measurement results of the patient's body temperature reading value with a reading range from 36 to 37 degrees centigrade.

3.2. Discussion

Overall, this study shows that the designed device is an effective human health monitoring tool that can be used in a variety of situations, including in a hospital environment. It has important benefits in healthcare endeavours and early detection of medical conditions that require further intervention. [19]. It is expected that the designed device can be an effective and valuable solution in healthcare, especially for early detection of medical conditions related to heart rate. The success of this research can be a foothold for further development in the field of LoRa and IoT-based health with the application of the MQTT protocol.

Previous research conducted by [12] which has discussed heart rate monitoring systems using NodeMCU and MQTT, the results of system functionality testing can be successfully carried out and the results of heart rate reading testing produce a percentage error of 2.6%. In testing sending heart rate data to the Thingspeak channel, sending SMS alerts, and replying to sms with the latest heart rate value can be done successfully.

In the design of heart rate and temperature monitoring devices, the system has been tested and runs well, in accordance with the results of the design that has been done. In the trial, there were 5 samples used to check heart rate and temperature through the tool. The test results show that there is a percentage error of 1.13% for heart rate and -0.27% for temperature. All data is directly sent in real-time to the web and application through the available internet network connection.

4. CONCLUSION

This research tests the aspects of RSSI, Packet Loss, and Delay on LoRa and IoT-based heart rate and body temperature monitoring tools using the MQTT Protocol. This test produces RSSI data from -72.5 to -93.5, Packet Loss 0% to 20%, and Delay ranging from 202.4 to 431.8. The findings were compared with a standardised tool using data from the heart rate sensor pulse sensor and the MLX90614 sensor. Testing of the oximeter sensor and heart rate sensor showed that the device provided relatively accurate readings with a difference of 0-6 numbers compared to the standard oximeter measuring instrument. The MLX90614 sensor successfully measured the patient's body temperature with a reading range between 36 to 37 degrees Celsius. Overall, the device was successfully implemented and has the potential to improve real-time patient health monitoring through LoRa and IoT technology.

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