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Prototype of Body Temperature and Oxygen Saturation Monitoring System Using DS18B20 and MAX30100 Sensors based on IOT

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Abstract

After people died from infections during COVID-19 epidemic, this attracted a lot of attention. COVID-19 causes symptoms such as fever, headache, sore throat, shortness of breath, and others. Many deaths are asymptomatic, which it makes the problem even bigger. Therefore, real-time system monitoring is needed. Monitoring will be carried out about measuring body temperature and oxygen saturation in patients. Monitoring body temperature is necessary because it can detect symptoms of COVID-19 in patients earlier. Concept of Internet of Things (IoT) is to enable devices to send and receive data over internet network. Monitoring system to be built uses NodeMCU ESP8266, DS18B20 sensor, and MAX30100 sensor. Data communication is used in exchange of information using WiFi. Applications made using MIT App Inventor are used to view body temperature and oxygen saturation data. This system is expected to reduce number of deaths due to COVID-19. DS18B20 sensor has a sensor accuracy of 99,73% and an average error of 0,27%. MAX30100 sensor has an accuracy rate of 99,18% and an average error of 0,82%. Delay test results show an average of 155,57 ms, and packet loss test results show an average of 0%. Result of system that has been tested said the both sensors can read well.

Keywords: *COVID-19, Happy hypoxia, Monitoring, Internet of Things*

1. Introduction

COVID-19 is gaining increasing attention after hundreds of people died from the infection in China [1]. This disease has also infected hundreds of thousands of people in various other countries, including Indonesia. Common symptoms of COVID-19 include fever, runny nose, headache, sore throat and shortness of breath. However, these symptoms are not felt by everyone affected by COVID-19. Asymptomatic COVID-19 patients make the virus difficult to detect and often delay treatment [2]. Happy hypoxia has been identified in some asymptomatic COVID-19 patients. This condition occurs when oxygen levels in the blood drop below the normal range and the body becomes deprived of oxygen. Fortunately, Happy hypoxia can be detected early by measuring oxygen levels. In medical facilities such as hospitals, this measurement can usually be done with a pulse oximeter. A healthy person has an oximeter saturation value of 95-100%. Happy hypoxia may unwittingly harm those affected by COVID-19. In addition, the luckiest happy hypoxia patients are asymptomatic COVID-19 (OTG) patients who appear normal, have no symptoms of physical illness, and are good at communicating [3]. Vital signs can also be monitored through the human body temperature. Body temperature is the difference between the amount of heat produced by body processes and the amount of heat lost to the external environment. Body temperature changes easily and is influenced by many factors, both external and internal factors. Changes in body temperature are closely related to maximum heat production and excessive heat expenditure. The nature of the heat changes greatly affects the clinical problems experienced by everyone, according to WHO, the normal human body temperature ranges from 36^{o}-38^{o} C [4].

Several articles were used as references in this study. A 2021 study by Agoes Santika H. and Yanuar Mukhamad discusses the design of an Android-based oxygen saturation monitoring system. This study aims to build a pulse oximetry monitoring system with two parameters, namely SpO2 and pulse rate using an alarm system as a marker of abnormal conditions in patients and an application on a smartphone as a display device for oxygen saturation and pulse rate data. This study uses the MAX30100 sensor to measure oxygen

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saturation levels and pulse rate [5]. In the research of Della Rahmawarni and Harmadi in 2021, they also made a level monitoring system for oxygen saturation and pulse rate. The difference lies in the platform used as a display of the data results, for this study using the telegram application as a viewer of the data results [6]. Research conducted by Ary Sulistyo U, Erda Hermono PN, and Mohamad Sofie in 2019 also created a monitoring system for oxygen saturation levels and pulse rate. The difference lies in the platform used as the data result viewer, for this study using the blynk application as the data result viewer [7]. Of the three articles used as references, none of them have used sensors to detect body temperature. Therefore, there are reference articles that use body temperature sensors such as the research conducted by Panji Wiratama, Randy Erfa S, and Casi Setianingsih in 2021 which discusses the monitoring system for body temperature and oxygen saturation levels based on a microcontroller. Where in this study the monitoring system has not used the Internet of Things (IoT) concept, the measurement data results from the two sensors used are still displayed on the LCD [8]. A 2018 study conducted by Tan Suryani S., Alamsyah, M. Bachtiar, Ardi Amir, and Benjamin Bontong discussed a heart rate and temperature monitoring system using the AD8232 and DS18B20 sensors as heart rate and temperature sensors. The tool made for this research does not discuss the concept of IoT, where the sensor data display still uses the LCD [9].

From several reference articles that already exist, there are still some shortcomings in each research, such as absence of sensors to detect body temperature, and lack of connection to tool system made with internet. In that case, to reduce risk of death from COVID-19, especially symptoms of happy hypoxia, it is necessary to have an IoT-based monitoring system for body temperature and oxygen saturation levels. Nowadays, smartphones are not a new thing, so making a monitoring tool that can be monitored via a smartphone is something that can facilitate the process of checking patients on a regular basis. The purpose of this research is to design and create an IoT-based body temperature and oxygen saturation monitoring system. In addition, there are tests carried out to test accuracy of the sensors used and the Quality of Service (QoS) of the network used in the monitoring system.

2. Research Methods

In making a monitoring system for body temperature and oxygen saturation levels, several tools are needed, the tools to be used both in the form of hardware and software are shown in Table 1.

Tools and materials in Table 1 are used as part of research on body temperature and oxygen saturation monitoring systems. In study of monitoring system for body temperature and oxygen saturation in this patient, several stages of research were carried out as shown in Figure 1.

Tabel 1. Tools and materials

No	Tools and materials	Amount
1	Laptop	1
2	Smartphone	1
3	NodeMCU ESP8266	1
4	Sensor DS18B20	1
5	Sensor MAX30100	1
6	OLED SSD1306	1
7	KY-012 Piezzo Active-Buzzer Module	1
8	MP1584 Step Down Module	1
9	Battery 9V	1
10	Software Arduino IDE	1
11	Software MIT App Inventor	1
12	Google Firebase	1

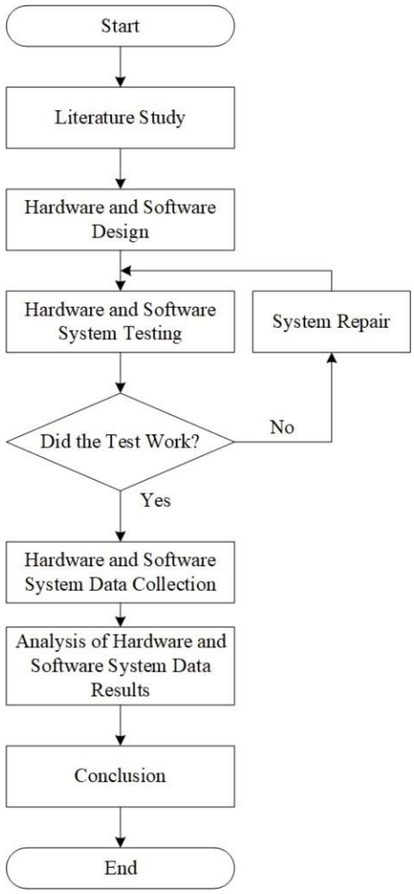

Figure 1. Research Flowchart

First step is literature study. This phase is used to research and find various types of information about monitoring system design. Next stage is to make a hardware design. This is done by collecting various tools and materials such as DS18B20 temperature sensor, MAX30100 oxygen saturation sensor, NodeMCU ESP8266 Microcontroller, OLED SSD1306, buzzer and using WiFi data communication in sending sensor data on Android application [10]–

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[15]. Schematic diagram of hardware design can be seen in Figure 2.

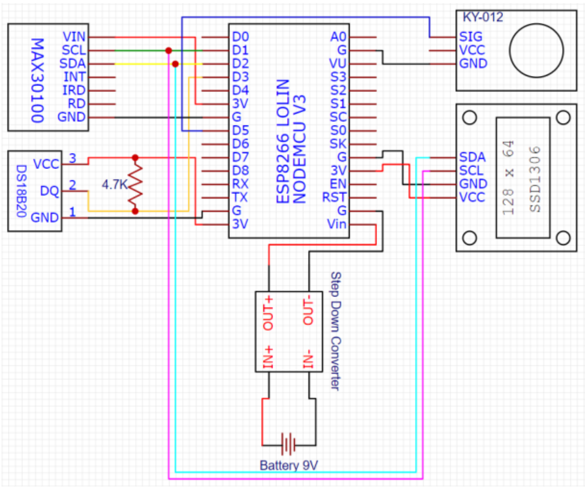

Figure 2. Schematic diagram

At the software design stage, Arduino IDE software is used to input program to microcontroller that will be used. Then the App Inventor software is used to create an application to display body temperature and oxygen saturation results. Data results are sourced from sensors whose data is sent to a real-time database provided by Google Firebase. The data is monitored using a smartphone [16]–[18].

Next stage is to test the tool that has been made, whether it is in accordance with the expected function of the tool or not. In testing the tool is done by calibrating the tool. For DS18B20 sensor, a comparison is made with a digital thermometer, while for MAX30100 sensor a comparison is made with a pulse oximeter. Next stage is to collect data. This data retrieval is in the form of data obtained from the results of tests carried out in the previous stage and data retrieval from testing the Quality of Service (QoS) parameters. QoS parameter testing scheme can be seen in Figure 3.

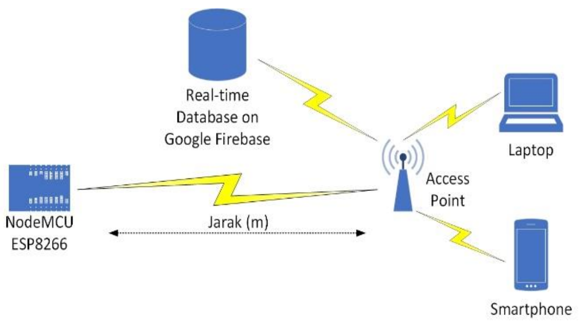

Figure 3. QoS testing scheme

Then after data collection process is carried out, next step is to analyze the data obtained from test results or from performance of the tools and software that have been made. Some of data analyzed are the results of comparison of each tool. Data will be calculated the percentage of error. Here is equation for calculating of percentage error.

$$\text{Relatif } error = \frac{(Measured\ value - True\ value)}{True\ value} \times 100\% \quad (1)$$

Where from the calculation of percentage error, the accuracy value is obtained with following equation [19].

$$\text{Accuration} = 100\% - \text{Relatif } error \quad (2)$$

After analyzing the comparison of sensor data results, then analyzing QoS parameters that have been tested. Some of parameters analyzed are delay and packet loss. In conducting the analysis of delay and packet loss, the ITU-T G.1010 category standard is as follows.

Table 2. ITU-T G.1010 standard for application data

Medium	Application	Key performance parameters and target values		
		Delay	Jitter	Packet Loss
Data	Bulk data transfer/retrieval	Preferred <15s Acceptable <60s	N.A.	Zero

To calculate the results of the QoS parameter testing, there are similarities, the equations for finding delay are as follows.

$$Delay = \frac{\text{Total delay}}{\text{Total packet received}} \quad (3)$$

The equation for finding packet loss is as follows [20].

$$Packet\ loss = \frac{(\text{Packet sent} - \text{Packet received})}{\text{Packet sent}} \times 100\% \quad (4)$$

For the last stage, namely making a conclusion from the overall process and analyzing the results that have been obtained in this research process.

3. Results and Discussions

3.1 System Design Results

In system design includes hardware design, software design includes Firebase and application development using App Inventor. The flow of this monitoring system starts from the DS18B20 sensor hardware in getting results of human body temperature and MAX30100 sensor in getting results of oxygen saturation levels. The data obtained from two sensors is sent to database in real-time, then the data in database will be sent to application that has been created using App Inventor. In Figure 4 below, is the result of hardware design of body temperature and oxygen saturation monitoring system using IoT-based DS18B20 and MAX30100 sensors.

In this device, there are several components, namely NodeMCU ESP8266 as microcontroller, NodeMCU base plate board to facilitate connectivity with other devices, DS18B20 sensor as a human body temperature

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reader, MAX30100 sensor as an oxygen saturation level reader, I2C OLED as a data viewer, KY-Buzzer module. 012 as an alarm if patient's condition worsens, a step-down converter module as a battery voltage reducer, and a 9V battery as a power provider. After receiving data received by the two sensors, NodeMCU as a microcontroller processes the data and sends it to database in real time.

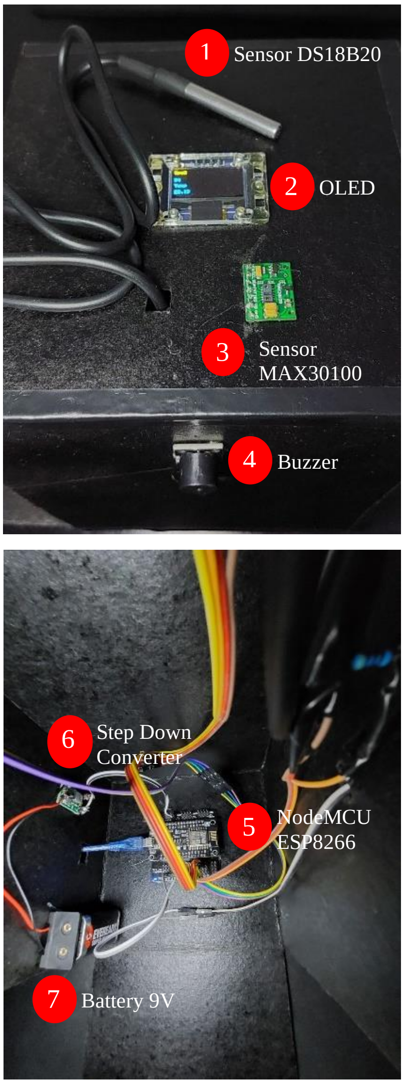

Figure 4. Hardware design results

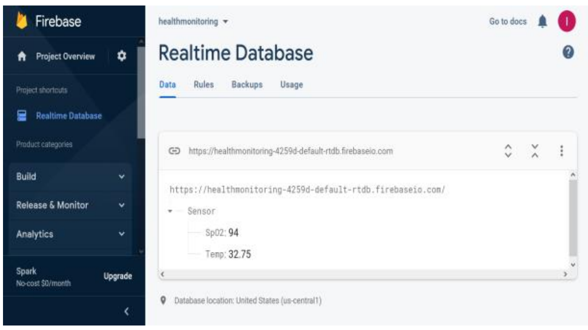

Figure 5. Real-time database view on Google Firebase

In Figure 5 is a view of the real-time database provided by Google Firebase. This database stores data on oxygen saturation levels obtained from MAX30100 sensor and body temperature obtained from DS18B20 sensor.

When all data is received in the database, it will be passed on to the application that has been created using App Inventor. In the design at the time of making the application, using two screens. Where the first screen as the opening display and the second screen as a data display of oxygen levels and body temperature. Here is a view of the first screen.

Figure 6. First screen display on the application

In Figure 6 is the display on first screen. The first display in this application is logo of application, this display is programmed to only appear for 3 seconds and after that it goes straight to the second screen.

Figure 7. Second screen display on the application

In Figure 7 is the second screen, users can see information on oxygen saturation levels and body

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temperature. The data is obtained from readings of two sensors that are sent in real-time. This application can also inform user if patient's oxygen saturation level decreases by using a notification.

Figure 8. Notifications when oxygen saturation levels drop

Figure 8 is result of notification test which shows if there are symptoms of mild happy hypoxia due to oxygen saturation levels between 90 – 95% [21].

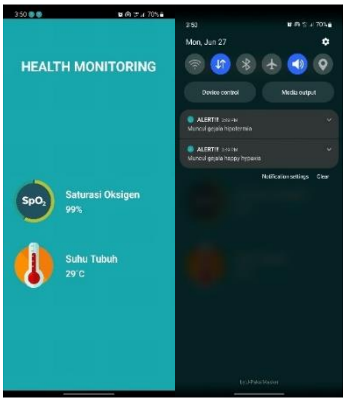

Figure 9. Notifications when body temperature drop

Figure 9 is result of notification testing which shows symptoms of hypothermia due to body temperature below 36˚C [22].

Figure 10. Notifications when body temperature increased

Figure 10 is a test result that shows symptoms of hyperthermia due to body temperature above 40˚C [22].

3.2 System Test Results

1) MAX30100 Sensor Test Data Results.

The results of this data are one of the processes of testing MAX30100 sensor readings in reading oxygen saturation levels. To compare the results accuracy of oxygen saturation levels read by sensor, comparison process uses a pulse oximeter, which is a tool to measure oxygen saturation levels that have been proven to be accurate. Data collection on oxygen saturation levels is differentiated based on age variations and each test is carried out 10 times per person in order to get an accurate value of oxygen saturation levels. In the test, the MAX30100 sensor is placed on the right thumb and the pulse oximeter is placed on the left thumb. The placement of the sensor and pulse oximeter is on the thumb, because the surface area of the thumb is wider than the other fingers so that reading of oxygen saturation levels is expected to be more accurate. The following are results of MAX30100 sensor test:

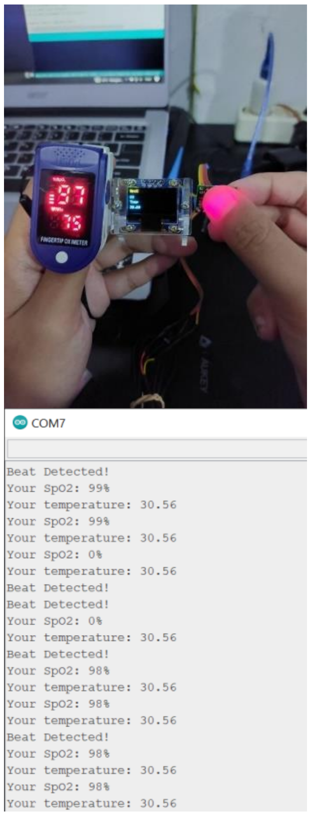

Figure 11. MAX30100 sensor test results

Figure 11 is result of testing MAX30100 sensor. Where the test is carried out by comparing the MAX30100 sensor and pulse oximeter.

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Table 5. Device comparison results

No	Patient	Sensor MAX30100 a	Pulse Oximeter b	Error % c
1	Patient 1	98%	98%	0%
2	Patient 2	99%	98%	1,02%
3	Patient 3	99%	97%	2,06%
4	Patient 4	98%	97%	1,03%
5	Patient 5	99%	98%	1,02%
6	Patient 6	97%	97%	0%
7	Patient 7	99%	99%	0%
8	Patient 8	98%	97%	1,03%
9	Patient 9	98%	97%	1,03%
10	Patient 10	99%	98%	1,02%
		Average		0,82%

Table 5 above is a comparison between oxygen saturation testing using MAX30100 sensor and using a pulse oximeter. In testing MAX30100 sensor with a pulse oximeter, it takes about 30-60 seconds to get accurate data results. The results of testing with MAX30100 sensor are displayed on OLED and android application. From test results of oxygen saturation readings, which are tested 10 times per person, have an average error percentage rate of 0.82%, which means that by using equation 2, sensor accuracy results are 99.18%, with a high sensor accuracy indicating that the MAX30100 sensor can is considered very good in reading oxygen saturation levels in human body. Errors that appear can be caused by several factors such as dirty finger conditions or external light that can affect the readings by the MAX30100 sensor.

2) DS18B20 Sensor Test Data Results

The results of this data are one of the processes of testing DS18B20 sensor readings in reading human body temperature. To compare the results accuracy of temperature read by sensor, comparison process uses a digital thermometer that has been proven to be accurate. Human body temperature data collection is distinguished based on age variations, same as in MAX30100 sensor test and each test is carried out 10 times data collection per person in order to get an accurate body temperature value. Where for DS18B20 sensor and digital thermometer it is placed in armpit. Placement of DS18B20 sensor and digital thermometer is placed in armpit because this method is easiest way than through the mouth or rectum. However, measurements through the armpit are not as accurate as measurements by mouth or rectum. The following are results of DS18B20 sensor test.

Figure 12 is result of testing DS18B20 sensor where the test is carried out by making a comparison between the DS18B20 sensor and a digital thermometer.

Based on Table 6 above is a comparison between testing human body temperature using the DS18B20 sensor and using a digital thermometer. In testing the DS18B20 sensor with a digital thermometer, it takes about 5-10 minutes to get accurate data results. The results of testing using the DS18B20 sensor are displayed on OLED and android application. From the test results of body temperature readings, which per person were tested 10 times, it has an average error percentage rate of 0.27% which means that by using equation 2 the sensor accuracy results are 99.73%, with a high level of sensor accuracy indicating that this DS18B20 sensor can be considered very good at reading body temperature in humans. Errors that appear can be caused by several factors such as outside temperature conditions that affect body temperature, it will result in sensor readings.

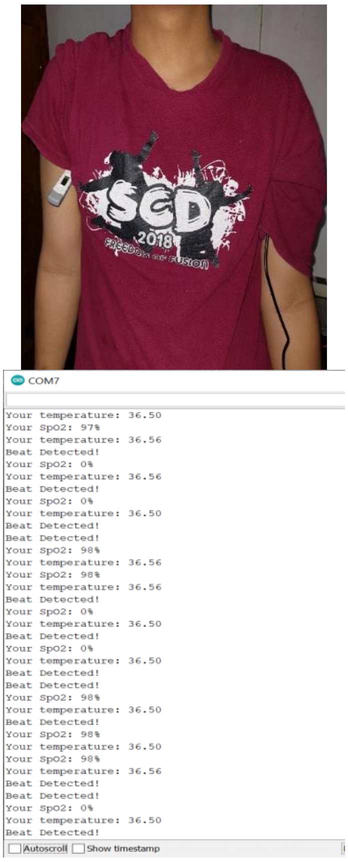

Figure 12. DS18B20 sensor test results

Table 6. Device comparison results 1

No	Patient	DS18B20 a	Thermometer Digital b	*Error* % c
1	Patient 1	36,60˚C	36,70˚C	0,26%
2	Patient 2	36,53˚C	36,63˚C	0,27%
3	Patient 3	36,68˚C	36,75˚C	0,19%
4	Patient 4	36,58˚C	36,67˚C	0,24%
5	Patient 5	36,36˚C	36,52˚C	0,43%
6	Patient 6	36,40˚C	36,42˚C	0,05%
7	Patient 7	36,72˚C	36,74˚C	0,05%
8	Patient 8	36,43˚C	36,47˚C	0,10%
9	Patient 9	36,47˚C	36,69˚C	0,59%
10	Patient 10	36,63˚C	36,83˚C	0,54%
		Average		0,27%

To prove that the DS18B20 sensor can read temperatures above 40˚C and below 36˚C, a

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comparison test is carried out using warm water. The following is a table of DS18B20 sensor test results:

Tabel 7. Hasil perbandingan alat 2

No	DS18B20	Thermometer Digital	*Error* %
	a	b	c
1	45,04˚C	45,13˚C	0,20%
2	42,85˚C	42,86˚C	0,43%
3	40,39˚C	40,55˚C	0,38%
4	39,01˚C	39,06˚C	0,16%
5	37,42˚C	37,30˚C	0,34%
6	34,59˚C	34,73˚C	0,45%
7	32,77˚C	32,93˚C	0,48%
		Average	0,35%

Based on Table 7 above, it is a test to prove that DS18B20 sensor can measure above 40˚C and below 36˚C. This test was carried out for 30 minutes and data were collected 3 times. In this test, average error percentage is 0.35%, which means that by using equation 2, the sensor accuracy results are 99.65%.

3) Delay Test Data Results

In testing delay in this monitoring system, the aim is to see how long it takes to send data packets. This delay test uses distance and time variations in data collection. The software used to perform this test uses the Wireshark application that is already installed on the laptop. The test is carried out with a duration of approximately 60 seconds and variations in distance ranging from 1-10 meters, and data collection is carried out 3 times.

Table 8. Delay test results

No	Length (m)	Packet	Time span (s)	Delay (ms)	Category
1	1	711	61,716	86,98	Preferred
2	2	641	60,766	94,75	Preferred
3	3	602	61,765	102,61	Preferred
4	4	540	60,904	113,21	Preferred
5	5	391	61,833	161,65	Preferred
6	6	458	61,188	137,86	Preferred
7	7	320	61,871	205,06	Preferred
8	8	284	61,164	215,99	Preferred
9	9	286	60,315	212,25	Preferred
10	10	269	60,687	225,34	Preferred
		Average		155,57	Preferred

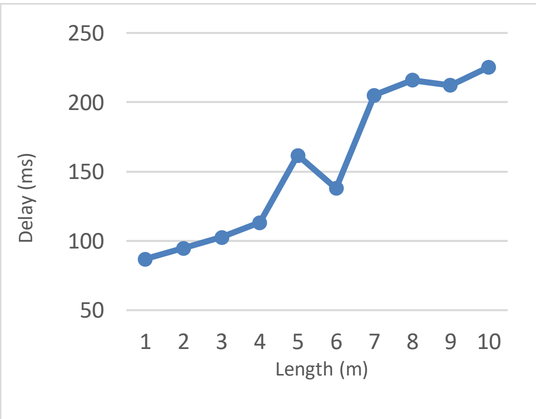

Figure 14. Delay test result graph

From the results of delay test in Table 8, the average delay value is 155.57 ms, when viewed from the category index according to ITU-T G.1010 it is included in the preferred category because the average delay is less than <15s. In this test, the lowest value of delay is at a distance of 1 meter with a value of 89.98 ms and the highest value of delay is at a distance of 10 meters with a value of 225.34 ms. It can be seen in Figure 4.11 that the farther of distance, the graph delay will be increases, although it is not stable. There are several other factors that affect the delay variation, such as the presence of a wall during testing which can cause feedback resulting in echo noise, besides that the outdoor temperature & temperature of the equipment used during testing can be one of the factors causing the variation in reception delay is called thermal noise.

4) *Packet Loss Test Data Results*

In packet loss testing in this monitoring system, the aim is to find out the number of packets that fail to reach the destination where the packet was sent. In this packet loss test, variations in distance and time are used in data collection. The software used to perform this test uses the Wireshark application that is already installed on the laptop. The test lasts for about 60 seconds and the distance varies from 1 to 10 meters, and is carried out 3 times for data collection.

Table 9. Packet loss test results

No	Length (m)	Packet sent	Packet received	*Packet Loss*
1	1	711	711	0%
2	2	641	641	0%
3	3	602	602	0%
4	4	540	540	0%
5	5	391	391	0%
6	6	458	458	0%
7	7	320	320	0%
8	8	284	284	0%
9	9	286	286	0%
10	10	269	269	0%
		Average		0%

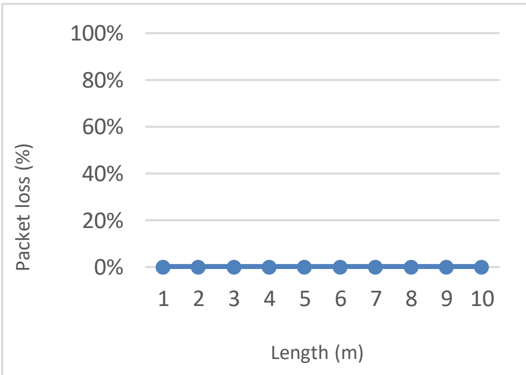

Figure 15. Packet loss result graph

From the results of packet loss testing in Table 9, average packet loss value is 0%, which means that no packets failed to be sent and all packets sent were 100% successful until the destination of the packet was sent.

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When viewed from the category index according to ITU-T G.1010, it is included in the category according to the parameters and target value, namely zero packet loss. Distance variations have no effect on packet loss testing, one of factors that can affect this usually lies in error of the provider used or the provider being used is experiencing network problems.

4. Conclusion

The design of monitoring system for body temperature and oxygen saturation levels in human body based on IoT is obtained that both sensors and the NodeMCU ESP8266 can function properly and can send the results of reading data to a database on Google Firebase which is then displayed on the android application with data communication using WiFi. After testing the two sensors by making a comparison with a digital thermometer and pulse oximeter, it can be said that DS18B20 sensor can work very well with an average error of 0.27% and a sensor accuracy rate of 99.73%. Meanwhile, MAX30100 sensor also works very well with an average error of 0.82% and a sensor accuracy rate of 99.18%. For Quality of Services testing which includes delay and packet loss testing also shows very good results where in the delay test an average value of 155.57 ms is obtained with preferred category, while for packet loss testing, an average value of 0% is obtained, which means it is already according to parameters and target value is zero packet loss.

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