IoT Smart Health for Monitoring and Control of Temperature and Humidity of Vaccine and Drug Storage based on Android at Health Center

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Abstract—Pharmacy service is one of the activities at the *puskesmas* (Public Health Center) that supports quality health services. One of the pharmaceutical activities is the storage of drugs and vaccines. The drug and vaccine storage room pays great attention to conditions, temperature sanitation, light, humidity, ventilation, to ensure product quality and staff safety. Most of the drugs in the *puskesmas* should be stored at room temperature between 18-28°C and air humidity 40% - 60%. The monitoring system built uses DHT22 as a room temperature and humidity detector. The sensor output is connected to the NodeMCU ESP8266 which acts as a microcontroller. While the control system uses a relay module as a liaison for the AC remote control and as an automatic switch. The room temperature and humidity control test is carried out using an existing air conditioner for the power on/off and temperature up/down functions. In addition, testing of room temperature and humidity control uses 2 different AC brands from 2 rooms. The test was carried out in the drug and vaccine storage room at the Pudak Payung Public Health Center. The test results show that the sensor can record data accurately and can be integrated with the transceiver device properly. Sending sensor data to the database has an average delay at each node of 21 seconds and sending sensor data to the database has good data loss quality, namely 9.68% for the vaccine room node, 13.4% for the medicine room, and the average temperature and humidity. Vaccine room is 24°C and 60%, while in Medicine room is 26°C and 50%. And the average temperature and humidity in the Vaccine room were 24°C and 60%, while in the Medicine room it was 26°C and 50%. This difference occurs due to several factors such as the location of the room, the area of the room, and the number of people in the room.

Keywords—Network Attached Storage, NAS, RAID.

1. Introduction

In the era of technology that can help users with various COVID-19 vaccine storage and management are the first things that must be considered before carrying out vaccinations. The aim is to keep the vaccine safe, and to maintain its temperature. Based on the storage procedure, the COVID-19 vaccine is divided into three, namely the COVID-19 vaccine with a storage temperature of 2-8 °C, the COVID-19 vaccine with a storage temperature of -20 °C (mRNA vaccine, Moderna) storage -70 °C (mRNA vaccine, Pfizer). The Sinovac Vaccine ampoule storage room is in the form of a cold chain consisting of a refrigerator and freezer [1][7].

Based on the Standard Operating Procedure at the *Puskesmas*, the storage room must be protected from direct sunlight. The storage of Covid-19 vaccines is arranged in such a way as to avoid retrieval errors, and therefore needs to be stored separately in different vaccine shelves or baskets so as not to be confused with routine vaccines. If possible, the COVID-19 vaccine is stored in a different vaccine refrigerator, and separated from routine vaccines. Vaccine storage for health care facilities that do not yet have a standard vaccine refrigerator (open top according to WHO PreQualification), can still use a domestic refrigerator (household refrigerator), where the arrangement of vaccines is carried out based on the classification of sensitivity to temperature and according to effective vaccine management. Vaccines should not be placed near the evaporator [4].

Most vaccines and drugs at Pudakpayung Health Center should be stored at a temperature between 68-77°F or 20-25°C [3]. Currently, the main device to control temperature and humidity is the air conditioner (AC) installed in the room, while temperature monitoring is done by looking at the thermometer installed in the room. So if there are several storage rooms for vaccines and drugs, the officers must physically come to each storage room to monitor and control the temperature. If one of the drug storage locations is exposed to heat and cold, causing the vaccines and drugs to physically change, the vaccines and drugs have the potential to lose their efficacy or even threaten the health of those who use them. Storage of vaccines and drugs should be the main concern considering that drugs have stability at a certain temperature [5].

To overcome this problem, an Android-based IoT smart health system was built for monitoring and controlling vaccine and drug storage rooms. The system can monitor and control the temperature and humidity of several storage spaces. Each storage room is installed with sensors. Data from the sensors is sent through nodes that are connected to the android phone via the internet. The android phone can display the temperature and humidity conditions of the room and simultaneously send commands to increase and decrease the temperature of the air conditioner as a medium for controlling the room temperature and humidity [6].

2. Device Design

In this study, a monitoring and control system for temperature and humidity in a vaccine and drug storage room based on Android was designed. The system uses one sensor node that sends data from the humidity temperature sensor readings and one other node that controls the air conditioner. The sensor used in this system is the DHT22 sensor which is used as a temperature and humidity detector that will be installed in several rooms and adjusted for readings based on the existing datasheet. The design of these two systems also uses the NodeMCU ESP8266 which acts as a microcontroller that is connected to the internet network to become a publisher which then sends sensor reading data to be displayed to subscribers. The microcontroller is connected to the AC remote (as a control node) to become a control system that can be done remotely using android device. The design and general description of the storage room monitoring and control system are shown in Figure 1.

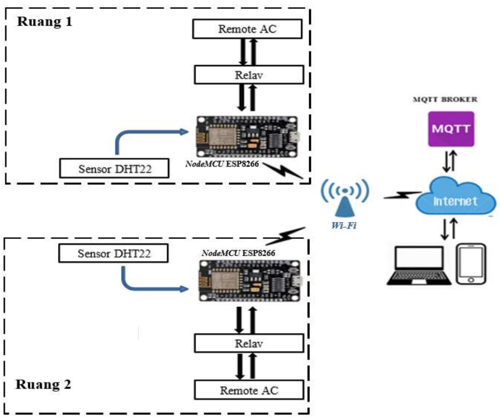

Figure 1 Overview of The Model

The results of the sensor data are then sent via the internet and can be viewed on android devices that have been connected to the MQTT broker through the Cayenne IoT platform for monitoring. This is carried out using the email and password that was created when opening a new project in Cayenne. Monitoring can also be performed by other users without entering email and password with the sharing dashboard feature accessible via the web browser desktop mode. Incoming data will be stored in the database for data analysis purposes.

2.1. *Node Monitoring Design*

In this system, the monitoring sensor node uses NodeMCU ESP8266 as a microcontroller for the communication system node. The NodeMCU ESP8266 is connected to the DHT22 sensor module. The DHT22 sensor is a sensor used to read the temperature and humidity of two computer laboratory rooms. The DHT22 sensor node uses a supply voltage of 3.3 Volt DC. The DHT22 sensor positive pin is connected to one of the 3V3 pins and the sensor negative pin is connected to the NodeMCU GND pin. The DHT22 data interface is in digital form, so the sensor data pin is connected to one of the data pins on the NodeMCU, namely D4. The following design of monitoring nodes in this journal is shown in Figure 2.

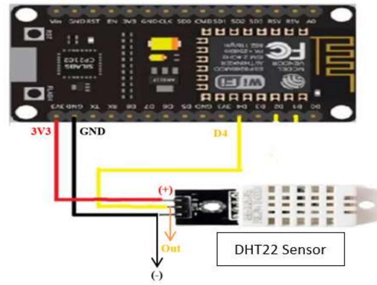

Figure 2 Node Monitoring Design

2.2. *Node Controlling Design*

The control system uses NodeMCU ESP8266 as a microcontroller for communication between the MQTT broker and the relay connected to the AC remote. The AC remote buttons used are the Power On/Off and Temperature Up/Down buttons. Users can control via Cayenne on android device wherever the user is. The relay is connected to the power supply switcher AC to DC output 5 Volts 3 Ampere then connected to the VCC and GND pins of the relay. The logic function of the microcontroller is to control the air conditioner which is read by the relay by connecting the relay input pin (IN) to the GPIO NodeMCU pin. Remote AC uses power from AAA alkaline batteries. The AC remote is connected to the NO (Normally Open) and COM (Common Pin) pins.

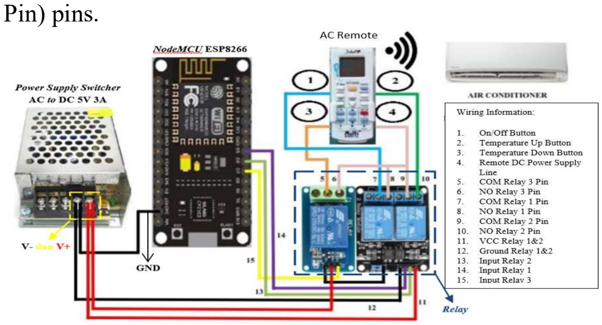

Figure 3 Node Controlling Design

2.3. *Hardware Design*

Figure 4 is a form and circuit of a temperature and humidity monitoring and control system. This sensor node module will be installed and tested in vaccine and drug storage rooms. This temperature and humidity monitoring and control sensor node module consist of one ESP8266 NodeMCU, one DHT22 sensor, four relays, one universal AC (air conditioner) remote equipped with 2 batteries, 5 Volts 3 Ampere power switcher for relays, and a 5 Volts 1 Ampere power adapter for the NodeMCU ESP8266. This series of sensors and control nodes are placed in a plastic box measuring 18.5 x 11.5 x 6.5 cm.

Figure 4 Node Monitoring and Control Module

2.4. ***Software Design***

The software used to configure the program to the NodeMCU ESP8266 on this temperature and humidity monitoring and controlling system is the Arduino IDE 1.6.12. The first step in designing the software is to make a flowchart first and then implement it in the form of a program. Figure 5 shows a flow diagram for the temperature and humidity monitoring system used in the study. The data taken by the microcontroller is data from the temperature and humidity sensors, then the data will be read by the system and sent to the internet cloud with the MQTT broker. MQTT Broker can work by connecting node to node so that data can go directly to the broker as a router. The inner publisher client can also be used as a subscriber. One of the MQTT brokers used in this system, namely Cayenne. The data that has been sent by the MQTT broker when the internet is detected and the MQTT broker is connected can be received by the client and displayed for further storage by the database system.

The monitoring program is inserted into the NodeMCU ESP8266 to run the storage room monitoring system. The program is created and entered using the Arduino IDE software, starting with the initialization of the DHT22 sensor type which the sensor pin is connected to the NodeMCU ESP866, then connecting the NodeMCU ESP8266 with the access point device that is used as internet access to connect with the MQTT broker. Then the initialization of the client ID used for the monitoring system that has been registered with the MQTT broker has to be completed. The sensor then reads the temperature and humidity of the environment which is then sent via the internet by the NodeMCU ESP8266 to the MQTT broker.

The control program in Figure 6 uses the Arduino IDE software to the NodeMCU ESP8266. The program starts by connecting the NodeMCU with the access point for internet access, then initializes the client ID which is used as the control system. In the NodeMCU, initialization of the channel which is used as a function of the remote button is carried out, namely channel 2 represents the command relay 1 which is active as an on/off function, channel 0 represents the command relay 2 which is active as a temperature up function, channel 1 represents the command relay 3 which is active as a temperature down function.

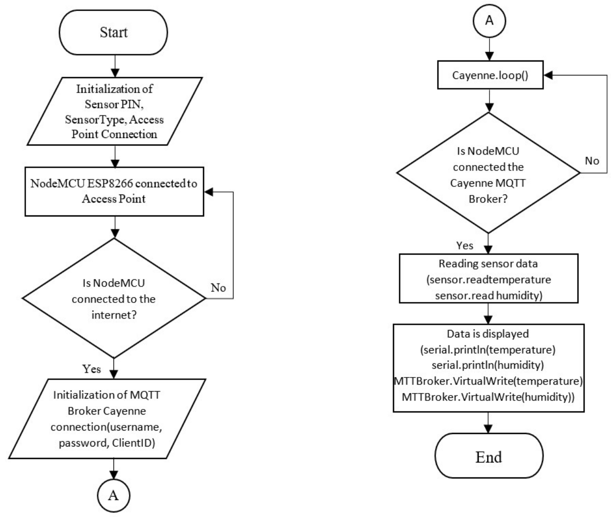

Figure 5 Monitoring Program Flowchart

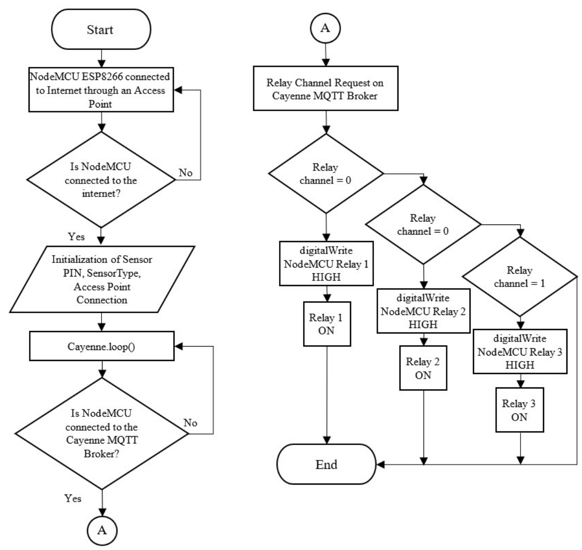

Figure 6 Control Program Flowchart

3. Result

There are 2 experiments in this research. The first experiment is sending sensor data to the database which is carried out to determine the quality of sending and storing data on the system running via the internet with the MQTT broker. This test compares the amount of data sent and received in 40 minutes. Every single packet of detected temperature and humidity sensor data is sent through the MQTT broker, and the data is stored in a database. Clients who open topic address data from the MQTT broker can view sensor data directly and the system can save the data into the database.

Between sending one data and the next data has a delay. The magnitude of the delay can be observed through the timestamp contained in the database. Data loss analysis is done by comparing the number of data packets sent and received to determine the amount of data lost. The number of data packets received can be calculated through the data stored in the database. Data loss testing was also carried out for 40 minutes. To measure the value of data loss, the following equation can be used:

$$Data\ Loss = \frac{\text{Data sent} - \text{Data received}}{\text{Data sent}} \times 100\%$$

Based on the data above, the data loss results for every 10 minutes of sensor data testing are as follows:

Table 1 Test Results of Vaccines Room Device Data Loss

Duration (minute)	Data sent count	Data received count	Data Loss (%)
10	28	27	3.57
20	57	50	12.28
30	85	76	10.58
40	114	100	12.28
Average			9.68

Table 2 Test Results of Drug Room Device Data Loss

Duration (minute)	Data sent count	Data received count	Data Loss (%)
10	28	26	7.14
20	57	48	15.78
30	85	71	16.47
40	114	98	14.03
Average			13.4

Tabel 3 Test Results of Vaccines Room Device Data Loss

Duration (minute)	Data sent count	Data received count	Data Loss (%)
10	28	27	3.57
20	57	54	5.26
30	85	78	8.23
40	114	103	9.64
Average			6.67

Tabel 4 Test Results of Drug Room Device Data Loss

Duration (minute)	Data sent count	Data received count	Data Loss (%)
10	28	25	10.71
20	57	51	10.52
30	85	75	11.76
40	114	100	12.28
Average			11.32

Based on the TIPHON (Telecommunication Internet Protocols Harmonization Over Network) standard, the results of the data loss test above are in the good category and there are also medium ones. Parameters of very good, good, medium, and bad data loss can be seen in the table 5.

The second experiment is testing the effect of room area to determine the working capacity of the air conditioner to maintain temperature and humidity in two computer laboratory rooms that have different areas and volumes. This test aims to see how the capacity of the air conditioner is and how the conditions of the room with the best temperature and humidity are, namely 18 – 28°C and 40 – 60%. Each room used for testing has 2 node modules.

This test is more focused on analyzing what amount or position of the air conditioner to stabilize the temperature and humidity in a room. There are 2 rooms that are used as test objects. Vaccine Room with a room area of 54m^2 and Medicine Room with a room area of 108m2. Both rooms are in Pudakpayung Public Health Center Semarang. The test was carried out by giving the same AC condition setting treatment for the entire room, namely a temperature of 16°C for 1 hour. The location of the sensor node used to monitor temperature and humidity is placed 4 meters in front of the air conditioner. Temperature and humidity data were sampled every 15 minutes from a serial data logger for all types of sensors for 1 hour of testing.

Table 5 Categories of Data Loss Quality Assessment

Category	Data Loss	Index
Very good	0 – 2%	4
Good	3 – 14%	3
Medium	15 – 24%	2
Bad	>24%	1

Source: TIPHON

Table 6 Results of Temperature and Humidity Experiments with Air Conditioner Set at 16°C in Vaccine Room

Time	Average Temperature (°C)	Average Humidity (%)
13:00	26.3	51.9
13:15	26.1	52.1
13:30	26.1	51.2
13:45	25.9	52.4
14:00	25.6	50

Table 7 Results of Temperature and Humidity Experiments with Air Conditioner Set at 16°C in the Drug Room

Time	Average Temperature (°C)	Average Humidity (%)
13:00	25	59.9
13:15	26	63.9
13:30	24.7	64.5
13:45	24.2	50.2
14:00	24.6	66

From the results shown in the table, a graph can be made to compare the temperature and humidity values in the two rooms. Based on the results of the experiments, the temperature value in the medicine room drops faster than the temperature in other rooms. Within 1 hour, the temperature of room 2 had dropped 2°C fasters than that of room 1. Meanwhile, the humidity value did not change much from the initial condition to the air conditioner.

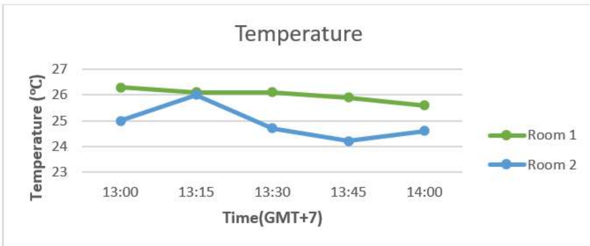

Figure 7 Graph of Room Temperature Value with AC Set at 16°C

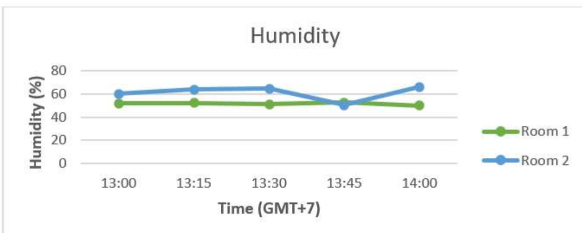

Figure 8 Graph of Room Humidity Value with AC Set at 16°C

Each air conditioner has the capacity to reduce heat or cool a room with a certain area and conditions for 1 hour expressed in BTU/hour. BTU or British Thermal Unit can be a reference in determining the need for air conditioning and finding out how much PK air conditioner a room needs. The BTU value can be found by multiplying the length (l) and width (w) of a room in meters (m) by 500 (standard BTU). Furthermore, after finding the BTU results, pay attention to the amount of PK by looking at table 8.

Table 8 Table of AC Capacity Requirements Based on AC PK

PK	BTU/*hour*
1/2	5000
3/4	7000
1	9000
1,5	12000
2	18000
2,5	24000
3	27000
5	45000

Based on mathematical calculations for the area of the drug room (room 2), which is 54m^2 multiplied by 500, the result is 27000 BTU/h. In fact, there are two ACs with 2 PKs, each one AC in room 2. This shows that the drug room already has sufficient air-conditioned rooms and even more because it means there are 4 PKs in one room or a capacity of 36000 BTU/h.

For the vaccine room (room 1), with an area of 144m^2, through mathematical calculations, the result is 72000 BTU/h. This shows that the vaccine room requires a larger capacity air conditioner than the drug room. The vaccine room also has a small space at the back of 36m^2. Although the main room divider with a small space does not reach the ceiling, 2/3 of the position of the AC is above the small space. This causes the movement of air out of the air conditioner into the vaccine room longer than the medicine room. It could be said that the vaccine room condition is similar to a room that has two air conditioners, if one air conditioner has a capacity of 2 PK, then the BTU is 36000 BTU/h for a 108m2 room, which should get an air conditioner with a capacity of 54000 BTU/h. This is what causes the temperature conditioning by the air conditioner in the vaccine room to take longer than in the medicine room. It can be seen according to the data table and graph that the vaccine room has a higher temperature than the medicine room. The larger the area of the room, the greater the AC capacity required.

4. Conclusion

From the results of making and experimenting with the system in this study, several conclusions can be drawn as follows:

1. The room monitoring system is built using DHT22 as a room temperature and humidity detector which is connected to the NodeMCU ESP8266 which acts as a microcontroller and as a communication tool for sending data from the sensor node.
2. The room control system uses a relay module to connect the AC (air conditioner) remote-control and acts as an automatic switch and NodeMCU ESP8266 as a microcontroller.
3. The room monitoring and controlling system can perform temperature up/down function automatically if the indoor temperature is outside the range of 18 °C – 28 °C.
4. The performance of the room monitoring and controlling system is influenced by the quality of the NodeMCU internet connection in the controlling system, the user's internet connection to the device, and the traffic on the Cayenne.
5. Sending sensor data to the database within a delivery period of 10 minutes has an average delay at each node, which is 21 seconds, and sending sensor data to the database has good data loss quality, which is 9.68% for the Vaccine Room node, 13.4 % for drug nodes, and 6.67% for drug room nodes.
6. The average temperature and humidity in the vaccine room were 24°C and 60%, while in the medicine room it was 26°C and 50%. This difference occurs due to several

factors such as the location of the room, the area of the room, and the number of people in the room. The more people in a room, the higher the temperature and lower the humidity. The wider it is, the higher the number of BTU/h, which means it has a need for AC (air conditioner) with a high PK.

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