Prototype of implementation of hybrid visible light communication technology for tele controlling systems in archives warehouse

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***Abstract*— Paper is one type of archive that is stored in the Archives Building. Maintenance of paper type archives needs to be considered to avoid mold growth and discoloration due to cigarette smoke. Therefore, a telecontrolling device is needed that can maintain a stable air humidity at 30% - 55% and a temperature of 15 °C - 22 °C. However, devices with a frequency of 2.4 GHz should not be used simultaneously in the same area because it will cause interference that can reduce performance. In this study, a temperature tele controlling system and smoke detection in the archive warehouse were made using hybrid visible light communication technology to improve data transmission performance. The system consists of 1 transmitter node connected to DHT 22, MQ 2, LED laser and WiFi network, as well as 2 receiver nodes to control the fan and water pump. The data from the receiver will be passed through the photodiode and then processed by the microcontroller. If the temperature value reaches the threshold, the receiver node will send a command so that the fan will turn on automatically, then if the smoke value reaches the threshold, the water pump will turn on automatically. The temperature and smoke values can be monitored in real time through the android application. The test results show that the use of hybrid visible light communication technology in the tele controlling system makes the delivery performance better.**

***Keywords*—DHT 22, MQ 2, Hybrid Visible Light Communication.**

I. INTRODUCTION

The existence of archives has an important role as accurate evidence of an activity. The archive warehouse is a storage room for recording activities or events in various forms and media designed with a special structure to meet the need for archive protection, as well as prioritizing the task of maintaining and maintaining archives. One type of archive that is widely stored is the type of paper [1]. Paper type archives include files, cards, computer printouts and the like. In the maintenance of paper type archives, special monitoring is needed by supervisors because of the instability of temperature and humidity conditions in the archive warehouse in the air humidity range of 30% - 55% and temperature 15 °C - 22 °C [2]. This instability can result in black spots and dark mold growth spots that can extend to cover the entire surface of the sheet. In addition, the absence of monitoring and control of cigarette smoke has resulted in some supervisors smoking in inappropriate places, resulting in the color of the paper turning black at the edges and leaving scorched spots, thereby destroying the information from the archive [3].

Therefore, there is a need for efforts to maintain the physical condition of the archive from pests and cigarette smoke by using a tele controlling device using DHT 22 and MQ 2 sensor inputs. Thermohygrometer [4]. However, in terms of making tele controlling devices, many still use technology with a frequency of 2.4 GHz, including Bluetooth, home RF, wireless LAN. The use of bluetooth electronic devices and WiFi services in public spaces allows both communications to work simultaneously and in the same area, resulting in interference resulting in decreased performance [5].

Based on the above problems, a device that is able to monitor and control automatically temperature, humidity and smoke is needed in the archive warehouse area by minimizing the occurrence of interference on the device. One of them is by using hybrid visible light communication technology for sending and receiving information by utilizing the visible light spectrum ranging from 380 nm – 780 nm in the Personal Local Area (PAN) [6]. Utilization of WiFi is used for sending data on android applications in real-time. Utilization of the visible light spectrum which is not affected by electromagnetic interference is more advantageous than the RF network system [7].

In this study, a prototype of the implementation of hybrid visible light communication technology for the tele controlling system in the archive warehouse will be made in order to improve data transmission performance. The system designed uses 1 transmitter node which is connected to the DHT 22 sensor, MQ 2, LED laser and WiFi. Where the LED laser is used for communication between nodes (Personal Area Network), while the WiFi network is used to send data readings on the android application. Laser LEDs are claimed to have more focused light and a longer beam of light compared to other types of LEDs [8].

The principle of a VLC-based communication system is to modulate the transmitted signal so that the LED light flashes at a high frequency so that it cannot be detected by the human eye and the sent light signal is detected by a photodetector which can capture changes in the state of the LED and has a response

[9]. Visible light communication has the features of high data transmission, wider bandwidth coverage, no interference in electromagnetic sensitive areas, high security, regulation free and safe for health so that visible light communication is attractive to be used as wireless communication in the future [10]. The combination of visible light communication technology and Wifi is proposed to be superior to a conventional single RF system with bandwidth capacity exceeding 1000 times than the conventional system [11,12].

MQ-2 sensor is used as a detector for CO gas levels in cigarette smoke in [13]. The MQ-2 sensor is considered to have fast and precise sensitivity, response time and measurements [14]. The choice of PWM modulation because of its ability to carry more bits in one pulse compared to OOK and provide communication access without causing the effect of dimming the illuminance level (dimming) and blinking the LED lights simultaneously (flickering/blinking). PWM is also considered as a simple and efficient modulation for digital data transmission [15].

There are 2 receiver nodes to control the fan and water pump. The data received by the receiver will go through the photodiode and be processed by the microcontroller. If the temperature value reaches the threshold, the receiver node will send a command to turn on the fan, while if the smoke value reaches the threshold, it will turn on the water pump automatically. Temperature and smoke values can be monitored in real-time on the android application. Laser LEDs connected to Arduino Uno and sensors are used to monitor the condition of the archive warehouse through the Android application as well as media for sending data between nodes. The ESP32 microcontroller connected to Wifi is used to control the turning on of the fan and water pump in the archive warehouse. So that it is hoped that it will be easy to control and monitor remotely by archive warehouse staff and minimize interference between devices due to electronic devices.

II. METHOD

A. System Block Diagram

The block diagram of this research is shown in Fig. 1. Based on Fig.1 there is 1 transmitter node and 2 receiver nodes. At node 1 of the transmitter there is a DHT 22 sensor to measure the humidity and temperature of the archive warehouse and an MQ 2 sensor as a smoke detector. Both sensors are connected to the microcontroller ESP8266. The data is sent using an LED laser component as visible light communication technology on the personal area network, while the data displayed in real-time on the archive warehouse monitoring application will be sent over the WiFi network by the transmitter node. The receiver node is used to control the ignition of the water pump and fan which is controlled by Arduino Uno in which there is a photodiode component as a data receiver in the form of voltage, and a 2 channel relay as an automatic switch to turn on the 12V water pump and fan.

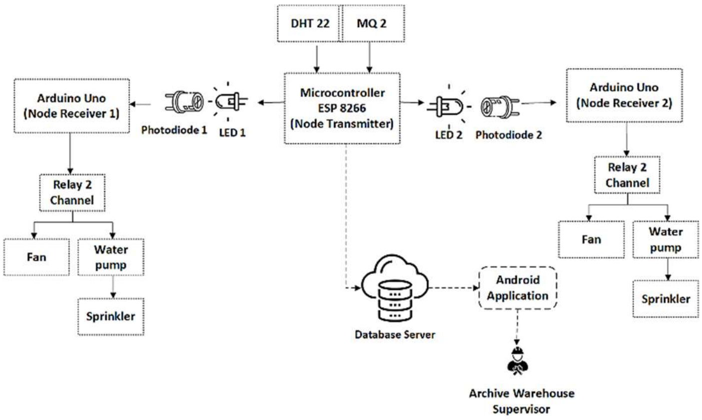

Figure 1. Block Diagram

B. The System Workflow

The system workflow is shown in Fig. 2. Where the receiver node uses temperature value input and humidity using DHT 22 sensors in the form of digital data and MQ 2 to detect smoke in the form of analogue data. The sensor will do scanning continuously until it is detected. Then the sensor reading data will be sent to the Android application by the microcontroller ESP8266 through the WiFi network, in addition to that by the microcontroller ESP8266 both of these data will be converted in binary to be sent to Arduino Uno using LED laser. LED laser controlled by the microcontroller ESP8266 will turn on to send data.

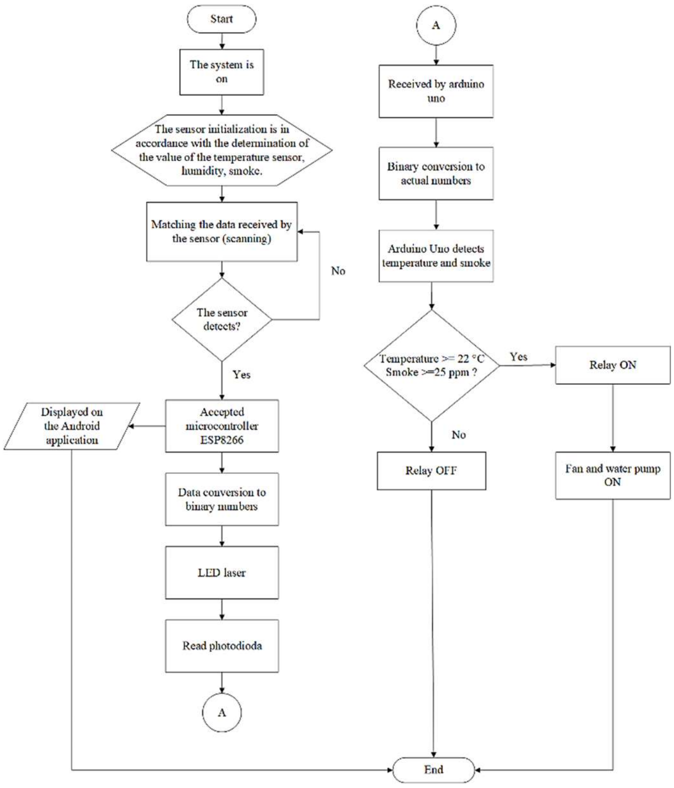

Figure 2. The System Workflow

On the receiving side of the photodiode will receive a voltage from the laser LED. This voltage will be considered data, if the voltage received is equal to the input, the voltage will be converted to a actual number. Delivery and receipt data will be displayed in the Arduino idea monitor series. In Arduino the idea will be displayed information according to whether or not the placement of the recipient and sender, the results of the Arduino Idea reading in the form of actual and binary numbers. However, if the data is received is not the same as the data sent, it will also be displayed in the idea monitor series and can be calculated and analysed by the BER (bit error rate). Research conducted previously standard on the visible light communication system, namely at 10^{-3}. The conversion data will be processed by Arduino Uno for fan control and water pump.

C. Hardware Planning

The hardware design in Fig. 3 shows the transmitter circuit scheme, the components contained in it include DHT 22 sensor, MQ 2, microcontroller ESP8266, LED laser. Both sensors are placed near air circulation and cooler which serves to retrieve data accurately in the archive warehouse, including temperature conditions, humidity and CO levels from cigarette smoke. Where the microcontroller ESP8266 is used as a conversion of temperature, humidity and smoke values into binary numbers. The lighting source of the transmitter circuit derived from LED Laser SYD1230 which is connected to the microcontroller ESP8266 on Pin D1 for laser 1 and D2 for laser 2 because binary values 1 and 0 are considered digital data. LED Laser SYD1230 was chosen as a transmitter to transmit data because it has a beam that focuses on 1 point and has a 5mW power and an input voltage of 5V, so it matches applicable on the tele controlling device for sending data on the personal area network.

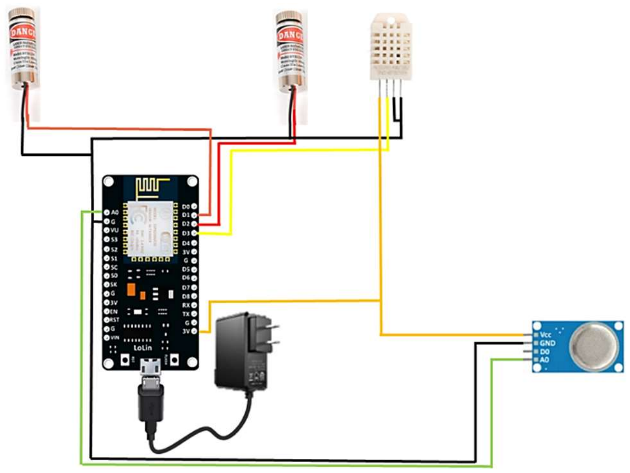

Figure 3. Diagram Hardware in Node Transmitter

Next in Fig. 4 shows the circuit scheme on the receiver node that functions as a series of recipients of information sent by the transmitter node (transmitter) and to control fans and water pump according to the program at Arduino Uno. The recipient circuit will be installed at 2 reading room points in order to control the whole room. Inside the recipient node there are components, namely arduino uno, 2 relay channels, and photodiode. The photodiode used is HW-477. The photodiode has a small power of 5V so it is suitable for use as reception of light in the prototype. Photodioode will read the voltage of the LED laser as data so that the microcontroller ESP8266 can process data for ignition fans and water pump.

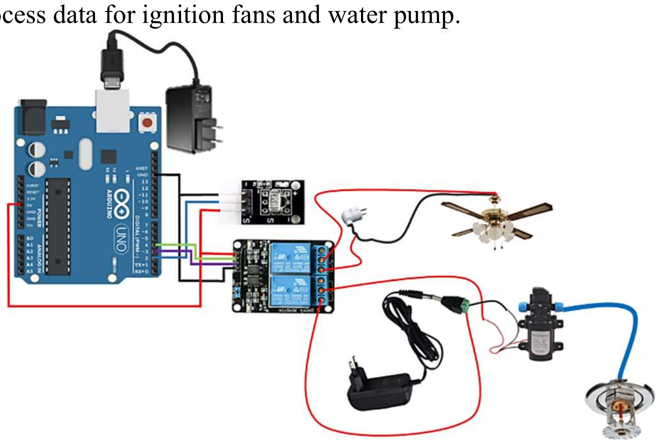

Figure 4. Diagram Hardware in Node Receiver

D. Android App Planning

Fig. 5 shows an android application design created to monitor temperature, humidity and smoke detection in the archive warehouse. In the display of the archive warehouse monitoring application there is information about room temperature (C°), room humidity (%), smoke content (CO). In addition, there is a "notification" button in the lower corner used to see a history of notification regarding the instability of the condition of the archive warehouse, both temperature and smoke detection.

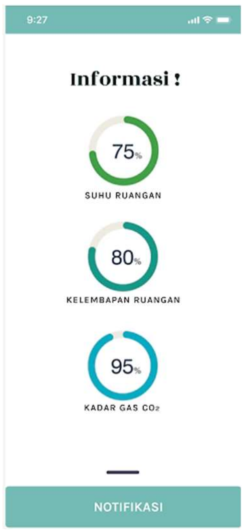

Figure 5. Android App Planning

III. RESULTS AND DISCUSSION

A. Hardware Circuit Results

The implementation of the transmitter node and receiver node has been assembled into a module shown in figure 6 and Fig. 7. Each component is connected according to its pin has been designed.

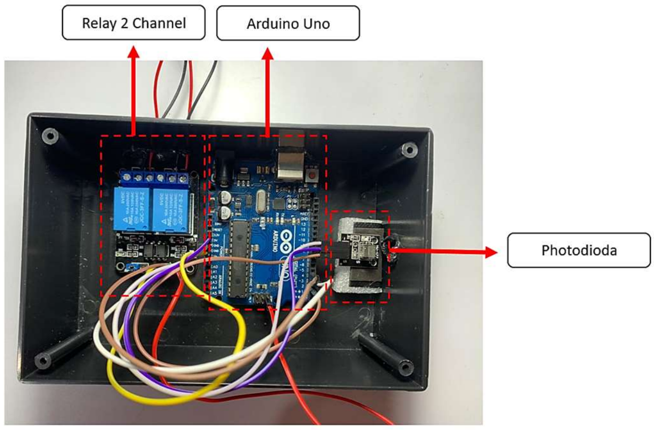

Figure 5. Implementation of Receiver Node

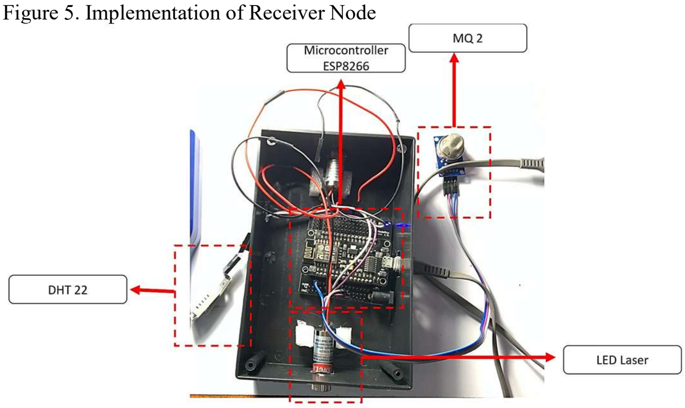

Figure 6. Implementation of Transmitter Node

B. System Installation

The system which consists of 2 node receiver and 1 node transmitter, is installed on the second floor of the Reading Room of the AH Polinema Building. Both receivers are placed in a symmetrical area with the transmitter node so that data transmission works well. Fig. 8 shows the whole node installation.

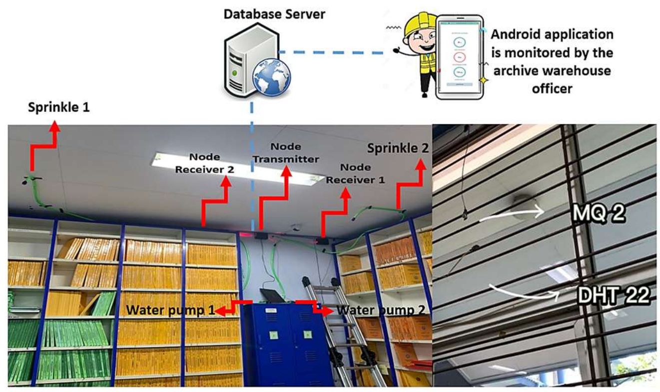

Figure 7. Overall Implementation

C. DHT 22 And MQ 2 Accuracy Testing

The test of the DHT 22 sensor aims to determine the level of accuracy of the data read by the DHT 22 sensor, namely the level of temperature and humidity. The accuracy of the DHT 22 sensor value is compared with the HTC -1 Thermometer Hygrometer. Prior to accuracy, the DHT 22 sensor was calibrated. Figure 9 is the result of the accuracy of the sensor in measuring temperature and humidity. The following is the formula to determine the error value of the DHT 22 sensor measurement results compared to the HTC -1 Thermometer Hygrometer measuring instrument.

$$\text{Error} = \frac{\text{Sensor Test Value} - \text{Test Tool Standard Value}}{\text{Test Tool Standard Value}} \times 100\% \quad (1)$$

$$\text{Average Error} = \frac{\text{Total Error Value}}{\text{Total Testing}} \quad (2)$$

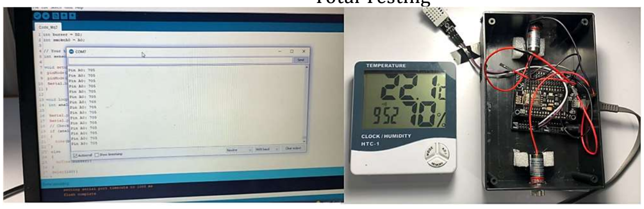

Figure 8. DHT 22 Accuracy Measurement

TABLE I.
ACCURACY OF TEMPERATURE AND HUMIDITY MEASUREMENT

Test to-	DHT 22 Sensor Measurenment		Thermometer Hygrometter Measurement		Erorr %	
	Temperature (°C)	Humidity (%)	Temperature (°C)	Humidity (%)	Temperature (°C)	Humidity (%)
1	21.1	72.8	20.8	71	1.4	2.5
2	21.1	72.8	20.8	71	1.4	2.5
3	21.1	72.8	20.8	71	1.4	2.5
4	21.2	71.6	21	70	1.0	2.3
5	21.8	71.3	21.6	70	0.9	1.9
6	21.8	68.9	21.6	68	0.9	1.3
7	22.4	68.7	22.2	68	0.9	1.0
8	22.4	68.2	22.2	68	0.9	0.3
9	22.4	67.5	22.2	67	0.9	0.7
10	22.8	67.3	22.6	67	0.9	0.4
Average (%)					1.1	1.6

Based on Table 1, it can be seen that the results of the comparison test of the DHT 22 d sensor value from temperature and humidity were carried out by taking 10 data measured using the DHT 22 sensor compared to the HTC -1 Thermometer Hygrometer measuring instrument, the average temperature error percentage was 1.1% and humidity 1.6% where The error percentage is small so that the DHT 22 sensor can be used for research.

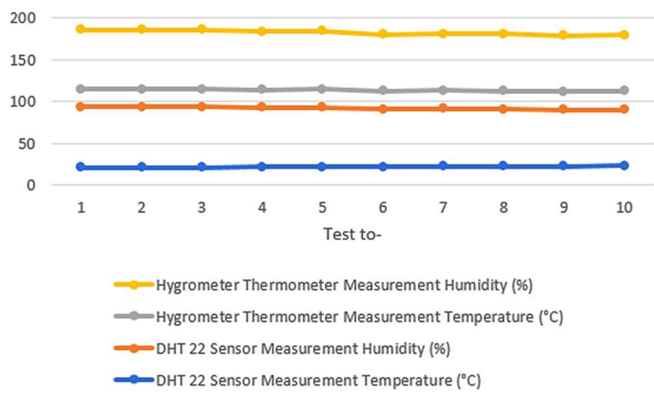

Figure 9. Graph of the DHT 22 Sensor Accuracy Test and the HTC-1 Thermometer Hygrometer

The percentage of measurement error is obtained from the sum of the total values of temperature or humidity divided by

10 times of testing and then multiplied by 100%. The following is Fig. 10 which is a graph of the DHT 22 Sensor Accuracy Test and the HTC -1 Thermometer Hygrometer, while Fig. 11 is a graph of the percentage error of temperature and humidity.

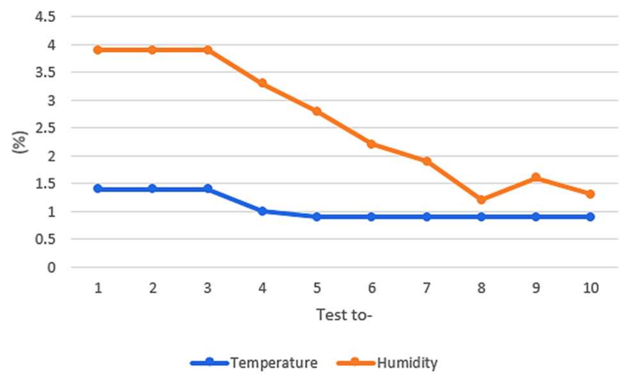

Figure 10. Graph of the Percentage Error of Temperature and Humidity

In this test, it is carried out by bringing the MQ 2 sensor closer and the standard air quality detector measuring instrument with CO gas. Sensor testing has been carried out 10 times just to see the sensor response to cigarette smoke. Before the accuracy process is carried out, the MQ 2 is calibrated first. Fig. 12 shows the results of the accuracy values of the MQ 2 sensor displayed on the Arduino IDE and on the air quality detector. The following is the formula for determining the error value of the MQ 2 sensor measurement results compared to the air quality detector measuring instrument.

$$\text{Error} = \frac{\text{Sensor Test Value} - \text{Test Tool Standard Value}}{\text{Test Tool Standard Value}} \times 100\% \quad (3)$$

$$\text{Average Error} = \frac{\text{Total Error Value}}{\text{Total Testing}} \quad (4)$$

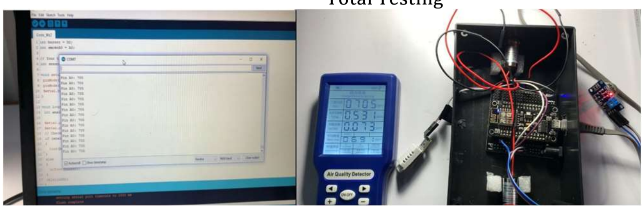

Figure 11. MQ 2 Accuracy Measurement

TABLE II.
ACCURACY OF CO GAS MEASUREMENT

Test to-	Test Result		
	CO Gas detection (ppm)	Sensor MQ 2 (ppm)	CO Gas detection (ppm)
1	551	550	0.181
2	551	551	0.000
3	552	551	0.181
4	558	554	0.717
5	558	554	0.717
6	562	562	0.000
7	562	562	0.000
8	610	601	1.475
9	610	601	1.475
10	630	628	0.317
Average (%)			0.506

Based on Table 2, the results of the comparison test of CO gas which were carried out by taking 10 data measured using the MQ 2 sensor compared to the air quality detector measuring instrument, the percentage error was 0.506 % where the error percentage was small so that the MQ 2 sensor could be used for research. The percentage of measurement error is obtained from the sum of the total values of temperature or humidity divided by 10 times of testing and then multiplied by 100%. The following is Fig. 13 which is a graph of the MQ 2 Sensor Accuracy Test.

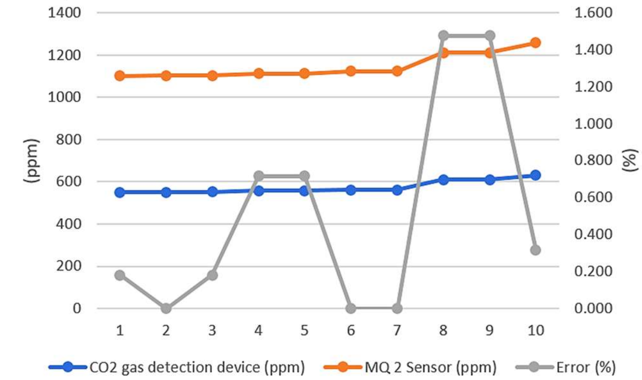

Figure 12. Graph of the MQ 2 Sensor Accuracy Test

D. Bit Error Rate Testing

In this test, it is done by testing the delivery and receipt of data to find out the number of bits that are error when sending data. LED SYD1230 and photodiode HW-477 must be symmetrical so that the data can be sent properly. Total bits of data sent depending on the results of the conversion from integers to binary numbers. In this test used is the data on the conversion of temperature and smoke sensors with a total of 6 bits each time transmission. The test is carried out 10 times each multiple of 50 cm to 300 cm only to test the number of bits that are error when sending data. The following is the formula for determining the Bit Error Rate (BER) value.

$$\text{BER} = \frac{\text{Bits Error}}{\text{Total Bits Sent}} \times 100\% \quad (5)$$

TABLE III.
RESULTS OF THE BIT ERROR

Distance (cm)	The number of bits sent (bit)	The correct number of bits received (bit)	BER
50	6	6	0
100	6	5	10-1
150	6	5	10-1
200	6	5	10-1
250	6	4	4 x 10-1
300	6	3	3 x 10-1

Table 3 shows the value of the BER, where the value is used to determine whether or not a data signal sending system from the transmitter to the receiver. From 10 times the tests that have been carried out at each multiple of a distance of 50 cm to 300 cm, the smallest value of the value is obtained at a distance of 50 cm. At a distance of 100 to 200 cm obtained a 10^{-1} value which means that from 10 times the test there are 1 bit of data that is not accepted (error). At a distance of 250 cm obtained a value of 4 x 10^{-1} which means that from 10 times the test there are 2 bits of data that are not accepted (error). Then at a distance of 300 cm obtained a 3 x 10^{-1} value, which means that from 10 times the test there are 3 bits of data that are not accepted (error) so that it can be analyzed that the farther the distance between the transmitter and receiver, the value of the bit error rate (BER) will be increasingly more big. In addition, the placement between LED laser and photodioda must be symmetrical because the laser LED has a focused light in 1 direction, so it has good quality for data transmission.

E. Quality of Service (QOS) Testing

This delay measurement is used to determine the time it takes for data to travel the distance from origin to destination. Experiment measurement of communication between sensors to the database using tPacketCapture. tPacketCapture is run while the system is starting and stopped when the system has been used to capture IPv4 TCP/UDP communications. Fig. 14 is the result of tPacketCapture.

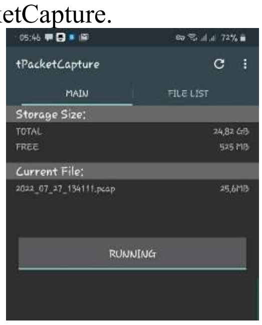

Figure 14. Result tPacketCapture

The captured tPacketCapture is opened using wireshark for analysis. The test was carried out using the ip source of the ESP 8266 microcontroller which was 34.120.160.131 while the destination ip was using the firebase server ip which was 10.8.0.1. The purpose of this test is to determine the delay in the communication system when performing attendance activities goes well or not. The following is a display of calling the firebase URL while running wireshark which is already connected to the ip access point. Fig. 15 is a data display on wireshark and Fig. 16 is data wireshark save using excel format (.csv).

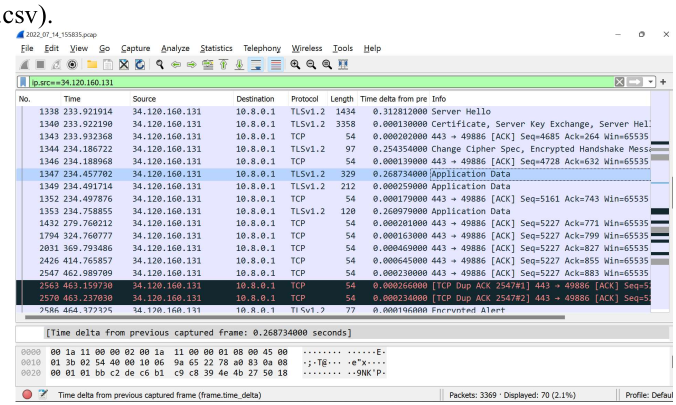

Figure 15. Display Data on Wireshark

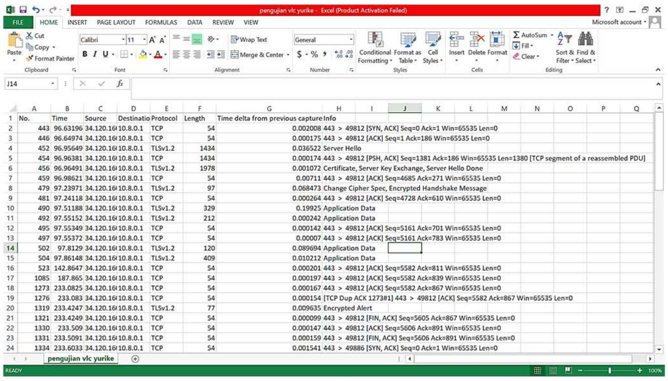

Figure 16. Data Wireshark save using Excel

Data readings on wireshark that have been stored using excel format (.csv) then the data results in Fig. 16 can be used to analyze delay at each transmission distance by testing 6 times track running using tPacketCapture software then track running results can be opened on wireshark software for analysis. The results of the delay can be seen in the column "Time delta from previous displayed frame". The following is a Table 4 of delay results.

TABLE IV.
RESULT OF DELAY

Distance (cm)	Ip Source	Ip Destination	Delay (ms)	Category
50	34.120.160.131	10.8.0.1	34	Very Good
100	34.120.160.131	10.8.0.1	40	Very Good
150	34.120.160.131	10.8.0.1	49	Very Good
200	34.120.160.131	10.8.0.1	259	Good
250	34.120.160.131	10.8.0.1	269	Good
300	34.120.160.131	10.8.0.1	271	Good

Table 4 shows the results of the delay measurement that has been made from the sensor to the database. Where there are 6 test samples based on the best value of each specified distance. In table 4 the smallest delay value is 34 ms which is included in the very good category while the largest delay value is 271 ms, which according to TIPHON standardization included in the good category.

Packet loss is a parameter that illustrates the number of data packages lost during the process of sending data to the server. Packet loss can occur due to collisions and congestion on the network and this affects all applications because transmission will reduce the overall network efficiency even though the bandwidth is sufficiently available for this application. In figure 17 is the packet loss value in Wireshark, there are 6 test samples based on each specified distance. This packet loss measurement is an experiment of measurement of communication between the sensor to the database using Wireshark.

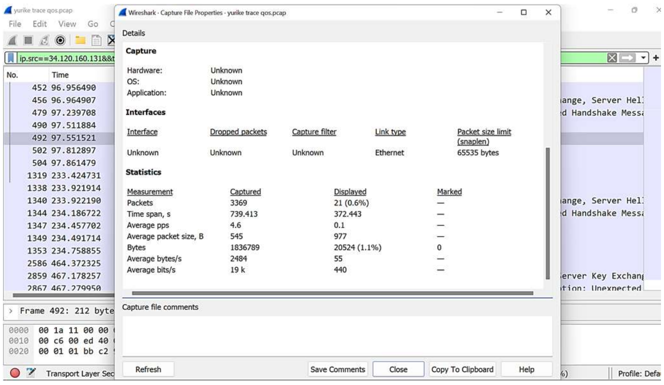

Figure 17. Result Packet Loss in Wireshark

From Fig. 17, the results of testing the number of packages that were successfully sent were 3,369 and the package that was not successfully received by Server 21. So that the package that was successfully received by the server was 3,348 packages. To calculate the value of packet loss using the following formula:

$$\text{Packet Loss} = \frac{(\text{Data Packets sent} - \text{Data Packets receive})}{\text{Data Packets sent}} \times 100\% \quad (6)$$

$$= \frac{(3.369 - 3.348)}{3.369} \times 100\%$$

$$= 0.006233 \times 100\%$$

$$= 0.6\%$$

From the results above, Table 5 is measuring packet loss.

TABLE V.
RESULT OF PACKET LOSS

Distance (cm)	Package sent (package)	Package received (package)	The number of missing packages (package)	Paket Loss (%)	Category
50	3.369	3.348	21	0.6	Very Good
100	3.369	3.348	21	0.6	Very Good
150	3.369	3.341	28	0.8	Very Good
200	3.369	3.341	28	0.8	Very Good
250	3.369	3.325	44	1.3	Very Good
300	3.369	3.321	48	1.4	Very Good

Can be seen in Table 5 The smallest packet loss value is 0.6% and the largest is 1.4 %. The loss package value is a low value in which based on TIPHON standardization included in the very good category.

IV. CONCLUSION

Based on the background, problem, planning, implementation, testing, and discussion, it was concluded that the prototype telecontrolling in the archive warehouse using the DHT 22 sensor and the MQ 2 sensor as input. Both sensors are controlled by the microcontroller ESP8266 as a transmitter node. Data transmission to the recipient node uses visible light communication technology for private areas and wifi networks for applications. The maximum distance between the nodes that can be taken based on the results of testing the quality of data delivery using the proposed system is 3 meters so that the optimal value at a distance of 50 cm with a value of 0. while at a distance of 100 to 200 obtained a BER value of 10^{-1}. At the farthest distance of 300 cm, the value is getting bigger, which is 3 x 10^{-1}, which means that from a total of 6 bits of data sent, there are 3 bits of error data. So that the farther the distance between the receiver and the transmitter, the greater the value of the BER. The use of this laser LED has good quality for data transmission because it has a focused light in one direction, therefore the signal strength will also have good quality. Utilization of hybrid visible light communication technology in sending data on a telecontrolling system in the archive building, producing the smallest delay of 34 ms which is included in the very good category and the largest delay value of 271 ms is included in the good category. While the smallest packet loss value is 0.6 % and the largest is 1.4 % included in the very good category so it can be concluded that the use of hybrid visible light communication technology on the telecontrolling system makes the performance better.

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