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Analysis Of The MQTT Protocol On Hydroponic System Based OnInternet Of Things And Antares Platform

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Abstract

The hydroponic system is a method of growing plants without using soil but using water. Even without soil, plants can grow well because the essential nutrients provided through the nutrient solution (AB Mix) are sufficient. Nutrients in a hydroponic system needs to be monitored regularly so that plants can grow optimally and not lack or excess of nutrients. This research proposed a hydroponic monitoring system that can monitor the condition of hydroponic nutrients remotely in real time using MQTT protocol and Antares platform. The sensors that will be used are Total Dissolved Solid (TDS) sensor to determine the level of nutrients in the water, a DHT11 sensor to check the temperature and humidity around the hydroponic system, and ultrasonic sensor to measure the water level in the reservoir. The result of this system design is a device for monitoring hydroponic using the Antares platform. What was observed in this study was the nutrient content and water level in the reservoir with parameters of the ideal nutrient levels are in the range of 1050-1500 ppm, while the water level was in the range of 6-8 cm. The results of Quality of Service (QoS) test of the MQTT protocol obtained an average delay of 2.5 s and a throughput of 2099 bps.

Keywords

Hydroponics, IoT, Antares, MQTT.

Introduction

Hydroponic is a method of growing plants without soil horizontally or vertically, in which mineral nutrients are provided through water (Singh & Dunn, 2021). Some of the benefits of growing plants with hydroponics are fast growth, high productivity, easy management, environmentally friendly (Dos Santos et al., 2013), and saving planting land (Son et al., 2015; Warman et al., 2020). In its application, there are several factors that need to be considered periodically for the growth of hydroponic plants, namely the water level, the temperature (Karthick et al., 2020) in the water and around the hydroponic system, as well as the nutrient levels in the water so that the circulation of nutrients can meet and not exceed plant needs (Changmai et al., 2018). However, there are still many hydroponic activists or farmers who monitor these things manually so the monitoring process can only be done if the activists or farmers come to their hydroponic gardens. To simplify the process of monitoring or monitoring hydroponics so that it can be done remotely, a hydroponic monitoring system based on the Internet of Things (IoT) (Nam et al., 2021) is needed.

In this study, data transmission carried out by the MQTT protocol (Bharti et al., 2019; Karthikeyan et al., 2021; Kodali & Valdas, 2018; Mandal et al., 2021; Nguyen-Hoang & Vo-Tan, 2019; Soni & Makwana, 2017) was integrated with the Antares platform, namely the Antares ESP32 board as the microcontroller, the use of libraries, MQTT broker, and the Antares cloud database. Data retrieval is carried out based on the distance from the microcontroller to the Wi-Fi Access Point that is sent with QoS (Al-Aqbi et al., 2021; Sivagar & Prabakaran, 2021) testing parameters, namely delay (Pandey et al., 2020), and throughput (Deeptha, 2021).

Related Works

There have been several previous studies using the MQTT protocol as a protocol for IoT-based systems. The first study (Sururuzzaman et al., 2020) discussed the performance of the MQTT protocol on a hydroponic control system for pakcoy plants using Wemos D1 mini as a microcontroller. In the second study (Dwipa et al., 2020), an air conditioning system was made for hydroponic lettuce plants using the MQTT protocol with Wemos D1 mini as the microcontroller. In the third study (Mailoa et al., 2020), the MQTT protocol was used to transmit data on an aquaponic automation system with node MCU as the microcontroller. Based on the results of the research above, the use of the Wemos D1 mini microcontroller is more often used, so a hydroponic monitoring system with the MQTT protocol was designed using the Antares platform, namely the Antares ESP32 board and the Antares cloud database.

Research Method

Figure 1 shows that, the microcontroller is programmed to connect with TDS, DHT11, and ultrasonic sensors. Then, the data from the ultrasonic TDS sensor, and DHT11 enters the microcontroller which is connected to Wi-Fi. After connecting with Wi-Fi, the data is sent via the MQTT protocol to the Antares cloud database, then the data is forwarded to the Antares MQTT Broker and stored in the Antares cloud database. The stored data can be accessed by the user through an Android application that has been programmed in such a way.

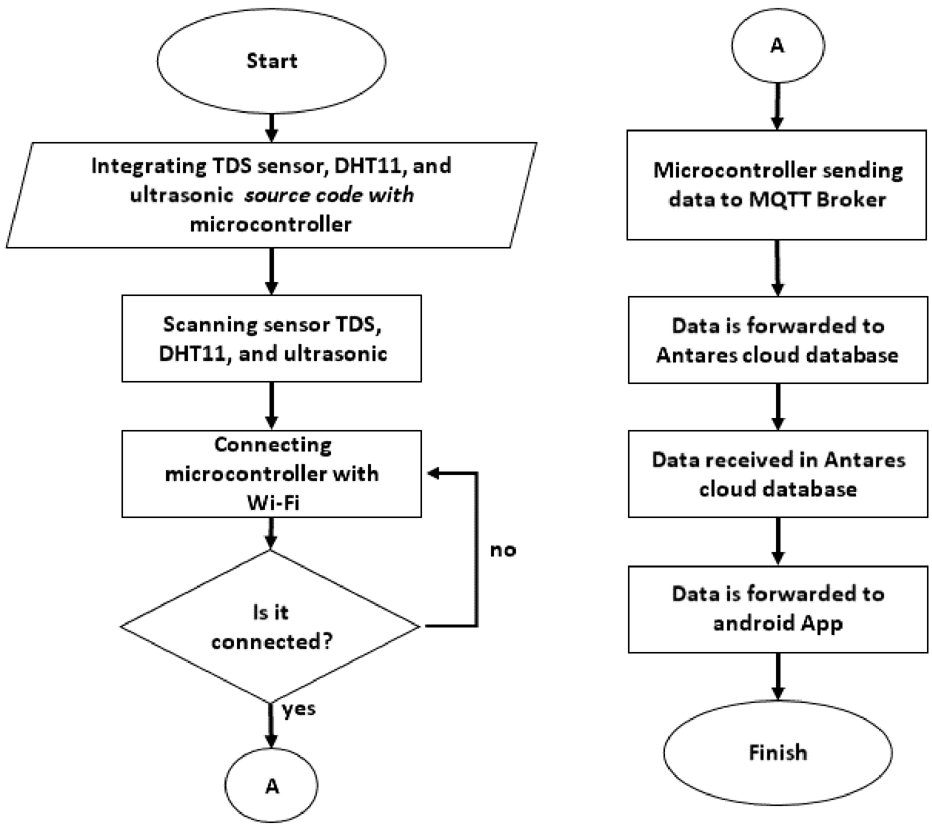

Figure 1 Flowchart System

The system design is divided into two, namely during the training stage and the test stage. Briefly, the training stage is a collection of datasets, while the test stage is the test stage after obtaining the dataset from the training phase, which is described in more detail below.

Hardware Design

In this study, a hydroponic monitoring system was designed using 3 sensors, namely a TDS sensor to measure nutrient levels in water, a DHT11 sensor to measure the temperature in the hydroponic environment, and an ultrasonic sensor to measure the water level in the reservoir.

1. Hardware and Components

The tools used in this study can be seen in Table 1. Based on the table, the hardware can be designed as shown below.

Table 1 Hardware and Components

No	Software	Function
1	Antares ESP32 Development Board	Microcontroller as a whole system access.
2	TDS Sensor	Used to detect the hydroponic nutrition.
3	DHT11 Sensor	Used to detect the temperature and humidity around hydroponic system.
4	Ultrasonic Sensor	To measure the water level in reservoir.
5	LCD 20x4	To display the data that are read by ESP32 Antares Development Board.

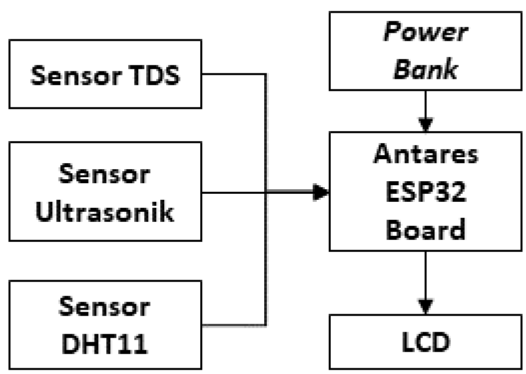

Figure 2 Hardware and components design

2. System Architecture

An overview of the IoT-based nutritions monitoring system architecture can be seen in Figure 3.

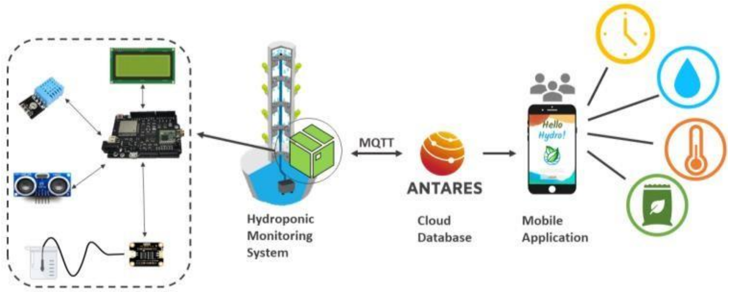

Figure 3 System architecture

Figure 3 is a block diagram of the hardware and its data transmission flow using the MQTT protocol. In the system, it can be seen that Antares ESP32 Board has 3 inputs from the TDS, ultrasonic, and DHT11 sensors and produces 5 data outputs, namely status, nutrient levels, temperature and humidity (Danar Wicaksono et al., 2017) around hydroponics, and water level in the reservoir shown in LCD 20x4. The data will be forwarded to the android application, so that the hydroponic monitoring process is more flexible and real-time.

Software and Application

1. Arduino IDE

To be able to program the microcontroller, a library from Antares is used which can be downloaded from the Antares website. The libraries used in this study are the ESP32 library, Antares MQTT for the use of the MQTT protocol, Gravity TDS for the TDS sensor, and DHT for DHT11.

```
TA_MQTT_BARU §
#include <AntaresESP32MQTT.h>
#include <ArduinoJson.h>
#include <PubSubClient.h>
#include <driver/adc.h>
#include <GravityTDS.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27, 20, 4);
#include "DHT.h"
```

Figure 4 Library that are used

2. Antares Platform

The Antares platform used in this research are the Antares ESP32 device as a microcontroller, Antares console as a database and broker for the MQTT protocol. As a database, data from sensors is stored on this platform. The stored data can be used to display in Android applications (Riski M. et al., 2018). Meanwhile, as an MQTT broker, this platform is a broker that connects publishers, namely sensors and subscribers, namely the MIT App.

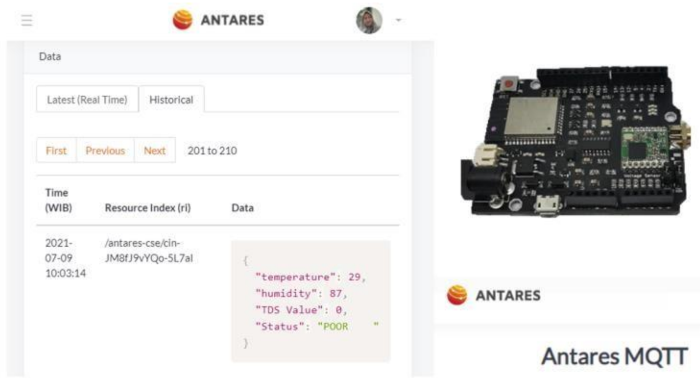

Figure 5 Antares platform that are used

3. MIT App Inventor

The MIT App is used to create an Android-based hydroponic monitoring application to display the results of the system condition so that it can be accessed by users flexibly. The appearance of the application is designed to be simple so that users can use it easily.

Result and Discussion

In this research, the testing would be in 2 scenarios, the first is monitoring hydroponic device test to measure if the device can run as programmed and functioning properly. Second is the MQTT protocol testing, to measure the Quality of Service of the MQTT protocol using the Antares MQTT library.

Hardware Testing

The test is carried out to measure whether sensors can function properly as it programmed. The results can be seen in the table below.

Table 2 Hardware Testing

No	Component	Function
1	ESP32 Antares can transmit data to Antares cloud database.	succeed
2	ESP32 Antares with TDS Sensor can read the ppm value in water reservoir.	succeed
3	ESP32 Antares with ultrasonic Sensor can read the water level in reservoir.	succeed

4	ESP32 Antares with DHT11 can read the temperature and humidity around the hydroponic system.	succeed
5	LCD 20x4 display nutrition status, nutrition value, water level, humidity, and temperature around hydroponic system.	succeed

Monitoring Hydroponic Device Testing

In this section, the purposed of the testing is to determine whether the TDS Sensor that integrated with ESP32 Antares and LCD can read the ppm value accurately if we compare it with TDS Meter (Brian P. et al., 2016). The following is the documentation of the test and data results from this testing.

Figure 6 TDS meter and hydroponic monitoring device

Table 3 Monitoring Hydroponic Device Testing

Nutrition Condition	TDS Sensor	TDS Meter	LCD Status
POOR	214	213	Poor
IDEAL	1400	1400	Ideal
TOO MUCH	1961	1960	Too much

Table 3 shows that three different nutrition conditions, the TDS sensor can return a value as much as TDS Meter value. It shows that the level of accuracy or similarity of TDS Sensor to TDS Meter are accurate and reliable.

QoS of MQTT Protocol Testing

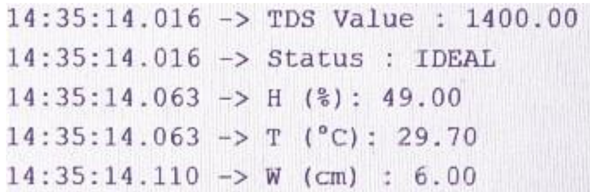

Figure 7 Data on serial monitor

Figure 7 shows the serial monitor when ESP32 Antares read the data from sensors. The nutrition value is 1400 ppm and the status is IDEAL.

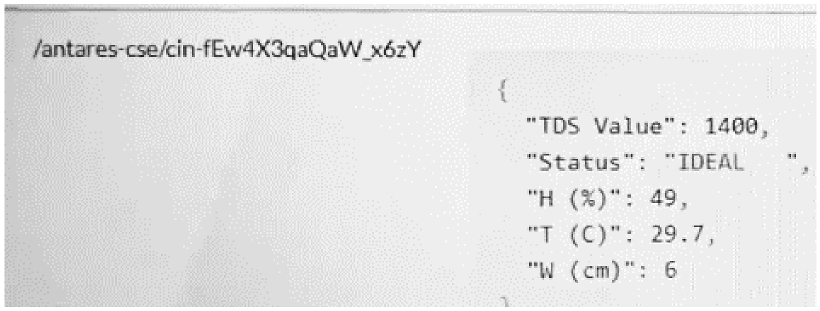

Figure 8 Data in Antares

Figure 8 shows the data that received in Antares cloud database is the same with the data on serial monitor. It can be concluded that the transmission data using MQTT protocol was successful.

Quality of Service (QoS) has an international standardization to categorize the QoS parameters whether it is preferred or acceptable quality. The standardization that is used in this research is ITU-T Recommendation G.1010.

Table 4 Monitoring Hydroponic Device Testing

Delay (s)	Data Size	Category
< 15 s	10kb – 10MB	Preferred
< 60 s	10kb – 10MB	Acceptable

The delay test is starting when the data from the TDS sensor, DHT11, and ultrasonic sensor is read, then sent by the Antares ESP32 to the Antares cloud database until the data is received.

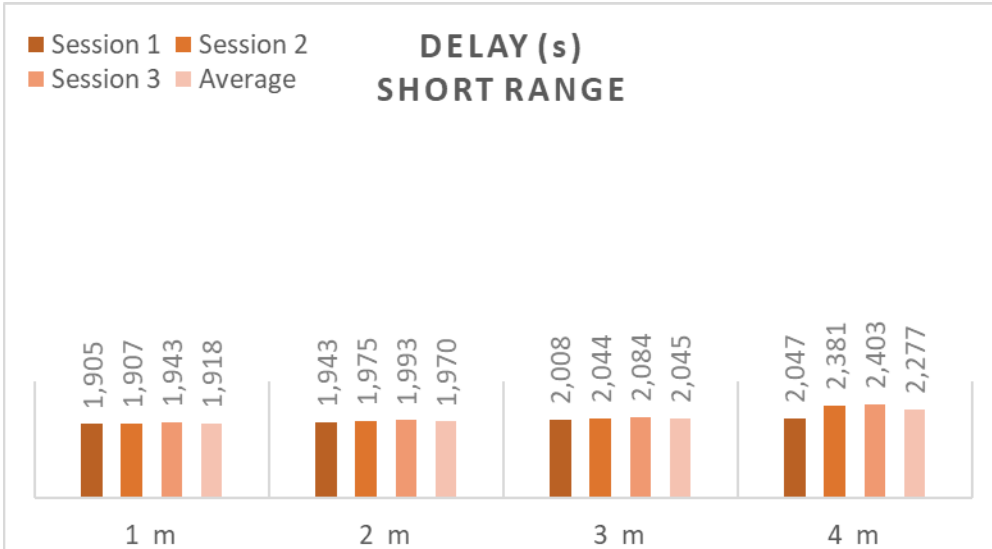

Figure 9 Delay in short range

Figure 9 is the results of the delay test at 1-4 m with a short-range classification. The lowest average value of delay is obtained at a point 1 meter from the access point with the value 1,9 s. For the highest average value is obtained at the 4 meter point with the value 2,4 s. Based on the ITU-T Recommendation G.1010 standard, the average delay on short range testing shows a value less than 15 seconds, so it is included in the preferred category. That way, the delay is considered very good because it fits the category recommended by ITU-T G.1010.

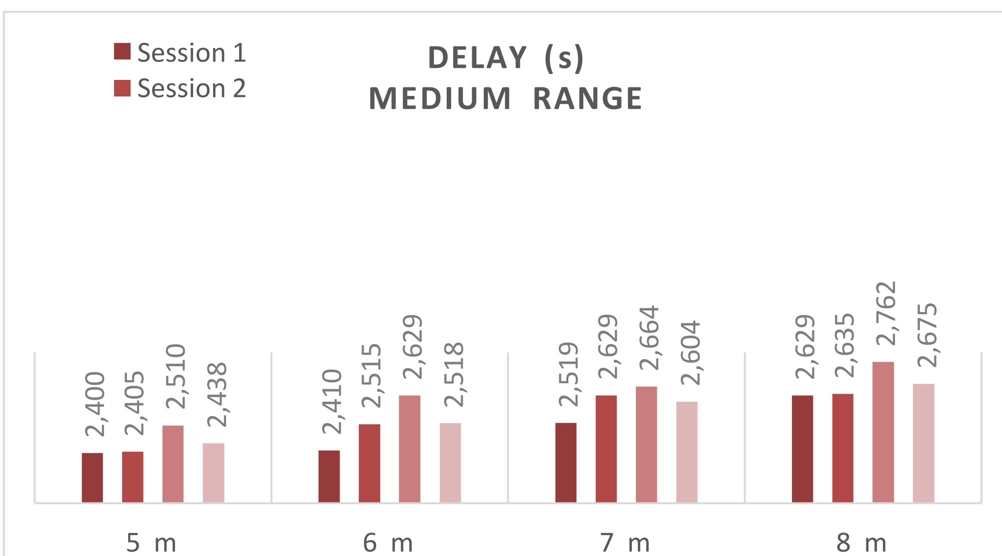

Figure 10 Delay in medium range

Figure 10 is the results of the delay test at 5-8 m with a medium range classification. The lowest average value of delay is obtained at a point 5 meter from the access point with the value 2,3 s. For the highest average value is obtained at the 8 meter point with the value 2,7

s. Based on the ITU-T Recommendation G.1010 standard, the average delay on medium range testing shows a value less than 15 seconds, so it is included in the preferred category. That way, the delay is considered very good because it fits the category recommended by ITU-T G.1010.

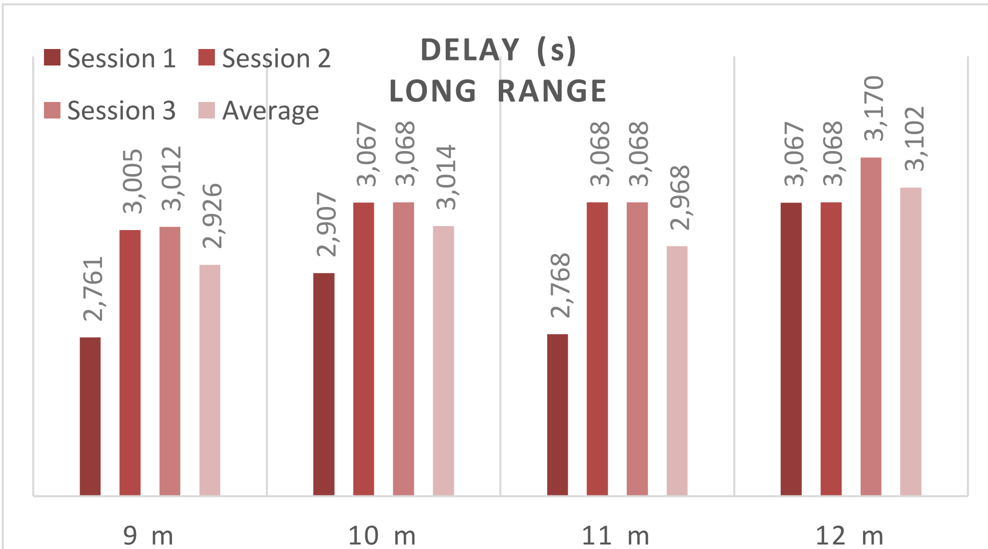

Figure 11 Delay in long range

Figure 11 is the results of the delay test at 9-12 m with a long-range classification. The lowest average value of delay is obtained at a point 10 meter from the access point with the value 2,8 s. For the highest average value is obtained at the 12 meter point with the value 3,1 s. Based on the ITU-T Recommendation G.1010 standard, the average delay on long range testing shows a value less than 15 seconds, so it is included in the preferred category. That way, the delay is considered very good because it fits the category recommended by ITU-T G.1010.

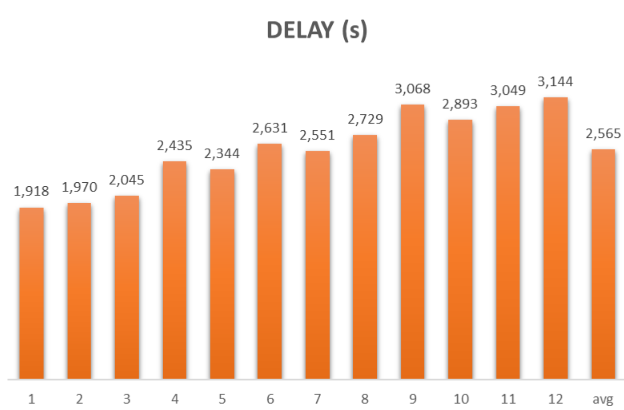

Figure 12 Delay in all range

Figure 12 is the results of all the delay test at 1-12 m. The lowest average value of delay is obtained at a point 1 meter from the access point with the value 1,9 s. For the highest average value is obtained at the 12 meter point with the value 3,1 s. Based on the ITU-T Recommendation G.1010 standard, the average delay of the testing shows a value less than 15 seconds, so it is included in the preferred category. That way, the delay is considered very good because it fits the category recommended by ITU-T G.1010.

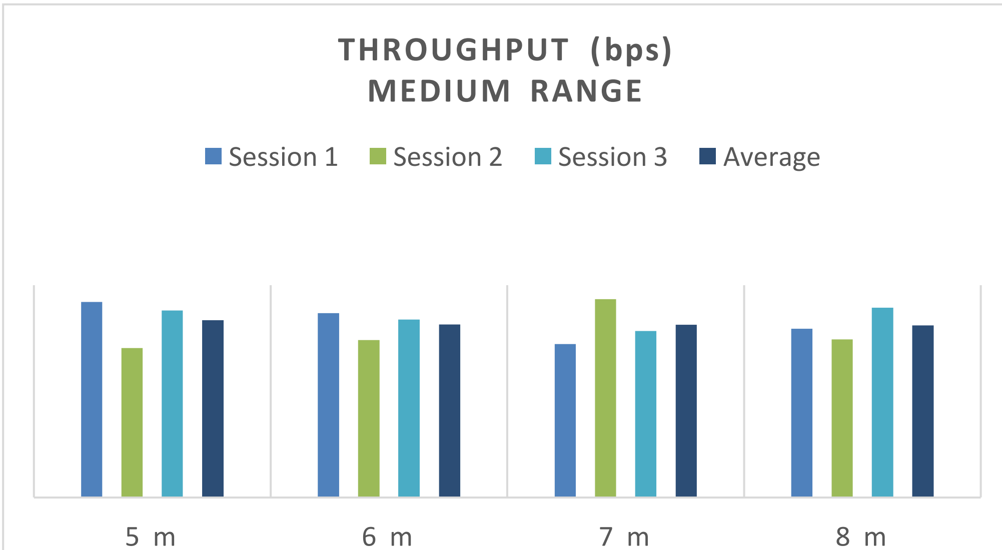

Figure 13 Throughput in short range

Figure 13 is the results of throughput test at 1-4 m with a short-range classification. The lowest average value of throughput is obtained at a point 4 meter from the access point with the value 2225 bps. For the highest average value is obtained at the 1 meter point with the value 2493 bps.

Figure 14 Throughput in medium range

Figure 14 is the results of the throughput test at 5-8 m with a medium range classification. The highest average value of throughput is obtained at a point 6 meter from the access point with the value 2061 bps. For the lowest average value is obtained at the 5 meter point with the value 1976 bps.

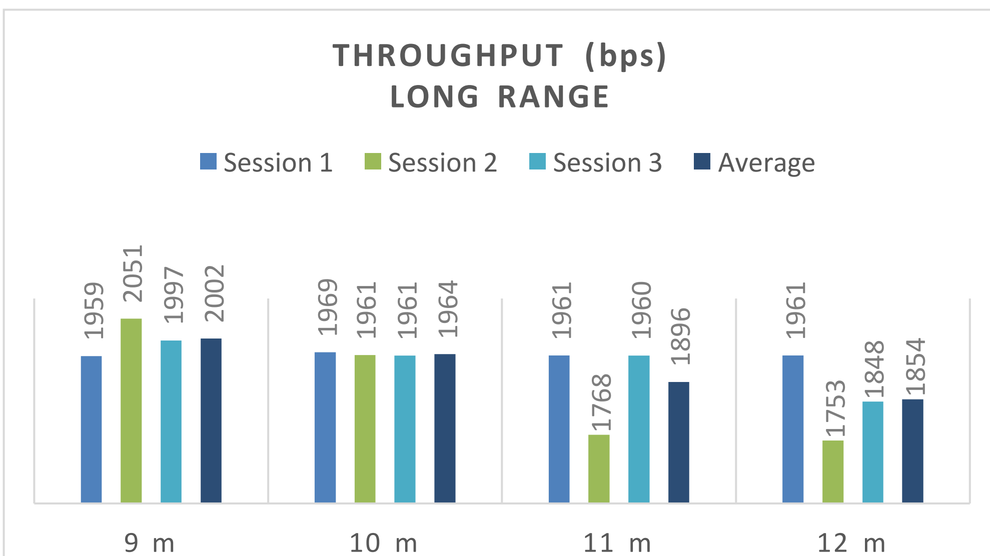

Figure 15 Throughput in long range

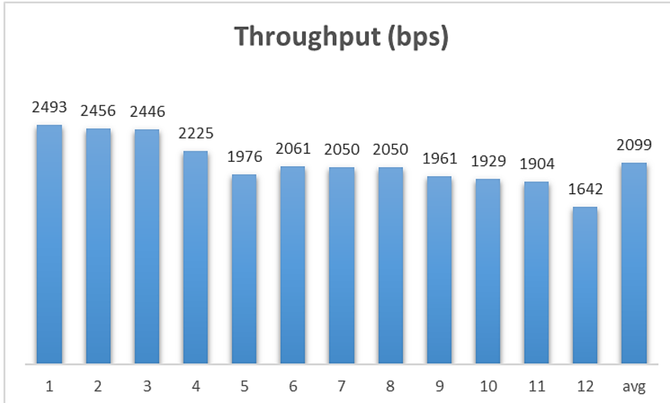

Figure 16 Throughput in all range

Figure 15 is the results of the throughput test at 9-12 m with a long-range classification. The lowest average value of throughput is obtained at a point 12 meter from the access point with the value 1642 bps. For the highest average value is obtained at the 9 meter point with the value 1961 bps.

Figure 16 is the results of all the throughput test at 1-12 m. The lowest average value of throughput is obtained at a point 12 meter from the access point with the value 1642 bps. For the highest average value is obtained at the 1 meter point with the value 2493 bps.

Conclusion

Based on the results of system design, testing, and analysis that have been carried out, it can be concluded:

1. Hydroponic monitoring system based on Internet of Things (IoT) consisting of hardware and software as well as data transmission via the MQTT protocol was successfully executed according to its purpose and functioning properly.
2. From the Quality of Service (QoS) test on the MQTT protocol for distance, the smallest delay is 1,9s at a distance of 1 meter, while the largest delay is obtained at a distance of 12 meters, with an average delay of 3,1s.
3. For throughput, the best value is at 1 meter with a value of 2493 bps, while the worst value is at 12 meters with a value of 1642 bps. The average throughput obtained is 2099 bps. With these data, distance affects the value of delay and throughput, and the best value is at 1 meter, while the worst distance is at 12 meters from the access point.
4. Antares cloud database and MIT App can display the readings from sensors accurately and on time so that hydroponic monitoring can be done in real-time.

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