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The Implementation of MQTT Protocol using PT-100 for Monitoring the Vaccine Temperature

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Abstract

A vaccine has an essential role for humans because it can reduce the effect of organism infection and activate the body's immune. The limitation of temperature when the vaccine is stored becomes one of the influential factors for its quality. Since the recent technique used for checking the temperature is manual, the process of real-time temperature monitoring cannot be done and becomes the main problem in the process of storing vaccines. This research is aimed to develop a system for measuring temperature on a chiller through a temperature sensor and the internet of things automatically. The methods used in the MQTT protocol are published and subscribed. The quality of service (QoS) to measure network capability and PT-100 is the sensor in this research because it has a high accuracy level, linear signal change, and fast response. This sensor can measure glycol liquid with a temperature range of 2-8°C. Data distribution uses an ESP module to connect the data to Antares through the wifi network. The temperature value measurement using PT-100 toward vaccine chiller temperature obtains an accuracy value of 99,32%. This accuracy value shows that the result is compatible with the logger data measurement tool development used with an error result of 0.58%. Delay parameter testing on the QoS level obtains the average value of 41.91 ms, while the Packet loss parameter obtains the value of 0%.

Keywords: ESP 32, MQTT, Quality of Service, PT-100 sensor, vaccine

1. Introduction

Both medication and vaccine are two essential components in supporting human life. The vaccine is a biological element sensitive to low and high temperatures and has its characteristics [2]. Vaccines can lose their potential quickly because of some influential factors such as storage, packaging, and distribution. This potential loss is irreversible and permanent.

One of the temperature monitoring system research is entitled "Sistem Monitoring Suhu Cold Storage Menggunakan Data Logger Berbasis Arduino Uno dan Visual Basic" by D. Saepul Ramdan and M. Nauval Wijaksana in 2017. The usage of visual Basic Application in making a system for vaccine monitoring is aimed to facilitate the cold storage operator, and it showed 82.5% of the expected result. However, there are some problems with the connectivity and limited database usage in this research [2]. Another study is fixing the database storage system problem. The research is entitled "Sistem Monitoring dan Pengontrolan Suhu pada Inkubator Bayi Berbasis Web" by Mesa Amelia in 2020. The database used a graphic view for the web-based controlling and monitoring of the temperature, which shrank the storage usage. This system is supported by the Thingview Application on Android, enabling real-time monitoring [6].

Moreover, the other research about network connectivity used for monitoring is entitled "COVID-19 Vaccine Distribution Tracking and Monitoring Using IoT" by I Ketut Agung Enriko et al. in 2021. The connectivity system used in this research is Longe Range, where transmitting data widely in kilometers is available. This research can track and monitor through sensors applied to the distribution trucks [18].

In addition, there is another research about the temperature sensor used in monitoring, which is entitled "Evaluasi Kalibrasi Transducer RTD PT100 dan Termokopel Type K" by Sumarkantini in 2018. The calibration of the temperature sensor with the E5EK Omron controller proved that this sensor has the accuracy in measuring. In the temperature range of 0 to 100°C, PT-100 has an increase in resistance value. This sensor could measure the vaccine temperature on the Chiller [7]. Besides, there is another research entitled "Rancang Bangun Mini Refrigerator Untuk

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Penyimpanan Vaksin Dengan Kapasitas 2250 BTU/HR" by Ferry Irawan and Tri Widagdo in 2018. The storage tool design used refrigerators to secure the vaccine quality for long-term storage based on this research. The methods used in the study are dimension calculation, component selection, tool assembly, vaccine storage, and tool assessment [4].

2. Research methods

The first step of this research was started with a literature study about vaccines. Then, it continued with PT-100 hardware design, Arduino IDE software design, and the analysis of the comprehensive system from the system created before. This diagram describes the research design process from the start until the end of the research.

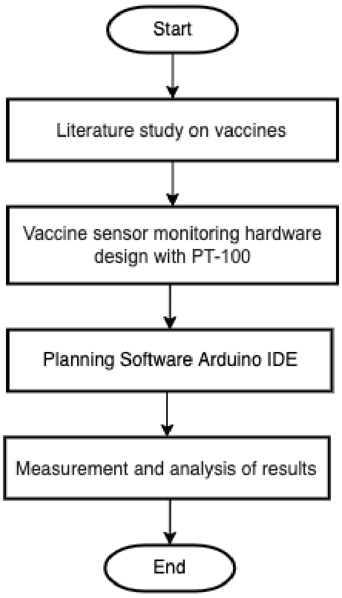

Figure 1. Research flowchart Diagram

In Figure 1, the research flowchart diagram describes the research process from the rise of problems until the analysis of the issues. The steps in this research can be explained below:

2.1 Literature study

Literature study in this step was collecting materials and references which will be the guidelines in comparing the previous studies.

2.2 Hardware design

This step explained the component that supported the tool design to produce the temperature monitoring tool. The system block diagram can be seen in Figure 2.

According to Figure 2. There are three steps in this system planning: input, process, and output. There is a PT-100 sensor for measuring temperature in the Chiller for information. Then the data is inserted into the microcontroller in the processing step through a wifi connection and transmitted into MQTT through Antares broker in the output step. The hardware design can be seen in Figure 3.

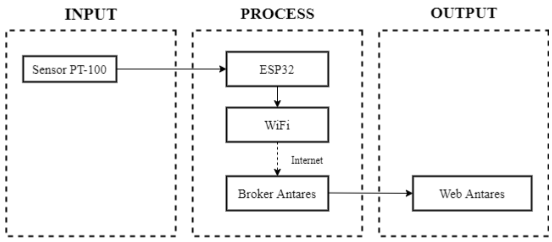

Figure 2. System planning block diagram

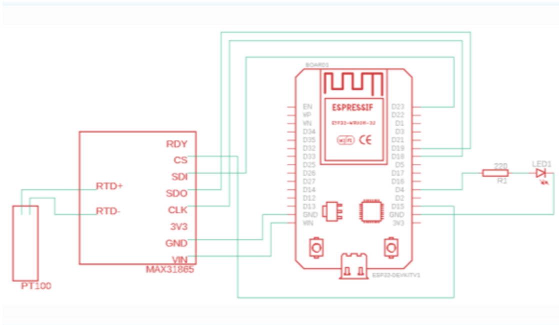

Figure 3. Hardware design schematic

In Figure 3, describes the schematic of the hardware design, including the PT-100 sensor, MAX31865 driver, and ESP 32.

2.3. Software design

This step used an Arduino IDE application. This application helps create a program that can interpret the entry from the sensor. Later, the program will be uploaded to the ESP 32 microcontroller by the wifi network for monitoring devices through the Antares platform using the MQTT protocol. The Figure below is the flowchart for software design in Figure 4.

Figure 4 shows the flowchart about the Antares Platform making, which will be the broker for monitoring the vaccine temperature and the broker for MQTT. MQTT (Message Queue Telemetry Transport) protocol is a publish/subscribe - based light communication designed for communication between low-power devices. QoS is an end-to-end architecture and not a feature owned by a network. Refers to the speed level and the reliability in delivering various data in one communication. In this study, there are two parameters used: Delay. It is the Delay in the data transmission time from the sender and receiver, and the delay unit is second. Packet loss is a parameter for the condition where the packet data is lost while crossing a computer and fails to reach its destination.

2.4 Wide-system test

This test covers all device testing from the system which has been created. The next test is QoS value testing, using delay and packet loss parameters.

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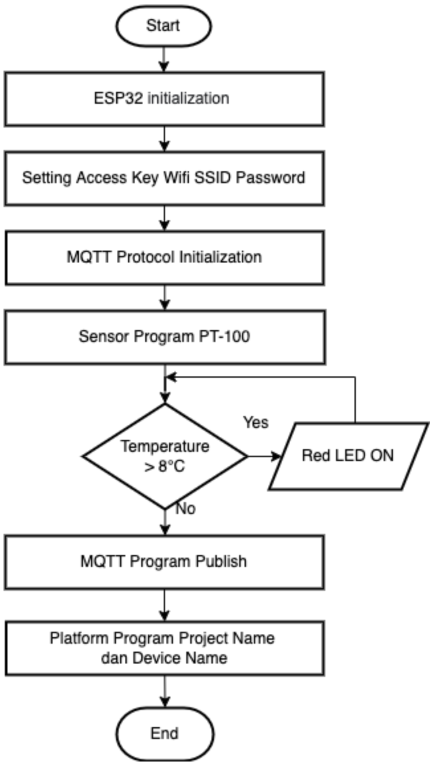

Figure 4. Software design

In this test, the standard output form is the data result that can be the material for analysis. The tests are PT-100 sensor testing and the measurement of QoS MQTT protocol using Delay and packet loss through the Wireshark application.

3. 1 System Testing

This system testing is aimed to get data results after all components have been installed and formed a monitoring system. Thus, the system can see whether it can run well or not. Test results are written in the form of tables and displayed in graphs to facilitate users in analyzing data while monitoring the test. The test was held by testing the temperature sensor, the sensor data measurement, and the sensor transmission. Hence, the data can be monitored using the MQTT protocol.

3.1.1 PT-100 Sensor Testing

PT-100 sensor testing aims to determine the temperature sensor's accuracy and the possibility of ESP 32 in reading this sensor correctly. The readable temperature value in a glass bottle containing glycol liquid will be compared to the Elitech data logger RC-4 for the vaccine temperature measurement. Figure 5 below shows the PT-100 testing display.

In PT-100 sensor testing, some parts were included as components contained in the system. Part number 1 is a box containing max31865 drivers and ESP 32 microcontrollers. Then, part number 2 is data loggers. Numbers 3, 4, and 5 are glycol liquids used for representing the vaccine temperature with the standardization from WHO for the freezing point of this liquid, 130ºC, which is very low. The vaccine placement in the Chiller can be seen in Figure 6.

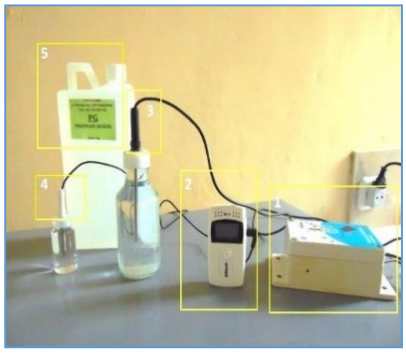

Figure 5. PT-100 sensor testing

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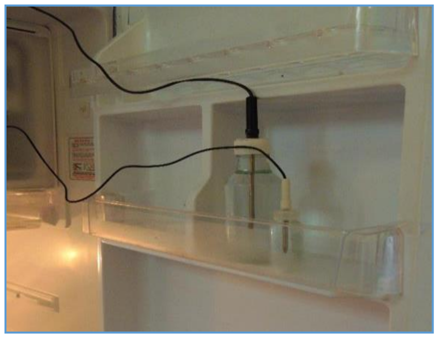

Figure 6. Vaccine placement in Chiller

Figure 6 shows the placement of the vaccine storage in the temperature sensor testing. The vaccines were placed in the refrigerator door. Since the refrigerator was used as the cold storage in the measurement, it was set to a temperature range of 2-8^{O}C. The refrigerator should be closed tightly to stabilize the temperature. SPI communication is used to obtain temperature data from the MAX31865 module while measuring instruments for comparison by connecting the PT-100 sensor output probe with a multimeter and inserting the sensor into a liquid temperature of 0^{O}C. The data results from testing the temperature value of the PT-100 sensor with the measuring instrument can be seen in table 1.

Table 1 shows the average comparison between temperature measurements using PT-100 sensors and the RC-4 Elitech data logger analyzer. Based on the results, the temperature measurement using the PT-100 sensor has a 0.58%error presentation. In other words,

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using the PT-100 sensor to read the vaccine temperature value has a 99.32% accuracy.

Table 1. Sensor comparison with temperature measurement tool

NO	Temperature sensor data (°C)	Temperature measurement tool(°C)	Error (%)
1	0.50	0.50	0.40%
2	1.00	1.00	0.40%
3	1.49	1.50	0.80%
4	2.01	2.00	0.40%
5	2.52	2.50	0.64%
6	2.99	3.00	0.20%
7	3.55	3.50	1.49%
8	4.00	4.00	0.10%
9	4.49	4.50	0.13%
10	4.98	5.00	0.48%
11	5.55	5.50	0.91%
12	6.01	6.00	0.20%
13	6.46	6.50	0.62%
14	6.91	7.00	1.26%
15	7.55	7.50	0.67%
16	7.99	8.00	0.10%
17	8.44	8.50	0.73%
18	8.97	9.00	0.33%
19	9.45	9.50	0.48%
20	9.864	10	1.36%
Rata-rata			0.58%

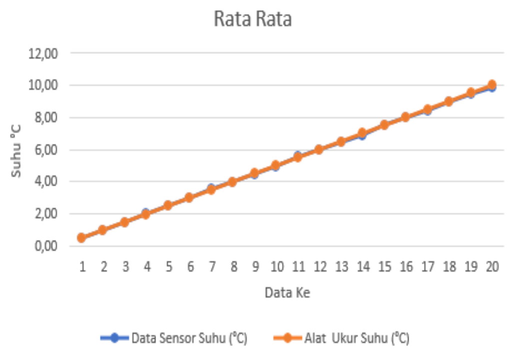

Figure 7. Average graphic of sensor testing

Figure 7 shows a comparison graphic between the temperature reading on the measuring instrument and the PT-100 sensor made. There are 20 different experiments on the X-axis, where each experiment has a 0.5 pressure difference according to the graphic on the Y-axis. This shows that the accuracy of the temperature sensor obtained the best values

3.1.2 Wide-system Testing

The hardware system in this test is the glass bottle containing glycol liquid and the sensor used to measure the temperature of the liquid. A box also includes a microcontroller and MX31865 driver, which transmits temperature data and alerts using a wifi network with MQTT protocol to Antares broker.

Figure 8 shows that obtained data from Antares can be displayed as a graphic platform Antares in the system testing time.

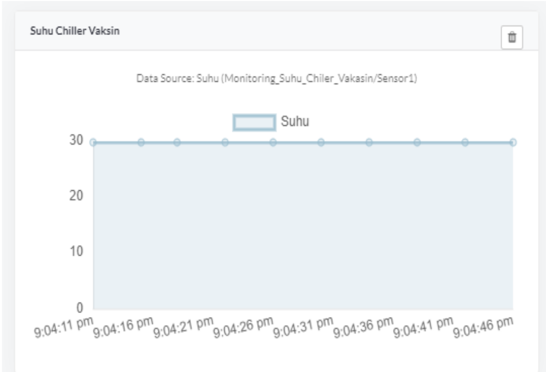

Figure 8. Temperature measurement graphic of vaccine chiller

3.2 The QoS Testing of MQTT Protocol

The test for this protocol is making observations for sending data for 3 hours a day because this test used a cellular network of as much as 47-55 ms. Thus, it took an hour for one delivery. There are three sessions to send 3 hours delivery: morning, afternoon, and night. The first step of the sensor is to read the temperature and send the data to esp32, and then the data is sent to the MQTT broker. Here is the network topology on the MQTT protocol .

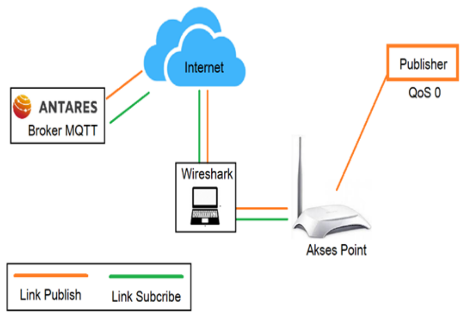

Figure 9. Network Topology

The usage of publishing and subscribe methods in communication uses the same network between the temperature monitoring device and the Wireshark application. QoS level 0 is used for sending data from publishers to MQTT brokers, where they can publish messages as they want. The test result used a mobile network at 47-55 ms, while network testing obtained 75 data.

3.2.1 Delay Testing

Delay is the time needed for a packet from origin to the destination. Delays can be influenced by distance, physical media, congestion, or long processing times. As one of the QoS parameters, Delay can affect the quality of service due to the delay time. Delay testing was held for five days to determine the Delay at the QoS 0 level with observation. QoS 0 can transmit data that send messages at one time without checking, obtaining an average value of <150ms. According to TIPHON standards, this value is an excellent criterion and pre-

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determined condition. Hence, the delay test takes time for five days. Delay test results obtained are shown in Table 2.

Tabel 2. Delay testing value

Average result		
Hari	Data Length (Bit)	Delay (ms)
1	4536	39.93
2	4536	41.16
3	4536	43.41
4	4536	46.20
5	4536	38.86
Avarage		41.91

Table 2 shows that the average Delay value is 41.91 ms. The device did publish data to brokers with excellent criteria, according to TIPHON. The formula for calculating the average Delay is as follows:

$$Delay\ Average = \frac{the\ total\ of\ Delay}{the\ total\ of\ Received\ packet} \quad (1)$$

In five days of testing, the Delay level on QoS 0 obtained an average value of 41.91 ms. Here is the graphic of the Delay each day

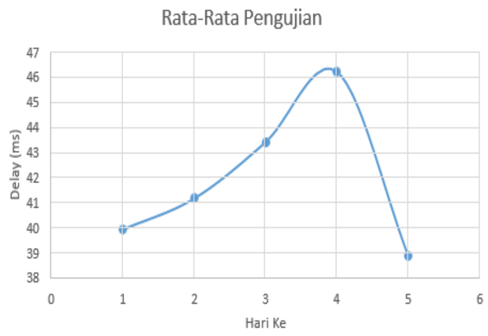

Figure 10. Delay testing graphic in each day

Figure 10 shows a testing graphic conducted for five days obtaining Delay at QoS level 0. The highest Delay is on the fourth day of testing, with an average value of 56.20 ms. Delay in testing according to TIPHON standards is classified as an excellent criterion because the total system value has a Delay value of <150ms. In applying the MQTT protocol in the Chiller monitoring system, the minor Delay is obtained using a 0 level of QoS. QoS applied the concept of data transmission that can send messages at one time without checking whether the transmitted message has arrived perfectly or not at level 0, and this has been proven in this study.

3.2.2 Packet Loss Testing

Packet loss is when the packet is lost or not delivered to its destination. The number of packages lost will influence the effectiveness of the communication network itself. The delivered data from the sensor device (publisher) to the broker was using 0 levels of QoS. Test results can be seen in table 3.

Table 3 shows 0% in every experiment of packet loss between delivered packet and received packet testing. The device is connected well to the broker using a stable and good internet network. Besides, the monitoring device had the package within 3 seconds. Hence, there is no waiting line at the time of delivery. Here is the formula to calculate packet loss.

Table 3. Packet loss testing

Average results			
Hari	Delivered packet	Received packet	*Packet loss* (%)
1	2	2	0%
2	2	2	0%
3	2	2	0%
4	2	2	0%
5	2	2	0%
Average			0%

$$P\ Loss = \frac{Delivered\ packet - received\ packet}{delivered\ packet} x100\% \quad (2)$$

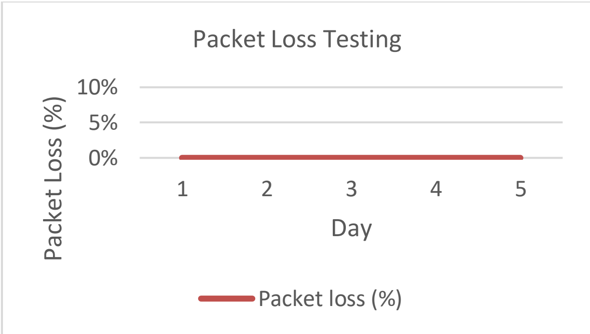

Figure 11. Packet loss testing graphic

Figure 11 shows the packet loss testing graphic obtained on the value from all the experiments held with 0%. Based on TIPHON, the value is included as an excellent criterion because there is no lost packet

4. Conclusion

Based on the tests and discussion about monitoring vaccine temperature on chillers using PT-100 sensors with MQTT protocol, there are three conclusions in the research. It includes the result of the PT-100 that can be used to read temperature accurately in the temperature range of 2-8^{O}C and has an accuracy rate of 99.32%, with the highest difference value of 0.5^{O}C with measuring instruments.

The overall test results for sensor readings can be monitored at the Antares broker according to the actual data on the Chiller. QoS testing for the Delay parameter at QoS level 0 obtained an average value of 41.91 ms, while packet loss testing obtained shows a value of 0%

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