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Monitoring System and Hydroponic Plant Automation Using Microcontroller Internet of Things Based (IoT)

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ABSTRACT

Hydroponics is a technique of cultivating plants without using soil media but using water as a planting medium. Important factors that must be considered in hydroponic plants are plant nutrition, water, temperature, and light intensity. These factors are necessary for hydroponic plants for the growth and reproduction of hydroponic plants. Due to the nutritional needs of hydroponic plants, farmers must take the time to check the concentration of nutrients in hydroponic plants so that the plants can grow well. Therefore, it is necessary to develop new methods of hydroponic farming so that they can grow and develop properly, which can be controlled and monitored automatically. Thus, farmers no longer need to come to agricultural locations. One of the technologies used is technology with the Internet of Things (IoT). This study uses a prototype methodology. For the plant sample used is the lettuce plant. The microcontroller is used as the main controller of all IoT components while the sensors used are the TDS sensor, temperature sensor and light intensity sensor. The research that has been done is IoT technology on hydroponic plants that can monitor and automate plant nutrition settings that are personalized to the needs of hydroponic plants. From the results of testing the IoT tool by reading data from the light intensity and temperature sensors, there is a link between the UV light intensity produced and the water temperature in the hydroponic plant reservoir, that is, the higher the UV light intensity, the higher the water temperature and vice versa. In addition, the other factors are weather and climate conditions around hydroponic plants. IoT data is stored in cloud storage which requires a rental fee.

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1. INTRODUCTION

The city of Bandung is an area that is densely populated with buildings and like other cities, Bandung does not have large areas of land. Not many people know that a narrow house yard can be used optimally by the community. Nowadays farming is a very strategic choice because it is beneficial for recreation, health, the economy, and the environment in the present. Communities can grow vegetables for food consumption needs at home by utilizing the land they own for gardening food crops so that they are self-sufficient in food supply[1], it is because the need for food will always increase with the increase of population[2]. In areas with high density, gardening with a large yard is difficult due to limited land. This encourages efforts to grow crops for family consumption on limited land using certain techniques. Hydroponics is known as soilless culture or the cultivation of plants without soil. The term of hydroponics is used to explain how to grow crops without using soil as a growing media [3]. Hydroponics is an option for people who want to garden with limited land and with a hydroponic system, the plants grow faster than those grown in soil [1]. Some of the advantages of hydroponics include: (1) can be used on limited land, because the hydroponic method uses a solution of mineral nutrients in water, without soil; (2) vegetables are safer, because the plants are free of pesticide residues and free of harmful microorganisms; (3) more resistant to disease; (4) relatively fast growth and relatively heavier in quantity; and (5) being able to enrich plants with a complete and good taste with higher nutritional value. Important factors that must be considered in hydroponic plants are plant nutrition, water, oxygen, humidity, and light intensity. Nutrients for plants are needed to meet their life needs, for growth and reproduction. Most of the plant or plant body consists of three elements, namely carbon (C), hydrogen (H) and oxygen (O)[4]. Due to the nutritional needs of hydroponic plants, farmers must take the time to check the concentration of nutrients in hydroponic plants so that the plants can grow well. In addition to the nutritional factors, light intensity and temperature around hydroponic plants also affect the growth and development of hydroponic plants. Besides that, IoT devices also require a monthly fee. Limitations on how to grow conventional hydroponic plants have prompted the need for the development of new patterns in hydroponic farming, which can be controlled and monitored automatically so that farmers no longer need to come to the agricultural location. One of the technologies used for the agricultural sector is technology with the Internet of Things (IoT). The Internet of Things (IoT) is a new paradigm with functionality that makes setting up modern and fast wireless telecommunications. [5]. IoT was created as a tool to make it easier to control and monitor nutrient levels from hydroponic plants [2]. By using IoT technology in hydroponic plants, plants can grow well and with good quality. Farmers' IoT technology can monitor and control in real time, where farmers with their daily activities can still grow hydroponics without having to check the plants manually every time. IoT technology can also lead to corrective actions so that plant growth becomes healthier without human intervention with the automation of nutrient arrangements for hydroponic plants. The use of IoT technology in agriculture can also be useful for reducing the time to harvest hydroponic plants. In addition, IoT technology on hydroponic plants itself is equipped with Message Queuing Telemetry Transport (MQTT) protocol technology, which is sending data in real-time and has a cloud-based database, where the data can one time be used for hydroponic plant production analysis.[6] Previous studies have successfully implemented an IoT-based temperature and humidity monitoring system in plant factories and properly stored data on blynk cloud servers [7] while research [8] IoT technology in hydroponic plants is used for temperature monitoring and control systems in rooms. Web-based hydroponic plants by measuring temperature and the average temperature is 30° Celsius and humidity is 70%, temperature and humidity data are sent to the web server every five seconds, then stored in the database and displayed on the web application in graphical form, to temperature regulation using a fan that is set to turn on if the plant room temperature exceeds 35° Celsius.Thus, it can keep the plants from overheating. The results of this study lead to the research objective, which is whether there is a relationship between light intensity in the environment around hydroponic plants and water temperature in hydroponic plant reservoirs. Whereas from research [9] the initial costs that must be budgeted in developing IoT technology in the hydroponic plant business are very large, and only last in the first month. While for the following month, businesspeople receive economic results from the hydroponic cultivation business using IoT technolog. In this research, it calculates the cost of maintenance raw materials, the cost of electricity usage and employees. So that the further research is needed that there are other costs such as for cloud storage (data storage). Therefore, it is necessary to have an analysis to find out the analysis of storage capacity requirements from the application of Internet of Thing (IoT) Technology in the cultivation of hydroponic plants, especially lettuce vegetables.

1.1. Lettuce Plants

Lettuce is a plant that comes from temperate countries. Lettuce (Lactuca sativa L) is an annual leaf vegetable that belongs to the compositae family which is usually consumed as fresh vegetables or salads. Types of lettuce that are widely cultivated are butter lettuce and crop lettuce. Butter lettuce, also known as bowl lettuce or leaf lettuce, has a loose, round crop shape. Lettuce (heading lettuce) or crop lettuce, the shape of the crop is round and oval, the crop is solid or compact. The color of lettuce leaves is bright green to yellowish white. Lettuce grows well in the highlands, optimal growth in fertile land that contains lots of humus, sand, or silt. The best planting time is at the end of the rainy season, although it can be planted during the dry season with sufficient watering.

Table 1. Nutrient Levels in Lettuce Plants

Age	**Nutrient (PPM)**
0-2 Hari	0 PPM

3-10 Hari	200 – 400 PPM
11 – 20 Hari	400 – 500 PPM
21 – 35 Hari	500 – 700 PPM

1.2. ESP32 Microcontroller and Arduino Uno

The ESP32 NodeMcu Microcontroller, known as the Espressif System, is a development of the ESP8266 Microcontroller. The ESP32 specifications are very complete, so this microcontroller is perfect for applications related to the Internet of Things, because this microcontroller can communicate using Wifi and Bluetooth [10]. In addition, the ESP32 microcontroller has many advantages over the ESP8266 with a greater number of General Purpose Input Output (GPIO) [11]. In this study, ESP32 was used due to faster Wi-Fi and lower power consumption. As for security issues, ESP32 features cryptographic acceleration, flash encryption, and secure boot which makes ESP32 a secure platform for building IoT. Arduino Uno is a Microcontroller board based on ATmega328 (datasheet). It has 14 input pins of digital output where 6 of these input pins can be used as PWM outputs and 6 analog input pins, 16 MHz crystal oscillator, USB connection, power jack, ICSP header, and reset button.

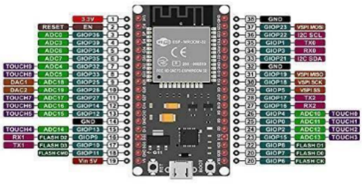

Figure 1. Architecture of ESP32

1.3. TDS *(Total Dissolved Solid)* Sensor

TDS sensor is a sensor that works by detecting the conductivity of a solution. The more conductive a solution is, the value will change. So that if the liquid contains a lot of minerals, the conductivity will be higher and the output will be greater, and vice versa if the liquid contains few minerals, the output will be smaller. The sensor is connected to the ADC pin on Arduino to read voltage changes. This analog TDS sensor is compatible with Arduino, plug and play and easy to use [12].

Figure 2. TDS (Total Dissolved Solid) Analog Sensor

In hydroponics, this sensor is used to measure the concentration of hydroponic solutions or nutrient concentrations. In hydroponics, the measurement of hydroponic nutrients is necessary because if the nutrient solution is not measured, the plants may lack of nutrients or excess of nutrients which result in being toxic to the plants themselves.

1.4. Light Sensor

The GUVA-S12SD UV Sensor Chip is used to detect UV (ultraviolet) radiation in sunlight. The GUVA-S12SD sensor has an ultraviolet detection wavelength of 200 nm - 370 nm, which covers the UVA and UVB spectra. This sensor uses UV photodiodes and the signal level from these photodiodes is very small, at the nano-ampere level. This sensor module has MISO (Master in Slave out), MOSI (Master out Slave in), CLK (Clock) and CS (Chip Select). The GUVA-S12SD sensor is connected to the microcomputer using a jumper cable with a breadboard intermediary [13].

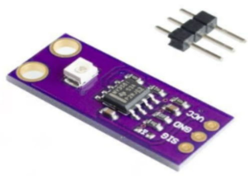

Figure 3. GUVA-S12SD UV Light Sensor

1.5. *DS18B20* Temperature Sensor

The DS18B20 temperature sensor is an easy-to-use sensor and the data generated from the sensor readings is quite accurate. A temperature sensor is a component used to detect or convert a certain quantity into an analog unit so that it can be read by an electronic circuit. The sensor can be defined as a type of transducer that is used to convert mechanical, thermal, magnetic, light and chemical variations into voltages and electric currents [12].

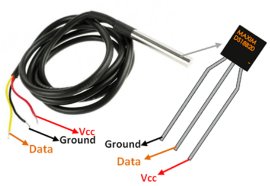

Figure 4. DS18B20 Temperature Sensor

1.6. Firebase Database

Firebase is a platform for realtime applications. When the data changes, the application that is connected to Firebase will update directly through each device, both website and mobile [3]. Firebase is an online database that can be used as a data storage media for applications. Firebase has comprehensive libraries for most web and mobile platforms. Besides that, it can be combined with various other frameworks such as node, java, javascript, and others. The Application Programming Interface (API) for storing and synchronizing data will be stored as bits in the form of JSON (JavaScript Object Notation) in the cloud and will be synchronized in real time [4]. There are several features provided by Firebase as follows:

1. Analytics, can observe user behavior in using the application and displayed in one dashboard.
2. Develop, divided into several features such as cloud messaging, authentication, realtime database, storage, hosting, testlab and crash reporting.
3. Grow, to publish an application product.

Figure 5. Firebase Realtime Database Feature

2. METHODOLOGY

The IoT software system development methodology begins with a business model design. The system is designed with the main capabilities, namely converting from reading sensor results and inverting, namely writing the actual data from the actuator results and then the results are transferred to the internet media.

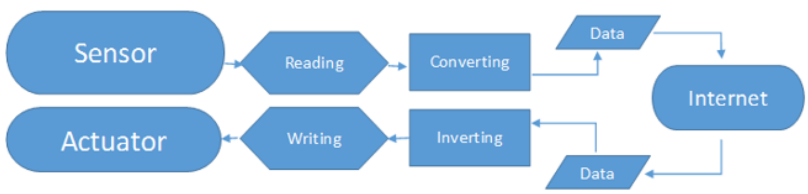

Figure 6. Internet of Things(IoT) System Design

Pengembangan Perangkat lunak IoT dengan metode *prototype*. Metode *prototype* bertujuan untuk memberi gambaran kepada pengguna bagaimana aplikasi ini akan di bangun dengan membuat sistem *prototype* terlebih dahulu.sehingga,pengguna dapan memberikan evaluasi [14]. Dengan adanya evaluasi dari aplikasi *prototype* ini, dapat dijadikan sebuah acuan untuk membangun sebuah aplikasi yang merupakan produk akhir dari penelitian ini[15]. IoT Software Development in this research is using prototype method. The prototype method aims to give an overview to the user of how this application will be built by first creating a prototype system. So that the user can provide an evaluation [14]. With the evaluation of this prototype application, it can be used as a reference for building an application which is the final product of this research [15].

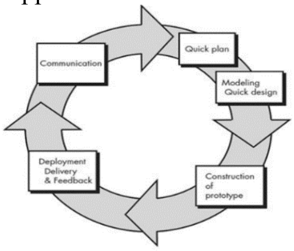

Figure 7. Sequence of the Prototype Method
(Source: Purnomo, 2017:55)

The stages in the prototyping method include:

1) Communication
The problem identification stage involves developers and stakeholders to find out the goals of system development, gathering requirements and system limitations.
2) Quick Plan
This stage is carried out quickly, where modeling is carried out related to the needs previously obtained at the communication stage.
3) Modeling Quick Design
This stage is carried out after obtaining the planning in the previous stage, the design is carried out related to system representations that can be understood by users, such as interface design.
4) Construction of Prototype
Prototype development is used to provide an overview to users about the needs that have been obtained and designed, then the function to be evaluated.
5) Deployment, Delivery and Feed Back
Existing prototypes are then evaluated to stakeholders, who provide feedback that is used to obtain other needs. So that repetition appears to meet the needs of stakeholders.

2.1. *Hardware and Components*

The tools used in this study can be seen in Table 2. The hardware tools are designed according to the data contained in table 2. For the IoT system monitoring and controlling hydroponic plants using 3 sensors, namely the TDS sensor, light intensity sensor and temperature sensor.

Table 2. Hardware Components

No	Hardware	Function
1	ESP32	Microcontroller that sends data from sensors to the firebase database
2	ARDUINO UNO	Microcontroller that reads sensor from IoT devices
3	TDS *(Total Dissolved Solid)*	Used to detect the nutritional needs of hydroponic plants
4	UV sensor (S12SD)	Used to measure the intensity of light around hydroponic plants
5	DS18b20 Temperature Sensor	Used to detect water temperature in hydroponic plant reservoirs
6	Modul OlED LCD IIC 0,96 Inchi	Used to display data read by ESP 32
7	Vitamin Pump	Used to flow nutritional vitamins (Vitamin mix A and Mix B)
8	Water Pump	Used to circulate water in hydroponic plant pipes

2.2. Running System Analysis

Growing vegetables in urban areas requires quite a large area of course, but due to limited land, a farming system using the hydroponic method was made. Another advantage of hydroponic cultivation compared to conventional cultivation is that its growth can be controlled [16]. Hydroponics is the process of growing vegetables using the water method. The hydroponic method applied is DFT (Deep Flow Technique) which applies the circular method. The way this method works is that the nutrient solution is pumped through the plant's root system. Excess solution will be collected back, refilled, and reused. So that the circulation of nutrients continuously for 24 hours works to provide nutrients to plants. Hydroponic plants are plants that require special attention from water circulation, temperature, light intensity and nutrition, and checks must be carried out regularly every day. The system used must be able to check the plant. As well as nutritional information is still in the form of simple tables so that it cannot be used as a consideration tool for further action.

2.3 Analysis of the proposed system

In building an Internet of Things (IoT) system for hydroponic plants, it is divided into three stages, namely:

a) Stage 1: Vertical hydroponic development of 22 holes with a height of 170 cm.
b) Stage 2: Development of an IoT system for monitoring the content of vitamins in water, sunlight, and water temperature.
c) Stage 3: Adding a vitamin pump actuator so that the addition of vitamins for hydroponics can be done manually and automatically based on a predetermined threshold.

The business process model for monitoring and controlling hydroponic plants can be seen in the figure below. In the business process model, you can see that there are two microcontrollers used, namely: ESP32 and Ardino UNO. ESP32 which is called the wifi module is for sending sensor data to the cloud while the Arduino Uno module is for reading sensors on IoT devices.

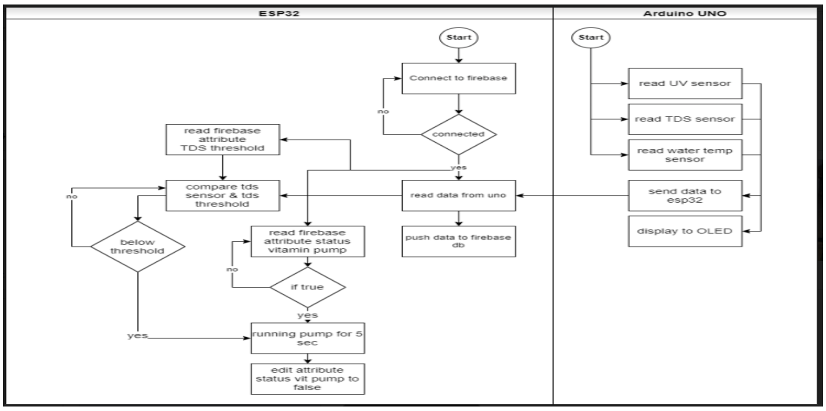

Figure 8. Internet of Things Business Process System Model

2.4. Internet of Things (IoT) System Block Diagram

The block diagram is a basic description of the system to be designed. Each system block has its own function, by understanding the block diagram, the system to be designed can already be built properly. For designing a diagram of the proposed business process is as below:

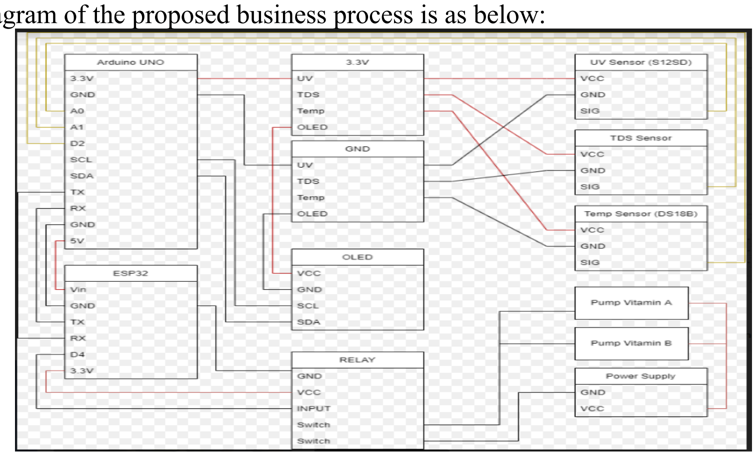

Figure 9. Hydroponic Plant IoT System Block Diagram

On the Arduino Uno microcontroller, the sensor reading results will have three inputs, namely the TDS sensor input, the light intensity sensor and the water temperature sensor. From the sensor reading results, the ESP 32 microcontroller will send data to the cloud to produce four outputs, namely nutritional value, light intensity, water temperature and the date and time when the sensor was read.

3. RESULT AND DISCUSSION

System implementation aims to obtain and apply the stages of adding new information to operations.

3.1. Hydroponic Plant Installation

The hydroponic plant method used for this research is the vertical garden method. Vertical gardens allow humans to recreate a living system that is very similar to the natural environment. Green areas in the form of vertical gardens show significant benefits in reducing the carbon monoxide content in ambient air because they can absorb pollution, cool the room by lowering the temperature and filter the movement of dust and other dirt particles [17]. Apart from vertical gardens, another farming technique that can be developed in dense urban areas is hydroponics. Besides being easy, hydroponics can also take advantage of the spaces in the house, or the sides and front of the house. Hydroponics is now widely used for vegetable crops. Various studies on planting media and fertilizers to improve the quality of vegetables grown hydroponically show that this technique has a great opportunity to continue to be developed. The two modern agricultural methods above can be used for architectural elements, both as outdoor elements (Titisari et al 2015) and as inner space elements (Eddy Prianto 2013). The benefits of having a green area in the house and environment according to LEED 2013 and GBCI 2013 (in Prianto 2013) are:

1) Energy reduction can be up to 30%
2) Carbon reduction up to 35%
3) Decrease in water consumption by about 30-50%
4) Reducing maintenance operational costs can reach 50-90%.

Figure 10. Results of Seeding Hydroponic Plant Seeds

Seeding in hydroponics has an important role because one of the success factors in hydroponic plants is seeding of plant seeds.

Figure 11. Vertical hydroponic plant installation

3.2 Hardware Implementation

The results of the IoT tool prototype for monitoring and automation of hydroponic plants can be seen in the figure below.

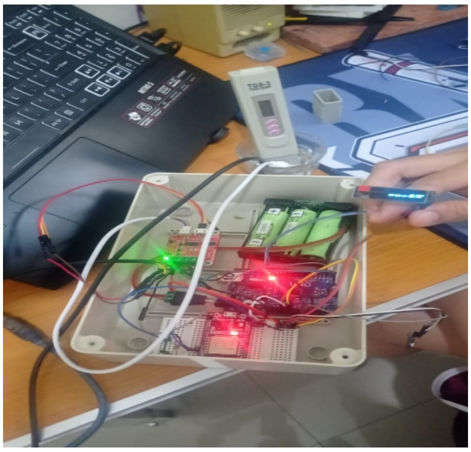

Figure 12. *Prototype* IoT version 1

In the first version of the IoT prototype, a trial was carried out using a battery for electricity.

3.3 Display on the Smart Farming User Interface

The firebase database will display data on the amount of nutrient content (ppm), light intensity (uv) and water temperature.

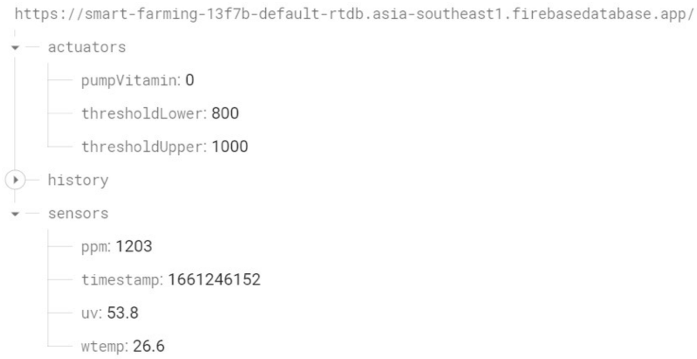

Figure 13. Data View on Firebase Database

The IoT tool is made in one control box where all sensors are connected and actuators are needed to run an IoT system with the Arduino Uno microcontroller which has an important role to read all data from all sensors that have been set, the system is made online, and the data is used to follow the parameters set. It has been specified in the regulation of nutrient requirements for hydroponic plants. This sensor is expected to provide data flow directly through a microcontroller that is connected to the internet. After the ESP 32 microcontroller is connected to the internet, it will simultaneously send and read data to the Firebase database. Firebase provides nutrition auto-setting[18]. The domain for the data server uses the firebase database, after being installed on the smartphone, all data will be displayed on the cellphone screen. The TDS sensor is installed through a nutrient bottle containing a nutrient solution which is then pumped into the system. There are two valves used in this IoT system which are used to execute a process where the resulting output is adjusted to parameters. For this study, valves were used for plant nutrition (vitamin A and Vitamin B).

3.4 Results of IoT Technology Implementation

The IoT technology created has a working system, which can control the stability of the density value of the nutrient content in hydroponic lettuce plants using a TDS sensor, where the TDS Meter is connected to Arduino Uno and ESP32. ESP32 is connected to wifi which will send sensor data to the firebase database to be stored as well as being the interface to this system. In addition to controlling the concentration of nutrients in hydroponic plants, this system can also monitor the nutrient concentrations of hydroponic plants, UV light intensity and temperature in the water contained in hydroponic plant reservoirs. Besides being visible on the Firebase database, monitoring results will also appear on the LCD which has been added to the tool panel box.

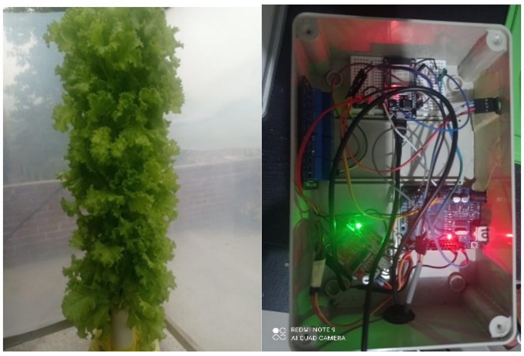

Figure 14. Implementation of IoT Devices in Hydroponic Plants

3.5 *Hardware Testing*

Lettuce plants (hydroponics) using IoT tools for monitoring and automation of plant vitamins are tested on the performance of the existing system, both component performance and program performance and execution that has been made. The shape of the tool can be seen in Figure 15.

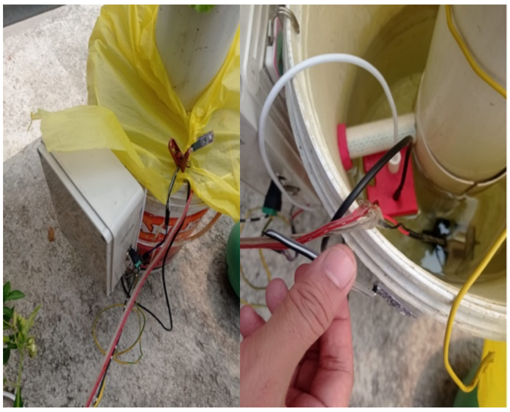

Figure 15. IoT device for monitoring and controlling hydroponic plants

Tests are carried out to measure whether the sensor can function properly as programmed [19]. The results can be seen in the table below.

Table 3. Hardware Testing Result

No	Hardware Component	Quantity	Good function	Trouble
1	ESP 32 can send data to firebase	1	√	X
2	Arduino Uno reads all sensors	1	√	X
3	The TDS sensor can read the nutritional value (ppm) in water reservoirs	1	√	X
4	The UV light intensity sensor can read UV light around plants	1	√	X
5	The temperature sensor can read the water temperature in the water reservoir	1	√	X
6	OLED LCD IIC 0.96 Inch The LCD displays nutritional status, light intensity around hydroponic plants and water temperature	1	√	X
7	A vitamin pump can circulate nutrients in hydroponic plant pipes	1	√	X
8	Water pumps can circulate water in hydroponic plant pipes	1	√	X

Information :
√ = successful
X = not working

In hardware testing in Table 3, the types of tools or hardware in the IoT Monitoring and controlling system are going well. Such as modules for ESP32 data communication, Arduino Uno, TDS sensors, UV light sensors, water temperature sensors, vitamin pumps and water pumps function properly. For resources uses a powersupply so that it can be used 24 hours.

3.6 TDS Sensor Calibration Testing

At this stage, the TDS sensor calibration test was carried out using TDS calibration fluid. The test results obtained the following data:

Table 4. TDS Calibration test results

TDS Sensor (ppm)	Calibration (ppm)
28	342
625	500
971	700
1096	1000
1168	1382

TDS calibration test is carried out to determine the lower threshold and upper threshold of the Nutrition system automation. From the results of this test, the lower threshold is 800 PPM while the upper threshold is 1000 PPM (depending on the age and type of plant). Threshold can be set in the firebase database.

3.7 TDS sensor testing

The TDS sensor test aims to get the results from the TDS sensor reading process where the vitamin pump will open (ON) if the lower threshold is below 800 ppm for 10 seconds, after five minutes of waiting for the vitamins to mix with water. The IoT system will check again whether the condition's vitamin levels are above the upper threshold (upper threshold), for example 1000 ppm. If it is appropriate, the vitamin pump will no longer secrete vitamins. If it has not met the upper threshold, the vitamin pump will reopen for 10 seconds. The upper and lower thresholds can be set in the database according to the age and type of plant. This test was carried out for 24 hours on the 19th, 20th, 21st, 22nd, 23rd, 24th and 25th of August 2022, the test began at 12.00 WIB, 18.00 WIB, 24.00 WIB and ended at 06.00 WIB. The IoT system has been set up and will read for 10 minutes. The data generated from the IoT system can be seen in the table below.

Table 5. TDS Sensor Test Results

Time	First test (ppm)	Second test (ppm)	Third test (ppm)	Fourth test (ppm)	Fifth test (ppm)	Sixth test (ppm)
12.00	1057	1052	1066	1097	1040	1059
18.00	1054	1143	1176	1176	1140	1147
24.00	1218	1205	1287	1243	1208	1147
06.00	1302	1294	1298	1342	1308	1022

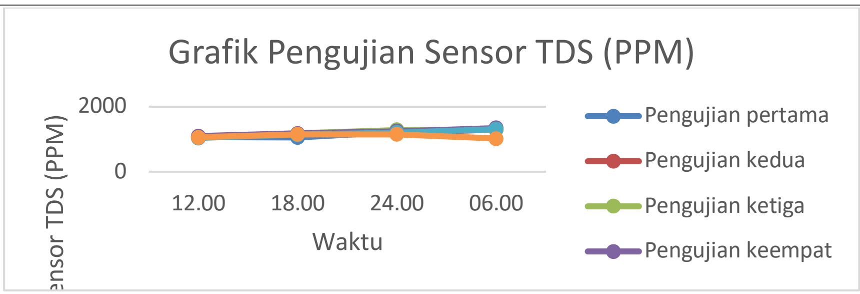

Figure 16. Graph of TDS Sensor Testing

Trials were carried out on lettuce plants that were over three weeks old, in the firebase database it was set for a lower threshold of 800 ppm and an upper threshold of 1000 ppm. From the graph above, the sensor tool can work properly, because it is stable above 1000 ppm. From the data above, the TDS sensor data is stable above 1000 PPM.

3.8 Testing of UV Light Intensity Sensor

This UV light test is carried out by comparing the display of the value of the amount of UV light in the IoT system from the results of reading the UV light sensor compared to manually calculating the intensity of UV light. The comparison results can be seen in the Table 6.

Table 6. Comparison of UV Sensor Data in Firebase database with Manual Count

Name	**UV Light Sensor**	**manual count**	**Error percentage**	**Time**
1660910826	2,5	2,6	0,1%	19/08/2022 12:07:06
1660932020	2,1	2,5	0,4%	19/08/2022 18:00:20
1660953958	2,0	2,2	0,2%	20/08/2022 00:05:58
1660975282	2,0	2,3	0,3%	20/08/2022 06:01:22
1660997333	2,3	2,5	0,2%	20/08/2022 12:08:53
1661018682	2,1	2,6	0,5%	20/08/2022 18:04:42
1661040007	2,1	2,2	0,1%	21/08/2022 00:00:07
1661061886	1,9	2,1	0,2%	21/08/2022 06:04:46
1661083203	43,6	45,0	1,4%	21/08/2022 12:00:03
1661105138	1,9	2,2	0,3%	21/08/2022 18:05:38
1661126693	1,0	2,0	1,0%	22/08/2022 00:04:53
1661148003	8,2	9,0	0,8%	22/08/2022 06:00:03
1661169867	43,9	45,0	1,1%	22/08/2022 12:04:27
1661191147	4,4	5,0	0,6%	22/08/2022 17:59:07
1661213068	0,9	1,2	0,3%	23/08/2022 00:04:28
1661234662	13,4	14,0	0,6%	23/08/2022 06:04:22
1661256025	54,1	55,0	0,9%	23/08/2022 12:00:25
1661277995	1,6	1,8	0,2%	23/08/2022 18:06:35
1661299268	3,9	4,0	0,1%	24/08/2022 00:01:08
1661321124	17,2	18,0	0,8%	24/08/2022 06:05:24
1661342426	31,3	32,0	0,7%	24/08/2022 12:00:26
1661364332	9,5	11,0	1,5%	24/08/2022 18:05:32
1661385593	14,6	16,0	1,4%	24/08/2022 23:59:53
1661407465	17,2	20,0	2,8%	25/08/2022 06:04:25
1661428775	26,8	28,0	1,2%	25/08/2022 11:59:35
1661450686	30,6	33,0	2,4%	25/08/2022 18:04:46
Average percentage error				0,008%

From the data read by the UV light intensity sensor, there are results that are not constant (fixed) even though at the same time, this is because the amount of UV light intensity depends on weather factors, such as cloudy, hot, rainy or sunny.

3.9 Testing the Function of the IoT System

Testing this function is done to find out that data stored in the firebase database can be stored and displayed

Name	Value.ppr	Value.timestam	Value.uv	Value.wtemp	Waktu
1661386198	1136	1661386198	13,6	26	25/08/2022 00:09:58
1661386800	1115	1661386800	14,1	26	25/08/2022 00:20:00
1661387415	1104	1661387415	13,3	25,9	25/08/2022 00:30:15
1661388025	1094	1661388025	13,4	25,9	25/08/2022 00:40:25
1661388631	1086	1661388631	13,1	25,9	25/08/2022 00:50:31
1661389231	1071	1661389231	12,8	25,8	25/08/2022 01:00:31
1661389836	1057	1661389836	12,3	25,8	25/08/2022 01:10:36
1661390447	1051	1661390447	9,3	25,7	25/08/2022 01:20:47
1661391052	1025	1661391052	8	25,6	25/08/2022 01:30:52
1661391660	1012	1661391660	7,6	25,6	25/08/2022 01:41:00
1661392274	989	1661392274	11	25,4	25/08/2022 01:51:14
1661392888	966	1661392888	6,6	25,3	25/08/2022 02:01:28
1661393496	933	1661393496	9	25,2	25/08/2022 02:11:36
1661394102	915	1661394102	4,6	25,1	25/08/2022 02:21:42
1661394708	860	1661394708	3,2	25	25/08/2022 02:31:48
1661395323	813	1661395323	10,9	24,9	25/08/2022 02:42:03
1661395933	803	1661395933	10,7	24,8	25/08/2022 02:52:13
1661396545	741	1661396545	4,3	24,6	25/08/2022 03:02:25
1661397151	712	1661397151	3,3	24,6	25/08/2022 03:12:31
1661397765	677	1661397765	3,7	24,5	25/08/2022 03:22:45
1661398376	656	1661398376	4,3	24,4	25/08/2022 03:32:56

Figure 17. Views of Measurement Results stored in Firebase

From the data above it can be observed that there is a sensor reading time every 10 minutes. Sensor readings are made every 10 minutes to keep the sensor components working optimally.

3.10 Testing the light intensity data with water temperature

From the results of the average data taken for five days with the time range at 12.00, 18.00, 24.00, and 06.00 WIB, it can be made like the table below:

Table 7. Light Intensity and Water Temperature Data

Period	12.00 WIB	18.00 WIB	24.00 WIB	06.00 WIB
Light Intensity	26,76	3,44	4,72	10,34
Water Temperature	30,4˚C	27,7˚C	25,54˚C	23,56˚C

From the Table 7, a graph is made as below (Figure 18).

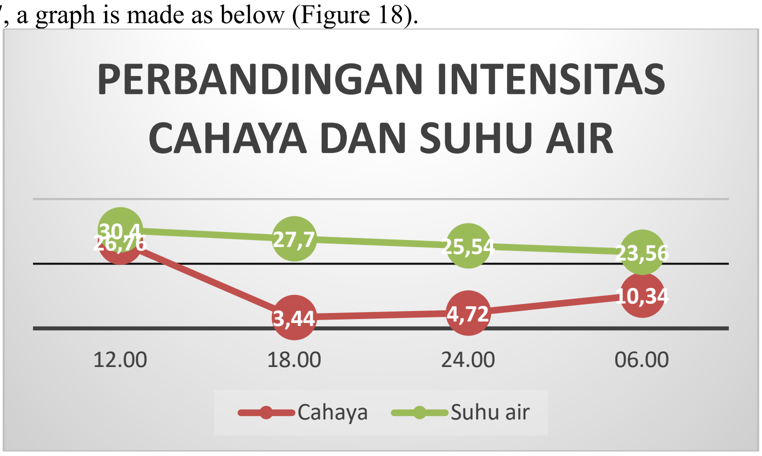

Figure 18. Comparison of Light Intensity to Water Temperature

From the picture above, the higher the light intensity, the water temperature will be affected. There is a decrease in light intensity at night so that it will affect the water temperature decrease. Of course, this is also influenced by other factors such as weather such as rain and climatic factors.

3.11 Storage Testing

When the client is connected to the internet network, Firebase will make automatic adjustments to the data change records stored on the client's storage media with the current conditions of the Firebase Server. Firebase's database is a non-relational or NoSQL database, where this database is a type of database that does not use a table system in its implementation and does not store data locally on the device but in the cloud. Firebase also provides storage facilities. Firebase can store and retrieve content such as images, videos, and audio. Uploading and downloading is also done in the background. The stored data will be safe and only authorized users can access it (Table 8).

Table 8. Storage Requirements

Date	Storage (KB)	difference (KB)
18/08/2022	2,97	2,97
19/08/2022	3,83	0,86
20/08/2022	8,17	4,34
21/08/2022	18,28	10,11
22/08/2022	22,81	4,53
23/08/2022	31,79	8,98
24/08/2022	45,14	13,35
25/08/2022	52,31	7,17
Total storage		52,31 KB
Average Storage requirement (Kb)		6, 54 KB

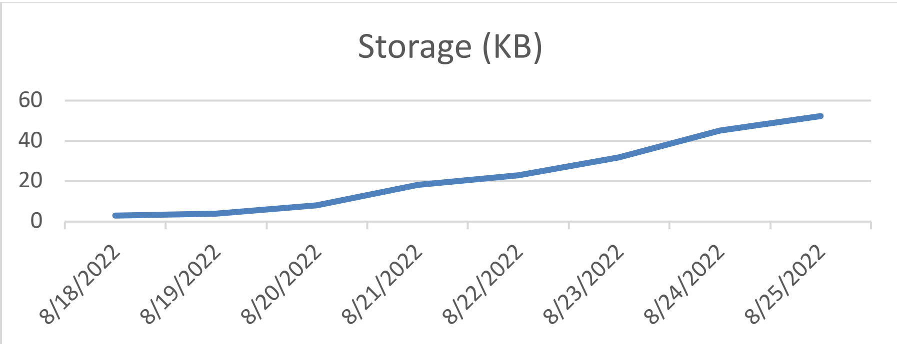

Figure 19. Graph of storage usage in the IoT System

From the graph above, the storage capacity required for the database is increasing, it is because the amount of data stored is increasing. From the data obtained in the database, it can be seen in table 8. The data was taken from the database from 18/08/22 to 25/08/22 with an average size of storage needed around 6.54 kb for one IoT device.

3.12 Testing Download Amount (downloaded data)

Download on the firebase database to exchange data on sensors and web servers. Firebase requests data stored on the database and all outgoing network traffic at the session layer (layer 5) of the OSI model. Outgoing traffic includes connection overhead and encryption of all database operations and data downloaded via database reads. Some of the data traffic that requires bandwidth includes: Downloaded data i.e. When a client gets data from the database, Firebase will request the downloaded data and there will be bandwidth required.

Table 9. Requirement Download data

Date	Download (MB)
18/08/2022	1,25
19/08/2022	5,63
20/08/2022	7,02
21/08/2022	10,58
22/08/2022	11,4
23/08/2022	10,79
24/08/2022	10,72
25/08/2022	10,74
the total amount required for downloads	68,13
Average	8,52

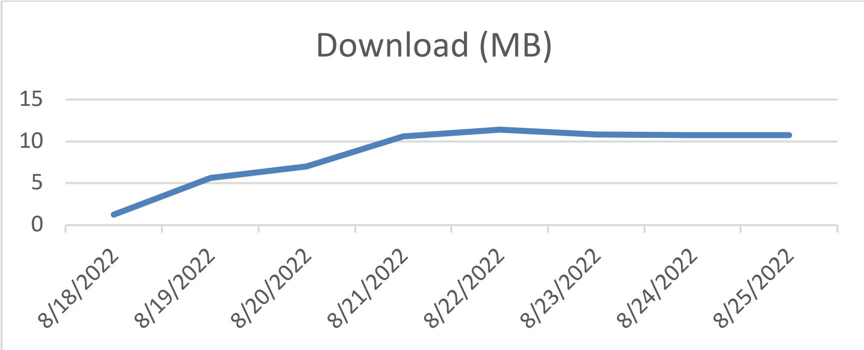

Figure 20. Graph of the amount of data download requirements on the Firebase database

From the data obtained, the average need to download the database is 8.52 MB for one IoT device.

4. CONCLUSION

The conclusions are:

1. With the IoT system prototype research on hydroponic plants, it will be possible to monitor plant nutrition, UV light intensity and water temperature and can be controlled automatically for nutrient concentration adjusted to the needs of hydroponic plants so that users can control easily on a smartphone where everything equipment can be controlled remotely and no longer must come to the farm site.
2. From the results of testing the data generated by the light intensity and temperature sensors, there is a relationship between the amount of UV light intensity produced and the amount of water temperature in the hydroponic plant reservoir, that is, the higher the intensity of UV light, the higher the water temperature and vice versa, but this statement still must pay attention to other factors such as weather conditions and climate around hydroponic plants.
3. Data generated by IoT device sensors must be stored in a database so that further analysis can be carried out. For storage, of course, adjusted to the size of the data stored.

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