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***Abstract*— Temperature and humidity control are required at the room of mushroom farming to get maximum results. The process of controlling temperature and humidity is currently and highly dependent on human labor. Therefore, human interventi is greatly affected. This paper discusses the existence of internet of things (IoT, hereafter) technology as a temperature and humidity controller by using the Message Queuing Telemetry Transport (MQTT, hereafter) protocol based on the publisher and supplier paradigm. The MQTT protocol was chosen because it has a faster data transmission rate than using The Hypertext Transfer (HTTP, hereafter) Protocol. Data transmission speed makes accuracy in controlling temperature and humidity more accurate. Therefore, it boosts the speed to ideal temperature and humidity. The tests in this study are conducted to analyze the rate of data transfer speed from the sensor to the ideal temperature conditions. It takes an average of 7 minutes in these conditions. Meanwhile, the ideal humidity condition requires an average of 6 minutes. The average time is the time required when the room temperature is at 34^{0}C and the humidity at the room is above 90%. Thus, the MQTT protocol is able to control room temperature and humidity in process of mushroom cultivation. It can be concluded that dependence on human labor is able to reduce.**

Keywords — MQTT Protocol, Internet of things, raspberry pi, temperature control and humidity

I. INTRODUCTION

Mushroom cultivation requires human intervention to grow mushrooms starting from composting to harvesting. Ideal conditions are needed for optimal growth. Mushrooms grow well at room temperature between 16-23ºC and relative humidity levels between 80% - 90% [1]. To achieve these ideal conditions, human intervention is significantly needed for a whole day. Currently, watering mushrooms for a whole day can either increase or decrease humidity level to achieve ideal conditions [2]. In addition, air circulation is needed in the room. Therefore, air conditions remain healthy. It can be analyzed that human intervention is required to have optimal mushroom growth.

The rapid technological advancement today has changed all aspects including agricultural production. Internet of things and cloud computing offers progress to increase connectivity between humans and agricultural objects [3]. This connectivity is able to bridge between humans and various objects in nature. Therefore, human intervention to an object can be reduced. The dependence on humans in controlling a job can be minimized due to an algorithm operating resembles the work done by humans. Internet of Things can also be used to overcome the limitations of agricultural land due to environmental pollution [4].

The data communication protocol used on the Internet of Things is the Message Queuing Telemetry Transfer protocol (MQTT, hereafter) [5]. MQTT protocol works with the concept of Publish/ Subscribe where the communication occurring uses a low power but it is sufficient enough to transmit data on the Internet of Things. There are several reasons why using the MQTT protocol as the basis of the work of the Internet of Things such as the existence of limited power on devices: sensors, relays. The device uses low power but it determines the success in the transmission process. Thus, it can be concluded that the use of MQTT protocol is the proper decision. The second reason is that limited bandwidth and connection are not always connected, while the Internet of Things requires speed in updating data.

There is a difference between the MQTT Protocol data transmission process and Transmission Control Protocol (TCP, hereafter) or Internet Protocol transmission (IP, hereafter) process. In TCP/ IP data transmission, there is a term called 3-way handshake that occurs by throwing Synchronize Sequence Number Acknowledgement (SYN-ACK, hereafter) among each other before data transmission occurs. It can also be stated that there is a request and response process. On the other hand, the working principle of the MQTT protocol is to apply the publisher-subscriber paradigm [5]. MQTT protocol does not recognize SYN-ACK process as in TCP or IP because the process of transmitting data from sensors or the other is directly sent without the "introduction" process between source and destination. Data obtained from the sensor will be sent through broker as an intermediary to the subscriber. The use of the MQTT protocol on Internet of Things technology is preferred over The Hyper Text Transfer (HTTP, hereafter) protocol because the MQTT protocol only requires low power and a small bandwidth but the accuracy and speed of data transmission can still be relied upon.

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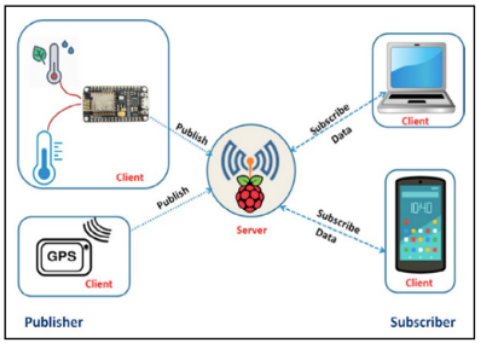

Fig. 1. MQTT Protocol Work Principle

Fig. 1 presents the working principle of the MQTT Protocol. As described in the figure, publisher with subscriber is connected to the broker or a server. Broadly speaking, there are three main components in the MQTT protocol namely publisher, broker or server and subscriber [6].

- Publisher is a component that collects the data from real-time sensors. Before being sent by the publisher, the data publishes certain topics such as temperature, humidity, and others.
- Subscriber is the recipient of data topics from the publisher in the form of sensor values, humidity values and others. Topic data can be displayed on the mobile application or the dashboard user interface.
- Broker is an intermediary third party that manages the transactions between publisher and subscriber. A broker mainly aims to collect and process data from the publisher and send to the subscriber. Here is where the process of data topics will be processed and therefore the broker is a smart-device that is able to process data topics at one time. Brokers can be called a server's ability to process data and can be a cloud service.

Based on those aforementioned advantages of the MQTT protocol, there are several MQTT protocol capabilities in terms of Quality of Service (QoS), namely QoS 0 (at most once), QoS 1 (at least once) and QoS 2 (exactly once) [7]. The use of the MQTT protocol is able to provide guaranteed bandwidth exchange, availability and guaranteed delivery of data and then this MQTT is able to handle 10,000 clients with guaranteed connectivity [8].

The purpose of this paper is how to maintain temperature and humidity towards ideal conditions so that the mushroom cultivation process takes place optimally by using the concept of the Internet of Things.

II. METHODOLOGY

This paper aims to discuss temperature and humidity control and monitor in the mushroom cultivation process using the Internet of Things technology by utilizing the MQTT protocol. As explained in the introduction above, the MQTT protocol is used because of its ability to transmit data from the sensor as a publisher to a subscriber with cloud services as a broker or a server. The application of the Internet of Things to mushroom cultivation is to reduce human intervention in controlling and monitoring temperature and humidity in the mushroom cultivation room in real time. Fig. 2 below shows the work processes of the Internet of Things in mushroom cultivation.

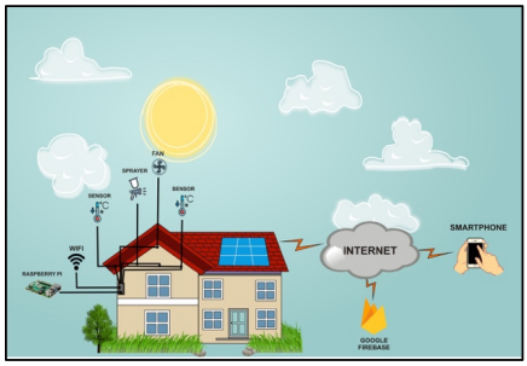

Fig. 2. Work process of Internet of Things

According to the aforementioned description, it can be identified that several materials and tools are needed in this study to achieve its objectives optimally. The following Table. 1 reports the list of materials and tools to support this research.

Table. 1. List of materials and tools

No	Materials	Function
1.	Dht 11	Utilized as humidity sensor
2.	Raspberry	Utilized as a microcontroller
3.	Relay	Utilized to control the opening and closing of the circuit contacts of an electronic circuit
4.	Power supply	Utilized to supply electric power to an electrical load
5.	Mushroom cultivation miniature	Set up mushroom farming
6.	Android studio	Utilized as a software
7.	Internet Modem	Utilized as internet supply
8.	DS18B20	Worked as a sensor
9.	Sprayer	Utilized as watering device
10.	Fan	Utilized to control air circulation
11.	Google firebase	Using as a real-time database
12.	Internet	Internet connection
13.	Jump wire	Used to interconnect the components

MQTT protocol works based on the publisher-subscriber paradigm with broker or server intermediaries. In the recent study, Raspberry Pi 3 works as a broker / server is a small computer device with large capabilities. This device will later connect the publisher with the subscriber via cloud services. The Raspberry Pi 3 specifications are used as follows:

SoC : Broadcom BCM2837
CPU : 4x ARM Cortex-A53, 1.2GHz
GPU : Broadcom VideoCore IV
RAM : 1GB LPDDR2 (900 MHz)
Network : 10/100 Ethernet, 2.4GHz 802.11n wireless
Bluetooth : Bluetooth 4.1 Classic, Bluetooth Low Energy
Storage : microSD

GPIO : 40-pin header, populated
Ports : HDMI, 3.5mm analogue audio-video jack, 4x USB 2.0, Ethernet, Camera Serial Interface (CSI), Display Serial Interface (DSI)

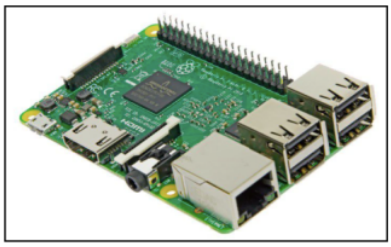

Fig. 3. Raspberry pi 3 model B

Fig. 3 be shown raspberry pi 3 model B is used as a server/broker. Raspberry pi is provided with by Python language to support the MQTT protocol through general purpose input output (GPIO) socket as the gateway of two-way communication. The hardware (sensor and the automatic tools) is connected with raspberry and user interface through Google firebase as the real-time database management. Firebase real-time database provides responses to process automation of DHT 11 sensor. This censor is a digital data processing type that will easily support the process of data storage in the firebase by utilizing database a service approach. Firebase is the solution of cross-platform messaging that allows reliable, free messages delivery [9]. Fig. 4 displayed the architecture of firebase. Firebase real-time database is a platform under Google's infrastructures that supports developers to create applications easily and in a fast way without concerning the scalability. As the results, the developers could focus more on creating the best application [10].

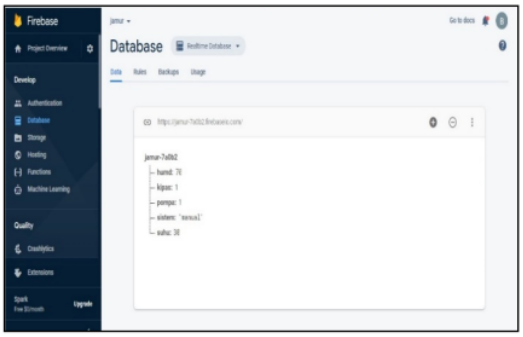

Fig. 4. The Architecture of Firebase

All the stored data in the firebase will be delivered to mobile device in form of processed information in the android programming. This information then is displayed to end user. The displayed data is the real-time room temperature and humidity of mushroom cultivation. Function button is added as the option to give direct control that works automatically (according to the sensor's condition) or manually. The design of user interface (UI) is displayed in Fig. 5.

This UI integration will later ease mushroom farmers in monitoring the ideal room temperature and humidity in the mushroom cultivation. As the results, the amount of possible decaying mushrooms could be minimized.

Fig. 5. The Design of User Interface in Android

III. Result and Discussions

The testing process of MQTT protocol generally refers to the entity categorization according to the architecture design of internet of things. Testing process of the first entity is conducted to observe the communication performance of data delivery from machine to machine extraction between DHT 11 temperature sensor, the fan and the spray integrated in the raspberry pi. On the other hand, the testing of the second entity aims to measure TCP/IP speed delivery during the automation process that occurs in the smart phone when the sensor delivers data to move the fan and the spray through SYN-ACK protocol HTTP. It involves firebase as the console database. The entities pattern is portrayed in Fig. 6.

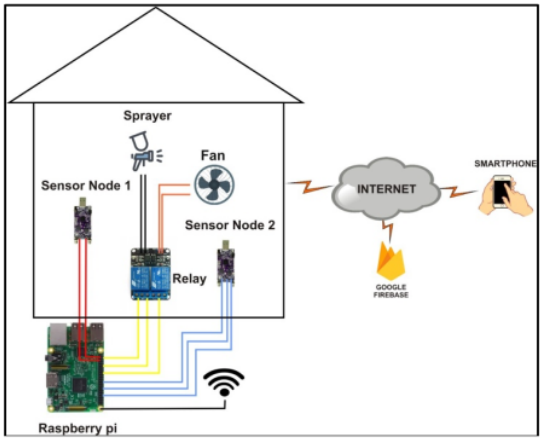

Fig. 6. The Design of Protocol IoT Entity

The first testing is done by measuring the average of overall temperature and humidity. From this test, it is revealed that, the DHT 11 sensor starts giving response on temperature data and delivers it to the raspberry pi when the power supply is on. The data is further stored in the firebase database. After conducting five tests, the results reveal that the average temperature is 32^0C and the humidity is 77%. This result is displayed in Table. 2. This average score is later used as the basis data to test the communication protocol.

Table. 2. The Average Temperature and Humidity

Test	Parameter (in room)	
	Temperature (^{0} C)	*Humidity (%)*
1	30	79
2	31	78
3	32	77
4	33	76
5	34	75
Means	32	77

In the first entity, the test result of data delivery from the hardware (sensor, fan, spray, raspberry pi) to the firebase for every second when the temperature is 32^0C and the humidity is 77% is 1.22 second and 1.18 second respectively. Meanwhile, the test of SYB-ACK in HTTP protocol reveals that the average time to transfer the data from firebase to smart phone is 1.74 second for the temperature 32^0C and 1.62 second for the humidity 77%. The reported results are displayed in Table. 3.

Table. 3. Calculation of Protocol Test

Tests	Data Transfer with HTTP (in second)		Data transfer with MQTT (in second)	
	Temperature (32^0C)	Humidity (77%)	Temperature (32^0C)	Humidity (77 %)
1	1,5	2,0	1,0	1,1
2	1,7	1,4	1,2	1,1
3	1,7	1,4	1,5	1,2
4	1,9	1,6	1,1	1,2
5	1,9	1,7	1,3	1,3
Means	1,74	1,62	1,22	1,18

The aforementioned tests indicate the results of average estimated time for each protocol. In this case, MQTT result is smaller than HTTP result. While in HTTP protocol needs 1.74 second, it only needs 1.22 second in MQTT. Thus, it can be inferred that MQTT is faster than HTTP in transferring the data. In addition, MQTT has better ability when it is integrated with IoT. As MQTT offers much better capability in transferring data, it becomes one the best choices in applying real-time controlled connectivity among hardware.

Generally, MQTT protocol has faster speed in transferring data than that of HTTP like be shown in fig. 7. The development of this protocol is suitable to be applied as assisting tools in cultivating mushroom. Besides, machine to machine automation has not been applied yet. The second test carried out in this study is regarding the speed (estimated time) to reach the ideal condition. The test in conducted by setting the temperature and humidity in random condition. By using MQTT protocol-based application, the condition is controlled in order to reach the ideal temperature and humidity. Table. 4 below illustrates the tests results of speed responses of raspberry pi 3 model B.

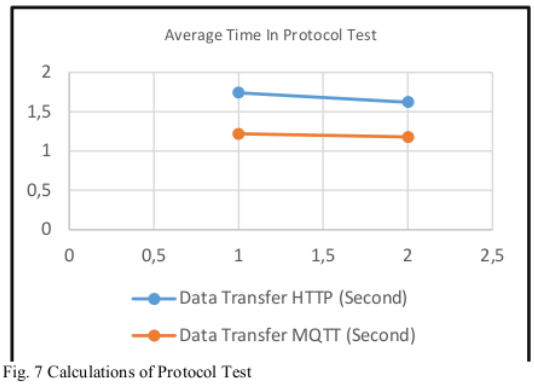

Fig. 7 Calculations of Protocol Test

Table. 4. Speed Rate to Reach the Ideal Condition

Tests	Parameter (in room)		Estimated time to reach ideal condition (in minute)	
	Temperature (^{0} C)	*Humidity (%)*	*Temperature (29 ^{0} C)*	*Humidity (80 %)*
1	30	79	3,0	4,0
2	31	78	5,0	5,0
3	32	77	5,5	5,5
4	33	76	6,0	5,5
5	34	75	7,0	6,0

When the temperature is 30^0C (not ideal condition), it needs three minutes to reach the ideal temperature, 29^0C. Meanwhile, when the humidity is 79%, it needs four minutes to reach 80%, the ideal condition for humidity. After conducting several tests, the longest time needed to reach the ideal temperature and humidity is seven minutes and six minutes respectively. Overall, the tests are conducted for five times. The temperature being tested is ranging from 30^0C to 34^0C. Besides, the humidity is also ranging from 79 % to 75 %. Such tests are examined according to the condition commonly occurs during the process of mushroom cultivation.

IV. Conclusions

From several tests that have been examined in this study, it can be concluded that the speed of data transfer from sensor by utilizing MQTT protocol is better than that of HTTP protocol. The average time is 1.22 second for the temperature and 1.1.8 second for the humidity. The estimated time that is required to reach the ideal temperature and humidity is seven minutes and six minutes respectively.

Therefore, MQTT protocol for internet of things can be used as a tool to monitor and control the room temperature and the humidity in mushroom cultivation. As the results, dependence on human labor can be reduced.

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